

# COATINGS MANUAL

## HRSD

### APPENDIX D

#### **BACKGROUND ON SUBSTRATES FOR COATINGS.**

##### **Soluble Salt Contamination of Steel**

###### Soluble Salt Contamination on Metallic Substrates

The presence of soluble salts such as chlorides or sulfates on metallic substrates to be coated can result in premature coating failure when present in sufficient concentrations. These salts are typically not removed by blast cleaning and, in fact, can be driven into the blast profile of the metal by blast cleaning. When coatings are applied over soluble salt contaminated steel, subsequent moisture migration (normal to coatings in humid or immersion environments) in and out of the coating film results in the moisture solubilizing the salts and condensing on the steel surface under the coating film. Over time, this creates small osmotic cells pulling more moisture to the concentrated solution causing osmotic pressure to develop. This pressure pushes the coating off the surface creating blistering of the coating with subsequent delamination. If you suspect that existing metals to be coated (in existing facilities) or new metals to be coated have been exposed to chlorides or sulfates from sea coastal exposure, industrial exposure, or wastewater exposure, etc., specific testing and surface preparation language should be added to the specifications.

Refer to Section 7, the Standard HRSD Coating Specifications, paragraph 3.04 C. 4.

##### **Coating Over Galvanized Steel**

###### Galvanizing and Zinc Coatings

Galvanizing and zinc-rich coatings are effective in protecting ferrous metal from corrosion under normal environmental conditions. To provide this sacrificial cathodic protection, the applied zinc must provide particle-to-particle contact to be electrically conductive. For this reason inorganic zinc-rich coatings are specified as having 84 percent or more zinc by weight in the applied dry film. Galvanized and zinc coated ferrous metal is suitable for nonpotable immersion within a pH range from 5 to 9 provided other conditions are right. Zinc being amphoteric, i.e., capable of reacting with either acid or base, will be rapidly attacked when acidic, alkaline, or halogenic conditions exist. Zinc coating and galvanized metal are not recommended for immersion in potable water due to the potential for chemical contamination or in non-potable immersion where lower or higher pH conditions exist.

The designations for inorganic or organic zinc refer to the binder used for the zinc powder in the coating. Inorganic zinc coatings refer to the use of an inorganic binders, typically ethyl silicate binders. Organic zinc coatings refer to the use of organic polymer based binders such as polyurethane or epoxy binders.

Organic zinc rich coatings can be single component coatings that can be brush or roller applied and provide excellent adhesion to the substrate. Also, two component organic zinc rich coatings

## **COATINGS MANUAL HRSD**

that are generally spray applied provide good adhesion and corrosion protection under the right conditions. However, organic zinc rich coatings have all the characteristics of organic paints in weather, such as sensitivity to sunlight (except for polyurethane binders) and a tendency to crack, chalk and blister in areas of high humidity or immersion. They can be solvent sensitive and may swell or dissolve when subjected to organic solvents, and their heat resistance is usually below 300 degrees F. Inorganic zinc rich coatings are usually two component, and spray applied. They are unaffected by weather or organic solvents and their heat resistance is much greater, being slightly below the melting point of zinc. Inorganic zinc rich coatings are very sensitive to being applied at the proper thickness. They are generally specified at 2 to 4 mils DFT. Excessive thickness results in splitting of the film when topcoated with epoxies or urethane coatings. Also because inorganic zinc rich coatings typically cure through reaction of their ethyl silicate binder with atmospheric moisture, they must be applied under relatively humid conditions. If not properly cured as under dry conditions, subsequent application of topcoats will result in delamination of the coating system due to splitting of the zinc rich primer. Top coating zinc coatings and galvanized metal with organic paints should be preceded with the application of a primer. Almost every manufacturer has a polyamide cured epoxy which serves as a tie coat used to bond different successive generic coatings.

Despite the apparent benefits of zinc-rich coatings, improper application has lead to numerous substantial failures. Zinc, being porous, is subject to contamination, which can cause delamination of topcoats. The use of zinc coatings alone (with no topcoats) is only specified for high heat applications.

### Coating Galvanized Steel

Galvanizing provides a layer of zinc which oxidizes quite readily with exposure to the atmosphere. The zinc corrodes and forms a passive zinc oxide layer or film. This layer slowly reacts with carbon dioxide in the air to form a stable, tightly bonded zinc carbonate film. These zinc oxides and zinc carbonates are extremely alkaline salts. And as such, alkyds or any oil based coatings should not be applied over galvanized steel. Any coatings that contain drying oils react with these alkaline zinc salts and fail by saponification. Also, partially weathered galvanized steel will have salts on its surface that prevent good adhesion of topcoats like epoxies. The most effective surface preparation method for galvanized steel surfaces prior to coating is sweep blasting. This consists of a fast pass of abrasive blast cleaning over the galvanized surfaces to remove loose material and to roughen the surface to achieve an anchor pattern. Care should also be taken not to remove excessive zinc thickness. All corroded steel that is exposed must be abrasive blast cleaned to bare metal.

