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Methods for Determining Moisture in Roofing Materials

Measurement and Limitations

key words: capillarity, dry range moisture content, equilibrium moisture content, gravimetric, hygroscopicity, thermal resistance ratio, wet range moisture content.

Without a doubt, moisture has one of the greatest negative influences on roof performance. Excessive moisture in roofing can lead to rot, decay, dimensional changes, corrosion, loss of strength, or resistivity etc. It is accepted that a roof, built with wet or moist materials, will yield inferior performance, when compared to roofs that are built with dry materials.

However, what continues to be debated are:

1. what level of moisture can be tolerated, and
2. how does one measure the amount of

Unfortunately, these questions are not easily answered as the amount of moisture reported will vary with the methods used. Moreover the effect of the moisture on performance will vary significantly with material type and system configuration.

This technical bulletin reviews the various methods used to calculate moisture content (MC) in materials and the applicability of these methods in determining the acceptable level of moisture of materials in the field.

At the outset we must acknowledge that no construction materials are ever completely dry. All materials contain some moisture. Some contain water in a bound form, such as gypsum (CaS04•2H20). When sufficiently heated, the water is driven out in a process called calcination. In this case, the moisture is required as it makes the gypsum a good thermal barrier.

Normally, the initial moisture content of a material will not have deleterious effects on the performance of the roof. However, this initial moisture content may be greatly exceeded if the materials are allowed to get wet during construction, or if the materials are stored in a very humid environment. One problem is that materials specifications and standards rarely list moisture within roof systems, subsystems, and material the initial moisture content of materials as they leave the plant. There are a few exceptions such as roofing felts, which are required to have a maximum moisture content of 3% by mass (CSA A123.3) and Mineral Aggregate Thermal Roof Insulation (CSA-A284) which limits the moisture content to a maximum of 3% by volume. As a result of the scarcity of information regarding initial moisture contents of most construction materials, it is very difficult to establish whether the levels of moisture in materials on site are greater than when they left the point of manufacture and what contributed to those levels.

The moisture absorption characteristics of roofing materials have been studied in the laboratory under conditions of high humidity and also when completely immersed in water. These studies have

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established a distinct range of moisture content for each individual roofing material. It is important to distinguish between the maximum moisture that can be absorbed by a material when immersed in water and that which can be absorbed from ambient air (i.e., relative humidity).

Each material has an equilibrium moisture content (EMC). This is the quantity of water held after long-term exposure at a constant relative humidity and a specific temperature. When the material contains more water than its EMC, it is wet, it cannot absorb any more and can give up water to the surrounding air or materials. (1) The property of a material which measures its ability to absorb and retain water from the ambient air is called its hygroscopicity. The more hygroscopic a material, the more water it will absorb and eventually have to release when subjected to heat. When a material is immersed in water until no further weight gain takes place, it is said to be saturated. That is, it has absorbed the maximum amount of moisture possible.

Many roofing materials are hygroscopic, absorbing a great deal of moisture from the surrounding air. Wood or cellulosic fibre insulation can tolerate considerable moisture because of its natural affinity for water, but may pick up excessive moisture if stored long on the job without proper protection. Excessive moisture in fibreboard will cause large dimensional changes, due to swelling the organic fibres. In addition, the capillarity of fibreboard is quite high, enabling it to draw liquid water into itself. For this reason if a leak occurs, the moisture will quickly spread.

Even when a material, such as a roofing felt, is saturated with asphalt, the saturation does not substantially affect the equilibrium moisture content which will be ultimately attained, but only affects the time required to reach its “moisture saturation”.(2) Asphalt saturated felts are not completely asphalt saturated, since they contain numerous small voids. Since the saturation process is not complete, these micro voids facilitate the entrance of moisture from the surrounding air. As a result, the water holding capacity of saturated felts is quite high and they will act somewhat like a sponge when wetted.

