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ASHRAE Standard 160P—Criteria for Moisture Control Design Analysis in Buildings

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ABSTRACT

In 1996, ASHRAE formed a new Standard Project Committee, ASHRAE 160P, to develop a standardfor moisture control in buildings. The draft standard — "Criteria for Moisture Control Design Analysis in Buildings" — intends to provide performance-based procedures for moisture design analysis for buildings. The standard sets criteriafor moisture design loads, moisture analysis methods, and building performance and applies to the above-grade portions of all types of buildings. It can be used for design analysis of the above-grade portion of the building envelope or help guide specifications for HVAC equipment and controls. Eventually it should form the basis for moisture design rules based on a uniform set of design assumptions and loads. This paper describes the rationale behind this standard, its current outline, and its potential uses.

INTRODUCTION

In April 1996, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) created a new Standard Project Committee l60P. The initial title of the Standard Project Committee (SPC) was "Prevention ofMoisture Damage," and the SPC was asked to "define the role that moisture plays in the degradation of building materials, components systems and furnishings." However, the SPC members felt that the original scope was too broad and that it threatened to parallel efforts within other standards organizations, in particular ASTM. The SPC recognized an emerging need for criteria for moisture design analysis and therefore redefined its purpose and scope and changed the title to "Design Criteria for Moisture Control in Buildings." In response to comments from public review (ASHRAE 2006), the title was recently changed once more, to "Criteria for Moisture Control Design Analysis in Buildings."

The need for criteria for moisture design has become .more urgent with a rapid improvement in the capabilities of computer-based moisture analysis tools that predict movement and accumulation of moisture in building components and materials. Although analytical tools are becoming more sophisticated and accurate, relatively little attention has been paid to appropriate inputs and boundary conditions. When using these tools to analyze a failure of an existing building this poses no problem, because only the data for conditions during the period before the failure are needed. Obtaining accurate and sufficient data in such a forensic application is often difficult enough. However, the choice of appropriate input values is even more uncertain when the analysis is used for design purposes before the building has been built and before actual loads can be measured.

Another reason for creating this standard is that current recommendations and rules for moisture control are not based on a set of consistent underlying assumptions. This has at times led to largely pointless discussions about the need for various design features, because the need often depends on what indoor or outdoor conditions are assumed. For instance, a computer analysis by Tsongas etal. (1995) of moisture accumulation in a wood frame wall in Madison, Wisconsin, showed that the need for including a vapor retarder in tlle design completely depended on the selection of indoor humidity. Thus the choice of input values for a design analysis is critical. Whether a design analysis will show acceptable or unacceptable performance of a particular design largely depends on the magnitude of the design loads operating on the building. Although it is difficult to imagine structural design

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decisions without knowledge of appropriate structural design loads, until now we have in fact made moisture control decisions without defining "moisture design loads."

TenWolde (2001) showed how the use of a moisture design standard such as 160P might have alerted manufactured-home builders to the potential of widespread decay of plywood sheathing that occurred in the mid-1980s in a group of manufactured homes in the Midwest (Merrill and TenWolde 1989). The article (TenWolde 2001) also shows how use of the standard could have led to the solution and prevention of problems that occurred, and could have circumvented a lot of the disagreements, and perhaps litigation, that took place following the discovery of the building failures.

In summary, the standard is intended to bring moisture design out of the realm of purely prescriptive measures and turn building moisture design into a performance-based procedure, with the potential for greater flexibility and a better ability to incorporate new designs and building materials. In addition to uniformity of design assumptions, the standard also seeks to make the moisture design analysis procedure more transparent by requiring documentation of the assumptions, material properties used, and other choices made for the analysis. The standard is attempting to strike a balance between simplicity of use and the actual complexities of the building environment, building performance, and design. This has led to many simplifications and sometimes parallel compliance pathways for the designer. The SPC is aware that other technically supportable choices could have been made in the standard. This is why it is important that the standard is following the consensus procedure required by ANSI.

Finally, the SPC also found that sufficient information was not always available to provide a solid technical basis for the criteria. In those cases, the criteria are based on our best professional judgment, with the expectation that they will be changed iftechnical information becomes available supporting different criteria or procedures.

Since ASHRAE has long been a leader in providing technical guidance for moisture control in buildings, we felt that a consensus standard procedure through ASHRAE provided the most logical vehicle for these needed moisture design criteria.

