Appendix C. Architectural Supplements

DESIGN CONSIDERATIONS

CLIMATE AND ENERGY

Of primary importance to the shell of a building is the mediation between the exterior and interior environment. Proper design and detailing of the building enclosure requires an understanding of the specific characteristics of both the desired interior environmental conditions and specific exterior environmental conditions, on both a macro and micro scale.

DEFINITIONS

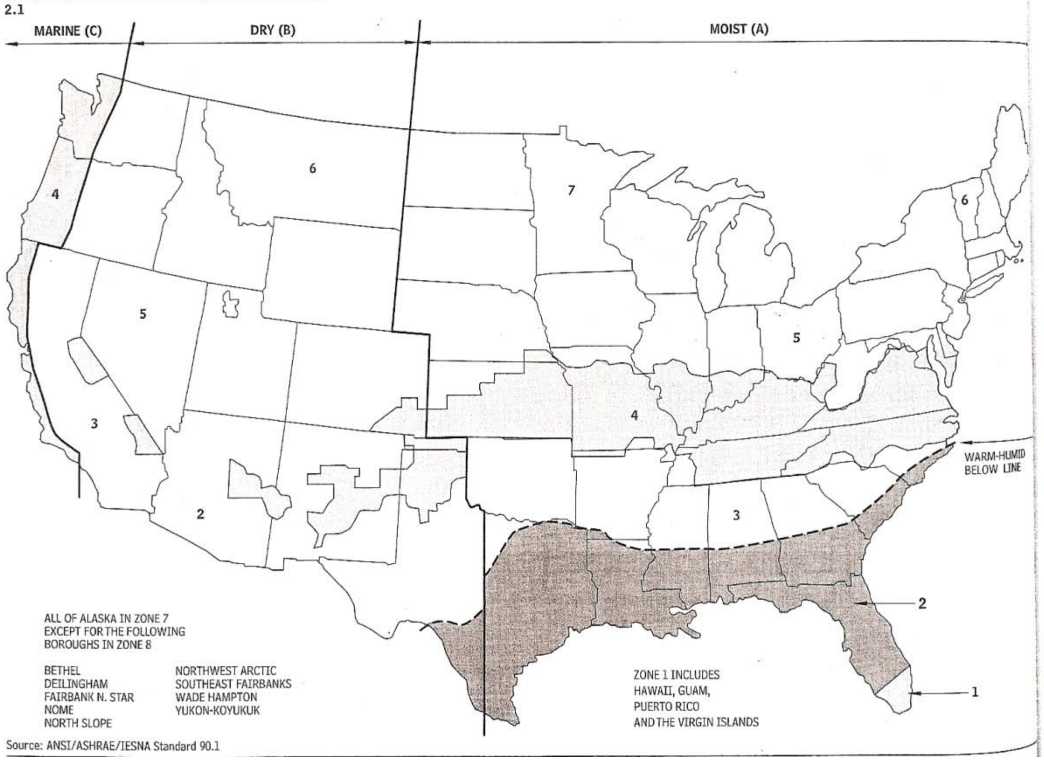
When reading the content of this chapter, keep in mind the following definitions of concepts and principles:

