Review of Parts 3 and 4 of the ASTM Manual on Moisture Control in Buildings

P.R. Achenbach

INTRODUCTION

This paper continues the review of the forthcoming ASTM manual on moisture control in buildings. This review is based on the unreviewed first manuscripts submitted by the authors. Parts 1 and 2 of the manual are described in a companion paper by Heinz Trechsel.

CHAPTER 3.1—GENERAL CONSTRUCTION PRINCIPLES, P.R. Achenbach

Building designers and builders should take moisture control into account in the design and construction of buildings since building deterioration is closely correlated with moisture conditions, occupant comfort is affected by indoor relative humidity, and moisture control can affect building energy use and its initial and maintenance costs.

Therefore, the objectives of the designer and builder with respect to moisture control can be stated as follows:

1. avoid premature deterioration of the building,
2. provide desirable indoor air conditions, and
3. provide economy in the use of energy and materials.

The principal moisture transfer processes that need to be considered or protected against in building construction are the following:

1. rainwater or melted snow leakage;
2. the rise of moisture from the earth into foundations, walls, and basements;
3. diffusion of indoor moisture into walls or ceilings with attendant concealed condensation in cold climates;
4. diffusion of outdoor moisture into walls or ceiling/roofs with or without solar exposure;
5. convection of indoor or outdoor moist air into elements of the building envelope, with or without pressure, accompanied by the transfer of moisture to envelope materials; and
6. disposal of indoor moisture load.

The various methods for moisture control in buildings, used singly or in combination, are the following: (a) infiltration; (b) chimney effect; (c) ventilation, natural and mechanical; (d) indoor/outdoor pressure difference; (e) humidification/dehumidification; (f) cyclic absorption and desorption of moisture by building materials; (g) drainage of water; (h) vapor retarders and air barriers; (i) caulking and sealants; and (j) landscaping.

CHAPTER 3.2—GENERAL CONSIDERATIONS FOR ROOFS, Wayne Tobiasson

Roofs may be categorized as water-shedding or waterproof with respect to the outer element of the roof. A water-shedding roof uses a series of overlapping elements, such as shingles or tiles, to prevent water penetration. Waterproof roofs require membranes on low-pitched roofs that are totally sealed against water penetration.

When considering condensation problems in roofs, it is important to distinguish between compact and framed types of roofing systems. A compact roof with membrane waterproofing has the insulation placed above the roof deck. There is little opportunity for air movement within a compact roof system because (1) it contains no air spaces, (2) the rigid insulations are usually of low permeability, and (3) wires and pipes are seldom routed within it. A framed roof has its insulation below the deck between the framing members. Relatively inexpensive batts of permeable glass or rock wool insulation are used. It is common for electrical wires to be placed among the batts and for lighting fixtures to be recessed up into the roof. A barrier to air and vapor may or may not be present. Many air leakage paths are available in such roofs.

The author discusses the following topics:

1. how and why multiply roofing felt becomes wetted;
2. why rubber, plastic, and modified single-ply systems are being more widely used;
3. protected membrane roofs;
4. the role of ventilation in moisture control in roofs;
5. the importance of sealing leaks in the ceiling;
6. roofing practice in Canada, Great Britain, and Denmark; and
7. guidance for improving or replacing roofs.

The author's organization has developed maps showing the magnitude of the wetting and drying potentials for roofs in various climatic zones in terms of time and vapor pressure difference between the interior and exterior of a building. It has been suggested as a basis for including or excluding a vapor retarder in a roofing system.

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CHAPTER 3.3—MOISTURE CONTROL FOR NEW RESIDENTIAL BUILDINGS, Joseph Lstiburek and John Carmody

It has been accepted by the building industry that many building assemblies become wet during service and, in many cases, start out wet. Furthermore, the industry has recognized that in many circumstances it may be impractical to design and build buildings that never get wet. This has given rise to the concept of acceptable performance. Repeated wetting followed by repeated drying can provide acceptable performance if, during the wet period, materials do not stay wet long enough under adverse conditions to deteriorate.

