



MOISTURE ISSUES IN CONCRETE FLOORS

A Guide for Moisture Issues in Concrete Floors and Their Relation to Floor Toppings

8329 Monticello Road, Shawnee, KS 66227 ♦ Tel: (913) 422-4443 ♦ Fax: (913) 422-8882
Website: www.murraydecorative.com ♦ Email: info@murraydecorative.com

This is a guideline of issues causes, remedies, concrete, installations, curing sealing, and toppings, decorative overlayment are also at risk because of their low permeability they also require “bond or primer” coats thus sealing the concrete surface.

Decorative Concrete toppings and repair products can be used effectively and give new looks and provide long lasting low maintenance flooring systems. Always follow the technical installation methods for each system installed and provide proper concrete surface profiles. Although one if not the most effective systems used care needs to be taken in installing decorative systems. How we respond to the moisture issues today will allow for continued successful use of these materials.

Construction of modern buildings would not be possible today without concrete floors. From warehouses, restaurants, schools, hospitals, and almost 100% of industrial and commercial buildings all pick concrete. Most provide useful floors and structures without problems while providing a long service life for owners.

If a concrete floor is allowed to remain relatively dry while in use many problems can be avoided. Concrete needs water in order to begin the hydration process; however unwanted moisture in concrete floors causes millions of dollars of damage and lost time each year to owners of concrete floors.

THE PROBLEM

Moisture problems have increased for a number of reasons:

- ♦ Curing and sealing of concrete; September of 1999 new VOC laws changed both formats and application methods and more than ten years later most do not understand the methods.
- ♦ Fast track construction also really began over the past 20 years. “Time is of the essence” is written in contract documents which put everyone under a certain time frame and general contractors in a bad mood.
- ♦ Lightweight aggregates and aggregates that absorb moisture are being used.
- ♦ Tighter time frames of building construction.
- ♦ EPA restrictions on land results in some buildings being built on marginal land.
- ♦ Changes in concrete mix designs including the use of both slag and fly-ash results in slower cure times. Set retardants and admixtures also have contributed to these issues.
- ♦ Failure of tradesmen to stay abreast of new emerging trends.

The previous has also contributed to moisture vapor transmission problems.

Moisture Vapor Transmission (MVT):

MVT is a natural migration of gaseous water from a high moisture source to an environment with a much lower concentration of moisture. An example of MVT is the relationship between the subgrade soil and grading materials and the concrete slab directly above it.

Many times water migrates into the concrete from the material beneath it in a gaseous or liquid state. The moisture then migrates to the top surface of the concrete. The migration takes place in the natural capillary pores within the concrete slab.

If the concrete slab is sealed with an impervious flooring system, the moisture vapor cannot pass through the floor. As the internal pressure increases, the flooring system or the adhesive may lose bond which results in flooring failures.

Just a simple understanding of the general physics MVT can go a long way in understanding the issues involved. When the humidity in the concrete is higher than the humidity in the air above, the water vapor begins to migrate to the concrete surface as a gas. If a flooring system has an impervious coating that prevents the moisture to pass failures can occur.

Note: 2-3 lb of pressure is not enough to cause failures in a well bonded floor. Larger amounts of pressure, however, can cause serious damage to floor coatings. This can present failures from minor trip hazards to costly repairs (which may also fail,) or worse yet, lawsuits. There are products now available that, when properly applied, will allow coatings to be applied when the MVT pressure is 12-15 lb. Each job should be evaluated when these conditions exist before application of coatings.

Pre-job conferences are important to discuss such issues (when moisture becomes an issue no job is too small). ASCC offers an excellent check list for meetings.

The following outline will address these issues:

- Damage caused by excess moisture.
- Discoloration of both floors and coatings giving an unacceptable appearance.
- Delaminating of floor coverings and coatings.
- Growth of microbes that can lead to poor indoor air, odors, and even some allergic reactions.
- Deterioration of wall coatings and mold reactions inside the walls.
- Corrosion of items embedded in the concrete or attached to the concrete.
- Damage to items stored on the concrete.
- Safety issues such as slipping.
- Issues that lead to MVT problems.
- Subgrade soil.
- Soils that did drain before construction that become compacted and do not drain.
- Subbase.
- Capillary breaks.
- Vapor retarders.