- *Air barriers*: Materials or combinations of materials that form a continuous envelope around all sides of the conditioned space to resist the passage of air. Joints, seams, transitions, penetrations, and gaps must be sealed. The air barrier must be capable of withstanding combined positive and negative wind load and fan and stack pressure without damage or displacement. The air barrier must be at least as durable as the overlying construction and be detailed to accommodate anticipated building movement. An air barrier may or may not be a vapor retarder.
- *Vapor barriers and retarders*: Without industrywide consensus, materials with a perm rating less than 1 are interchangeably called vapor barriers or vapor retarders (IBC and IEC 2003 use "vapor retarder"). More important than the term is to understand a few basic principles:
  - Vapor diffusion through materials with perm ratings less than 1 is nearly inconsequential, but even small gaps or holes can easily transport many times as much water vapor.
  - All materials have some greater or lesser degree of resistance to diffusion, and their placement in an enclosure assembly, whether intended as a retarder or not, will affect wetting and, more importantly, drying of an assembly.
- *Insulation*: A material that slows the flow of heat through conduction.
- *Radiant barriers*: A material, usually metallic or shiny, that reflects radiant thermal energy.
- *Weather barrier (water-resistant barrier)*: A material that is resistant to the penetration of water in the liquid state, or is waterproof. It may or may not be an air barrier or vapor retarder. The face of the weather barrier is sometimes called the *drainage plane*.
- *Barrier wall*: A wall assembly that resists moisture with a continuous waterproof membrane or with a plane of weather barrier material thick enough to prevent absorbed moisture penetrating to the interior.
- *Drained cavity wall*: A wall assembly with an outer water- ding layer over an air cavity, and with a weather barrier. The ity is flashed and weeped to drain incidental water.
- *Drainage plane wall*: A wall assembly with a continuous wa resistant barrier under an outer water-shedding layer. The la a cavity limits the amount of water that can be quickly drai
- *Pressure-equalized rainscreen wall*: A wall assembly resists all the physical forces that can transport water acr joint in the outer or "rainscreen" layer. Kinetic energy forces controlled by venting a cavity behind the rainscreen and, allowing the pressure differential across the joint to be eq ized. An air barrier and compartmentalization of the cavity required to control the pressure equalization. The cavi flashed and weeped to drain incidental moisture.

EXTERIOR CLIMATIC INFLUENCE

The United States has widely varying climates. More than the ous extremes of Miami and Alaska are the subtler—and ju important variations—within the contingent states. The AS ASHRAE/IESNA Standard 90.1 Map of Climate Zones for the U

CLIMATE ZONES FOR UNITED STATES LOCATIONS
2.1



Source: ANSI/ASHRAE/IESNA Standard 90.1

Figure 76 – US Climate Zones
(Architects, 2007)

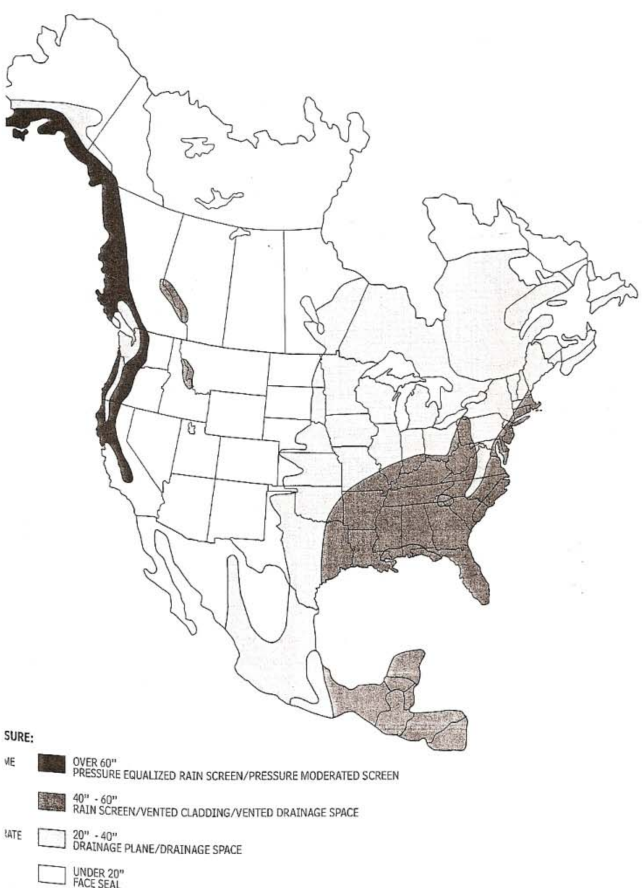
reproduced in Figure 2.1 dictates zones based on heating oling requirements. (Note: A simplified map of climatic zones found in the book, *Moisture Control Handbook: Principles actices for Residential and Small Commercial Buildings*, by W. Lstiburek and John Carmody, 1996.) There are six zones the continental states and Hawaii, plus two more for Alaska. these zones are subzones for moist, dry, marine, and warm-

: chapter will demonstrate, solutions appropriate for one ay be totally unsuited for another. SEI/ASCE 7, "Minimum Loads for Buildings and Other Structures," and other simi- ndards establish the wind, snow, and seismic structural on buildings. Again, there is wide variation in wind speed, ll, and ground movement. In addition to the base loads, localized conditions such as surrounding topography and adjacent buildings can cause wide variances in the environmental influences. Figure 2.2 shows the annual precipitation for North America. Suggested types of exterior enclosure systems that will meet the minimum level of service and reliability are correlated to the rainfall levels.

