LATICRETE and Moisture Vapor Emission Rate, Relative Humidity and Moisture Testing of Concrete

TDS 166

Materials used in tile and stone installation applications can be affected by moisture during the installation and curing phases. Some materials, such as waterproofing membranes, may not cure properly or may delaminate from a continually wet substrate, or a substrate with a high moisture vapor emission rate (MVER). A substrate which is damp or has a high MVER may also contribute to the formation of efflorescence. Concrete with a high moisture vapor emission rate may also have an impact on a tile or stone installation.

There are generally three tests that are used to determine moisture content in concrete. The three tests are:

1. Calcium Chloride (ASTM F1869 – Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloors Using Anhydrous Calcium Chloride)

   The Calcium Chloride test involves placing a Petri dish of calcium chloride (covered by a plastic dome adhered to the concrete) on the concrete and allowing the Petri dish to remain in place between 60-72 hours. The calcium chloride absorbs any moisture vapor that transmits through the concrete within the plastic dome. The results of a calcium chloride test measures the amount of moisture absorbed and results are stated in pounds per 1,000 ft^2 (92.9 m^2) in a 24-hour period. Please note that the ASTM F1869 test should only be conducted in interior conditions when the building is completely enclosed and the air conditioning or heating system is turned on, unless otherwise instructed by the test kit manufacturer. This is not a test recommended for exterior use.

2. Relative Humidity (ASTM F2170 – Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using In-situ Probes)

   The Relative Humidity (RH) test involves placing probes in the concrete and taking readings with a hygrometer. A relative humidity reading of 75% or below is acceptable for most tile applications. Please note that the ASTM F2170 test should only be conducted in interior conditions when the building is completely enclosed and air conditioning or heating system is turned on, unless otherwise instructed by the probe manufacturer. This test is not recommended for exterior use.

3. Relative Humidity (ASTM F2420 – Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood)

   This test method involves placing a purposely-made, thermally insulated hood onto the surface of a concrete slab thereby creating an entrapped and impervious air pocket. Once placed, the hood is left undisturbed until the pocket is equilibrated (≥ 72 hours). Once equilibrated, a humidity probe is inserted into a lined access hole in the top of the hood to measure RH, temperature and dew point. Please note that the ASTM F2170 test should only be conducted in interior conditions when the building is completely enclosed and air conditioning or heating system is turned on, unless otherwise instructed by the probe manufacturer. This test is not recommended for exterior use.

4. Plastic Sheet Method (ASTM D4263 – Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method).

   The Plastic Sheet Method involves taping a 24” x 24” (600 mm x 600 mm) piece of plastic on the concrete and allowing the plastic to remain in place for 18 - 24 hours to determine if any moisture has accumulated under the plastic when it is removed. Please note that the ASTM D4263 test should only be conducted in conditions as stated in the ASTM D4263 document and should not be relied upon to provide reliable data.

ASTM F1869, ASTM F2170 and ASTM F2420 are quantitative tests (stating approximately how much moisture is present) while ASTM D4263 is a qualitative test (stating that moisture is present but not how much), and all are a "snapshot" of moisture vapor emission during the testing period.

Figure 1.1 – (Clockwise from top left) ASTM F1869 Calcium Chloride Test Kit, ASTM F2170 Relative Humidity Meter, ASTM F2420 Insulated Hood with probe attached, and ASTM F2170 Pin Type Moisture Meter (Photos courtesy of George Donnelly Testing & Inspections at www.moisturetesting.com, www.tramexltd.com and Delmhorst Instrument Co. at www.delmhorst.com.)

Concrete contains moisture from the day it is poured and a generally accepted minimum cure time of 28 days is required before a finish material is applied. It may be important to note that 28 days is not a magic number that relates directly to every concrete installation. Simply relying on 28 days can be insufficient and can lead to failure of materials which may be affected by high moisture levels. The cure time of the concrete can vary depending on;

1. The water to cement ratio at the time of placement – the higher the amount of water in relation to the cement at the time of pouring can have a profound effect, not only on the amount of time that is required to reach acceptable moisture levels of the concrete, but also on the physical properties of the concrete. Excess water in the mix can have a negative impact on the performance of the concrete throughout its life.
2. Concrete thickness – thicker concrete means more water. More water means more time to reach sufficient moisture levels.
3. Method of curing –concrete slabs can be wet cured, damp cured or allowed to dry without additional water placed on top of curing concrete to improve the physical properties of the concrete. Wet curing and damp curing can have a profound effect on the time it takes the concrete to reach a level where the moisture content is suitable for installation of waterproofing membranes and/or finish materials.
4. Environmental conditions - Temperature, humidity, exposure to water, placement of vapor retarder, foundation drainage, when the building is fully enclosed, and when heating or air conditioning is turned on will all affect the amount of moisture in a concrete slab over extended periods of time.