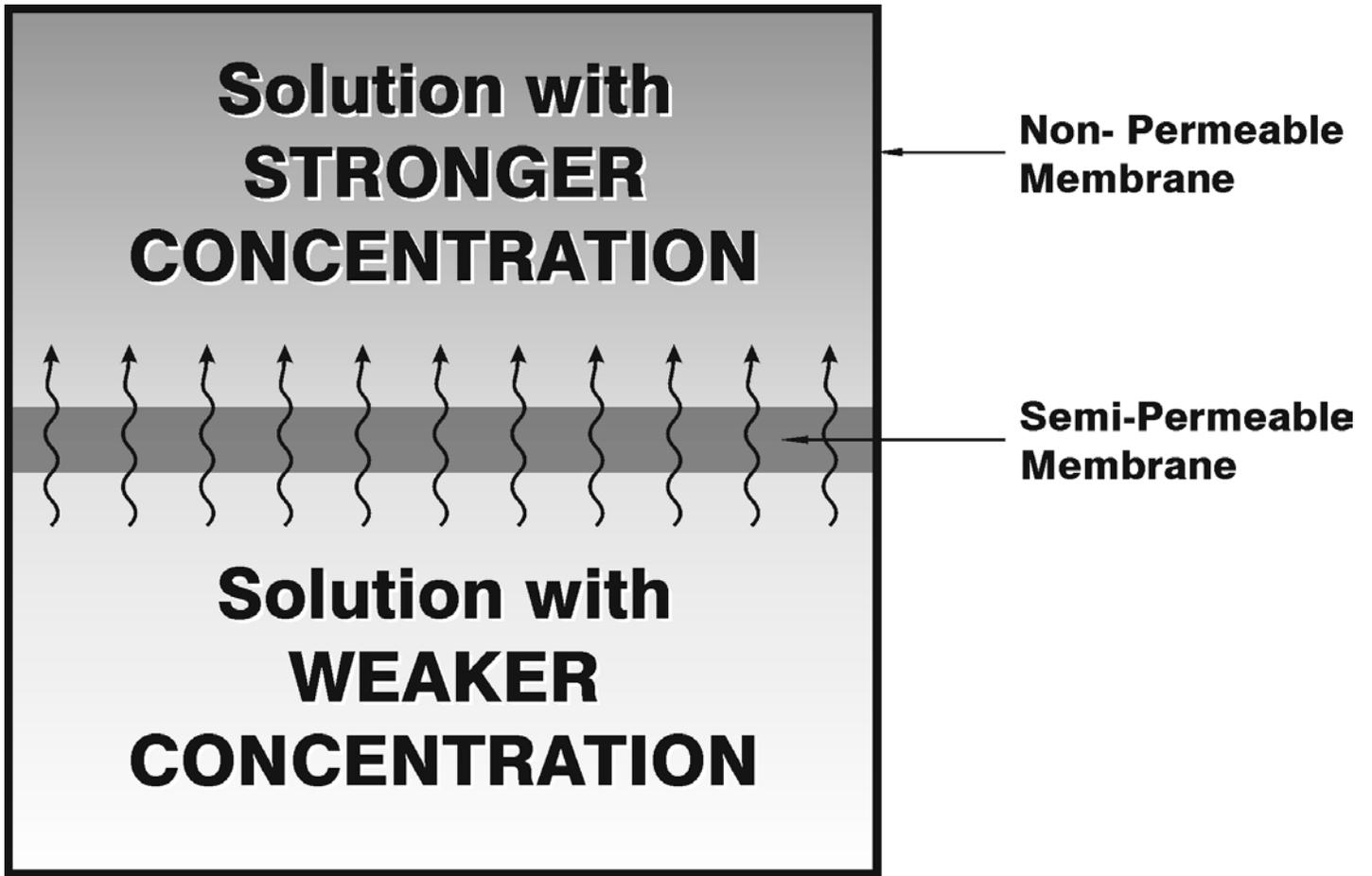
### Understanding and Testing for High Moisture Vapor Transmission Through Slabs on Grade or Below Grade Concrete Structures.

This section of the Coatings Manual explains the causal mechanisms of osmotic blistering of coatings related to High Moisture Vapor Transmission through concrete. Furthermore, this section presents recommendations for prevention and corrective measures associated with osmotic blistering and high moisture vapor emissions.

## COATINGS MANUAL HRSD

### CAUSAL MECHANISM(S)

Osmotic blistering occurs when coated substrate conditions create the opportunity for osmotic cells and related osmotic pressure to develop. Osmotic blisters are invariably associated with the presence of soluble salts or minerals on one side of a semi permeable membrane towards which the migration or permeation of water or another solvent occurs. These blisters often occur when interior steel substrates in various tanks containing water are contaminated with chlorides or other soluble ions prior to coating application. Once the tank is filled, water slowly is absorbed on the molecular level through the coating film. At the same time, water molecules are desorbed through the coating film. Where good coating adhesion and no substrate contamination is present, absorption and desorption are equal and all is well with coating performance. Where contaminants like chlorides are present on the substrate, water reacts with the ions and remains under the coating film. The reaction creates a solution under the coating having a higher chloride concentration than the tank water. The result is the formation of an osmotic cell. Figure 1 shows a simple osmotic cell.



## SIMPLE OSMOTIC CELL

Note:

The solvent (water) is drawn through the semi-permeable membrane from the weaker solution to the stronger solution. This *drawing force* creates **Osmotic Pressure**.

