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UNDERSTANDING CONCRETE MOISTURE ISSUES

MOISTURE CONTROL USING SPECIALIZED EPOXY ISOLATION COATING SYSTEMS

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In the early life of the concrete slab, water is present in abundance and must be retained during the initial curing period to produce high quality concrete. However, the concrete must give up most of its water during the subsequent drying period to become suitable for low permeability flooring. Flooring such as sheet vinyl, vinyl composition tile and polymer floor coatings are very dense and allow for little passage of concrete moisture. Wood flooring is very sensitive to moisture. When low permeability flooring is installed over concrete with unacceptably high moisture content, this moisture will migrate upward through the slab, dissolve alkalis inherently present in the concrete and transport this corrosive material to the concrete/flooring interface. The alkalinity will become concentrated and this moist, high pH environment at the flooring bond line and can cause failure. This failure may be evidenced by disbonding, adhesive breakdown, osmotic blisters, staining or microbial growth with the related reduction in indoor air quality. Concrete moisture is the number one cause of flooring failure and accounts for approximately $3 billion of loss annually. Liability exposure for moisture related flooring failures may extend to several members of the construction team, including the flooring contractor, general contractor, flooring and adhesive manufacturers and the project architect.

This paper will examine the following concrete moisture/flooring issues:

1. Reasons for the rise in moisture related flooring failures
2. Sources of concrete moisture and the drying process
3. Methods of moisture measurement
4. Moisture related failure in flooring adhesives
5. Moisture related failure in concrete coatings
6. Reactive silicates and coating failure
7. Moisture and ASR
8. Moisture control using specialized epoxy isolation coating systems

Reasons for the Rise in Moisture Related Flooring Failures

Those of us in the flooring and concrete coatings industry have witnessed a sharp increase in failures due to excessive concrete moisture over the last two decades. Industry experts have concluded that reasons for this increase may include:

A. <u>Changes In The Physical Composition Of Flooring And Adhesives</u> – Vinyl asbestos tile (VAT), the most commonly installed flooring from the 1930's to the 1960's has been replaced by vinyl composition tile (VCT) because of health concerns regarding asbestos. VCT has been shown to be less permeable than yesterday's VAT and more likely to trap moisture below the flooring. VAT had a fibrous nature and more joints that allowed for more moisture to pass.

   The chemical composition of adhesives has also changed. Today's adhesives are water-based and manufactured to comply with VOC regulations. Although there is disagreement about whether the newer VOC compliant adhesives are more moisture sensitive, most experienced flooring people agree that there seemed to be fewer moisture problems when the use of solvent-based asphaltic "cutback" adhesive was common.

B. <u>Fast Track Construction</u> – In every construction project there is pressure for early completion. "Time is money". The use of curing compounds that actually delay concrete drying is so prevalent in part because it allows construction activity on the concrete more quickly than wet curing or cover curing. **Concrete moisture conditions cannot be accurately assessed until the building is enclosed and the HVAC system operational.** It is not uncommon to see floor coatings or other low permeability flooring installed before the building is climatized and accurate moisture measurements can be taken. The pressure to meet the completion schedule combined with poor understanding of concrete moisture issues can lead to premature flooring installations resulting in moisture related failures.

C. Lack of Effective Vapor Retarder – In designing concrete to prevent damaging vapor emissions, the vapor retarder is the first line of defense. **With an effective vapor retarder in place, the concrete must still go through the initial drying process but once this has occurred, future moisture intrusion from sub-slab sources is not a factor.** However, there has been substantial resistance to the use of vapor retarders in the concrete industry. A misguided attempt to cut costs combined with a poor understanding of the critical role of the vapor retarder may lead to its elimination from the plans. The concrete contractor may lobby for the omission of the vapor retarder because it makes placing the concrete more difficult and may contribute to undesirable shrinkage cracking or curling. Even if a vapor retarder is specified, it must be strong enough to resist tearing during construction activities and be impermeable enough to block high levels of moisture vapor for the life of the slab.