- Cleaning compounds.
- Cures and sealers.
- Primers and adhesives.
- Excessive cleaning with water.
- Putting the concrete into service too soon.

CONCRETE

Concrete is what usually gets blamed for failures and it is concrete finishers who place, finish and cure the concrete. It is important to take a closer look at what happens with the concrete, how the problems might be avoided, and what finishers should look for, do and know. Not only should the concrete finishers be aware of these issues but the flooring trades and decorative concrete overlay installers also must be up to date on issues that may affect their materials and workmanship.

Concrete finishers should be able to successfully pour, finish and cure concrete slabs, as well as, have a basic understanding of concrete, its properties and field testing methods. A successful heart surgeon must not only be skilled with tools to perform the operation but must also understand how the heart works.

Concrete is the most widely used building product today yet how it works and “gets hard” is many times misunderstood. Concrete is a mixture of a fine aggregate (usually sand), coarse aggregate (usually crushed rock or natural stones), cement and water:

- ♦ 11% cement
- ♦ 16% water
- ♦ 6% air
- ♦ 26% sand
- ♦ 41% coarse aggregate

The cement is the binder for the concrete is made from a combination of materials. These materials include limestone, shale, clay and iron ore. They are ground and heated in a kiln at approximately 3000° F. In the heating process, these natural materials are made into calcium silicates and aluminates. A mixture of about 5% gypsum is then added and reground to form the powder like substance we call cement. When batched and mixed with water and the aggregates, the material then becomes the product we can concrete. The mix we call concrete does not get hard by drying but curing that takes place through a series of chemical reactions with the mixing water called hydration.

Today’s concrete mixes may also contain several supplementary cementitious materials (SCM’s). These materials can be either natural minerals or industrial byproducts. They may also contain admixtures for air-entraining, water reducing, and set control.

Concrete is poured and placed with several natural materials. Water occupies a certain volume of the concrete mix design ranging anywhere from 8-20%. This volume will leave the concrete as the hydration process begins quickly at first and then slower over time. This is where many problems can occur. People begin to think just because it is hard enough to walk on or even drive on, people can therefore do anything to it. The fact is that this just is not true.

Although hydration begins when the cement and water make contact, it takes weeks and even years for the concrete to fully reach its final strength. An old saying is “when it dries it dies” simply put, concrete keeps gaining strength until all the water is gone.

Over the years, the use of materials such as fly-ash and slag-cement slow early set and hold the hydration water in for longer periods of time. Simply put the finishing time might be about the same but days have been added to the so called 28-day curing time frame.

The use of better grading of coarse and fine aggregates in mixes today have been good for placing and finishing but the better grading also holds the hydration water for longer time. Some mixes contain smaller coarse aggregates which require higher water/cement ratios.

Knowing these things enables both finishers and overlay installers to finish and install materials and concrete with a greater understanding of the set times and components of concrete.

Putting the concrete into service too soon causes many issues as well. How many times have we seen a floor poured one day and the next day arrive on the job to find?

- ◆ Scissor lifts with workers on the floor.
- ◆ Job boxes, ladders or other equipment being stored on the slab.
- ◆ Masonry, pallets of brick or block, concrete mixers, etc. being stored on the slab.
- ◆ A form of acid cleaner used to wash finished walls dripping on fresh concrete slabs.
- ◆ The new slab being used as a cleaning area or a water source or the use of power-washers on the concrete before the concrete is 28 days old. This can raise water/cement ratios at the surface of the concrete and force water into the concrete during early strength development. This can also affect the aggregate-to-paste bond needed for a durable concrete slab.

Water-cement ratios are key to a modern concrete mix design. Lower water-cement ratios result in:

- ◆ A better product.
- ◆ Fewer cracks.
- ◆ Less curling.
- ◆ Lower permeability.
- ◆ Tighter capillary structure in the concrete

- ◆ Less issues on coatings

Many issues today can also be traced to new finishing methods and the fact that cement is ground finer resulting in tighter floors. The demand for fast turn around and early entry for buildings has also caused issues.

