Drying of Concrete
TDS 183

As the occurrence of fast track construction continues to rise, the need to install a finished floor on a "wet" concrete slab is typically far too soon for the floor covering. Vinyl (tile or sheet), epoxy coatings, paint, rubber floors, vinyl backed carpet, and flooring over a waterproofing membrane will all be negatively affected by high moisture content, high moisture vapor emission rate and/or high relative humidity (RH) within the concrete. Concrete scheduled to receive flooring must be dry enough to permit an adhesive to bond properly and prevent damage to the flooring. For epoxy based materials, the concrete must be dry enough to develop adequate bond and allow the epoxy to properly cure. Ceramic tile and stone, installed without a membrane, are much less sensitive to moisture and high moisture levels.

It is very important to note that the only way to properly control moisture in, and moving through, a concrete slab-on-grade is to have a properly specified, placed and correctly installed vapor barrier under the slab. If a vapor barrier is not present then it will be impossible to guarantee that the moisture content, relative humidity and moisture vapor emission rate of the concrete will ever achieve or maintain necessary levels during the life of the slab. In practice, the RH in sub-grade soil will almost always be close to 100%, so unless the ambient indoor RH in the building is 100% the drive of moisture will always be into the structure.

Floor moisture issues can be avoided with proper planning, good design, implementation of moisture control measures (e.g. foundation drainage, vapor retarder), extensive moisture testing, and the specification and application of appropriate installation materials. However, there is always the potential for conditions and circumstances which are beyond the control of designers, building owners and contractors which can have a direct effect on the moisture level in a slab.

CONCRETE MOISTURE

For the purposes of this technical data sheet, the term "concrete moisture" means the total water used in the concrete batch, plus curing water, minus the water used to hydrate the cement.

A typical cubic yard of concrete with a water/cement ratio of 0.5 contains 275 lbs. (125 kg) of water. Approximately half of that water will be used to hydrate the cement, while the other half, which comprises approximately 3.2% of the weight of the concrete is considered "free water" or "water of convenience". This water must evaporate to reduce the RH in the concrete to an acceptable level for the floor covering. If the concrete is moist cured, the additional water can raise the "free water" to 7% of the weight of the concrete. Based on the 3.2% figure, it would be necessary for several pounds of water to evaporate from every square foot (kg/m^2) for the slab to be considered adequately dry for many floor finishes.

Factors which affect the time needed for concrete to dry to required moisture levels include;

- Type of cement
- Type and amount of aggregate
- Water/cement ratio
- Presence of a vapor barrier (slab-on-grade)
- Curing and drying conditions
- Thickness of the concrete slab
- Specified moisture condition set forth by flooring material manufacturer

Typically, the water/cement ratio is the single most important determining criteria for the drying of concrete. For a concrete with a water/cement ratio of 0.50 to 0.70, the drying time to reach 90% RH is anywhere from 3 to 9 months, under suitable drying conditions. Concrete utilizing a water/cement ratio of 0.38 – 0.5 typically take 2 to 3 months to reach 90% RH under suitable drying conditions. Keep this in mind: it took 3 months for concrete, with a water/cement ratio of 0.38 – 0.5 to get to 90% RH!! Many moisture sensitive flooring materials and adhesives can require as low as 75%

RH as tested per ASTM F2170 "Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes" prior to installation!! For more information on moisture vapor transmission and test methods, please refer to TDS 166 "LATICRETE and Moisture Vapor Emission Rates".

Over the years, the flooring industry has come up with a "rule of thumb" which states that the time necessary for concrete floors to reach an acceptable content is: 1 month of drying for each inch of concrete or 1mm per day.

MOISTURE MOVEMENT THROUGH CONCRETE

Moisture can move through concrete slabs as water vapor or as liquid water. Concrete which is not saturated with liquid water will transmit moisture as vapor (gas) by diffusion through the capillaries of the cement paste. This moisture vapor is driven to the surface by the difference in RH at the bottom and at the top of the slab. This is how moisture can accumulate under a floor covering even though the concrete does not appear to be saturated with water. This is also why concrete, poured in a building which is not completely enclosed and in which the HVAC system is not turned on, will not begin to dry until such time as the building is enclosed and the HVAC is turned on. Relative humidity in concrete and in the air work toward a state of equilibrium, so, at any time the concrete will actually be pulling moisture out of the air if the humidity of the air is greater than the concrete. The same is true in reverse. Once the building is enclosed and the HVAC system is turned on, the RH within the air in the building can be controlled and the concrete can actually begin to dry. It is at this point that the clock (actually calendar) begins. All too often, someone in the decision making team feels that drying of concrete begins as soon as it is poured and installation of flooring will proceed based on this false belief.