**Figure 1**

## **COATINGS MANUAL HRSD**

In the water tank example, water is drawn from the tank side through the coating to the substrate where the solution concentration is higher. The thin film water tank coating here behaves as the semi-permeable membrane on the molecular level. The movement of water through the film creates osmotic pressure under the coating. Once this pressure exceeds the adhesion of the coating to the substrate, the blister begins to form.

In the case of osmotic blistering in concrete floor coating systems, the presence of soluble salts or minerals and moisture migration are also fully relevant. Here again, osmotic cells and osmotic pressure promote blistering. To illustrate the osmotic mechanism, Figure 2 describes the requirements for osmosis.

# OSMOSIS REQUIRES:

- \* **Solvent** ..... **Water**
  
- \* **Solute** ..... **Dissolved chemical salts or minerals**
  
- \* **Solvent with varied solute concentrations** ..... **One solution having more concentration than the other**
  
- \* **Semi-permeable membrane** ..... **All coatings are to some extent permeable on the molecular level**
  
- \* **Non-permeable border that contains the mechanism** ..... **A coating or substrate material of extremely low permeability**

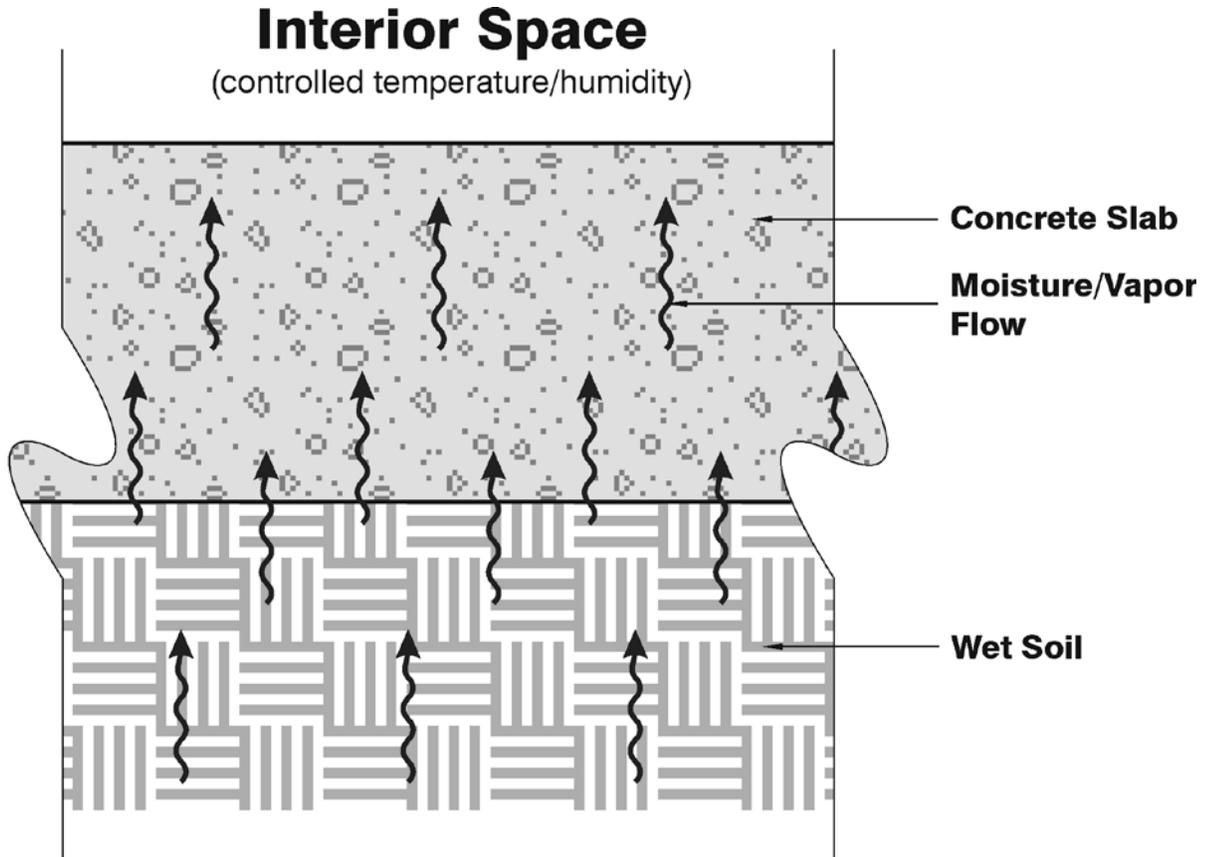
Figure 2

## COATINGS MANUAL HRSD

As Figure 2 shows, we need a solvent source for osmotic cells. In the floor coating example, that source is the water vapor that is drawn and/or pushed through or out of the concrete slab over which the floor coating system has been applied. This water can come from wet subbase soil or from within concrete that has not sufficiently dried out as reported by Pfaff and Gelfant in 1997.<sup>1</sup> Figure 3 shows a slab on grade example where moisture vapor transmission is illustrated.

---

<sup>1</sup> F. A. Pfaff & F. S. Gelfant, "Osmotic Blistering of Epoxy Coatings on Concrete," JPCL (December 1997), pp. 52-64.



