

# Simplifying Moisture Measurement in Concrete

By Kip Gatto, PE, SE; Grace Wong, AIA, LEED AP; and Kari Klaboe, PE

Most people familiar with applying coatings, adhesives, or other moisture-sensitive materials to concrete surfaces understand the frustration of assessing when the concrete has been adequately moisture-conditioned. That is to say, how do we know when the concrete is “dry” enough to install the material? Although there are numerous ways to measure moisture levels in concrete, commonly accepted methods used in the context of moisture-sensitive material applications are relatively limited. This article proposes what are believed to be more intuitive and useful alternatives for measurement in evaluating moisture conditioning for application of moisture-sensitive materials.

The vast majority of industry guidance regarding moisture measurement is currently limited to concrete in interior, conditioned environments. There are well-established test protocols and thresholds for acceptable moisture vapor emission rates (MVERs)<sup>1</sup> and in-situ relative humidity (RH)<sup>2</sup> for regulated interior environments, as well as more recent emphasis placed on RH testing. But, as the authors have noted in a separate article in this issue [see page 20], there is limited guidance on what is

acceptable for concrete elements during construction prior to the HVAC system being commissioned or for concrete elements in an exterior environment that will never be conditioned (roof decks, parking garages, etc.). Conditioning the environment and concrete to 70°F (21°C) or some other temperature for the sole purpose of verifying moisture conditions is usually impractical.

In exterior applications, industry guidance is generally limited to the Plastic Sheet Method,<sup>3</sup> which essentially consists of placing a polyethylene sheet against the concrete surface to see if it condenses. Some manufacturers provide RH as a guideline as well, but RH is a poor measure of conditioning in a variable temperature environment. A better system of measurement is needed.

A major limitation of current methods of measuring acceptable moisture levels in concrete is that none of the commonly used and accepted methods actually quantifies the level of moisture vapor contained within the concrete in a direct way. RH measures the moisture vapor in the concrete relative to how much moisture that air can contain at a given temperature. If all that is known is the RH of the concrete, then almost nothing is known regarding the amount of moisture vapor in the concrete—of obvious interest when assessing moisture. For

example, concrete that is 80°F (27°C) with an RH of 30% contains more moisture vapor than concrete that is 50°F (10°C) with an RH of 80%. Imagine if similar methods were used for measuring other aspects of building construction. If, for instance, length were measured relative to a standard length that varied with temperature (say the height of mercury in a standard thermometer). Every length measurement would be a relative length, requiring an associated temperature. Although RH is useful for some purposes (e.g., assessing condensation potential), it is an inefficient tool for the measurement of moisture in concrete in a changing environment.

As a first step to better understanding moisture in concrete elements, it is proposed that consideration be given to the total water content contained in vapor form within the concrete. For example, a concrete element that has an RH of 80% at 70°F (21°C)—a commonly accepted threshold for flooring applications—has a moisture density within the vapor of 0.00092 pounds of water per cubic foot of air. For convenience, this moisture vapor density can be multiplied by 105 and defined as the Absolute Humidity Number, or AHN. In the case of an RH of 80% at 70°F (21°C), the AHN is 92. This can be performed for a range of RH

Absolute Humidity Number = (pounds of water vapor per cubic foot of void space) × 10 <sup>5</sup>												
RH	Temperature (°F)											
	50	55	60	65	70	75	80	85	90	95	100	
0%	0	0	0	0	0	0	0	0	0	0	0	
10%	6	7	8	10	12	14	16	18	21	25	29	
20%	12	14	17	20	23	27	32	37	43	49	57	
30%	18	21	25	29	35	41	47	55	64	74	86	
40%	24	28	33	39	46	54	63	74	85	99	114	
50%	29	35	41	49	58	68	79	92	107	124	143	
60%	35	42	50	59	69	81	95	110	128	148	171	
70%	41	49	58	69	81	95	111	129	149	173	200	
80%	47	56	66	78	92	108	126	147	171	198	228	
90%	53	63	75	88	104	122	142	166	192	222	257	


Table 1 - Absolute humidity number.

and temperature combinations to obtain the AHNs shown in Table 1. Although the AHN can be calculated for an RH of 100%, this value is stricken from Table 1 because it no longer represents moisture in pure vapor form.