For concrete which is saturated with water, the driving force for moisture movement is capillary action, and, when the concrete is exposed to air, the driving force is evaporation from the surface.

The drying process begins (under ideal conditions) when water is no longer available at the exposed surface, so concrete cured by sealing in the original mix water with wet burlap or plastic sheets, drying will begin when these covers are removed. Spray applied membranes (curing compounds) reduce the rate of moisture evaporation and help retain moisture in the concrete; thus expediting the hydration (curing) process. But, curing compounds are somewhat breathable and drying begins shortly after the membrane is applied (under ideal conditions). However, curing compounds significantly reduce the drying rate and significantly extend the drying period. Curing compounds must be physically removed from the concrete before a normal curing period can begin. Therefore, a moisture sensitive material cannot immediately be applied to a concrete slab from which curing compounds have been removed. Once the curing compound has been removed, it will still be necessary to wait an extended period of time to allow the concrete to reach a suitable moisture level for the floor covering.

Concrete is a porous material which experiences three distinct stages of drying; a constant rate period followed by two falling rate periods;

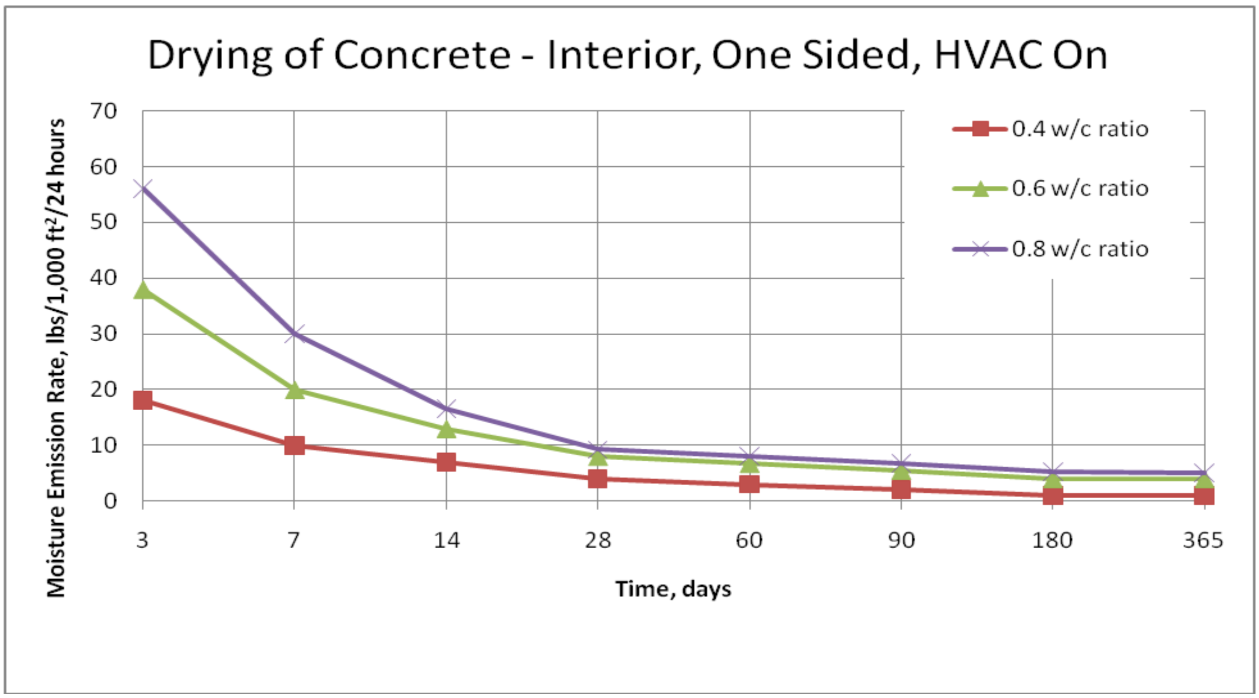
Stage 1 – During the first drying stage, liquid water is present at the surface which evaporates into the air above the concrete. The rate of evaporation depends upon the temperature, RH and air flow over the concrete surface. Warm, rapidly moving air will cause faster evaporation than cool, stagnant air. As water moves from within the concrete to replace water which has evaporated at the surface, the concrete will shrink to make up for the volume of water which has now left. If the evaporation rate is very high, the concrete can shrink excessively before the cement paste has developed sufficient strength. This is the cause of "plastic" shrinkage which may occur within the first few hours of placement. See Figure 1.