Numerous strategies can be implemented to minimize the risk of moisture damage. The strategies fall into three groups:

1. control of moisture entry,
2. control of moisture accumulation, and
3. removal of moisture.

For the purpose of describing specific moisture control measures for residential buildings, the United States has been divided into three climatic zones, namely, (1) a zone having more than 4,000 heating degree-days and intermittent air-conditioning requirements, (2) a mixed climatic zone having 4,000 or fewer degree-days of heating and a significant number of cooling hours, and (3) a cooling climatic zone having a significant number of air-conditioning days that generally follow the ASHRAE definition of a humid climate.

The moisture control practice in each of these three climatic zones is discussed by the authors under the following headings:

- key concerns and control strategies,
- rain and groundwater,
- condensation within building assemblies,
- ice damming (except for the cooling climatic zone),
- high interior humidity, resulting in mold and mildew.

Mechanical systems concern combustion appliances and whole-building systems.

The authors provide recommended designs for six wall constructions: crawl spaces, basements, floor slabs, attics, and ventilated and unventilated cathedral ceiling constructions.

CHAPTER 3.4—HIGH-RISE BUILDINGS, Gustav Handegord

The main differences between low-rise residential buildings and high-rise buildings with respect to moisture control relate to the materials used and the methods of construction. Most low-rise buildings involve some form of wood-frame construction on load-bearing masonry and wood framing, while high-rise buildings involve steel or reinforced concrete framing with noncombustible materials such as concrete, brick masonry, metal, and glass in the exterior envelope.

The effect of wind and wind-driven rain can be more severe on high-rise buildings because of their greater height, and, in some cases, the air pressure differences across the building envelope due to stack effect may be greater. In cold climates, stack effect will have a greater impact on the performance of central air-handling systems that are used in high-rise buildings.

The types of problems attributed to moisture in high-rise buildings include the following:

- condensation on windows;
- wetting and staining of interior and exterior finishes and walls and walls beneath the windows;
- mold and mildew on gypsum sheathing and interior and exterior finishes;
- water entry or wetness at the junction of a wall and the floor slab;
- deterioration or delamination of gypsum sheathing and interior and exterior coatings;
- effluorescence of exterior masonry;
- spalling of exterior masonry;
- corrosion of ties, anchors, fasteners, metal roof decks, studs, structural members, and exterior metal cladding;
- dislocation and bulging of masonry components; and
- deterioration of mortar joints.

The author has discussed the causes of these problems and has suggested methods for alleviating them.

CHAPTER 3.5—REMEDIAL AND PREVENTIVE ACTIONS FOR EXISTING RESIDENTIAL BUILDINGS, William Rose

There are three basic strategies for dealing with moisture control in existing residential buildings:

1. identify and reduce the moisture source,
2. modify the building envelope, and
3. provide mechanical equipment and control.

In general, it is wise to apply these remediation strategies in this order; one should not modify the envelope or add mechanical equipment until all the excess moisture sources have been removed or reduced. Modification of the envelope may involve cost, and adding equipment involves not only capital cost but also operating costs.

Remedial actions that can be classified under source reduction include:

- controlling groundwater by ensuring the proper slope of soil adjacent to the house,
- ensuring the delivery of downspout water into runouts,

- venting combustion devices to the outdoors and checking for backdrafting,
- keeping humidifiers clean and calibrating the controls occasionally, and
- calculating the probable moisture release rate by building occupants and by repetitive occupant activities and determining the amount of outdoor ventilation required.