Power trowels are now “ride on types” and weigh much more than the walk behind machines of the 1970’s and 1980’s. As little as 15 years ago, most floors were finished with walk behind machines that weigh between 150-180 lb. New ride on machines approach weights of 2500 lb. The finish with these types of machines results in much “tighter” floor surface and helps hold more water for a longer time.

There are many other instances that cause moisture issues in concrete. Saw cuts allow for water entry into concrete floors either from rain or water sources during the construction process. Vapor barriers beneath the concrete force water to find a way out or evaporate. VOC laws have changed over the last 10 years and have resulted in confusion with both adhesives and curing compounds.

Both curing and curing materials have changed greatly over the past decade. Understanding the materials, intended use of the concrete, coverage rates and application methods is very important.

In the concrete industry, when there is more water than necessary for the hydration process to take place it is called “water of convince”. The hydration process can begin with water -cement ratios of around 0.27 but the concrete cannot be placed efficiently or economically at that ratio. Concrete dries from the top during placement and then internally over time. The time frame for the concrete to properly complete the hydration process and for the construction timeline to continue on schedule often conflicts with one another.

During the past few years, installing a vapor barrier has become a part of concrete floor installation procedures. Many problems have arisen from this. Vapor barriers provide a service in that they do not allow for ground water transmission, the concrete floor to stay dry, protect coatings and stored materials and thus some of the “sweating” seen on older floors is eliminated.

When poured, concrete has an internal relative humidity of 100% top to bottom. As the slab dries it does so from top to the bottom. When an impermeable coating is applied the drying stops and humidity levels can once again reach 100% and result in failures. To avoid issues the internal moisture should be checked before coating are applied.

Following both ACI Hot and Cold weather placement methods can help avoid issues. Protection of fresh concrete in less than ideal conditions is vital for its success.

In hot weather, one might assume that hydration water is gone quickly while in many cases this may be true, more water might be added to the mix during placement, and

many times during hot weather there is high humidity, and heavy rain storms which may affect the subgrade.

Temperature has one of the greatest effects on set and cure times of concrete. Cold weather results in a longer cure time. Provide a sub-grade that is within 25-30° F of the concrete temperature and never pour on frozen ground or snow/frost. In cold temperatures set time is delayed and finishing time slowed. It is sometimes a bad practice of finishers to begin finishing too soon and trap bleed water just below the paste.

Both hot and cold weather can affect the concrete surface and decorative overlay. Installers should ask when the concrete placed. With today's use of the internet it is relatively easy to find weather conditions during placement.

References:

- ♦ *ACI 305*
- ♦ *ACI 306*
- ♦ *ACI 308 2.4.2.3 Liquid membrane-forming compounds*
- ♦ *ASTM C09*
- ♦ *ASTM C 156*
- ♦ *ASTM C 309 (Sodium silicate solutions are chemically reactive rather than membrane-forming and they do not meet the requirements of ASTM C 309 specification.)*
- ♦ *ASTM C 1315*

HOW TO TEST FOR MOISTURE

There are 3 common tests:

- ♦ **ASTM F 1839**
This test measures the (moisture vapor emission rate) “MVER”. It is done with a kit and a small amount of calcium chloride that is placed in a plastic dome and sealed for 60-72 hours. The calcium chloride then absorbs the moisture leaving the concrete slab. The MVER is translated to test the pounds of water leaving the slab in a 24 hour time frame. Rates for most floor coverings are 3-5 lb.

A 20x20” area is needed for the test. The area must be properly cleaned. The International Concrete Repair Institute (ICRI) requires a light sanding of the area, then vacuum and wipe clean. The area should be exposed to the conditions that it will see in the building when it is put into service. This includes:

- Fans
- Air conditioners
- Heat

- Lights
- Normal operating temperature

Although this is the most widely used test, there are some concerns:

- It only measures the moisture in the top ½” of the slab.
- Curing compounds and how the floor was troweled will affect the test.
- How carefully the test concrete area was prepared.
- Ambient temperature and humidity.
- The test also requires that the vapor barrier is properly installed.

- ◆ **ASTM F 2170: INTERNAL SLAB RELATIVE HUMIDITY**

This is considered to be the most accurate test for testing moisture throughout the slab. It requires three tests to be done for the first 1000 square feet and one more for each additional 1000 square feet.