PURPOSE AND SCOPE

The purpose statement of ASHRAE Standard 160P reads as follows: Given the role that moisture plays in the degradation of building envelope materials, components, systems and furnishings, the purpose of this standard is to specify performance-based design methods for predicting, preventing, mitigating or reducing moisture damage depending on climate, constmction type and system operation. These methods include (a) criteria for selecting analytic procedures, (b) design input values, and (c) criteria for evaluation and use of outputs.

Thus the standard specifies the minimum attributes for analytical procedures, depending on the building design and other parameters. For instance, if the construction is a brick wall, the analytical procedure should be able to handle water absorption and redistribution in the brick. In contrast, in the unlikely event that the construction does not contain hygroscopic materials and is airtight, a simple vapor diffusion analysis may be sufficient. The standard also defmes design input values, or "design moisture loads," primarily by prescribing default values in case the designer does not have actual design specifications. This includes interior as well as exterior (such as rain, humidity) loads. Finally, the standard describes how the results from the analysis should be interpreted. It provides criteria to determine if the building component is likely to perform satisfactory or not.

Standard 160P is intended to apply to new buildings, additions, or retrofit and renovation of existing buildings. It includes all types of buildings, building components, and materials. An important limitation in the scope is that the standard will not address extraordinary loads due to gross water leakage from sources such as rain water, ground water, flooding, plumbing leaks, or ice dams. The SPC believes that massive intrusion of rain water should be prevented by proper detailing and flashings, and intrusion of ground water by proper site grading and drainage. However, the committee also realized that occasional intrusion of a small amount of water, especially around doors and windows, is probably inevitable, even in a building with proper detailing and flashing. These loads may still be significant, and the standard therefore includes small rain penetration loads that the building will be expected to be able to accommodate.

The standard is most easily used for the design of the above-grade portion of the building envelope. Because no analytical procedures are yet available for reasonably accurate moisture analysis of below-grade building elements, it is not yet feasible to apply the standard to such building elements. Below-grade moisture loads are also far more variable and complicated, and quantitative data are very scarce. The performance of the building design is evaluated under design loads using the performance criteria in the standard. If the performance is unacceptable, the design should be changed and reevaluated. Another viable option is to use the standard to design the HVAC equipment and controls. The indoor design loads are manipulated by varying the design of HVAC equipment and controls, and the design analysis is used to evaluate the building performance in response to this manipulation.

In the following section, an outline of the content of the draft standard is given. Some of this information may change during the second public review and finalization of the standard. Some of the following also reflects the opinion of the author, which mayor may not be shared by all SPC members.

DESIGN LOADS

Ideally a design analysis involves determining the probability of failure, treating all design parameters and loads as stochastic variables (Geving 1997). However, sufficient data are usually not available to make a full statistical treatment practical. Instead, a moisture design protocol will have to be based on a combination of statistical data and professional judgment where only limited data exist. Another judgment involves the choice of an acceptable probability of the occurrence of damage. Although imposing very stringent criteria for structural design is common because of safety concerns, moisture damage usually occurs over a long period of time and usually has less catastrophic, although sometimes costly, consequences. An international consensus has emerged that a 10% likelihood of failure is an appropriate level in building moisture design analysis, and this standard has adopted this approach. To the extent possible, the loads prescribed in the standard are based on this 10% exceedance approach.

Design Initial Moisture Conditions

Some building materials, such as concrete, wet-spray cellulose insulation, and wood, may contain large amounts of water at the time of building enclosure. This moisture is often called construction moisture. A design analysis should account for this initial moisture load by assuming high initial moisture contents for those materials, unless specific plans have been included in the construction cycle to dissipate this moisture or to prevent this moisture from accumulating in the materials through proper storage and protection from rain and flooding during construction. If such measures are included in the design and construction plans, the initial conditions to be used, according to Standard I60P, are the equilibrium moisture content (EMC) of each material at 80% relative humidity (rh). This moisture content is named the EMC80 in the standard. This level was chosen because the standard defines this as the highest possible moisture level that does not lead to mold growth (see Performance Criteria section), thereby allowing for a reasonably high, but not destructively high moisture content. As discussed in the section on Performance Criteria, there is no guarantee that no mold will be present at lower moisture contents, but the SPC needed to strike a reasonable balance between accuracy and simplicity. The design initial moisture content of concrete is EMC90 (EMC at 90% rh) if specific care is taken to limit initial moistme conditions. If no such measures are planned, the design moisture contents must be doubled (i.e., 2 x EMC90 for concrete and 2 x EMC80 for all other materials). The factor of2 was chosen somewhat arbitrarily, but no published quantitative data are available on construction moisture, actual moisture contents are likely to be extremely variable, and the SPC felt strongly that some form of accountability for construction moisture and dryout procedures should be included.