   There has been a good deal of controversy in the concrete industry regarding the proper placement of the vapor retarder. Many concrete experts previously believed that if a vapor retarder was specified, it would be better to have an intervening layer of compacted granular material on top of the vapor retarder and directly under the concrete. The thinking was that this blotter layer would absorb some of the concrete bleedwater and reduce shrinkage cracking and curling. Moisture experts now believe that using this blotter layer under the slab is not advisable because it can become water saturated and contribute to future moisture problems. In 2001, ACI Committee 302 recommended that any slab which is to receive moisture sensitive flooring should have a vapor retarder placed directly under the slab with no intervening blotter layer. It is certain that many concrete slabs have been poured over the years using the earlier detail and the improper placement of the vapor barrier has contributed to the large number of moisture problems we see today.

D. Lack Of Moisture Testing Or The Use Of Poor Testing Methods – Many moisture failures have occurred because of the lack of understanding of the absolute necessity of conducting meaningful moisture testing prior to installation. This is especially true in the floor coating industry. Methods of testing for moisture in concrete are continually evolving. What was considered a good test at one point in time is exposed as misleading or meaningless when more scientific evidence becomes available. Many flooring failures have occurred as a result of a “false negative” from a moisture test that was inherently flawed. Also, many moisture tests are done without adhering to strict ASTM guidelines controlling the methodology of the test. Poor Methods → Bad Data → Poor Decisions → Flooring Failures.

Sources of Concrete Moisture and the Drying Process

Concrete is a mixture of fine and course aggregate, cement and water. After placement, concrete must both cure and dry. When the batch water is added to the dry components, a portion of the water chemically reacts with the cement particles and a process called hydration begins. Hydration produces the cement paste that adheres the aggregates together. The quality and strength of the cement paste depends upon the availability of moisture in the early stages of curing. Concrete is often kept wet for up to 7 days after initial placement to insure the best possible cure. During the curing process, a portion of the initial batch water is used up in hydration. It is chemically bound into the concrete and does not leave the slab.

The batch water not used up in hydration is present in the mix to facilitate placing by enhancing the workability of the concrete. It is called water of convenience or free water. The total amount of batch water added to the concrete is thought of in relationship to the amount of cement in the batch. The water/cement ratio (weight of water ÷ weight of cement) must be kept as low as possible. Concrete scientists have determined that ratios between 0.4 and 0.5 are optimal. Water of convenience makes up the largest portion of water that must leave the slab during the drying process. High water/cement ratios (more water of convenience) substantially increase the concrete dry time and the wait necessary for flooring installations. Other sources of water that must leave the slab during drying include water used to keep fresh concrete moist for curing, rainwater and construction water that may have inadvertently entered the slab. As concrete dries, its internal relative humidity drops. **Although concrete typically obtains 90% of its cured strength properties within 30 days of initial placement, the actual drying process takes much longer**. The internal relative humidity must be 75-85% for the successful installation of most flooring. The industry rule of thumb is that concrete must dry for one month for every inch of thickness to be ready for flooring, assuming normal drying conditions. Higher temperatures and lower humidity conditions above the slab reduce the dry time. Cooler, humid conditions extend the dry time. Concrete poured in very high humidity conditions will not dry sufficiently until the building HVAC system is operating to lower the humidity above the slab. Curing compounds, so commonly used today as an alternative to keeping the concrete surface physically wet during the initial curing period, will substantially lengthen the drying period. Long drying times may delay the construction schedule; necessitate the use of a moisture remediation system, or worse, result in flooring being placed over wet concrete that will be subject to failure.

It is worth noting that suspended slabs can also have moisture problems when poured into non-perforated steel pans. Concrete used for suspended slabs always has a high water/cement ratio to make it more liquid and easier to pump. Also, lightweight aggregate used in these mixes absorbs more water and releases it more slowly than conventional aggregate. The result may be much longer drying times.

The previous discussion of concrete drying does not factor in the possibility that the slab may be in direct contact with ground moisture. The only way to take ground moisture out of play is by using a properly placed vapor retarder. With a vapor retarder in place, the concrete will only have to give up the finite amount of moisture in the slab from the water of convenience, curing water and other sources of water mentioned earlier. The concrete will eventually be dry enough for the installation of low permeability flooring.