5. Placement of the concrete pour – installations of concrete on grade or below grade can lengthen the amount of time required for a concrete slab to reach suitable moisture levels.
6. Proper placement of a vapor retarder and drainage layer – on grade or below grade concrete usually requires the proper placement of a suitable vapor retarder and moisture drainage layer. Properly designed and installed these two components can greatly reduce the movement of moisture and moisture vapor through a slab and allow the concrete to maintain a reasonably consistent moisture level for many, many years.

There are essentially two types of moisture that can move through a concrete slab; negative hydrostatic pressure and moisture vapor emission.

Negative Hydrostatic Pressure is actual water in contact with the bottom of the slab. This water freely moves through to the top of the slab by high head pressure through the capillaries of the concrete slab. Essentially, concrete is a very dense, very hard sponge. Concrete will use any available moisture to continue the hydration process and get harder and harder over time. In other words, concrete can continue to cure indefinitely when exposed to water. Negative Hydrostatic Pressure is a fairly rare occurrence and can be alleviated or dissipated by the use of sump pumps, foundation drainage (French drains, curtain drains, etc…), or good landscaping practices.

Moisture Vapor Emission is moisture that passes through a concrete slab caused by slight pressure differentials between the exterior and interior of the slab. Moisture vapor emission from concrete is a natural and necessary process for any concrete pour. Since the portland cement in concrete only requires approximately 25% water content to hydrate properly then any excess water will more than likely pass out of the concrete slab as moisture vapor moving upwards through the slab into the structure. Considering that concrete, without the addition of plasticizers or superplasticizers, can have water content of 50% means that there can be a considerable amount of water that must pass through the slab as moisture vapor.

The amount of moisture that passes through a slab is often governed by the permeability of the slab, which in turn is significantly governed by the water/cement ratio of the concrete mix. In other words, the more water added to a concrete mix, in relation to portland cement, can have a profound effect on the permeability, density and porosity of the concrete. The more water, the lower the performance of the concrete in relation to moisture vapor transmission.

		RELATIVE HUMIDITY %									
		100	90	80	70	60	50	40	30	20	10
	100 (38)	0.948	0.854	0.758	0.663	0.569	0.474	0.379	0.284	0.189	0.095
	90 (32)	0.639	0.621	0.551	0.482	0.414	0.344	0.275	0.209	0.138	0.069
	80 (27)	0.506	0.455	0.405	0.357	0.303	0.253	0.202	0.152	0.101	0.051
TEMPERATURE	75 (24)	0.429	0.386	0.343	0.3	0.258	0.214	0.172	0.129	0.086	0.043
F° (C°)	70 (21)	0.362	0.326	0.29	0.253	0.217	0.181	0.145	**0.108**	0.072	0.036
	65 (18)	0.305	0.274	0.244	0.213	0.183	0.152	0.122	0.091	0.061	0.03
	60 (16)	0.256	0.23	0.205	0.179	0.153	0.128	0.102	0.077	0.051	0.026
	55 (13)	**0.214**	0.192	0.171	0.149	0.128	0.107	0.085	0.064	0.042	0.021
	50 (10)	0.178	0.16	0.142	0.124	0.107	0.089	0.071	0.053	0.036	0.018

Figure 1.2- Pressure / Diffusion Chart (Temperature & Relative Humidity)

Moisture vapor tends to travel from areas of high pressure to areas of low pressure and low temperature (known as diffusion) following basic principles of physics. The chart above helps to explain how temperature and humidity work to draw moisture into a structure through walls and concrete slabs. If the temperature of the soil under a structure is 55°F (13°C) and the relative humidity is 100% then the vapor pressure* equals 0.214; if the building interior is at 70°F (21°C) and the humidity is 30% then the vapor pressure (relative humidity in relation to temperature which increases or decreases in a non-linear fashion.) equals 0.108. This means that the moisture is driven into the building through the slab moving from the area of high pressure (0.214) to the area of low pressure (0.108). Proper placement of a suitable vapor retarder and drainage layer can help to minimize moisture vapor transmission.

When testing concrete using pin type moisture meters, it is necessary to determine exactly what the information provided by the meter is showing. For instance, many meters provide a value showing the Moisture Content of the surface being tested. However, the moisture content is **NOT** the percentage of Relative Humidity in the concrete and should not be used as such. The chart below shows sample correlation between Moisture Content and Relative Humidity.