Stage 2 – The second stage of concrete drying begins when the concrete can no longer shrink due to liquid water evaporation. Water recedes from the exposed surface of the concrete into the pores where it clings to the sidewalls and forms a curved surface (meniscus). Water evaporates from the meniscus in each pore into the air over the concrete. The rate of evaporation is still mostly dependent upon temperature, RH and air flow over the concrete surface. The surface may appear to be "dry", but the concrete is just beginning to dry in a very thin layer. It is during Stage 2 that the drying rate steadily decreases. See Figure 2.

Stage 3 – The third stage of drying begins when enough water has evaporated from just below the surface that the pores are no longer continuously filled with water. Pockets of liquid will still exist, but moisture must now move by vapor diffusion within the body of the concrete before arriving at the surface where it can evaporate. This is the second falling rate stage, because the rate of drying continuously decreases over time and is slower than the previous stage of drying. The rate of drying depends less on temperature, RH and air flow above the concrete surface because moisture must evaporate and diffuse within the body of the concrete before arriving at the surface. This is the stage that causes extended cure time for concrete to reach acceptable moisture levels prior to installation of moisture sensitive materials. The rate of drying during Stage 3 is determined by the quality of the cement paste: low water to cement paste offers more resistance to vapor diffusion than high water/cement ratio paste. While it may sound good to have a low quality cement paste, to allow the moisture in the concrete to evacuate more quickly, the increased water content of low quality cement paste can extend the drying time significantly. See Figure 3.

ESTIMATION OF DRYING TIME

The chart below shows the average expected drying time of an interior 4" (100mm) thick concrete slab which is drying from one side when the building is enclosed and the HVAC system is operating normally. This chart graphically shows how important the initial water/cement ratio is to the expected drying time of concrete. Concrete mixed with a water/cement ratio of 0.4 can achieve 5 lbs/1,000 ft^2/24 hours in 28 days per ASTM F1869 (under ideal conditions) while concrete mixed at a water/cement ratio of 0.8 may take a s long as a year to achieve the same level. Thicker pours will require longer expected cure times.



The Swedish Concrete Association describes a method to estimate drying times for concrete slabs. Correction factors make it possible to allow for deviations from a known set of base conditions. The purpose of this calculation is to enable the <u>estimation of a minimum drying time(s) for concrete slabs (under conditions stated below) during the planning stage</u>. This calculation can be useful for general planning but should not be relied upon to determine precise drying times due to variability of actual concrete composition and jobsite conditions.

Factors used in this calculation include:

- Portland cement concrete slab measuring 7.2" (180mm) thickness
- Drying temperature of 64°F (18°C)
- Relative humidity of the air of 60%
- Drying from both sides of the slab (elevated)
- Curing conditions prior to drying – 2 weeks of rain and 2 weeks of high RH
- Water/cement ratio is the parameter used to characterize the concrete
- 85% and 95% RH are used to characterize the moisture condition of the concrete after drying

Standard Drying Time

The standard drying time is based on the actual water/cement ratio and the RH of the concrete.

Table 1 - Standard Drying Time

RH%	w/c = 0.4	w/c = 0.5	w/c = 0.6	w/c = 0.7
85	50 days	90 days	135 days	180 days
90	20 days	45 days	65 days	95 days

Dimensional Correction Factor
The thickness of the slab will have an effect on the drying time. Use the correction factor as shown in Table 2 using the appropriate water/cement ratio and actual thickness of the concrete slab.

Table 2 – Correction Factor for Different Slab Thickness

Thickness	w/c = 0.4	w/c = 0.5	w/c = 0.6	w/c = 0.7
4" (100mm)	0.4	0.4	0.4	0.4
6" (150mm)	0.8	0.8	0.8	0.7
7" (180mm)	1.0	1.0	1.0	1.0
8" (200mm)	1.1	1.1	1.1	1.2
10 (250mm)	1.3	1.4	1.5	1.8

One- or Two-Sided Drying
Drying from two sides requires a shorter time than drying from one side only. Use the correction factor as shown in Table 3 using the appropriate water/cement ratio and drying condition. Note that elevated concrete poured over steel pan is considered one sided drying.

Table 3 – Correction Factor for One-Sided or Two Sided Drying

Drying Condition	w/c = 0.4	w/c = 0.5	w/c = 0.6	w/c = 0.7
One-Sided	2.0	2.3	2.6	3.2
Two-Sided	1.0	1.0	1.0	1.0

Temperature and Humidity
Lower humidity and higher temperature during drying will increase the rate of drying. Use the correction factors using the appropriate RH and temperature of the ambient air.