For slabs placed on-grade with no vapor retarder, everything changes with regard to moisture. Without a vapor retarder, the concrete is subject to moisture intrusion from sources below the slab. The soil, subgrade and subbase will maintain 100% humidity even under dry weather conditions and provide an infinite source of moisture that can move through the slab. Moisture moves through the concrete as liquid water or water vapor. High levels of water vapor can accumulate to the point of saturation and condense into liquid water. Capillary action can draw liquid water through the fine soil and into the concrete. Capillary breaks of crushed stone are placed below the slab to stop the capillary rise of liquid water but they will not stop the free movement of moisture vapor. The availability of moisture vapor from below the slab is not influenced by the depth of the water table. Other sources of moisture that can find their way under the slab and eventually move upward through the concrete include rainfall, broken pipes, landscape irrigation, snow banking or runoff from inadequately designed gutters and downspouts. Although rare, if the slab is below the water table, hydrostatic pressure can play a role in moisture failure.

The amount of moisture that moves through a slab on-grade without a vapor retarder is determined not only by the extent of moisture available, but by the concrete's pore structure. Here again, water/cement ratio plays a major role. **High water/cement ratios create more porous and permeable concrete**. As the water of convenience leaves the cement paste, it creates capillary pores. The more water that leaves, the more pores are created and the greater the likelihood that the pores will be interconnected. A continuous pore system from the bottom of the slab to the top will serve as an avenue of transport for liquid water or water vapor to move through the slab. Conversely, in low water/cement ratio concrete, the interior pores are more likely to be discontinuous and isolated from the surface making it more difficult for moisture to travel to the concrete/flooring interface. Overly porous slabs poured without a vapor retarder and having a continuous source of moisture from below will never dry enough for the installation of low permeability flooring.

Methods of Moisture Measurement

There are several methods of moisture detection that were used when the science of concrete moisture testing was in its infancy and are now considered unreliable. The plastic sheet test involves taping a piece of polyethylene sheeting to the concrete for 16-24 hours and then examining the area under the sheet for moisture. In the mat bond test, a three foot square section of the actual specified flooring is glued to the floor using the manufacturer's recommended adhesive and the edges of the flooring are taped to the concrete. After 72 hours the flooring is pulled up and the adhesive is examined. Both of these tests are very subjective and considered to be inherently flawed for various reasons.

Electronic instruments used for moisture detection include the electrical resistance meter and the electrical impedance meter. The resistance meter uses sensing pins placed in contact with the concrete. They were originally developed to measure the moisture content of wood and are not considered an accurate method of measuring concrete moisture. The impedance meter measures comparative moisture across a floor up to two inches deep. Although impedance meters are not considered as valid, stand-alone concrete moisture tests, they can be useful in selecting locations for industry approved tests or in surveying a floor with a known moisture problem.

The two tests currently accepted by the flooring industry for measuring moisture in concrete are the calcium chloride test and the relative humidity probe test. In the United States the calcium chloride test is the most commonly used and is governed by ASTM F-1869. It was first developed by the Rubber Manufacturer's Association in the early 1960's. In this test, the concrete is cleaned by light grinding. After a wait of 24 hours, a dish of anhydrous calcium chloride is pre-weighed and placed on the cleaned concrete. The dish is covered with a plastic dome and sealed to the floor. After 60-72 hours, the dome is removed, the dish reweighed and the weight gain is calculated. Calcium chloride is a desiccant and absorbs moisture from the concrete, increasing the weight of calcium chloride in the dish. Through a special calculation, the weight gain is expressed in pounds of moisture emitted from 1,000 sq. ft. in a 24 hour period. Safe levels of moisture vary from 3-5 pounds depending upon the flooring manufacturer's recommendation.

For calcium chloride tests to give meaningful results, the building must be climatized to the anticipated service conditions for 48 hours prior to testing. This means the windows and doors in place with the HVAC operating. If the test is done in an "open air" setting, the results may be lower than if the heating or air conditioning is operational because without the HVAC, a relative state of equilibrium exists with the concrete moisture and the environment above the slab. When the building becomes climatized, warmer, drier air on top of the slab draws moisture out of the slab and higher test readings may result.