Internal Loads

In a moisture analysis for building envelope design, the choice of indoor environmental conditions is extremely important, especially for buildings in cold climates. This standard opts for a design indoor climate definition that is based on engineering principles and reflects the influence of ventilation and air-conditioning equipment and controls that mayor may not be part of the building design. In buildings where indoor humidity and temperature are explicitly controlled, the building envelope performance should be evaluated with the intended indoor design conditions. In residential buildings, indoor humidity is rarely explicitly controlled, and default design assumptions are needed for these buildings. In general, the standard encourages designers to use their own design parameter values if they are known and part of the design. If they are unknown or not included in the design, the standard provides default values for those loads and parameters.

Internal moisture design conditions include temperature, humidity, and air pressures. In case design values are available from HVAC or other design specifications, they should be used. If design values are not available, the standard prescribes default design values.

Design Indoor Temperature. If the operating indoor temperature is specified, or the design temperature is prescribed by code or law, that temperature should be used for a design moisture analysis. If the indoor temperature is not specified, the default indoor design temperature is 21.1°C (70°F) during heating and 23.9°C (75°F) for cooling, if air-conditioning equipment is included in the design. Heating is assumed to take place when the 24-h running average falls below l8.3°C (65°F), and cooling when the running average rises above 21.1 DC (70°F), if air-conditioning equipment is included in the design. When the 24-h running average outdoor temperature falls between 18.3°C (65°F) and 21.1°C (70°F), the default indoor temperature is assumed to "float" at 2.8°C (5°F) above the 24-h mnning average outdoor temperature. If no air-conditioning equipment is included in the design, the indoor temperature is assumed to "float" at 2.8°C (5°F) above the 24-h running average outdoor temperature when the 24-h running average temperature is above 18.3°C (65°F).

Design Indoor Humidity. If the HVAC equipment and controls are included in the design, the standard requires that the intended design indoor humidity shall be used. If HVAC equipment and control are not included, the standard provides t1u:ee different default pathways for the determination of indoor design humidity: the Simplified Method, the Intenne-diate method, and the Pull Parametric Calculation.

The Simplified Method for indoor design humidity is based on measured data from buildings without air-conditioning, primarily in northern Europe. It provides a simple correlation between outdoor temperature and indoor humidity but is not based on engineering principles. Although the standard allows use of this method for air-conditioned buildings, it should be understood that humidity conditions in air-conditioned buildings tend to be lower. The Intermediate Method provides more realistic conditions for air-conditioned buildings. The simplified method is also likely to produce high values for dry climates, even with air-conditioning.

The Internlediate Method distinguishes between indoor design humidity with dehUlllidification or air-conditioning and indoor design humidity without. The methodology is largely described by TenWolde and Walker (200 1). Ifmoisture removal is only by ventilation with outdoor air, the Intermediate Method uses a simple mass balance between moisture sources and ventilation. Residential source rates are provided in the standard, but the designer is encouraged to use appropriate source rates for non-residential construction. Ventilation rates are those specified in the design or by code, or default values are given in case they are not. The calculation is done with 24-h running averages to account for the effect of moisture storage (buffering) in the building.

The simple mass balance approach does not always work when dehumidification or air-conditioning takes place. If the equipment is temperature-controlled, the rate of moisture removal may be difficult to predict, especially in improperly sized installations. While condensate removal calculations should be encouraged where possible, the especially SPC did not require these calculations in the standard because these are default calculations, to be performed when the HVAC design and controls are not available. The SPC also was concerned about unduly complicating the Intermediate Method, The standard therefore resorted to a correlation between indoor design humidity and outdoor design humidity for cooling (TenWolde and Walker 2001). This approach does produce reasonable levels of indoor humidity, which are related to outdoor humidity conditions, and are more realistic than the values prescribed under the Simplified Method.

The situation becomes much simpler when air-conditioning or dehumidification equipment is controlled with a dehumidistat, in which case the anticipated humidity setting can be used (a default of 50% rh is provided in case the setting is not known).