Modifications to the envelope to improve moisture control include:

- dampproofing or waterproofing the outside of basement walls;
- installing a sump pump in the basement;
- installing a polyethylene vapor retarder against the foundation wall;
- placing a polyethylene ground cover over the entire soil surface in the crawl space;
- inspecting the crawl space for exposed soil, puddles of water on the ground cover, plumbing leaks, and mold and mildew;
- sealing all leaks around light fixtures, wiring, plumbing, and air-conditioning grilles in the floor, walls, and ceiling;
- painting interior walls with low-permeability paint;
- controlling indoor humidity to prevent condensation on windows or installing storm windows;
- providing attic ventilation in accordance with building codes;
- considering the installation of an airtight vapor retardant on the ceiling;
- venting exhaust fans from kitchens and bathrooms to the outside; and
- applying a vapor retarder to the underside of cathedral ceilings.

Providing mechanical equipment to overcome moisture problems includes:

- the installation of self-contained mechanical dehumidifier units to lower indoor relative humidity,
- the installation of a second small room air conditioner to supplement the dehumidification capacity of a central air-conditioning system, and
- the use of a whole-house ventilation system with or without heat exchange or enthalpy exchange.

CHAPTER 3.6—RECOMMENDATIONS FOR REMEDIAL AND PREVENTIVE ACTIONS FOR EXISTING COMMERCIAL, INSTITUTIONAL, AND HIGH-RISE BUILDINGS, Warren French

The author discusses in considerable detail the prevention of moisture problems in the design process and also the procedures for inspecting and identifying the array of problems that could develop in commercial, institutional, and high-rise buildings. He recommends the use of trained personnel to perform renovation work and emphasizes the use of standard or recognized procedures in identifying the causes of moisture problems. He discusses the "how to do it" aspects of remedial procedures in broad, general terms. His presentation includes an extensive bibliography of specifications, design standards and guidelines, and test methods for materials properties.

CHAPTER 3.7—MANUFACTURED HOUSING, Michael Werner

Factory assembly of housing places some restrictions on design and also results in some benefits that contribute to differences from site-assembled housing.

Due to over-the-road height restrictions, the height of the attic cavity is relatively small in manufactured housing. This can result in restricted air movement in the attic. While factory assembly of an open roof/ceiling structure allows close attention to the application of the vapor retardant and the ceiling insulation, it is virtually impossible to inspect it on site.

The accuracy of cut framing leads to tight construction joints, and the application of putty or caulking at wall/ceiling, wall-to-wall, and wall/floor joints contributes to low air leakage. Spray application of vapor retardant is often used in construction, but the HUD standard manufactured house construction and safety document requires a film vapor retardant. Walls may be designed to be ventilated or unventilated.

Site installation has an important influence on moisture control. Effective site drainage is crucial. The site should not allow standing water to accumulate beneath the home. Manufacturers usually recommend a polyethylene ground cover but do not usually recommend a ventilated crawlspace.

Manufactured houses use sealed-combustion, fuel-burning furnaces and water heaters. Most suppliers offer power-driven roof air intakes connected to the return side of the heating system to introduce fresh air into the living space. Eave, ridge, and gable vents provide air change in the attic. Air-conditioning equipment is usually installed after the purchase.

The HUD standard is applicable only to houses designed for erection on site-built, permanent foundations with the expectation that they will never be moved. This standard requires a vapor retarder on the underside of the ceiling and describes alternative ventilated, unventilated, and vapor retarder constructions for walls. It does not require a vapor retarder on the floor board.

The author has identified some of the manufacturing defects, site installation problems, and occupant operation practices that cause moisture control problems and has provided recommendations for remedial actions.

CHAPTER 3.8—MOISTURE IN HISTORIC BUILDINGS: PRESERVATION GUIDANCE, Sharon Park

Historic buildings, by their very designation, are special resources that are irreplaceable. A methodology that is specific to historic buildings involves (1) researching existing drawings or earlier studies of the building, (2) undertaking a condition assessment of the historic resource, (3) monitoring moisture levels in materials, (4) identifying structural and material assembly systems to understand how moisture moves and dissipates through materials, and (5) evaluating the various sources of moisture affecting the resource.