A hole is drilled (dry drilling only) and completely cleaned of any dust. A small sleeve is inserted to the bottom of the concrete slab and left for 72 hours. A probe is inserted and the humidity at the bottom of the slab is recorded. The results can be used to see if the floor covering can be safely installed.

Note: All surface preparation must be done dry.

- ◆ **ASTM F 710: PH TESTING**

High PH levels at the concrete surface can result in failures of adhesives and coatings. New concrete has PH levels of about 12.5. As the hydration process continues, these levels will drop to around 7.5-8.5. This PH reading is about 1/8” deep and can be changed by surface preparation methods. When aggressive methods are used the PH should be checked after the preparation and not before. For most installations levels of 7-10 will be fine.

PH testing should be done at each place a moisture test is done. When testing PH levels the area should be sanded and cleaned.

Before installation of coatings begins, floors must also be properly prepared. This can be done with liquid cleaning (which may require large amounts of water) or by mechanical means (several of these methods, especially the older methods, also require the use of water). New dust free methods now greatly reduce clean up by water cleaning.

ICRI Guideline #03732 gives a surface preparation instruction on what profiles should be done for almost any floor coating containing both polymers and epoxies. This includes an inspection of the concrete for both soundness and MVP before work begins. The guideline uses nine different profiles for coatings and preparation. Methods range from coating of a sealer, polymer

overlay, detergent scrubbing and milling. In most cases, the concrete will be the weakest link in the overlay process and requires that both moisture tests and surface preparation be done correctly to provide for successful overlays.

Note: ICRI will begin offering a certification program that will involve both written and performance tests.

References:

- *Guide #03741 – Guide for Design, Installation and Maintenance of Protective Polymer Flooring Systems for Concrete.*

CONCRETE CURING

Freshly placed concrete must be protected from rapid moisture loss for the surface to be strong and durable. Lack of proper curing will result in a surface loss of the desired strength as great as half the desired strength. For example, 4000 psi concrete with no curing or lack of curing can result in strength of 2000-2800 psi at the surface.

Tests have shown that when the internal relative humidity of concrete drops below 80%, hydration comes to almost a complete stop. This is why curing and holding in hydration water as long as possible is so important.

Concrete finishers should always check curing compounds for compatibility with any floor coatings and adhesives that might be applied at later dates. Pre-job conferences and meetings should address all curing issues. See NRMCA and ASCC checklist for the Concrete Pre-Construction Conference, Section 20.

Curing compounds should be used according to the manufacturer's specifications and applied according to the proper coverage rates. Use of compounds containing fugitive/dyes can aid in helping provide a "look" to check for even coverage. Their use can also be helpful in reflecting heat in hot weather. Application is best done by spraying. If manual methods are used, a spray and back-roll method is best when using a wide short nap solvent resistant roller.

Curing compounds have pros and cons. Holding in the hydration water for an extended period of time will result in a harder, durable and more abrasion resistant floor, however, it extends the drying time. Some compounds may affect future floor coatings (all coatings and cures should be addressed before construction begins). The use of sheet plastic or curing papers is being used in place of membrane curing compounds. These materials offer effective curing, but unless special non-wrinkling paper is used will create a blotchy appearance on the concrete where sheets are in complete contact with the slab. When admixtures like calcium chloride are used the floors can become much darker. Issues may also arise with use of sheeting since the material can be a slip hazard. It is often removed too soon and torn easily. When curing is done with this method, follow ASTM C 171 specifications. Water or wet cure methods should be pre-planned and completely addressed before construction begins. Joints and water confinement can be

an issue with this method. When the use of water for cure is specified, ACI 308 states it should be within 20° F (this is now under consideration for changes).

DRYING OF CONCRETE

The role of water in concrete has been previously addressed. In a normal yard of concrete, there will be around 275 lb of water. About half of the water used in the hydration process must evaporate in order for the humidity in the concrete to drop below 100%.

Note: This does not address issues with wet curing which can raise the concrete moisture another 7% in most cases. This means that several extra pounds of water must leave each square foot of concrete.