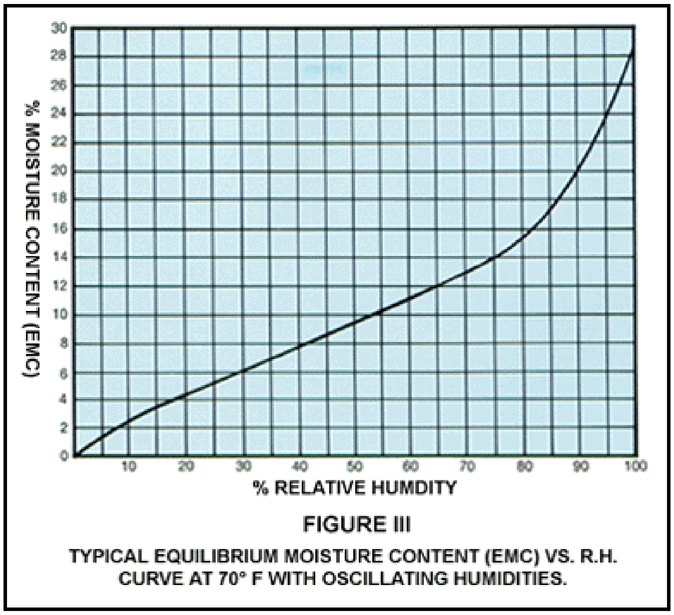

Figure 1.3 - % Moisture Content to % Relative Humidity Chart (source Delmhorst Instrument Co.)

A reading, taken using a moisture meter, which shows 14% Moisture Content correlates to approximately 75% Relative Humidity in the concrete at the area being tested at that particular time. Please be aware of what the moisture meter is showing and contact the meter manufacturer for any correlating data to get the proper information.

A common misconception is that concrete actually begins to dry as soon as it is poured. While it may appear to be dry fairly quickly, a concrete slab will actually not begin to lose significant amounts of moisture until the building is fully enclosed and the heat or air conditioning is turned on. A building which is not fully enclosed will not show a pressure differential that will cause the concrete to begin losing moisture. This is why moisture testing performed on a concrete slab that is not in an enclosed and temperature controlled building will give inconsistent and false readings.

Effects of Dew Point Temperature on Flooring Installation

The effects of moisture vapor transmission, humidity, temperature, and dew point typically have a more deleterious effect on vinyl composition tile (VCT), linoleum, rubber flooring, membranes, floor coatings (e.g. epoxy, polyaspartic, paint, etc…) or any other type of flooring which is sensitive to moisture related issues than on a tile or stone installation without a membrane.

For our purposes we will define dew point as the temperature at which the humidity in the air begins to condense in and on the concrete substrate.

In all circumstances, please check with the finished flooring manufacturer for any installation guidelines, cautions or limitations prior to proceeding with the installation. When installing these types of floor finishes (other than direct adhered tile or stone without the use of a membrane) it may be wise to follow some basic floor laying practices:

1. Test and read the air temperature
2. Test and read the relative humidity of the air in the room
3. Test and read the concrete surface temperature
4. Find the air temperature on the left hand side of the dew point chart below
5. Find the relative humidity of the air in the room on the dew point chart below
6. Intersect the air temperature with the relative humidity of the air in the room
7. Take note of the reading at this correlation point
8. Compare this figure with the actual concrete surface temperature
9. **If these two figures are within 5˚F (3˚C) of each other, the floor covering should not be installed**

Relative Humidity (Air in Room)										
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Air Temp.	Dew Point (Concrete Surface Temperature)									
40˚F (4˚C)	5	8	14	18	24	28	31	34	37	40
45˚F (7˚C)	5	9	16	23	28	32	36	39	42	45
50˚F (10˚C)	6	13	21	27	33	36	40	44	47	50
55˚F (13˚C)	8	16	25	31	36	41	45	49	52	55
60˚F (16˚C)	9	20	29	35	41	46	50	54	57	60
65˚F (18˚C)	10	24	33	40	46	51	55	58	62	65
70˚F (21˚C)	13	28	37	45	50	55	60	64	67	70
75˚F (24˚C)	17	31	42	49	55	60	64	68	72	75
80˚F (27˚C)	20	35	46	53	60	65	69	73	77	80
85˚F (29˚C)	24	40	50	58	64	69	74	78	82	85
90˚F (32˚C)	27	43	54	62	69	74	79	83	87	90
95˚F (35˚C)	30	48	59	67	73	79	84	88	92	95
100˚F (38˚C)	34	52	62	71	78	83	88	93	97	100

Figure 1.4 – Dew Point Temperature / Concrete Temperature Comparison Chart (source Altro)

Please note that other factors influence the installation of the moisture sensitive flooring types mentioned above. These factors include, but may not be limited to, the pH of the concrete, the presence of negative hydrostatic water pressure and/or presence of curing compounds or sealers on the concrete.

