Comparative Study of Water Vapor Transmission Ratings and Material Properties of Different Waterproofing Systems

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Maintaining optimum moisture levels within a structure has become a critical objective in both above- and below-grade construction design. Moisture damage is a major contributing cause of unhealthy indoor environments, mildew, and fungus that all contribute to "sick building syndrome." Failure to effectively regulate moisture within building structures results in corrosion of steel reinforcement in concrete and beams, rotting of timber structures, swelling of plasterboards, electrical hazards due to short circuits of power points, blistering and peeling of paint, efflorescence of masonry, rotting of wood floors, mildewing of carpet, and invasion of termites. It also makes it more difficult to control heating and cooling.

The role of waterproofing/vaporproofing materials is to protect building structure and aesthetic integrity by providing a barrier to the movement of water (liquid as well as vapor) from passing into or out of a structure. Waterproofing and vaporproofing are complimentary to each other and complete moisture protection of a building cannot be achieved by just waterproofing while ignoring the vapor infiltration.

The most effective waterproofing/vaporproofing materials for protecting the building envelope have physical properties that are effective in controlling the movement of water in both its liquid and vapor forms. Without considering the consequences of moisture entering the structure in both the liquid and vapor forms, the objective of controlling the moisture in the structure may not be viable. Waterproofing is the formation of a barrier to prevent water in its liquid form from infiltrating a structure with or without hydrostatic pressure. Water moves into the building by natural gravity, surface tension, wind/air currents, capillary action, and hydrostatic pressure. Whenever hydrostatic pressure is exerted against a building component, it is accompanied by water vapor pressure from the wet to the dry side of the building. Vaporproofing is the formation of a barrier to prevent or significantly retard water vapor infiltration into a structure resulting from diffusion caused by water vapor pressure. Waterproofing systems must therefore resist both pressures from liquid water (resistance to hydrostatic pressure) as well as water vapors (resistance to water vapor permeability).

There are two basic elements of waterproofing any structure:

1. Identify the water source (or sources) likely to be encountered; and
2. Select appropriate systems to prevent leakage from these sources.

The main water sources for aboveground structures are rainwater and moisture-laden winds, and for belowground structures, groundwater and water from such sources as melting snow, sprinklers, and gutters.

Water moves into the building by natural gravity, surface tension, wind/air currents, capillary actions, and hydrostatic pressure. The microscopic pores and capillaries in concrete substrates create the ability for the concrete to allow water to move through the below-grade walls and floor toward the less humid interior space. The hydrostatic pressure is created by the weight of water on lower areas. Water under hydrostatic pressure will seek any outlet in the structure to relieve pressure. The water vapors move into the building by diffusion from areas of high vapor pressure to areas of lower vapor pressure. Physical forces like temperature and humidity, by effecting differences in vapor pressure, cause moisture migration underground. Once inside the building, the vapor-laden air cools, and should it cool sufficiently to its dew point temperature, condensation takes place.

To prevent water/vapor movement into the building, an appropriate waterproofing system must be selected. The above-grade waterproofing material must be ultraviolet radiation resistant if left exposed to sunlight and capable of withstanding thermal movement due to environmental conditions. Furthermore, the above-grade material must be aesthetically pleasing. The below-grade material must be able to withstand hydrostatic pressure.

Water vapor transmission (WVT) is a vital property of any waterproofing system. To understand the effectiveness of any waterproofing system, it is important to understand the meaning of WVT—the amount of water vapor passing through a given area of film in a given time when the film is maintained at a constant temperature and when its faces are exposed to certain relative humidities. It may be measured in: grains/ft^2/h, g/m^2/24 h, g/100 in.^{2}/24 h. It is not a constant value; it depends on the relative humidity and temperature of the sides of the barrier material.

Another important vaporproofing/waterproofing term is perm rating. If a material has a perm rating of 1.0, it means that in 1 h, when the vapor pressure difference between the cold side and the warm side of the material is equal to 1 in. of mercury, 1 grain of water vapor will pass through 1 ft^2 of the material. One grain of water is equal to1/7000 of a pound. Vapor pressure depends on the temperature and relative humidity (RH) of the air. As the RH and the temperature go up, vapor pressure gets higher. The greater the vapor pressure differential across the material, the greater the tendency for water vapors to migrate from a high-pressure to a low-pressure side. The perm rating is a constant value of a material for stated thickness. Generally, for a homogenous material, there is an inverse relationship between the material thickness and perm rating.

Relationship Between Perm and WVT

WVT = $A \times T \times \Delta P \times$ perms

A = area in ft^2; T = time in h, ΔP = difference in vapor pressure between inside and outside measured in inches of mercury (Hg).

Effective water/vapor proofing systems must possess the following qualities:

- It must be impermeable to water;
- It must have low water vapor permeability;
- Good elastic properties and should be capable of accommodating any normal movement that may occur in the building without becoming cracked;
- If liquid is applied, it should be able to cure to a uniform membrane within a reasonable time—2 h or less;
- It must be non-toxic, as well as user friendly; should be handled and applied safely; and must be suitable to withstand environmental and climatic conditions; and
- It must have good puncture resistance to be able to resist damage from the job site. It must be durable and able to retain its integrity over a long period of time.

