Chapter 6. Desired Properties of a Wall System

6.1 Introduction

A wall should not just be an enclosure. It provides far more than just protection from the elements. An appropriately designed and constructed wall is a fundamental part of the home and has far-reaching impact on the health of occupants.

A properly constructed wall should be designed to provide the following benefits:

1. Self-regulation of moisture year round.
2. Storage of heat in winter and cool in summer.
3. Optimally-phased distribution of heat and cool.
4. Radiant heating and cooling.

These benefits are achieved by judicious choice of materials and smart design. Materials should be breathable, allowing what moisture that inevitably does enter a wall cavity to be transported through it in the form of water vapor. Superior thermal performance must not be compromised.

A healthy, ecological wall should ideally incorporate three design elements:

1. Heavy thermal mass towards the inside of the wall
2. Medium core in between
3. Lighter "out"sulation as the outer layer (thicker in northern climates)

From the standpoint of the entire dwelling, the wall and foundation systems recommended in this manual not only possess these characteristics, but they fulfill most of the 25 goals of the Building Biology® profession described in chapter 5 even before additional aspects are considered. This is because the envelope of a house, that is, the floors, walls, and ceiling, is the single greatest component affecting the health of its occupants. If you use the relatively inexpensive mainstream methods of today to build your envelope, then you can expect some degree of "sick building syndrome." If, on the other hand, you invest in a healthy building envelope as described in this manual, you are well on your way to preventing and avoiding many of the sources of building-induced illness that have plagued home and business owners in modern industrial society for decades.

This chapter will fundamentally cover all of the desirable properties of a wall system: vapor permeability, hygroscopicity, capillarity, thermal mass, "out"sulation, radiant heat transfer, structural integrity, and the subtle energies associated with using natural materials. It is also often desirable to build an envelope that protects the occupants from incoming radio frequencies from outside broadcast sources such as TV, radio, pager, cell phone and wireless Internet (Wi-Fi) antennas. But first we introduce the reader to "breathability," which encompasses the first three of these properties and is of paramount importance.

6.2 What is a "Breathing Wall?"

In the 1850's a professor named Max von Pettenkofer studied the permeability of air and moisture through porous building materials, by blowing out a candle from the opposite side of a wall.[24] One hundred years later the man sometimes referred to as "the father of Building Biology®," a German medical doctor named Hubert Palm, popularized the term breathability (Atmungsfähigkeit).[25] Early building biologists promoted the idea of a "breathing wall."

As properly understood, the "breathing wall" is an extremely important concept for high indoor air quality and mold-free construction. Unfortunately some people (both laypersons and professionals) interpret the expression literally, as if we are saying these walls have lungs. To avoid such confusion this writer puts the term in quotation marks. The terms "breathable" and "breathability" are preferable, as they indicate a passive rather than an active function. Moreover, common parlance (at least in English) uses "breathable" to describe such materials as Gore-Tex®, the porous fabric designed to pass water as vapor but not liquid. Nevertheless, as explained in the remainder of this chapter, breathability in buildings is considerably more complex!

The authors of this manual are among the relatively few American building biologists involved in new construction and the design of building envelopes and therefore they work with the concept of breathability. However to obtain a broader perspective the editor queried two dozen European building biologists, scientists, designers and architects concerning "breathing walls."

These correspondents expressed many different viewpoints on the topic. Our distillation resulted in an appreciation that breathable wall systems actually incorporate several different physical properties that are fundamental to healthy home construction. Building scientists refer to these as *hygrothermal* properties, as all of the related phenomena involve in some way the transport of moisture:

1. Permeability and diffusion
2. Hygroscopic adsorption/desorption
3. Capillary absorption/desorption

Each of the following sections will explain one of the above types of breathability and why it may be essential for a healthy building envelope. We

[24] Max von Pettenkofer, "Sur le comportement de l'air au logement de l'homme" (On the behavior of the air in human abodes), Brusnwick 1877. For a very brief description of this work, see http://de.wikipedia.org/wiki/Atmende_Wand.

[25] Hubert Palm, *das Gesunde Haus* (The Healthy House), Tenth edition, © Ordosan AG; Kösel, Kempten (1992), pp. 84-85. The first edition was published in 1968. *[The date may actually be earlier and we are trying to find out. –Ed.]*

thank Neil May of Natural Building Technologies in the UK for his enlightening online manuscript that rather thoroughly explains these concepts as well as their application. His paper, entitled *Breathability: The Key to Building Performance*, was extremely helpful in writing the next three sections and can be found online.[26]

6.3 Vapor Permeability and Diffusion

Vapor permeability is a property reflecting the rate of movement of water molecules, H_2O, directly *through* a material. It should not be confused with *infiltration*, which is leakage through gaps *between* separate pieces of material. Rather, permeability is determined by the openness of the physical structure *within* the same material, such as wall board, insulation or a vapor barrier. Moisture transport due to permeability is usually small compared to that from infiltration and ventilation, wherein the major water vapor transport mechanism is its movement in flowing air. However, as we shall see below, permeability in the right kind of materials does play a profound role in allowing moisture to escape from building materials before mold formation becomes a problem.

The physical process responsible for vapor permeability of a building envelope is called *diffusion*. Matter is transported spontaneously as a result of the intrinsic kinetic energy and random thermal motion of molecules. Within a gaseous medium such as air the individual molecules mix and redistribute. There is no bulk flow; that is, no net transfer of mass to or from any region of interest.

Diffusion of moisture in air involves movement of water molecules as well as the molecules of oxygen, nitrogen, and minor components such as carbon dioxide. Net diffusion is driven by a gradient of airborne water vapor concentration or H_2O partial pressure. Water molecules dissolved in the vapor phase are spontaneously transported from volumes of higher concentration to those of lower concentration, until the concentration is uniform. This slow process is affected by both temperature and pressure.

The reader will hopefully gain a better understanding by looking at the illustrations in Figure 5 on page 26. In the initial phase of diffusion, the molecules of different gaseous components are far from equilibrium. In the extreme, simplistic case that is illustrated, let us suppose that *all* of the molecules inside the "home" are water vapor (O) and that all of the molecules outside are oxygen (●), just one component of air. (Of course, there is no such thing as an "air" molecule!) As diffusion proceeds (intermediate drawing), water molecules begin to move outside and are replaced by oxygen molecules moving inside. Finally, if and whenever the system reaches equilibrium, all of the molecules are uniformly distributed although still moving randomly.[27]

[26] Neil May's article was last accessed in April 2008, when it was found at http://www.greensteps.co.uk /tmp/assets/1163178050906.pdf.
[27] In the real world we seldom if ever attain equilibrium because the outside humidity, temperature and pressure are continually changing.