Another reason for the necessity of climatizing the building is that calcium chloride test results are significantly affected by ambient humidity and temperature above the slab. If the flooring temperature is higher than anticipated service conditions, the test results will be higher. Conversely, if the floor is colder, the test reading will be lower. High humidity above the slab will produce an artificially high test result. This is because concrete absorbs moisture from the environment as well as transmits it.

Although calcium chloride testing has been the accepted standard for moisture testing in the United States, we are beginning to understand its limitations. It had always been believed that the test measured the dynamic of moisture vapor moving through the slab. However, scientific evidence has shown that the test actually measures static moisture in the top ½ - 1 inch of the concrete and does not detect moisture deep in the slab. With this in mind, a high calcium chloride reading from a properly conducted test would be a good indication that the moisture level at the top of the slab is too high for moisture sensitive flooring. **However, a low reading may only indicate that the upper portion of the concrete is dry enough to receive flooring, but moisture deeper within the slab has not been measured and may be at unacceptably high levels just waiting to rise to the top of the slab.** The analogy of a loaded cannon could be used. Once low permeability flooring is installed, the total moisture within the slab redistributes itself to reach equilibrium and **the upper portion of the concrete will become wetter.**

This information helps explain the occurrences of false negatives observed from properly executed calcium chloride tests that resulted in unanticipated and discouraging moisture failures.

In several European countries, the preferred method of measuring moisture in concrete is the relative humidity probe. This method of moisture testing was developed in the 1980's and is governed by ASTM 2170. In this test, holes are drilled into the concrete at specified depths and fitted liners are inserted to the bottom of the hole. The liners are capped and allowed to equilibrate for 72 hours before inserting the probe and taking the relative humidity reading. **If this reading is taken at close to mid-slab depth, it will be representative of the level of moisture that the flooring will be exposed to after the slab is covered and a new equilibrium reached**. Acceptable levels of relative humidity within the slab range from 75-85% depending upon the flooring installed.

Because the relative humidity probe testing is done on the interior of the concrete, it is much less susceptible to atmospheric conditions above the slab that can skew the results of a calcium chloride test. For this reason, it is more useful in determining moisture levels in non-climatized areas. **It has been firmly established that the calcium chloride test and relative humidity probe test measure different aspects of concrete moisture. Data from both tests should be used to accurately assess concrete moisture conditions.**

In conjunction with moisture testing, conducting pH testing on the concrete is also sometimes done. This testing is always very subjective and the results are often misleading or meaningless. To effectively measure concrete alkalinity, the surface must be abraded to break through the carbonated layer that always shows a low pH. Once into the concrete interior, pH readings will be lower than after the final flooring is installed. If abundant moisture is available in the concrete, once low permeability floor is installed, moisture will migrate upward, increasing the alkalinity at the concrete/flooring interface.

An important caveat with all moisture testing is that the tests give only a snapshot of conditions at the time of the test. If an effective vapor retarder is in place, it is likely that the moisture levels will not rise substantially in the future. If there is no vapor retarder, future concrete moisture conditions are much more difficult to predict, and **flooring not protected by a surface-applied moisture barrier is subject to possible future moisture problems.**

From the above discussion, it is easy to conclude that concrete moisture testing involves many variables and requires a good deal of expertise. Specialized moisture test companies are available throughout the country. We recommend that these professional companies be used.

Moisture Related Failure in Flooring Adhesives

Concrete is a naturally alkaline material. Soluble sodium, potassium and calcium hydroxides are abundantly available in all concrete. Liquid water or water vapor that condenses into liquid water will dissolve these alkalis and transport them to the upper regions of the concrete. Moisture in concrete moves primarily from the high humidity environment deeper in the slab to the drier building environment above the slab.