## **HYDRAULIC FORCES**

- \* Capillary Suction
- \* Pressure & Temperature Differences
- \* Capillary Pressure



**Draw/push moisture through the  
concrete toward the  
drier/warmer interior space.**

**Figure 3**

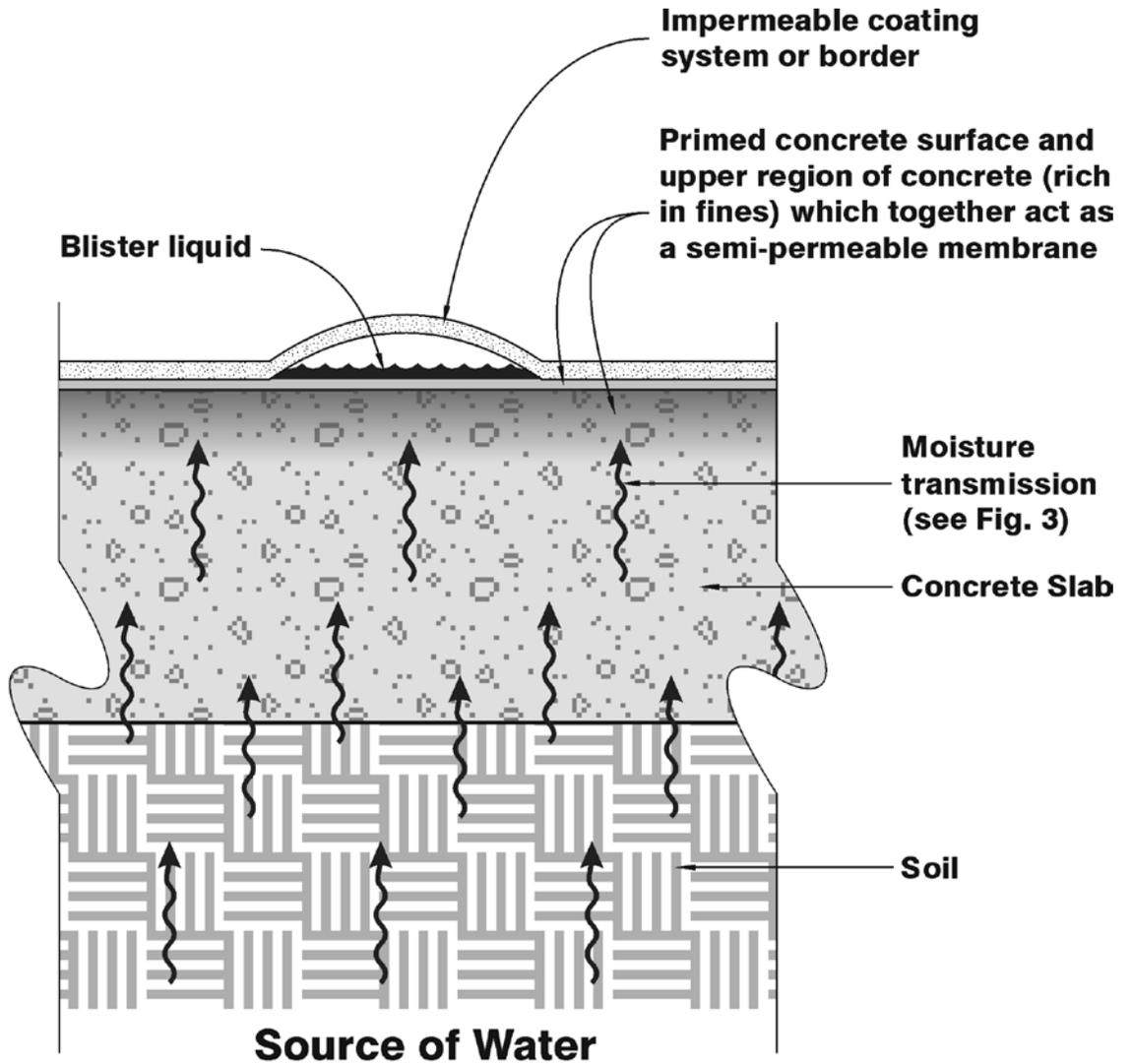
## COATINGS MANUAL HRSD

As Figure 3 demonstrates, the hydraulic forces associated with moisture vapor transmission through concrete include capillary suction, pressure/temperature gradients, and capillary pressure. These forces cause the water as vapor to travel through the concrete. It is, however, generally agreed by researchers that these hydraulic forces create insufficient pressure to exceed the adhesion of properly applied floor coating systems over well-prepared concrete substrates.<sup>2</sup> However, these forces do provide the solvent (water) necessary for osmotic cell development. The soluble salts (solute) in this scenario are typically provided by the calcium silicate hydrates from the hydrated Portland cement paste in the concrete. These cement paste fines are typically found in higher concentrations at the top of concrete slabs due to both hydration and the concrete finishing processes. This upper zone of the concrete slab often accompanied by thin floor system primers behaves as the semi permeable membrane in the subject osmotic cell. The thicker mortar or filled and topcoated layers of the floor coating system function as a non-permeable or confining border layer.

As water passes through the semi-permeable upper zone of the concrete, calcium hydroxide and other soluble alkaline hydrates are dissolved, and collect beneath the low-permeability coating. When stopped by the non-permeable membrane, a more concentrated solution accumulates creating an osmotic cell. More moisture, having a lower concentration of salts, is drawn through the semi-permeable layer creating osmotic pressure. Once the osmotic pressure exceeds the tensile pull adhesion of the floor coating system to the concrete, a blister begins form at this location. Figure 4 illustrates osmotic blistering in our slab on grade example. The blister is, of course, adhesion related because blister formation and size are influenced by the quality of adhesion. And as the osmotic pressure exceeds the strength properties of the coating system, a blister is formed and the coating system is locally deformed.