Failure to understand and follow these guidelines may cause premature failure of the flooring which are beyond the scope or responsibility of the flooring or installation material manufacturer.

Effects of Moisture on Tile and Stone

When membrane materials (e.g. HYDRO BAN®, 9235 Waterproofing Membrane, HYDRO BAN Sheet Membrane, etc…) are installed over a concrete slab, these materials inhibit the moisture attempting to move through the concrete slab. If the amount of moisture moving through the slab is high (greater than 5 lbs/1,000 ft^2/24hrs [283 µg/s m^2] per ASTM F1869 or 75% relative humidity as measured with moisture probes per ASTM F2170) moisture can collect, and possibly condense under the membrane. Residual moisture from mortars may also get trapped between the tile and membrane and cause problems (e.g. slow drying, warping of moisture sensitive tile or stone, etc…).

The collection of moisture can result in an increase of alkalinity of the concrete, which may exert some pressure in the form of moisture vapor on the membrane and can activate naturally occurring alkaline salts in concrete, creating a variety of chemical reactions within the concrete. Certain types of moisture sensitive stone and agglomerate tile can be affected by excessive moisture in the form of differential moisture expansion. This type of expansion can result in warpage of tile and possible delamination of the tile caused by the warpage. In some cases, a high moisture vapor emission rate can cause spalling of natural stone with organic content, such as limestone.

High MVER is a major concern if the adhesive used to install the tile or stone is organic (e.g. mastic) which can re-emulsify due to the high moisture level and increased alkalinity of the concrete.

LATICRETE Installation Materials and Moisture Levels

LATICRETE International, Inc. manufactures a wide variety of tile installation materials, many of which can be affected by high moisture levels within the concrete. We will look at several LATICRETE® product categories and discuss how each can be affected by high moisture levels.

LATICRETE® Waterproofing Membranes and Anti-Fracture - Maximum amount of moisture in the concrete substrate should not exceed 5 lbs/1,000 ft^2/24hrs [283 µg/s m^2] per ASTM F1869 or 75% relative humidity as measured with moisture probes per ASTM F2170. Consult with finish material manufacturer to determine the maximum allowable moisture content for substrates under their finished material.

125 Sound & Crack Adhesive - Maximum amount of moisture in the concrete substrate should not exceed 5 lbs/1,000 ft^2/24hrs [285 µg/s m^2] per ASTM F1869 or 75% relative humidity as measured with moisture probes per ASTM F2170. Consult with finish material manufacturer to determine the maximum allowable moisture content for substrates under their finished material.

Plaza and Deck System & Unbonded Mortar Beds – No limit to moisture vapor emission rate.

LATICRETE Bonded Mortar Beds, Thin Sets, Large and Heavy Tile Mortars, and 170 Sound Crack Isolation Mat – We have had success with moisture vapor emission rates as high as 10 lbs/1,000 ft^2/24hrs [570 µg/s m^2] per ASTM F1869 when no membrane is installed in the system. Please note that the use of a membrane (e.g. HYDRO BAN®, 9235 Waterproofing Membrane, etc…) can significantly lower the allowable MVER. Consult with finish material manufacturer to determine the maximum allowable moisture content for substrates under their finished material.

The use of a high performance cement based grout (e.g. PERMACOLOR® Select Grout), when compared to an epoxy grout, will usually allow moisture vapor to easily pass through the floor system.

LATAPOXY® 300 Adhesive - Maximum amount of moisture in the concrete substrate should not exceed 8 lbs/1,000 ft^2 /24hrs [455 µg/s m^2] per ASTM F1869. Consult with finish material manufacturer to determine the maximum allowable moisture content for substrates under their finished material.

NOTE: Please note that no LATICRETE product is suitable for use in negative hydrostatic pressure situations as defined and stated previously.

NXT Vapor Reduction Coating

For instances where the MVER exceeds the recommended levels for the type of finish material being installed, NXT™ Vapor Reduction Coating is an excellent choice. NXT Vapor Reduction Coating is a 3-component, roller applied epoxy coating and has been specifically designed to significantly reduce vapor emission from the concrete slab and be compatible with most tile thin-sets.

NXT Vapor Reduction Coating can lower the MVER of a concrete slab, having an MVER of up to 12 lbs./1,000 ft^2/24 hours (678 µg/s m^2) down to 3 lbs./1,000 ft^2/24 hours (170 µg/s m^2) with a single coat. For concrete slabs which have an MVER between 12 lbs./1,000 ft^2/24 hours (678 µg/s m^2) and 20 lbs./1,000 ft^2/24 hours (1,130 µg/s m^2) a second coat may be necessary. Please refer to the NXT Vapor Reduction Coating data sheet (DS 312.0) at www.laticrete.com for more information and specific installation guidelines.

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