INTERIOR CLIMATIC INFLUENCE

Environmental conditions to be maintained within the building also influence the design of the shell. Buildings with requirements for high or low levels of humidity, tight temperature tolerances, pressure differentials to the exterior, high-reliability containment, acoustic isolation, protection from blast or forced entry, high indoor air quality, or other extraordinary requirements will require particular attention to system selection and detailing, in concert with consideration of the exterior climate.

AL PRECIPITATION IN NORTH AMERICA



ASHRAE Journal, February 2002

HEAT, AIR, AND MOISTURE

In addition to the obvious structural loads, the building enclosure must resist the transfer of heat, air, and moisture (HAM). The laws of physics dictate that heat always flows from hot to cold. Air moves through building enclosures by passing through porous materials, or through holes and gaps in nonporous materials, based on differential air pressures. Moisture, as water in the liquid state (such as rain, snow, and groundwater), moves through enclosures by four methods: capillary action, surface tension, gravity, and kinetic energy (e.g., wind-driven rain). Moisture in the vapor state moves through enclosures from zones of higher to lower vapor pressures, by diffusion through solid materials or by air transport through holes.

CONTROL OF HAM

Control of the flow of HAM across the building enclosure is an interrelated problem, in that air movement can create the kinetic energy that pulls water through joints, dramatically reduce thermal insulation effectiveness, or cause massive vapor transport. Improper thermal insulation can cause condensation on uncontrolled surfaces.

To control HAM, three components must be considered separately: heat, air, and moisture.

Heat is most commonly controlled by thermal insulation. Keep in mind the following:

- Air movement around thermal insulation can seriously degrade its effectiveness, so avoid systems that ventilate the conditioned side of the thermal insulation.
- Radiant barriers may be effective, particularly in hot climates, but they must have an airspace on the warm side. Generally speaking, radiant barriers have virtually no insulating value and should not replace but, instead, enhance typical thermal insulation and conductive losses.
- Thermal short circuits can dramatically reduce the U-value of thermal insulation. The most common example is metal studs, which may reduce the effective value of thermal insulation between the studs by half.

Air transfer is controlled by a coordinated and continuous system of air barriers for all six sides of the enclosure (i.e., the lowest grade level, foundation walls, exterior walls, and the roof).

- Common approaches to wall air barriers are continuous membranes applied to sheathing and sealed to windows, doors, and penetrations.
- Below-grade assemblies can utilize either the concrete walls and slabs or applied waterproofing membranes.
- Most typical low-slope roof membranes will provide an air barrier, except for mechanically fastened systems that may not be able to resist all of the required loads.
- It is possible to design the gypsum board as an air barrier, if all joints and cracks are sealed.
- Many air barrier systems require a combination of a membrane and a structural panel to resist loading, such as spun-bond polyolefin membranes stapled to sheathing or bituminous membranes adhered to CMU.

Moisture management consists of controlling moisture entry, moisture accumulation, and allowing for drying.

- Perfect barriers to moisture are virtually impossible to achieve; therefore, it is important that measures taken to keep out moisture do not also trap moisture—for example, waterproofing membranes that trap thermal insulation between a vapor retarder.
- It is essential to maintain a balance of the moisture that is able to accumulate in an assembly between drying cycles. Accumulation and drying are extremely dependent on the local climate. Some materials such as wood-framed walls and masonry have the capacity to absorb relatively large quantities of moisture and to then later dry out without damage or deterioration. Other systems such as gypsum board on metal studs have very little capacity for the storage of moisture.