The principal document outlining the National Park Service's policy on historic preservation is the Secretary of the Interior's "Standards for Preservation Projects." These standards were developed as a response to the National Historic Preservation Act of 1966, which established a program of historic preservation nationwide.

Because moisture is a complex subject, this chapter breaks the building down into different components using the major headings and subheadings shown in the outline below. The discussion under each subheading and with respect to the historic site follows this sequence: (a) evidence of moisture decay, (b) sources of moisture, (c) remedial treatments, and (d) treatments to avoid.

Historic Exteriors
- Foundations
- Exterior wall surfaces
- Windows
- Roofs

Historic Interiors
- Structural systems
- Mechanical systems
- Interior finishes

Historical Site

The author incorporates a number of photographs to illustrate various types of moisture problems in historic buildings.

CHAPTER 4.1—SPECIFICATIONS, Richard Mundle

The purpose of construction specifications is to ensure the quality of materials and direct the methods of installation of these materials. The specifications complement the drawings that show the location of the various materials and the relationship between them.

Four basic specification methods are commonly used:

1. A descriptive specification defines, in detail, the required features or properties of materials or manufactured products, including workmanship standards for proper installation. The use of descriptive specifications was once widespread, but use of this method of specifying is waning.
2. Performance specifications state the required final results rather than describe the means of methods to achieve that result. Few, if any, limitations are placed on the means used to obtain the performance required.
3. The emergence of nationally recognized standards published by trade associations, the government, and institutional organizations has led to the increasingly popular method of specifying by adherence to those standards. The standards are referred to by number, title, and date (or other designation) and become incorporated into the specification by reference.
4. Proprietary specifications define the required products by the manufacturer's name and model number, brand name, or other indications. The specifier has the advantage of knowing precisely which product will be incorporated into the work.

The specification, which forms a part of the contract, has evolved over time into a relatively structured format with a consistent organization. The driving force in this move toward organization has been the Construction Specifications Institute (CSI). In the early 1960s, a system was developed that is now known as the "CSI 16 Division Format." It is widely accepted by architects, engineers, and contractors. The format has 16 divisions with fixed titles. Division 7 is entitled "Thermal and Moisture Protection." The sections within a division are subdivided into three levels of complexity, namely, broad scope, medium scope, and narrow scope.

The specification for a particular material is often nearly the same from job to job. For this reason, most design firms and others regularly producing construction specifications have created an office master specification system, which contains standard sections, including clauses usually applicable to the type of work and a number of standard paragraphs that can be used in the final specification, if applicable. There are a number of commercial master specification systems available that have the advantage of being continually updated.

The U.S. Navy has produced a publication that lists a number of the master guide specifications sections, namely, AIA Masterspec, CSI SPECTEXT, Navy, Army, NASA, General Services Administration (GSA) Masterspec, and National Institutes of Health (NIH).

CHAPTER 4.2—APPLICABLE GUIDELINES, STANDARDS, AND CODES, Wayne Ellis

The terms *guidelines*, *standards*, and *codes* are sometimes misconstrued. Each of these concepts has a related, but different, meaning.

A guideline is a written statement or outline of policy practice or conduct.

There are at least three consensus definitions of the term *standard*: (1) a concept that has been established by authority, custom, or agreement to serve as a rule in the measurement of quality or the establishment of a practice or procedure; (2) a document, established by consensus and approved by a recognized body, that provides for common and repeated use, rules, guidelines, or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context; and (3) a prescribed set of rules or requirements concerned with the definition of terms; classification of components; delineation of procedures; specification of dimensions, materials, performance, design, or operations; measurement of quality and quantity in describing materials, products, systems, services, or practices; or description of fit and measurement of size.

A code (in the law) is a collection of laws (regulations, ordinances, or statutory requirements) adopted by governmental (legislative) authority. Codes are further classified as model codes, building codes, energy codes, fire codes, plumbing codes, mechanical codes, and electrical codes.