Several other factors can affect the dry time and moisture content:

- ♦ Type of cement.
- ♦ Type of aggregates.
- ♦ Water-cement ratio (higher water-cement ratios will affect the capillarity structure of concrete allowing for easier vapor transmissions).
- ♦ The curing used and the weather the concrete is exposed to.
- ♦ Thickness of the slab.
- ♦ Extended rains, wet and cool periods during construction.
- ♦ Landscaping water systems that are too close to the concrete and along un-waterproofed walls and slabs (should thickened slab be waterproofed? Or at the very least sealed?).
- ♦ Unclean gutters and poorly placed downspouts.
- ♦ Excessive cleaning with water both before and after service (excessive use can allow water into joints and cracks creating a reservoir for water to pond in).

VAPOR RETARDERS/VAPOR BARRIERS

Vapor Retarders:

Vapor retarders are materials used under concrete floors to restrict moisture flow while restricting growths of mold and mildew. These materials are 6-10 mil polyethylene that needs to be overlapped at least 6” at the seams.

Care needs to be taken when installing vapor retarders around plumbing and electrical outlets. Many times, contractors have failed to properly seal and cut around these pipes or conduits.

Puncture holes and tears must be repaired before concrete is placed.

Sub-grades should be even and have uniform bearing capacity (be aware that thickened slabs will dry slower in most cases). Most thickened slabs also support walls and may, in

many cases, have pipes extending out of the slab. It has been poor construction practice to not take as much care as needed along these thickened slabs.

Understanding Vapor Retarders:

Vapor retarders should be placed. Floor coatings should be able to comply with the concrete and its curing time. There are specifications for vapor retarders (see ASTM D 1745 or ASTM D 4397).

The following table outlines a classification of vapor retarders. Class A has the most resistance while Class C has the least:

	Class A	Class B	Class C
Water Vapor Permeance (ASTM E 96)	0.3 Perms	0.3 Perms	0.3 Perms
Tensile Strength (ASTM D 828 or D 882)	7.9 kN/m (45.0 lbf/in)	5.3kN/m (30.0 lbf/in)	2.4 kN/m (13.6 lbf/in)
Puncture Resistance (ASTM D 1709)	2200 g (5 lb)	1700 g (4 lb)	475 g (1 lb)

Some finishing methods like newer ride on laser screeds may tear some types of polyethylene sheets. These methods should also be covered in pre-job meetings before the concrete is placed.

Where Should Vapor Retarders be installed?

ACI 302 still has issues on where and even how vapor retarders should be placed. One thing that has become clear over the years, however, is that each job must be individually looked at. Some jobs may require a layer of a granular fill be placed over the vapor barrier (though in recent years this seems to have been phased out in most construction practices).

Careful installation can also avoid issues. Too long it has been practice to not repair tears or holes, not extend the sheets up along perimeter walls, and have too large of cuts where utilities like plumbing and electrical extend out of the slabs. Other problems arise from improperly installed wire mesh in floors which can result in tears, cutting of the material along construction joints or failure to properly overlap at seams. Vapor retarders should also be installed over graded sub-bases and compacted to a uniform bearing capacity. Uneven subgrade can result in both tears and standing water pockets.

Many fast-track construction projects are of the tenant finish type, meaning both plumbing and electrical is added after construction. These can get installed quickly and often no thought is given to installation or repair of vapor retarders. Also in today's market, the floor may be cut up as plans change and areas remain open for a length of time. When the concrete re-poured, it is many times not with the same care, materials or labor as the rest of the concrete floor.

ACI 360 states that a “vapor barrier should be installed with the same care as a roofing material”. Leaks from underneath can be just as destructive as those from above. Making sure everyone on the job understands the importance of vapor barriers should help eliminate many problems.

References:

- ♦ *ACI 301 4.1.5*
- ♦ *ACI 301 (302 IR-96)*
- ♦ *ACI 302*
- ♦ *ACI 360*
- ♦ *ASTM E 1643: Standard Practice for Installation of Water Vapor Retarders used in Contact with Earth or Granular Fill under Concrete Slabs*

This guide is to offer assistance in installation of both concrete and decorative concrete toppings and sealers. It is designed to bring contractors, architects, general contractors and owners to understand issues that might occur before, during and after construction. Working together during the construction process and understanding what may occur, understanding of materials and having material suppliers at pre-job meeting can be effective means of understanding potential issues.