Figure 77 – US Rainfall Data
(Architects, 2007)

ELEMENT B: SHELL DESIGN CONSIDERATIONS

- The source of water is primarily rain, which should be limited by a reasonably detailed assembly based on the expected amount of precipitation. The precipitation map in Figure 2.2 shows recommended enclosure types along with the required performance to minimize water entry.
- Below grade, the primary source of moisture is through capillary action that can be controlled through membranes and capillary breaks.
- Sources of vapor may be in the interior or exterior environment. Vapor retarders have been the traditional method used to control vapor movement, but their use in mixed heating and cooling climates must be carefully evaluated to allow drying.
- Moisture control in the solid state (i.e., ice) depends on not letting liquid water freeze; or, if it does, allowing room for expansion. For example, cold roof surfaces that eliminate thawing also prevent ice buildup, and air-entrained concrete provides room for ice crystals to expand.

Figures 2.3 and 2.4 show details of wall assemblies that can be used for analysis of drying under various climatic conditions. The various assemblies are somewhat independent of the cladding type. Other wall assemblies, including face-sealed or massive barrier assemblies, should receive similar analysis of HAM control. Two useful tools for this purpose are:

- *Computerized modeling of wetting and drying of walls:* This is widely available and is very helpful to understanding moisture accumulation and drying. Analysis is recommended for large projects and any assembly that requires seasonal drying. Mixed climates may be the most difficult to predict by rule of thumb or empirical analysis. WUFI, developed by the Fraunhofer Institute for Building Physics in Germany with a North American version developed jointly with Oak Ridge National Laboratory (www.ornl.gov) is widely recognized modeling tool. Similar software is available through www.virtual-north.com/download/OrderForm.pdf and www.architects.org/emplibrary/HAMtoolbox.pdf.
- *Manual analysis of simple two-dimensional diagrams of wall sections:* This involves using temperature gradients plotted against dew point temperature or vapor-pressure gradients plotted against saturation pressure. For instructions refer to "Design Tools," by Anton TenWolde (Chapter 11 in the manual *Moisture Control in Buildings* [MNL18], Heinz R. Trechsel, editor, published by ASTM, 1994).

CONSIDERATIONS FOR CLIMATE ZONES

GENERAL

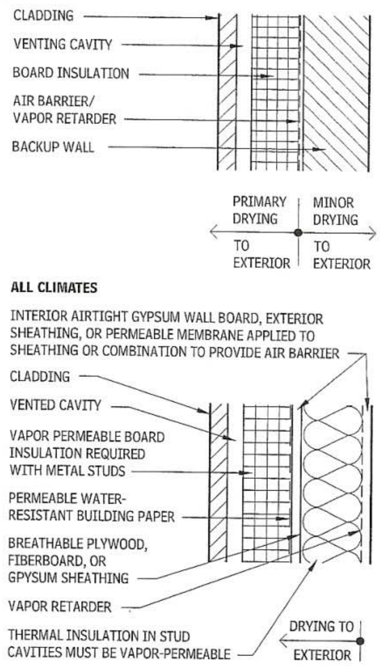
- Refer to specific information for each material for more information regarding selection criteria and proper detailing.
- Include only one vapor retarder in a wall assembly, and ensure that all other materials are increasingly permeable from the vapor retarder out.
- It is acceptable (and sometimes desirable) to provide more than one air barrier in a wall assembly.
- It is generally desirable to protect blanket insulation from air-washing with an air barrier on the cold side.

ALL CLIMATES

- Highly reliable enclosure system to control HAM in all climate zones, without relying on building mechanical systems to dry interior air.
- Thermal insulation located outside of structure and wall framing allows easy installation of continuous air barriers and vapor retarders.
- Thermal insulation must be continuous to prevent the vapor retarder from reaching the dew point.
- Excellent choice for masonry veneer over CMU or metal stud backup systems.
- If metal stud backup systems are used, do not place thermal insulation between the studs.
- Any paint or wall covering is allowed on interior finish.

COLD CLIMATES (Zones 5 to 8)

- Materials should be progressively more permeable, because they are located closer to exterior face.
- Any paint or wall covering is allowed on interior finish.