Moisture movement begins early in the concrete drying process as the free batch water evaporates from the freshly placed slab, and slows as the moisture reaches a state of equilibrium with the environment above the slab. When the building is enclosed and the HVAC system is turned on, moisture movement is accelerated as the moisture is driven toward the drier environment created by the HVAC. Finally, when low permeability flooring is installed, moisture within the slab redistributes itself again to reach a new state of equilibrium. Moisture from deeper in the slab moves upward carrying soluble alkalinity to the upper regions of the concrete. **If moisture levels in the concrete are excessively high and the concrete has a well developed and continuous pore system, the result is the creation of a moist, highly alkaline environment at the concrete/flooring interface.**

Most flooring adhesives today are water-based and have good moisture resistance when properly cured. However, if the concrete has a severe moisture problem and becomes saturated with liquid water before the adhesive dries, the adhesive will stay wet and uncured. This mode of failure is relatively rare. **By far the most common reason for adhesive failure is the exposure of the adhesive to the combination of moisture and corrosive alkalinity found in concretes with high levels of water/vapor transmission.**

Moisture Related Failure in Concrete Coatings

Moisture related failures in concrete coatings can happen if the concrete becomes water saturated before the coating can properly bond or if the coating does not have enough adhesion strength or resistance properties to succeed when exposed to continuous water and/or alkalinity.

Amine cured epoxies are generally known to be the best family of coatings for adhesion to concrete. They have excellent long-term resistance to both water and high levels of alkalinity. Yet epoxy materials can still blister and disbond from concrete with severe moisture problems. Assuming that the epoxy was initially well bonded and properly cured, a mechanism called osmosis is usually involved in moisture related epoxy flooring failures. Osmosis is defined as the diffusion of a pure liquid through a semi-permeable membrane into a more concentrated solution on the other side of the membrane. For osmosis to occur, the following conditions must be present:

1. a dense, well adhered coating
2. a semi-permeable membrane
3. water-soluble alkalinity in the concrete
4. the presence of moisture as water

The osmotic process is thought of as two distinct cells, a top cell and a bottom cell separated by the concrete, a semi-permeable membrane. The upper cell contains highly concentrated water soluble alkalinity that was transported by earlier moisture movement through the slab or by topically applied alkaline curing compounds or densifiers. The bottom cell is the lower region of the slab that contains relatively pure, non-alkaline water being drawn up from deeper regions of the concrete. **The primary force in osmosis is nature's drive to equalize the concentrations of materials on both sides of the membrane. In our case, pure water is pulled into the highly concentrated alkaline upper area in an effort to lower the concentration**.

As water is drawn into the upper regions of the concrete by osmosis, pressure filled blisters are formed in the coating. Exactly why the blisters are formed is not known for certain. Concrete scientists do not believe that the blister formation is the simple result of the osmotic process generating enough pressure to separate the coating from the substrate. **This would take pressures greater than 300-400 psi and there seems to be no mechanism at work that could create these kinds of pressures**. There are three other proposed explanations for the blister formation. One theory is that the aggressive alkaline environment present at the bond line damages the concrete at the concrete/coating interface. The degraded concrete slowly becomes an unsound substrate and releases the epoxy which was previously well bonded when the substrate was sound. Most experts, however, doubt that the concrete itself can be damaged by the alkaline environment because concrete itself is highly alkaline in nature.

The second possibility is that water soluble or unreacted material could migrate out of the cured epoxy after prolonged exposure to the moist, highly alkaline environment at the bond line. This fugitive material may serve to increase the concentration of the solution in the top cell and increase the rate of osmosis. As the fugitive materials leave the coating, the bond to the concrete is substantially weakened. Once the bond has been weakened, it takes much less pressure to form the blister. **A blister is a type of bond failure.** This theory of blister formation is bolstered by the fact that when the fluid inside the blister is analyzed, organic materials that could only have come out of the epoxy such as amines, phenols or plasticizers are sometimes found.