Table 4 – Correction Factor for Temperature and Humidity

RH%	50°F (10°C)	64°F (18°C)	77°F (25°C)	86°F (30°C)
35	1.2	0.8	0.7	0.6
50	1.2	0.9	0.7	0.6
60	1.3	1.0	0.8	0.7
70	1.4	1.1	0.8	0.7
80	1.7	1.2	1.0	0.9

Variations for Curing Conditions
Variations in concrete mix and curing conditions can affect the drying time of concrete. Use the correction factors in Table 5 using the appropriate conditions shown.

Table 5 – Correction Factors for Variations in Curing Conditions

Curing Condition (drying to 90% RH)	w/c = 0.5	w/c = 0.6	w/c = 0.7
Dry	0.5	0.5	0.7
4 weeks of high moisture (tight cover)	0.5	0.7	0.8
4 weeks of rain	1.0	1.3	1.3

The estimated drying time for a given concrete slab is obtained by multiplying the five factors selected from the above tables. Adding 10% silica fume to the concrete reduces the drying time by approximately 50%. For concrete with a water/cement ratio less than 0.5 and the addition of 5% silica fume can reduce the drying time approximately 50%.

APPLICATION OF CORRECTION FACTORS

Below is an example of how to use the standard time and correction factors for estimating the approximate time for drying of a concrete slab during the planning stage.

During the planning stage, it was estimated that the time between pouring a concrete slab and the installation of a floor covering would be 3 months for a 4" (100mm) slab. It was also estimated that it would be a month before the building was enclosed and the HVAC turned on, effectively allowing for a 2 month drying period. It was specified that the floor slab must attain a maximum relative humidity of 85% at the equivalent depth, and drying would be one-sided. The water/cement ratio was to be 0.4 and the construction was going to take place during the rainy season. Once the building is enclosed, the drying climate will be 64°F (18°C).

- From Table 1, the standard time is **50** days
- From Table 2, the correction factor for thickness is **0.4**
- From Table 3, the correction factor for one-sided drying is **2.0**
- From Table 4, the correction factor for temperature and humidity is **0.9**
- From Table 5, the correction factor for a rainy season is **1.4** (not shown in table)

The total time is determined by the following calculation: **50 x 0.4 x 2 x 0.9 x 1.4 = 50 days**, which is acceptable compared to the 2 months available. However, this apparently short drying time is possible only if the concrete has the specified low water/cement ratio and the building is enclosed, with the HVAC running to provide 50% RH and the proper temperature. If these parameters, or others as estimated, are incorrect then the drying time will be considerably longer.

CONCRETE DRYING AND TILE

As stated earlier, unlike many floor coverings, ceramic tile, stone and the majority of their adhesives are not sensitive to the affects of moisture and high pH. Tile and stone can be installed on concrete, with certain cement based setting material (e.g. 254 Platinum, or 211 Powder gauged with 4237 Latex Additive) directly to concrete with a 5 – 7 day cure time. It will be necessary to allow for additional movement joints to compensate for excessive concrete shrinkage. However, the use of a waterproofing/anti-fracture membrane (e.g. HYDRO BAN® or 9235 Waterproofing Membrane) will require that the concrete reach moisture conditions of 5 lb / 1,000 ft^2 / 24 hours (283μg / sec • m^2) or 75% RH prior to installation. Please consult the data sheet for the particular LATICRETE product(s) to determine acceptable concrete cure time or moisture levels prior to installation.

LATICRETE Moisture Vapor Membranes

For cases where the MVER or RH exceeds the recommended levels for the type of finish material being installed, NXT™ Vapor Reduction Coating, DRYTEK(TM) Moisture Vapor Barrier and SUPERCAP(TM) Moisture Vapor Control can be used to minimize the moisture allowed to pass through to the flooring layer. These membranes are a single-coat, 100% solids, liquid applied 2-part epoxy coating specifically designed for controlling the moisture vapor emission rate from new or existing concrete slabs.

These products reduce MVER from > 20 lbs/1000 ft2/24hr (1,133 µg/(s • m) to below 3 lbs/1000 ft2/24hr (170 µg/(s • m) in a single coat. These membranes allow for the installation of vinyl, rubber, VCT, carpet, wood, ceramic tile, stone and other moisture sensitive floor coverings and floor adhesives.

Please refer to the respective product data sheets www.laticrete.com, drytek.com, www.laticretesupercap.com.

The information contained in this document should be used as a guideline only, and should not be used as part of any construction document. Actual field concrete installation drying time calculations must be conducted by qualified personnel, based on actual jobsite conditions.

The basis for, and much of the content, of this Technical Data Sheet was taken from the outstanding resource, "Concrete Floors and Moisture" by Howard Kanare and is available for purchase from the Portland Cement Association at www.cement.org.

Please refer to LATICRETE TDS 166 "LATICRETE and Moisture Vapor Emission Rate, Relative Humidity and Moisture Testing of Concrete" for more information.

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