---

<sup>2</sup> W. H. Riesterer, "Hydrostatic, Capillary, Osmotic, and Other Pressures" presented at SSPC 93, New Orleans, LA. November 13-18, 1993. Not in proceedings.



## MECHANISMS OF OSMOTIC BLISTERING

Figure 4

## COATINGS MANUAL HRSD

Unlike the hydraulic forces responsible for moisture transmission through concrete (See Figure 3), osmotic pressure can easily exceed the maximum tensile pull adhesion values for coating systems applied over well-prepared concrete floor slabs.<sup>3</sup> This finding is supported by FeRFA (the Resin Flooring Association) in the United Kingdom in its Guide Document published in July of 2003.<sup>4</sup>

Well-adhered floor coating systems generally exhibit tensile pull adhesion values (in accordance with ASTM D4541) that are roughly equal to 10% of the concrete's strength in compression. So for 4,000 psi concrete, the tensile pull adhesion value should be approximately 400 psi. Due to differences in the strength of concrete at full section depth and at the upper surface of carbonated concrete, these tensile pull values may be somewhat lower, i.e. between 250 and 300 psi. Most coating manufacturers and researchers agree that tensile pull adhesion values equal to or greater than 300 psi are generally acceptable. This is because the upper region of concrete slabs are generally lower in strength than the full section depth of the concrete slab or member. This is due to natural effects of atmospheric carbonation, the presence of more fines at the upper surfaces, and to other salient factors.

The hydraulic forces which promote moisture vapor transmission are not sufficiently high to cause disbondment or blistering of well-adhered coatings to concrete substrates. For instance, capillary measures have been measured experimentally to be no higher than about 30 to 35 psi. Capillary pressure is actually the strongest of these vapor emission related hydraulic forces. The literature suggests that combined, capillary suction and pressure, hydrostatic pressure exerted on non-continuous pores in concrete, pressure gradient, and temperature gradient effects produce pressures well below 300 psi. Conversely, osmotic pressure has been experimentally shown to exceed 650 psi.<sup>5</sup> This data clearly supports the conclusion that the blisters experienced at the four case facilities are osmotic in nature. This is further evidenced as the blisters contain liquid which primarily consists of water and the liquid is typically high in pH. Also, the blisters occur in floor systems where aggressive surface preparation was performed. Finally, in support of this finding, the blisters occur only where high moisture vapor emissions test results are obtained.

This discussion has focused a great deal on osmotic blistering in slab on grade applications. The same osmotic blistering mechanism takes place in elevated concrete floor slabs. The only difference is the source of the water (or solvent). Rather than coming from wet soil, the moisture source is from within the concrete or is passed through the concrete from another source such as leaking drain piping. This blistering can also occur when new concrete does not sufficiently dry out prior to floor coating application. New concrete dry out times are extremely dependent upon the original water to cementitious material ratio (w:c) used in the mix design and are strongly influenced by the ambient conditions under which the concrete cures over time.

---

<sup>3</sup> M. Gunter and H. K. Hilsdorf, "Stresses Due to Physical and Chemical Actions in Polymer Coatings on a Concrete Substrate," 1986, Adhesion Between Polymers and Concrete (Aix-en-Provence, France: Chapman and Hall, 1986), pp. 8-21).

<sup>4</sup> FeRFA (The Resin Flooring Association) of the U.K., FeRFA Guidance Note: No. 2, July 2003.

<sup>5</sup> M. Gunter and H. K. Hilsdorf, "Stresses Due to Physical and Chemical Actions in Polymer Coatings on a Concrete Substrate," 1986, Adhesion Between Polymers and Concrete (Aix-en-Provence, France: Chapman and Hall, 1986), pp. 8-21).

## COATINGS MANUAL HRSD

Osmotic blistering of floor coating systems can be avoided if there is insufficient moisture transmission through the slab. Experience has shown that if the moisture vapor emissions are (MVE) below 3 lbs per 1,000 sq.ft. per 24 hours in accordance with ASTM F1869, osmotic blistering does not occur. This is why nearly all coating manufacturers use the 3 lbs. per 1,000 sq. ft. per 24-hour threshold. This threshold value must be qualified carefully. The concrete must be properly prepared to provide ample surface profile. Osmotic blistering can occur when MVE rates are at or below 3 lbs./1,000 sf./24 hours where inadequate surface preparation resulted in poor coating adhesion.

So to prevent osmotic blistering of epoxy, MMA, or other resinous flooring systems, the moisture vapor emissions must be kept sufficiently low. This can be achieved in slabs on grade with a continuous puncture-free vapor barrier, low water to cement ratio concrete, sufficient dry out time for the concrete, and other measures. For elevated slabs, moisture sources external to the concrete must be eliminated and enough dry out time must be achieved. Also, large disparities in temperature and humidity between the top and bottom of elevated slabs must be prevented or avoided.