Table 1 or a similar table could potentially be useful in assessing concrete that has not been conditioned to the test temperature. For example, assume the concrete moisture conditioning requirement for a given moisture-sensitive material is an RH of 80 percent at 70°F (21°C). If the concrete happens to be at a temperature of 80°F (27°C) during a given RH test, and the RH is measured to be 70%, then from Table 1, the AHN is 111, which is higher than 92 and an indication that the concrete has not yet been appropriately conditioned. However, in another application, if the concrete happens to be at 60°F (16°C) and the RH is measured at 90%, the AHN is 75, an indication that the concrete has been adequately conditioned and should satisfy material application criteria for moisture conditioning of concrete. In this example, all of the green cells in Table 1 satisfy typical material application criteria. Ultimately, the industry could move toward measurement of the AHN directly, and Table 1 would not be needed. AHN levels could be adopted by manufacturers so that moisture measurement could be made independent of temperature.


The wood industry has been using a similar concept of Wood Moisture Content for many years. Most people familiar with wood construction are aware that wood members should not be installed in most building applications until the wood moisture content is below a given threshold, commonly 19%, a very simple criterion to assess. There could be much benefit to introducing this type of simplicity in concrete moisture measurement. Even though moisture-sensitive materials are known to be more sensitive to moisture vapor within concrete as opposed to free water,<sup>4</sup> which is of interest in wood, the concept is similarly useful.

Knowing the RH alone does not say much about the amount of moisture vapor in the concrete, but knowing the AHN provides insight into how much vapor moisture is contained within the concrete. For example, concrete with an AHN of less than 25 is likely adequate for most material applications. Conversely, an AHN greater than 150 is likely inadequate for most applications, also




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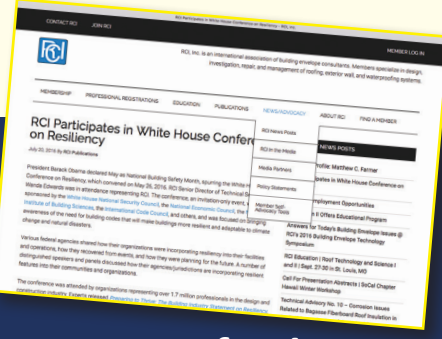
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regardless of temperature. As more experience is gained in the industry, these types of guidance numbers can certainly be tightened or supplemented with other moisture-related parameters of interest (e.g., total moisture content). In the meantime, they at least provide some reference as to the conditioning of the concrete so that informed decisions can be made.

In addition to the absolute humidity concept, another parameter related to moisture measurement that would be useful for consideration in regard to concrete moisture measurement is the well-known concept of vapor pressure. Current practice suggests that moisture vapor transmission within the concrete is the phenomenon that has the greatest effect on moisture-sensitive material performance, which is directly related to the vapor pressure that is expected between the moisture-sensitive material and the concrete during its service life. If the vapor pressure imposed on the material (vapor pressure demand) is greater than the vapor pressure capacity of the material, failure can be expected. Vapor pressure capacity is the time-dependent ability of the material to resist vapor pressures imposed

by moisture emission. If the vapor pressure demand is less than the vapor pressure capacity, adequate performance should be achieved. Although it is difficult to measure vapor pressure directly, a companion article to this one (pages 20-28) provides a framework for assessing expected vapor pressure demand analytically. Knowing the AHN can be useful in this assessment.

Design specifications can be greatly simplified if the vapor pressure capacity is specified as a design parameter. Since the vapor pressure capacity is a material property that should not be significantly affected by environmental conditions (at least within a range), designers can assess expected coating performance by comparing vapor pressure capacity (a constant) with vapor pressure demand calculated analytically. Consideration could be given to providing multiple vapor pressure capacities: one for early age during the curing phase when the coatings are more sensitive and conditioning should be managed more carefully, and another for a fully cured coating that may be more tolerant to higher vapor pressures, allowing more accommodation for service life variations and extremes.

Current measurement techniques and analytical tools for the rational assessment of moisture in unconditioned environments are lacking in the industry. It is hoped that manufacturers will transition from the MVER and RH tests, intended for assessment of concrete prior to receiving flooring in interior environments, to more globally applicable testing that applies to concrete in all environments, such as allowable AHN and/or vapor pressure capacities. 

#### REFERENCES

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2. ASTM F2170-16b, *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes*.
3. ASTM D4263 - 83, *Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method*.
4. *Concrete Floors on Ground*, Tarr and Farny, Portland Cement Association, 2008.



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