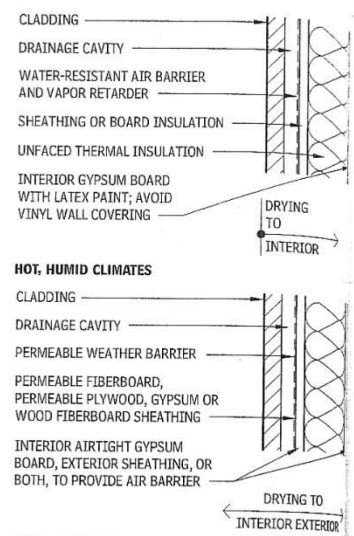
- Mechanical system is not required to dry interior air.
- Failure of the building paper may allow moisture accumulation that cannot be overcome by drying.
- Elements penetrating thermal insulation, (such as beams supporting a projecting canopy or the sump pan of roof drains) can cause condensation problems, unless they are insulated with closed-cell thermal insulation or a thermal insulation with a vapor retarder to keep moisture-laden air from getting to these surfaces. This is particularly true for occupancies with high humidity, (including residences, hospitals, museums, swimming pools,).

HOT CLIMATES (Zones 1, 2, and 3)

- The mechanical system must provide dehumidification of interior air for drying.
- Avoid any vapor-impermeable interior finishes (e.g., a vinyl wall covering that will trap moisture).
- A radiant barrier may be incorporated into the cavity.
- Taped joints in sheathing, board insulation, or a combination may provide air barrier.
- An air barrier is crucial to limit moisture transport through imperfections in the vapor retarder.

MIXED CLIMATES (Zones 3 and 4)

- All materials must be relatively vapor-permeable to allow drying in both directions, because seasons change direction of heat flow and vapor drive.
- Detail system with interior and exterior side-permeable air barriers to limit moisture transport and infiltration/exfiltration.
- May be possible to use board insulation with taped joints as sheathing, which will form a vapor retarder if board and blanket insulation have approximately the same U-value.



SUSTAINABILITY AND ENERGY

The building shell should be a major part of the sustainable strategy. At a minimum, the shell should:

- Contribute to minimizing energy usage.
- Incorporate environmentally sensitive materials.
- Ensure good indoor air quality and occupant comfort.
- Be durable.

For high-performance building projects, the enclosure could be generate energy, return nutrients to the environment, and filter pollutants.

One area of special concern for the building shell is durability, even though it currently is not included in LEED evaluations in the United States. (It is included in Canadian LEED programs). The building superstructure and enclosure are frequently portions of the building that should last the longest and are the most difficult to repair or replace. Buildings that perform well for many years slow and reduce the consumption of resources and the wastestream. Failures of the enclosure can lead not only to water-damaged materials needing repair or replacement but also to unnecessary long-term energy consumption, toxic mold, and sick buildings.

Buildings are major consumers of energy, so the enclosures should be part of a strategy to reduce energy consumption. In fact, creating a well-performing enclosure is considered to be the first step in reducing energy usage, ahead of other more sophisticated strategies, such as high-performance mechanical systems. A thorough understanding of the interior and exterior environments is paramount. For residential buildings in cold climates, heat loss through the enclosure may be the largest component of total energy consumption. For large commercial buildings in a moderate environment, daylighting schemes may save more energy, even if they may result in an enclosure with lower thermal resistance.

Most jurisdictions require compliance with an energy conservation code. ASHRAE 90.1 and the International Energy Code (in various editions) are common model codes. These minimum standards should be exceeded by 20 to 50 percent, if possible.

NOTES

2.3 and 2.4 Provide an air barrier in the assembly at one or more of the locations noted by properly detailing either the inner layer of gypsum board, the sheathing layer, or the permeable weather barrier. The inner gypsum board can be made an air barrier by sealing the perimeter, penetrations, and transitions to adjacent air barrier assemblies. The sheathing can be made an air barrier through similar means of sealing all joints, penetrations, and transitions. Using a membrane over the sheathering (either fluid-applied or sheet material) that is vapor permeable, weather-resistant, anmd airtight is extremely effective for providing an air barries with the added benefits of simple installation and inspection.

Figure 78 – Shell Design
(Architects, 2007)