On the subject of new concrete drying rates, field testing by this author has shown that the lower the water:cement (ratio), the faster the drying rate will produce  $\leq 3$  lbs. per 1,000 sq. ft. per 24 hour values. For example, concrete four inches thick (sealed completely on the bottom) having a w:c of 0.40 will reach the threshold in about 28 to 35 days at 50% R.H. and 73°F. Similar sealed samples having a w:c of 0.50 won't reach the threshold until 60-65 days under the same conditions. This data is based on controlled laboratory conditions and does not consider ambient humidity and temperature effects on a construction site. If water is externally added to concrete via washing, rinsing, or leakage, this too can cause osmotic blistering if sufficient drying time is not allowed.

### Methods of Detection/Threshold Moisture Limits

To determine whether too much moisture is present within the concrete or is migrating through the concrete, ASTM D 4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method", is useful. An 18" x 18" transparent polyethylene sheet plastic (minimum 4.0 mils thick) is placed on bare concrete, and the edges are taped to form an airtight seal. The sheet is left in place for a 16 hour period (minimum). The shortcomings of this method are that the test takes 16 hours to perform and does not quantify the amount of moisture present. Also, floors and tank walls to be coated are often indoors and no sunlight is present. In this case place a light (100 watt) approximately 8"-12" over the plastic sheet. However, it can be stated that if any amount of water is detected, during or subsequent to the test there is probably too much moisture to install a coating system.

The other test method previously referenced above is ASTM F1869, "Standard Test Method for Measuring Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride." Test kits for this test method are available through a variety of sources. Individual tests can be performed using either the visual/qualitative method or the referee/quantitative method. The required materials and use instructions for the referee/quantitative test method are described below:

# COATINGS MANUAL

## HRSD

### Materials

- Calcium chloride (powder) in small sealable container (approximately 3” diameter x 5” high or similar).
- Sealing tape.
- Plastic cover (capable of encapsulating the calcium chloride container).
- Scale accurate to the nearest centigram (.01 gram).
- Suitable label marking materials.

### Procedure

- Place calcium chloride in container, attach label to lid, and weigh the container, lid, and tape used to seal the lid to the container. During this process do not spill any of the contents of the container.
- Record weight on attached label.
- Place the open container, lid and tape on bare/clean concrete floor. It may first be necessary to remove old coating, debris, dust, etc. During this process do not spill any of the contents of the container.
- Place the plastic cover over the container and seal edges. It is vital that a complete air tight seal is achieved.
- Place caution tape or other signage to prohibit test unit from being disturbed.

Note: Although the frequency of testing can be determined on a per job basis, the following can be used as a general guideline:

- 1 - Test for areas up to 250 sq. ft.
  - 2 - Tests for areas 250-500 sq. ft.
  - 3 - Tests for areas 500 -1,000 sq. ft.
  - 4 - Tests for areas 1,000-5,000 sq. ft.
- Leave test unit in place for 60 hrs. (minimum) to 72 hrs.
  - Following the prescribed test period, carefully place the previously weighted lid onto calcium chloride container, seal, weigh and record the weight on the label. During this process, do not spill any of the contents of the container.

The formula for calculating moisture emissions is as follows:

$$\frac{1,000 \text{ sq. ft.} \times \text{weight gain} \times 24 \text{ hrs.}}{\text{Area of test} \times \text{Exposure time} \times \text{Grams/pound}} = \text{Pounds/1,000 sq. ft./24 hr. period}$$

Notes: 1,000 sq. ft. = 144,000 sq. in.  
Area of test = 70 sq. in.  
Exposure time = hrs. to the nearest .1 hr.  
Grams per pound = 454

## COATINGS MANUAL HRSD

The visual/qualitative method assessment is done in the same manner as described above, but pre and post test weighing is not done. Rather, the calcium chloride is viewed for the presence of clumps and/or dark spots. If particularly high vapor emission rates are present, the calcium chloride may dissolve. For reasons stated previously, however, this method is not recommended.

### Threshold Limits/Criteria for Assessment of Vapor Emission Rates.

Test result values which are in excess of 3.0 lbs./1,000 sq. ft./24 hr. period can be considered as problematic relative to the installation of highly impermeable type coating or flooring materials. It should be noted that floor coating failures related to vapor emissions are common and very expensive to rectify. Hence, a conservative approach is advisable. Additionally, it should be understood that vapor emission rates can change throughout the year due to precipitation variances and geological events - natural or man-made (i.e. construction or landscaping activities). This is why it is recommended that questions regarding potential water problems, moisture vapor barriers, etc. always be addressed prior to the installation of thick film coating or floor coating systems.

So to prevent osmotic blistering of epoxy or other flooring systems, the moisture vapor emissions must be kept sufficiently low. This can be achieved in slabs on grade or tanks with a continuous non-permeable vapor barrier or exterior waterproofing, low water to cement ratio concrete, sufficient dry out time for the concrete, and other measures.

# COATINGS MANUAL HRSD

## PREVENTION METHODS: NEW CONSTRUCTION

Methods and measures used during new construction for prevention of osmotic blistering are well known. Ensuring that these measures are properly implemented requires thorough and rigorous inspection in the field.

Below is a brief discussion of the major prevention methods:

### A. Proper Subbase Drainage and Water Control

These methods are typically covered under the Division 2 Specifications for Site Work and in the site work drawings. Removing the source of a sustained water supply beneath slabs on grade is crucial to preventing osmotic blistering problems in floor coating systems.

