



Moisture in Concrete Substrates and Alternatives to Traditional Mitigation Methods

Accelerated construction schedules have become common building practice and the use of insufficient or improperly installed moisture barriers are resulting in structures with concrete slab substrates exhibiting moisture contents outside tolerances established by most manufacturers' flooring product and adhesive systems capabilities and warranties. The costs to mitigate high moisture are rarely considered up front, but with awareness and planning can be addressed in a cost effective manner. Failure to account for and accommodate high levels of moisture in concrete often occurs due to inadequate cure times associated with compressed construction schedules, wet building sites, inadequate building materials, poor workmanship with concrete pour or mix of material, and insufficient or improperly installed moisture protection (Craig, 2003). Identification of the sources of moisture in the concrete, proper moisture testing, and utilization of appropriate moisture mitigation techniques can alleviate these costs and increase the likelihood of a long-lasting quality flooring installation.

Sources of Moisture in Concrete

There are two primary sources of moisture in concrete slabs: free water (also called water of convenience) and water originating from the ground below the concrete slab.

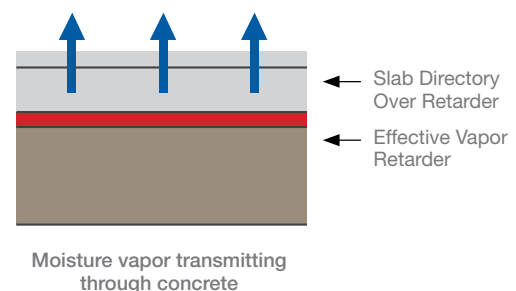
I. Free Water/Water of Convenience

Concrete requires water to develop and maintain its strength. For a typical 4000 psi concrete, the water-to-cement ratio of 0.5 or 275lbs of water per cubic yard of concrete is needed to achieve a workable consistency. However, only a water-to-concrete ratio of about 0.25 is needed for proper concrete hydration. Any water in excess of 0.25 – 0.28 is considered water of convenience and only serves to ameliorate the placement of the concrete. Therefore, after mixing and pouring the slab, 137.5 pounds of free water needs to be extracted and evaporated during drying and curing times. Excessive moisture caused by free water is generally a result of inadequate drying times (Craig, 2014).

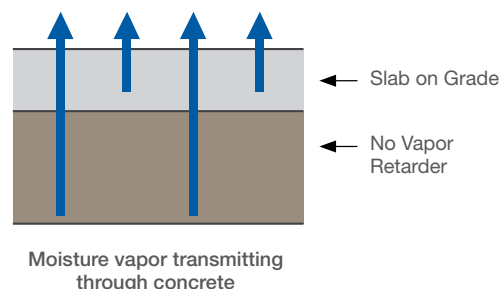
II. Water Originating in the Ground

Water from the earth below the slab is the second source of moisture in concrete. Unrestricted, water vapor moves upward from areas of higher concentration of molecules to areas of lower concentration. This natural process is called diffusion or evaporation. When concrete is laid, this upward migration of water vapor is slowed but not halted. Concrete is porous, and so, requires a vapor barrier to stop rising water vapor from entering the slab. A vapor retarder is a protective barrier installed directly below the slab that serves to block the moisture from entering the concrete (White, n.d.; Craig, 2003). Without this barrier, moisture vapor continues to rise through the concrete where it can become trapped between the slab and nonporous flooring. Costly, flooring system failures are likely when moisture gathers at the surface of the slab with no way to evaporate (Kanare, 2007).

Closed Slab System



Open Slab System

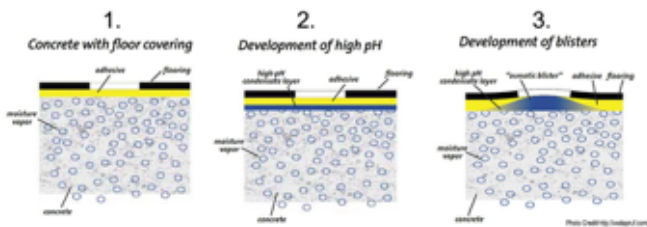




Impacts of Moisture on Flooring

Estimates indicate that up to 1 billion dollars is spent annually in the United States correcting moisture-related issues with concrete slabs (White, n.d.). Too much moisture in a slab is associated with post installation problems such as: blistering of the flooring or flooring coatings, breakdown and release of adhesives, growth of mold and other microbes, and swelling of flooring materials (Craig, 2003; Kanare, 2007). Any excess water that fails to evaporate into the air (most often due to inadequate drying or curing times) can inhibit proper bonding of flooring adhesives. Moisture trapped below and within the slab migrates upward; bringing salts from the concrete to the surface. This creates a highly alkaline environment and a PH imbalance, of which many adhesives are intolerant, leading to flooring system failures (Craig, n.d.).

How Does Moisture Vapor Harm Flooring Systems?



Identifying and correcting moisture issues before a floor covering system is in place is far less complicated and less costly than correcting these issues once flooring is installed. To do this, industry professionals must test the concrete slab for its moisture levels.