Relatively few uncontested, reliable guidelines have been developed for control of moisture problems in buildings. A principal reason is that not enough understanding exists to translate the results of numerous laboratory and field tests into universal design guidelines. One widely referenced work is the *ASHRAE Handbook—Fundamentals*, in which chapters prepared by ASHRAE technical committees on such topics as thermal insulation and moisture retarders, ventilation requirements, and infiltration provide moisture control guidance.

The author cites 11 references to ASTM and industry guidelines and to a large number of standards issued by ASTM, Great Britain, industry, and others, dealing with building materials and components of building envelopes and relating to air leakage, moisture, and heat transfer.

The three model building codes in the United States do not cover the control of moisture in buildings except to warn against possible damage from water vapor condensation. Ignored is the fact that the transfer of moisture may result in increased heat transfer and energy use in the building.

More than 20 sources of guidelines, standards, and codes have been cited by the author. There is no single information source, index, data base, or compendium in which the designer or practitioner may find all standards, codes, and guidelines dealing with moisture control in buildings. Obviously, such a resource would be widely used provided that it could be available in electronic form and be periodically updated.

CHAPTER 4.3—LEGAL CONSIDERATIONS AND DISPUTE RESOLUTION: THE WATER-RELATED CONSTRUCTION FAILURE, Bruce Ficken

A construction failure occurs any time that construction fails to perform as intended or required. Thus, not only is a construction failure the bridge that collapses or the structural support system that fails, it is also the paint that peels prematurely, the roof that leaks, or the glue that fails to hold. Every construction failure raises key issues and considerations that must be understood for the contractor, architect, specification writer, or owner to protect himself.

In every jurisdiction, the contractor is required to perform construction fully in accordance with the contract documents. He is responsible for the resulting damages. Conversely, a contractor's compliance with plans and specifications is universally recognized as a contractor's defense against liability in construction failure cases.

The contractor who knows that there is a significant risk of a construction failure if he complies with applicable plans and specifications has a duty to bring these deficiencies to the attention of the owner. If there is a subsequent construction failure as a result of the specified deficiency, the contractor can be liable for his failure to warn. Similarly, a contractor has the duty to warn of defective site conditions if the contractor knows or should know of the defect.

In virtually every jurisdiction, design professionals, including architects and engineers, are required to follow accepted standards of practice. Therefore, they are liable for damages that may arise from failing to follow these standards. In a leading case on architect liability, the Pennsylvania Supreme Court held, "An architect is bound to perform with reasonable care the duties for which he contracts. His client has the right to regard him as skilled in the science of the construction of buildings, and to expect that he will use reasonable and ordinary care and diligence in the application of his professional knowledge to accomplish that for which he is retained. Thus, it has been held that a design professional impliedly warrants that his plans and specifications are free from defects and fit for the purpose for which they were produced."

Under this doctrine it can be argued that if the finished construction is built in accordance with plans and specifications, it

(a) will not leak,
(b) will not allow the accumulation of water where the building will be adversely affected,

(c) will not be duly affected by predictable influx of moisture in the physical construction,
(d) will expel water that enters the construction predictably, and
(e) will not utilize materials that tend to trap excessive amounts of water under predictable circumstances.

In any construction failure dispute, the owner is likely to argue that he hired a design professional to design and a contractor to build the building, so that if anything goes wrong with the job, it must be the responsibility of one or the other. That perspective ignores the owner's responsibility to maintain the building and not to modify the structure in a deleterious manner.

The author presents a case study on the court settlement of a construction failure involving a 16-story oceanfront hotel in which major mold and mildew problems developed almost as soon as the hotel was occupied. The case shows that the owner was able to collect only small damages from the architect and contractor, partly because during the court hearing he did not adequately develop and present the facts surrounding the operation of the hotel.