Materials that are ostensibly non-hygroscopic can be affected by prolonged exposure to moisture. PVC membranes, by example, can experience accelerated plasticizer loss from repeated cycles of ponding and evaporation. This may, in turn, lead to embrittlement and shrinkage of the membrane. In the case of cellular glass insulation, although highly resistant to wetting, it takes on moisture and decomposes rapidly when exposed to freeze/thaw cycling(3).

There are, therefore, two distinct MC classifications that can exist. The first is the dry range moisture content which is a function of the humidity of the ambient air and the absorption characteristics of the material. Studies indicate that the dry range MC is never zero, but varies, from a minimum EMC to a maximum EMC at approximately 90% relative humidity (4). Wet Range MC is a function of contact with liquid water from roof leaks or dew point condensation and varies widely among materials (5).

When determining what level of moisture is acceptable it is essential to distinguish between the dry range and wet range moisture content. Simply stating what the equilibrium moisture content of a material is will be meaningless, for it provides no benchmark for determining an acceptable level of moisture. Carl Cash, of Simpson, Gumpertz & Heger, Inc. has proposed that a material be considered “dry” when it contains less water than its equilibrium moisture content (EMC) at 45% relative humidity; “moist” when its moisture content is greater than its EMC at 45% RH but less than its EMC at 90% RH; and “wet” when it contains more water than its EMC at 90% RH (6).

Measuring Moisture

There are many ways of extracting and measuring moisture in materials. These range from the relatively simple technique of oven-drying to the more sophisticated techniques of distillation, Fischer Titration and calcium carbide pressure.

The most common method of measuring moisture in materials is the oven-drying method. This involves merely weighing the specimen before and after drying to constant weight in an oven maintained at a specified temperature (i.e. wood - 103 C). Principle sources of error in the oven drying method are: incomplete removal of water, removal of volatiles other than water, and moisture regained during weighing.

Another widely used method is distillation. If the specimen contains volatile material other than water, such as oil, this volatile will be evaporated in oven drying. The resulting weight loss cannot be distinguished from that caused by the evaporation of water. In these instances, a distillation process is used. The method involves fragmenting the specimen and boiling the fragments in a volatile solvent. The solvent vapour and water vapour are then removed by boiling and condensed into calibrated traps. The amount of water in the trap is measured and the dry weight of the specimen fragments is obtained after the solvent has been removed from them by oven drying.

Gravimetric Measurement

Although there are several methods used to extract moisture from a sample, all gravimetric methods (measuring by weight) involve the comparison of the weight of the sample before and after any moisture has been removed. Precision of this method depends on;

1. Ensuring that the specimen has been completely dried of any potential moisture before the final weighing.
2. The initial weight of the specimen must include all of the moisture which it had when the sample was taken and only that moisture. (No moisture can be permitted to escape or added before its initial weighing.)
3. The accuracy will be dependant on the accuracy and sensitivity of the balances and scales used to measure the sample.

Volumetric Method

If all insulations were of the same density, or if only one density of insulation was tested, a comparison of the moisture content on a percent by weight basis would provide an acceptable measurement of moisture [7]. However, insulations are available in a wide range of densities and a comparison of moisture or a percent by weight basis may be very misleading. Under these circumstances a more acceptable method of comparing the moisture content of insulations with varying densities is on a volumetric basis (percent by volume).

The following example illustrates how different results may be obtained using the gravimetric method as opposed to the volumetric method.

Assume that two different insulation samples with dimensions of 1m x 1m x 1m ($1m^3$) containing no initial moisture have the following properties:

Insulation A	*Initial Weight (dry) = 5kg* *Initial Density = 5kg/m³*
Insulation B	*Initial Weight = 2kg* *Initial Density = 2kg/m³*

Assume that each sample is allowed to absorb 1kg of moisture. Using the gravimetric method, the moisture content of each sample is calculated as follows:

Insulation A
(moisture % by weight) = 1kg ÷ 5kg (100) = 20%

Insulation B
(moisture % by weight) = 1kg ÷ 2kg (100) = 50%

Using the gravimetric method, it would appear that insulation B contains 2 ½ times more moisture than insulation A.