Reactive Silicates and Coating Failure

The third possible scenario for osmotic blister formation involves concrete treated with reactive silicate materials. Reactive silicates are used in the concrete industry for concrete curing and densifying. The silicates are soluablized in an alkaline solution of sodium, potassium or lithium and water. These materials penetrate into the concrete and react with calcium hydroxide to form calcium silicate hydrate, the desirable reaction product of the concrete hydration process. When the silicate materials are used properly and in the right amounts, they improve the quality of the concrete. **However, if these materials are over-applied and can find no calcium hydroxide to react with, they will remain unreacted as a water-soluble, unstable bond breaker in the pores of the concrete**. Excess concrete moisture can resolubilize the unreacted silicate and trigger coating adhesion failure. Even well-formulated 100% solids epoxies applied over well profiled concrete will lose adhesion and form blisters when applied over severely silicate contaminated concrete. **Silicates can penetrate as deep as 1/8 – ¼ inch into the concrete and normal shot blasting will not always remove them.** In addition, over-application of these materials can add to the concentration of alkalis in the upper regions of the concrete and contribute to osmosis.

Concrete Moisture and ASR

Alkali silica reaction (ASR) is a destructive mechanism that can occur in concrete that is also related to moisture. Certain aggregates that may find their way into concrete mixes can react with alkalis present in the concrete. This reaction needs sufficient concrete moisture to occur. The ASR reaction creates a gel that expands as it draws available water out of the concrete paste. As the gel swells, it creates pressure, expansion and cracking of the surrounding concrete which is reflected in the finished flooring. It was previously thought that ASR only occurred deeper in the slab where the larger aggregate is found. We are now finding ASR much nearer the top surface of the concrete with the smaller aggregate being involved. This has been termed NSAR (near-surface alkali reaction). Generally, if concrete stays below 80% relative humidity, ASR will not occur. Often, ASR does not evidence itself until the installation of low permeability flooring draws moisture to the upper regions of the concrete, increasing the relative humidity. Concrete with ASR is very difficult to remediate.

MOISTURE CONTROL USING SPECIALIZED EPOXY ISOLATION COATING SYSTEMS

The purpose of surface-applied moisture control coatings is to keep moisture and related corrosive alkalinity isolated from moisture sensitive flooring. **Moisture control coating systems are used when the concrete has a known moisture problem, when the concrete is drying too slowly to allow application of moisture sensitive flooring and the construction schedule must be met, and as a preventative measure when the concrete has no vapor retarder in place and future concrete moisture conditions cannot be predicted.**

As a family of coatings, amine-cured epoxies are inherently well suited for moisture control applications because they achieve very high bond strengths to clean, profiled concrete and have excellent water and alkalinity resistance. However, as previously discussed in our analysis of osmotic blisters, not all epoxy formulations are successful over concrete with moisture issues. While properly formulated 100% solids epoxies bond permanently to normal, uncontaminated concrete, they are more prone to adhesion failure when applied to concrete previously treated with excessive amounts of silicate based densifiers or curing compounds. Concrete cores taken from concrete coated with failed 100% solids remediation epoxy and subject to ion chromatography analysis often show silicate contamination at the concrete/coating interface.

Arizona Polymer Flooring has developed two special epoxies for solving concrete moisture problems. The first is EMS 100, a low viscosity 100% solids material for use over concrete where no silicate materials have been previously applied. The second is EMS-P, a water-based epoxy primer for use over concrete where silicates have been applied or the concrete history cannot be positively determined. Both products use highly specific resin engineering to achieve long term success in moist, highly alkaline environments. These materials are used in the two EMS (Epoxy Moisture Stop) remediation systems described below:

EMS Remediation System #1

EMS Remediation System #1 is a one coat application of EMS 100 over concrete where reactive silicates have not been previously applied. The application rate is 100 sq. ft. per gallon to yield a dry film thickness of 16 mils. The single coat application improves the economics and saves a trip to the jobsite in fast-track construction projects.

EMS Remediation System #2

EMS Remediation System #2 uses a unique water-based epoxy primer, EMS-P over the concrete and finishes with EMS 100 to give a two coat system. Both materials are applied at 200 sq. ft. per gallon to yield a dry film thickness of 11.44 mils. **System #2 must be used if reactive silicates have been previously applied to the concrete or if the history of the concrete cannot be positively determined. The use of EMS-P is guaranteed to eliminate adhesion failures due to silicate contamination.**

EMS 100 is a modified Bisphenol F epoxy crosslinked with special hydrophobic amines. The ability of this resin system to displace moisture on the substrate allows it to bond and cure completely on damp or wet concrete. EMS 100 can be applied underwater.