Testing

Because concrete interacts with ambient conditions, it can be challenging to determine moisture levels (Spangler, n.d., Six outside sources). The amount of moisture that remains in the slab is dependent upon a number of external factors, including: temperature, humidity, drying and curing times, vapor retarders, bond breaking agents, and heating ventilation and air-conditioning (Spangler, n.d., External

sources). Thus, accurate and appropriate moisture testing must be performed on substrate surfaces before beginning a flooring system installation.

The most accurate, reliable, and consistent method of testing for moisture vapor is the in-situ Relative Humidity test (ASTM F2170). This test calculates the amount of moisture throughout the slab by measuring the concrete's internal relative humidity (RH) (Craig, n.d.). The rate of moisture vapor diffusion is a product of the degree of saturation (a function of the RH) at the top and the bottom of the concrete slab. The relative humidity differential through the slab's depth triggers the moisture vapor movement through the slab (Powers, 1958). When the slab is covered with a non-breathable surface (i.e. a flooring system) moisture is unable to evaporate. It gathers at the surface and then redistributes back into the slab in order to achieve an even distribution of molecules or to achieve equilibrium (Portland Cement Association, n.d.). The RH is a measure of this equilibrium. Relative humidity is the amount of moisture present at a certain temperature expressed as a percentage of saturation at that same temperature (Perry & Green, 2008).

Relative humidity testing requires professionals to drill holes and place probes in the slab at 40% depth. This method allows one to get a quantitative reading of moisture levels. The target RH at 40% depth is usually 75% - 80% after 72 hours. Importantly, if a vapor retarder was not installed beneath the slab, the moisture level will increase once flooring is installed. With no way for moisture to escape, RH can reach 100% and will likely result in damaged flooring systems (Craig, n.d.; Kanare, 2008).

Solutions for Excessive Moisture in Concrete Slabs

Once a RH reading has been attained one must make decisions for how to move forward with the building project. If the moisture levels are low enough, flooring installation can begin. However, if the moisture level is too high, one must weigh the options for addressing the issue.



I. Mitigation

Moisture mitigation systems are one way to address high RH in concrete. Topical applications such as, modified cementitious overlays, moisture retarding coatings, dispersive membranes, and reactive penetrants, are applied to the set concrete slab to keep water from seeping to the surface (Craig, 2003). While these systems are very effective, they are time consuming and expensive, costing upwards of \$4 per square foot. Proper application occurs in multiple steps beginning with sand-blasting the concrete; applying the PH blocker; applying a skim coating to ensure flooring adhesion; and finally, flooring installation. The added materials, labor, and time are disadvantages to this solution (DiNardo, 2013).

II. Flooring Systems with High RH Tolerance

An alternative to moisture mitigation is to select a flooring system that can tolerate high RH. Resilient flooring adhesive, pre-applied polyacrylic adhesive, moisture tolerant hard surface products, and non-adhered interlocking tiles are examples of such flooring systems. These options for addressing slab moisture allow builders and installers to avoid the costs of time delays associated with traditional mitigation systems.

- **Resilient flooring adhesive** is a water-based acrylic adhesive used in the installation of glue-down luxury vinyl sheet and tile. These adhesives can be used on substrates with an RH of up to 95% and high pH levels between 8 and 10. They are more time efficient than traditional mitigation systems as there is no need to wait for an epoxy to dry before beginning installation.
- **Pre-applied polyacrylic adhesive systems** are used in vinyl composite tile, sheet vinyl, rolled rubber, and rubber tile flooring systems. The adhesive used in these systems is water based and, like the resilient flooring adhesive, is designed to maintain a strong bond in the presence of high RH (99%) and pH. The pre-applied adhesive system is installed quickly and requires no drying time allowing construction projects to remain on a fast tracked schedule.

- **Moisture tolerant hard surface products** eliminate the need for a full spread of adhesive over the slab. Instead, the heavy tiles have a non-skid backing and are floated over the concrete slab. Similar to the pre-applied adhesive system, using these tiles is a time efficient way to address slab moisture. This flooring system can tolerate up to 95% RH. The size and weight of the tiles helps to prevent common flooring failures related to moisture.
- **Non-adhered interlocking carpet tiles*** require the simplest installation with the highest RH tolerance of these systems. They can be applied to concrete slabs with up to 99% RH (essentially eliminating the need for RH testing). Adhesive is applied only at the perimeter of the slab and interlocking tabs hold the tiles together as they are floated across the subfloor. This technology cuts down on time, material, and labor costs. More, the interlocking installation drastically reduces the risk of flooring failure. The breathable nature of these tiles allows moisture vapor to pass through and evaporate rather than gather at the surface.

* Manufacturers may recommend use of tabs with specific carpet tile backings to achieve adherence to slabs with 99% RH

Summary

In summary, when applying flooring to concrete slab substrates, moisture is a compulsory consideration. Free water in the concrete mix and water vapor from the earth below the slab create the potential for high moisture levels in the concrete. Installing flooring over a slab with too much moisture can lead to flooring system failures that are costly and time consuming to repair. Relative Humidity testing can be used to determine if moisture levels within the concrete slab are too high to proceed with flooring installation. If moisture levels are high, they can be addressed with a costly and time consuming mitigation system; or more efficiently, with a high RH tolerant flooring system.



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