### B. Properly Installed, Continuous Vapor Retarders

Most people mistakenly refer to vapor retarders as vapor barriers. A reinforced polyethylene vapor retarder beneath slabs on grade approximately 10 to 20 mils in thickness has given the best results. These should be installed with 6" minimum overlaps that are double tapped and sealed. Also, the sheets must be sealed around all slab penetrations changes in slab thickness i.e. pile cap to slab transitions. The vapor retarder or barrier design that uses a compacted sand layer has provided better results than barriers applied directly over coarse fill. Additionally, it is very important to prevent construction damage to the vapor barrier.

Ensuring that a proper and continuous vapor barrier is installed can only be controlled by proper specification and drawing detail requirements and dogged inspection in the field.

ACI 302.1R as published in the ACI Manual of Practice explains that a 6 mil thick plastic sheet has been a suitable vapor retarder, but strongly recommends that a thickness of not less than 10 mils be used. The increased thickness provides increased resistant to moisture transmission and more durability during construction. Section 3.2.3 of ACI 302.1R covers the recommended practices for placing vapor barriers or retarders. In summary, this section of 302.1R states that the vapor protection should be placed under a minimum of 4" of trimable, compactable, granular fill (not sand). If such crusher run material is not available or practical, the vapor barrier or retarder should be covered by at least 3 inches of fine graded material such as crusher fines or manufactured sand.<sup>6</sup> Section 4.1.5 goes on to recommend that if the vapor barrier is to be placed over a rough granular fill, a thin layer of fine graded material should be rolled or compacted over the fill prior to installation of the vapor barrier to reduce the possibility of puncture. Also, it recommends that vapor barriers be overlapped 6 inches at the joints and carefully fitted around service openings.

---

<sup>6</sup> American Concrete Institute, Part 302.1R, Concrete Floor and Slab Construction, Chapter 3 Design Considerations, 3.2.3 Vapor Retarder, pp. 6-7.

## COATINGS MANUAL HRSD

ACI 302.1R goes on to state that, “True vapor barriers are products, such as rugged multiple reinforced membranes, that have water transmission ratings of 0.00 perms per sq. ft. per hour when tested in accordance with ASTM E96.”

### C. Use Lowest Possible Water to Cementitious Materials Ratio

This relates to new concrete dry out times. The Portland cement used in concrete requires approximately 0.19 lbs. of water to 1 lb. of cement for hydration to occur. Approximately twice this amount of water or 0.38 is required to achieve a high percentage of conversion for hydration related to proper wetting out of all the cement particles. Any additional water added to concrete will result in further concrete shrinkage and related cracking. Also, the dry out time for the concrete to reach a 3 lb./1,000 sq.ft/24 hour vapor emission threshold will increase as more water is added beyond 0.38 lbs. of water per lb. of cement. Hence, keeping the w:c (ratio) at or below 0.38 will reduce the likelihood of osmotic blistering problems associated with excess mixing water in new concrete. Practice has shown that superplasticized concrete starting with a w:c of 0.40 produces 30 to 60 day dry out times provided the slabs are in controlled temperature and low humidity conditions. This is based on this author’s experience.

### D. Allow Sufficient Drying Time for Concrete in the Schedule

If at all possible, allow sufficient dry out times for concrete to reach the threshold vapor emissions level of 3 lbs./1,000 sq.ft./24 hours. Knowing that most construction schedules require that concrete is placed well ahead of HVAC system operation, much more dry out time is required.

Assuming that concrete slabs are no longer exposed to the weather, these dry out times can still last for up to 9-12 months, and this assumes that dehumidification has been implemented 2 to 3 months prior to floor coating installation. Floor coating systems should not be installed until the HVAC systems have been balanced and run for a few months. If this is not possible, portable dehumidification equipment can be brought in to control the environment. Allow as much dry out time as possible for slabs whether elevated or on grade after the building envelope has been sealed up, and allow for approximately 2 to 3 months of controlled temperature and humidity prior to floor coating application to compensate for further wetting of the concrete during exposure to the elements, water clean-up, etc.

### E. Pay Special Attention to Embedded Drains and Other Piping In Concrete Slabs

Close inspection should be conducted to ensure that all embedded drain piping connections, drain sumps, and other pipes, are sealed and connected to be watertight. Several osmotic blistering problems investigated over the years in both elevated and on grade slabs were related to leaking embedded drain piping.

## COATINGS MANUAL HRSD

### F. Avoid Thermal Gradients Across or Through Elevated Slabs

Whenever elevated concrete slabs are placed above furnaces, boiler rooms, mechanical rooms, or other sources of radiant heat, be certain to take measures to prevent the thermal gradient assuming the rooms above the slab will have controlled temperature and humidity. These measures will include proper insulating of piping and equipment, insulating of the underside of metal decking (stay in place forms), and/or increased ventilation of the room(s) below the slab. Achieving a  $\Delta T$  of no more than 10°F on each side of the slab and a humidity difference of no more than 10% has been effective historically. Insulating hot air ductwork may also be required to prevent this driving force for osmotic blistering.