EMS-P is a water-soluble amine crosslinked with Bisphenol F Epoxy. The amine curing agent used in EMS-P has an outstanding track record as a primer over damp, wet and green concrete of more than 30 years. It will achieve superior adhesion compared to 100% solids epoxies when applied to silicate contaminated concrete. Why is EMS-P the preferred primer in these adverse conditions?

The first reason is the differing chemical nature of the 100% solids epoxy primer and the water-based epoxy primer. A properly formulated 100% solids epoxy primer is hydrophobic (doesn't like water). Its mechanism for adhesion to damp or wet concrete is to displace water on the substrate. A water-based epoxy uses special emulsifiers and surfactants to become hydrophilic (water loving). **This hydrophilic nature gives it more affinity for the concrete paste which is also very hydrophilic. This increased compatibility with the substrate results in improved adhesion in adverse conditions**.

Another special feature of the primer that contributes to its superior adhesion qualities is extremely low application viscosity (25 cps) that improves substrate penetration. Testing conducted by an independent laboratory measured the depth of penetration of EMS-P and a low viscosity (250 cps) 100% solids epoxy designed for use over moist concrete. The substrate was cleaned and given a 10 mil profile (texture similar to 120 grit sandpaper). Both materials were applied in a single coat at the rate of 150-200 sq. ft./gallon. After a 7 day cure, cores were taken and sent to the lab for analysis. Using a special method to examine the depth of penetration into the concrete pores, **the results showed that the EMS-P had penetrated 25-30% deeper into the concrete than the 100% solids material**. This deeper penetration gives the primer more surface area to attach itself and increases the possibility that it may actually penetrate past the surface contaminants, find healthy concrete deeper in the slab and gain adhesion there.

EMS 100 and EMS-P have certain elements in common that make them especially well suited for use in moisture remediation systems. Both incorporate effective surface tension reduction additives to improve substrate wetting and adhesion. Both utilize a silane adhesion promoter to provide an additional adhesion mechanism to further increase the bond strength.

Both EMS 100 and EMS-P are highly crosslinked to insure long-term moisture and alkalinity resistance. Both coatings are based on Bisphenol F epoxy resin rather than the standard Bisphenol A material. **Bisphenol F resin contains more crosslinking sites and produces denser coating films with superior resistance properties**. This extra crosslinking also contributes to the low permeability nature of the coating system. ASTM E-96 testing showed very similar results for both systems when tested for water vapor transmission rate and water vapor permeance. Our uncoated control for the testing showed a very high vapor transmission rate of 19.10 pounds/24 hours/1000 sq. ft. Remediation System #1 reduced the transmission rate to 1.06 pounds and Remediation System #2 reduced the transmission rate to 0.28 pounds, an average reduction of 95%. Perm ratings averaged 0.69.

The EMS coatings are formulated with perfect stoichiometry and without water-soluble, non-reactive components that could migrate out of the cured material exposed to continuously wet, highly alkaline concrete at the bond line. Epoxy resins and amine curing agents each have a definite number of crosslinking sites for a given weight of the material. The weight ratio of epoxy to amine that reacts all of the available sites without leaving an excess of either component unreacted is called perfect stoichiometry. If a coating is formulated with perfect stoichiometry, there will be no epoxy or amine left unreacted and not linked into the polymer network. This guarantees that there will be no epoxy or amine free to migrate from the coating after cure that could trigger a bond failure.

The Epoxy Moisture Stop system has been designed to mitigate all moisture problems regardless of severity. It is important to use the "best" system in all circumstances because results from moisture tests may not be accurate and the condition may be worse than the testing indicated. Also, as we have seen, if there is no effective vapor retarder in place, future moisture conditions within the slab may worsen after remediation.

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Dean Owen is the founder and technical director of Arizona Polymer Flooring which has been formulating and manufacturing specialized coatings for concrete since 1985.