Using the volumetric method, the moisture contents of each sample is calculated as follows:

The density of water is $1000\ kg/m^3$

The volume of water *(Vm)* in insulation A and B can be calculated as :

$$Vm = 1kg/1000\ kg/m3 = 0\ .001\ m^3$$

The volume of both insulations is $1m^3$

The moisture content of insulation A as a percent of volume is, therefore,

$$0.001m^3\ \ x\ \ 100 = 0.1\%$$

For insulation B, the moisture content is also 0.1%

$$(0.001m^3\ x\ 100 = 0.1\%)$$

It becomes apparent that the moisture content of both insulations is equal on a by volume basis.

Why is the distinction between the two methods important? A weight-based moisture content of X% means that the water in the sample weighs X times as much as the dry sample. In the case of lightweight materials, such as low density polystyrene by example, it is possible to obtain values of 1000% moisture content using the gravimetric method. This can lead to erroneous conclusions when materials of differing densities are being compared. By example, a moisture content (by weight) of 50% may have serious consequences in heavy materials such as fibreboards, yet have little effect on lightweight insulations such as polystyrene.

There are difficulties in using either methods when attempting to measure moisture content of samples taken from the field. Measuring the volume of samples precisely is very difficult. In addition, it is important to recognize the role played by the facer of an insulation when taking samples from the field. Once an insulation facer is adhered to the substrate or a membrane is adhered to an insulation facer it is very difficult to separate the insulation and its facers from those components.

Even if it can be done, some asphalt or adhesive will have entered the facer, or even the insulation core, causing weight gain that introduces errors. In addition, some facers are more adsorptive to moisture than others, again introducing error.

Both methods of determining the moisture content of the sample measure the average moisture content of the sample. Studies have indicated that moisture is often not uniformly distributed throughout an insulation sample from the field. Depending on exterior conditions, and temperature gradients, it is possible to have insulation samples that are wetter or drier than the average moisture content in specific locations or layers (top or bottom).(8)

Once the moisture content of the insulation has been calculated, the problem then becomes in determining the effect of the moisture measured on the performance of the insulation. As stated earlier, simply to say that an insulation has a moisture content of X by itself is meaningless. What is important is to establish is the relationship between the moisture content and the material's important performance properties, such as its thermal resistivity.

Wayne Tobiasson, recommends the concept of the Thermal Resistance Ratio (TRR), which is the ratio of an insulation's wet thermal resistivity to its dry thermal resistivity.(9) Based on his extensive research, he proposes that an insulation with a TRR of less than 80% is "wet" and unacceptable due to the reduction in its insulating ability. This is not an absolute, however. For some insulations, less moisture than that required to reduce the TRR below 80% can be detrimental to their performance (i.e. can lead to corrosion, rot, delamination).

Conclusion

1. Water, as vapour or liquid can enter the roof assembly in many ways and its effects can be serious. The sources of water may include:
2. Construction process
    a. improper shelter, excessively long storage of materials, working in inclement weather.
    b. applying the material over wet decks
    c. improper venting (when pouring concrete);
3. Leaks - flashings and penetrations;
4. Condensation;
5. Roof damage and defects;
6. Improper curing of materials (particularly insulations using a manufacture)

The effects of moisture on the functions and performance of the roof components and the system as a whole will depend on the properties of the materials. Measuring the moisture content of materials is a difficult task. There are numerous methods for testing for and measuring moisture in materials. Each has, however, its limitations. The way moisture is measured and reported can have large impact on the decision to repair or replace. Even more difficult is ascertaining what levels of moisture are acceptable and what the consequences of the measured moisture will be. Determining the amount of moisture that is acceptable should be the responsibility of individuals with a thorough understanding of moisture mechanics and the materials behaviour. All too often, the level of acceptance is arbitrarily determined, with little basis in science.

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