The Full Parametric Calculation allows the designer to go beyond the previous two methodologies and use more sophisticated tools. This may include building ventilation modeling, using design weather data (see the next sections), and equipment models that can estimate moisture removal rates. It also may involve models that include the effect of adsorption and desorption of water vapor in various building materials and furnishings. However, the principle of using design loads (i.e., higher than average loads) must be adhered to.

External Loads

External design loads include loads from wind, rain, temperature, humidity, and solar radiation. To ensure that the analysis is done with appropriately severe weather conditions, the standard requires using 10 consecutive years of weather data, or the use of a "Moisture Design Reference Year" (MDRY). A Moisture Design Reference Year is defined as the 10th-percentile warmest and 10th-percentile coldest years from a 30-year weather analysis. An ASHRAE research project is underway (ASHRAE RP 1325) to develop a methodology for producing MDRYs from local weather data.

Rain. The standard includes simple formulas for design rain loads on walls for those users who are not inclined, or capable to perform a full wind-driven rain analysis. The formulas are based on work by Lacy (1965). The standard assumes that a small amount of this rain water will penetrate behind the cladding, even when adequate flashing and properly installed water-resistive barriers are included in the design. Very few data are available on the amount ofrain that penetrates through various types of claddings. Based on unpublished data for· brick walls, the committee decided that at this time 1% of the rain incident on the cladding is the best estimate for this amount, lacking better data.

Air Pressures aud Air Flow. How to handle the effect of air pressures and air flows presented a special difficulty to the SPC. On the one hand, we know that air flows are important to moisture distribution, and can completely dominate over water vapor diffusion. On the other hand, analytical procedures to calculate these effects are not readily available, and appropriate design air pressure boundary conditions are not easily established. In that light, the SPC decided to make the inclusion of air flows in the analysis optional. If the user chooses not to include air flow analysis, the standard requires that this be explicitly stated in the analysis report. If analysis is included, the standard contains default values for component air tightness in case better data are not available and prescribes minimum pressures and direction to be used. However, this section of the standard is still under review and discussion within the SPC, and may therefore still change significantly.

Performance Criteria

Performance criteria are needed to evaluate the results from the design analysis. The standard focuses on surface mold growth because under most circumstances it is likely to be the most stringent of all performance criteria. If mold is of no concern (rarely), if the material is not conducive to mold growth, or if temperatures are too cold or warm for mold growth, other criteria such as surface condensation or structural degradation may become critical. The criteria for mold growth have been adapted from IEA Annex 14 (1991). To avoid mold growth, the following conditions must be met:

1. 30-day running average surface RH < 80% when the 30-day running average surface temperature is between 5xC (41xF) and 40xC (104xF), and
2. 7-dayrunning average surface RH < 98% when the 7-day running average surface temperature is between 5xC (41 xF) and 40xC (104xF), and
3. 24-h running average surface RH < 100% when the 24-h running average surface temperature is between 5xC (41 xF) and 40xC (104xF).

The SPC understands that conditions for mold growth are complex, and that some mold growth may occur at lower relative humidities. The SPC also realizes that conditions for growth vary with mold species and that the rate of growth varies with temperature and other parameters. However, it was important, as in the rest of the standard, to strike an appropriate balance between the complex reality and needed simplicity of use of the standard. The standard allows less stringent criteria for materials that are naturally resistant to mold growth (e.g., concrete, masonry, glass, and metals) or have been chemically treated to resist mold growth.

SUMMARY

In 1996 ASHRAE formed a new Standard Project Committee, ASHRAE 160P, to develop a standard for moisture control in buildings. The current title ofthe draft standard is "Criteria for Moisture Control Design Analysis in Buildings," and the standard intends to provide performance-based procedures for moisture design analysis for buildings. The standard sets criteria for moisture design loads, moisture analysis methods, and building performance and applies to the above-grade portions of all types of buildings. It can be used for the design analysis ofthe above-grade portion of the building envelope or help gnide specifications for HVAC equipment and controls. The standard hopes to accomplish the following goals:

- Reduction in building failures in service
- Performance-based quantitative criteria for moisture design analysis
- Consistency in design approach and recommendations
- More flexibility in design for moisture control
- Better ability to incorporate new materials
- Transparency (i.e., reporting of design assumptions)

In addition to providing a performance-based design procedure, we hope the standard will form the basis for any future prescriptive moisture design rules that are based on a uniform set of design assumptions and loads.

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