### G. Don't Allow Over Finishing of Concrete

When concrete is to receive seamless resin rich floor coating systems, the power trowel finishing should not be overdone. First of all, over burnished concrete results in higher surface preparation costs involved with removal of cement paste rich upper layers. Secondly, over-finishing brings more fines to the upper surface exacerbating the semi-permeable membrane effect of soluble calcium silicate hydrates and calcium hydroxide on osmotic blister formation.

Careful specification language spelling out the finishing requirements can prevent this problem.

### H. Avoid the Use of Lightweight Concrete for Seamless Floor Coatings

Lightweight concrete utilizes porous coarse aggregates to reduce elevated slab loading on lighter structural steel framing systems. Invariably, lightweight concrete experiences fairly extensive drying shrinkage cracking due to the moisture that is pushed into the coarse porous aggregates during mixing and pumping. This water also presents ideal conditions for high vapor emissions especially when extensive drying times for the concrete are not permitted by the “fast track” construction schedule.

Dry out times can be well over 1 year in lightweight concrete slabs to reach the threshold vapor emission value of 3 lbs./1,000 sq.ft./24 hours.

### I. Perform Adequate Surface Preparation for Floor Coatings

Well performing floor coatings must be applied over properly prepared concrete substrates. Because blistering failures are adhesion related failures, the better the profile and degree of cleanliness, and the lower the cement paste fines concentration at the top of the slab, the less frequent and likely osmotic blistering will form. It is strongly recommended that the upper fascia of the coarse aggregate be exposed by shotblasting to achieve optimum adhesion and reduce the cement fines concentration at the upper zone of the slab. This recommendation in no way justifies no or poor vapor barrier placement, low w:c values for concrete, or the other prevention methods delineated herein.

## COATINGS MANUAL HRSD

However, better surface preparation will help in marginal scenarios when moisture vapor emissions are slightly above the 3 lb. threshold.

### J. Perform Moisture Vapor Emissions Testing Early and Routinely Through the Slab Dry Out Time

Moisture vapor emissions testing should be conducted starting no later than 30 days after concrete slab placement. It should then be performed weekly in accordance with ASTM F1869 as the dry out time progresses prior to scheduled flooring application. This will allow project teams to determine if a downward trend in vapor emissions is occurring. If not, the results may drive the need for other measures such as the use of portable dehumidification equipment. If the trend is downward, it allows the project to make schedule adjustments.

### K. Use of Topically Applied Vapor Emission Reduction Systems

Where all other measures are not possible or the schedule excludes many of these prevention methods, the use of topically applied vapor emission reduction systems has been shown to reduce vapor emissions to the 3 lb. threshold value or lower. The use of these systems does add appreciable costs to the project which can be avoided through the other measures discussed above.

Sodium silicate based vapor reduction products rely on the reaction of silicates with calcium hydroxide in the hydrated Portland cement paste to form calcium silicate to close off capillaries and hence reduce vapor emissions. These silicate based products do penetrate concrete quite deeply (up to ½” or so). However, this author’s experience has shown that the silicate based products are slow to react in older concrete and are not effective after a few months on new concrete. The moisture vapor emission rates drop initially, but rise again after a few months to a year.

The waterborne epoxy based vapor reduction products have shown more favorable results over 2 to 3 years of experience by this author.

## COATINGS MANUAL HRSD

### CORRECTIVE METHODS FOR EXISTING OSMOTIC BLISTERING PROBLEMS

Once osmotic blisters have formed in a resinous floor coating system, there are several corrective steps which need to be taken. They are as follows:

- A. The blisters should be examined relative to frequency, type of slab, location with respect to thermal gradient, and installation records (inspection reports), etc.
- B. Next, vapor emissions testing should be performed in the blistered floor coating area in accordance with ASTM F1869. Several tests should be performed both over the blistered areas and in adjacent non-blistered areas. The results will likely be over the 3 lb. threshold, but should be identified.
- C. If thermal gradient issues are discovered for elevated slabs, insulation and ventilation measures should be taken to reduce the temperature disparity across the slab. This should be verified by performing temperature and humidity measurement surveys on both sides of the slab. Once corrected, the blistered flooring should be removed and replaced when scheduling permits.
- D. If the blistering areas are found in slab on grade situations, it is unlikely that the problem can be corrected from the underside or positive side of the slab. As such, removal of the blistered coating areas should be followed by application of the topically applied vapor reduction system and reapplication of a similar floor coating system. Another option is to utilize a more permeable floor coating material such as a waterborne water permeable epoxy system that will permit the moisture vapor emissions to pass through it. Some notable work was reported on this rectification option in JPCL by Cook, Lohe, and Klippstein in 2002.<sup>7</sup>

When this work is done, vapor emissions testing must be performed to verify reduction of the moisture migration to at or below the 3 lb. threshold or to a level acceptable to the vapor emission reduction system manufacturer.

---

<sup>7</sup> M. Cook, M. Lohe, A. Klippstein, "Novel Technology for 2K Water Vapour Permeable Epoxy Floor Systems: A European Perspective", JPCL (February 2002), pp. 51-56.

# COATINGS MANUAL

## HRSD

### **SUMMARY**

Osmotic blistering type failures of resinous floor coatings is becoming more and more prevalent with fast track construction in all types of projects. Attention to simple preventative measures can help facility owners to avoid the costly problems associated with this growing type of floor coating failure. This article provides some straightforward and practical guidance on prevention and correction of this all too common floor coating problem.