Figure 1: Spray application of cold-applied polymer-modified emulsion

Figure 2: Roller application of cold-applied polymer-modified emulsion

Above-Grade Waterproofing

For vertical applications, the above-grade waterproofing systems could be divided into three main classes.

- Water repellants. These include penetrating sealers such as silanes, siloxanes, and silane-siloxane blends used on absorptive surfaces such as masonry block and bricks, and film-forming sealers used on concrete, previously painted surfaces, and exposed aggregates. These include acrylics, urethanes, silicones, and methyl methacrylates. The penetrating sealers offer better weathering and permeability ratings than the film-forming sealers.
- Cementitious coating, cement-based coatings offer satisfactory waterproofing with excellent weathering and bonding capabilities. Cementitious coatings are capable of resisting both positive and negative hydrostatic pressure. These coatings, however, have a serious disadvantage with no movement capability.

Figure 3: Polymer-modified asphalt emulsion applied on insulated concrete forms

Figure 4: Rubberized asphalt sheet membrane applied to concrete foundation wall

- Rubberized asphalt sheet membranes provide not only water and vapor protection but also act as an air barrier and flashing membrane. The self-healing characteristics of these sheet membranes facilitate recovery if damage is sustained.

For horizontal applications, several deck coatings are available with different chemical formulations. Deck coatings are applied to parking garage floors, plaza decks, balcony decks, and pool decks. These include acrylics, cementitious coatings, epoxies, urethanes, and asphalt overlays. Among these coatings, urethanes are frequently used for their excellent crack-bridging capabilities and good weathering even though these coatings have poor water vapor transmission ratings.

Below-Grade Waterproofing

Below-grade building structures are subjected to water damage by water vapor transmission through porous surfaces and by direct water leakage due to hydrostatic pressure from groundwater tables. The material selected for below-grade waterproofing must have an excellent water vapor permeability rating in addition to the previously mentioned characteristics. There are numerous systems available for below-grade waterproofing. The following is a summary of the most frequently used systems.

- Cold-applied asphalt/coal tar, a common below-grade waterproofing for the residential market, is good only for dampproofing, not for waterproofing. It has poor elastic and crack-bridging properties, and the membrane becomes very brittle at low temperatures. The presence of solvent makes these coatings toxic.
- Bentonite systems are traditionally popular waterproofing systems due to their fast and easy installation. Under sufficient hydrostatic pressure, bentonite becomes a water-repelling agent. It has very poor water vapor permeability ratings. If bentonite materials are exposed to rainfall before concrete is placed, the material swells and loses all of its capabilities to seal the joints after the concrete is placed.
- Hot-applied polymer-modified asphalt membranes exhibit excellent waterproofing characteristics, as well as elasticity, flexibility, good adhesion to concrete, overall resistance to cracking, and provide seamless application. The necessity of having heating equipment at the job site, accidental burn injuries, thermal degradation of polymer due to prolonged heating, and the emission of hazardous hydrocarbons has reduced the overall effectiveness of this technology.
- Cold-applied bitumen-modified polyurethane cured membranes show very good elastic and hardness properties. These membranes have good resistance to hydrostatic pressure but poor water vapor permeability (0.2 perms). Overnight curing time is required (longer if at lower temperatures and humidity). The presence of solvent makes them unsafe and unpleasant to work with. As these membranes are moisture sensitive, they are susceptible to pinholes, wrinkles, and blistering. Due to the presence of solvent, these membranes are not suitable for insulated concrete forms. Overall, they show good waterproofing, but poor vaporproofing.
- Rubberized asphalt sheet membranes show good waterproofing and vaporproofing, as well as factory-controlled thickness,

excellent resilience, and self-healing properties. These sheet membrane waterproofing systems provide a cost-effective way to waterproof foundations, vertical walls, and below-grade floors in residential and commercial constructions. These membranes are equally effective for use as a between-the-slab waterproofing on plaza decks, parking decks, and structural slabs.

- The cured membranes of polymer-modified asphalt emulsion exhibit excellent waterproofing/vaporproofing properties as well as elasticity, flexibility, good adhesion to concrete, and resistance to cracking and failure. There is no need to have heating equipment at the job site. These are one-component water-based waterproofing membranes with excellent resistance to hydrostatic pressure and water vapor permeability (0.02 perms.). Typically, these materials cure within 2 h (compared with 24 h for other cold-applied urethane systems). As these are solvent-free, they are ideal for insulated concrete forms. It can be applied immediately to newly stripped below-grade green concrete walls as well as masonry blocks. They are easy to install with a sprayer, heavy mop, roller, or soft bristle brush.

Under-Slab Vapor Retarders and Barriers

Vapor retarders and barriers reduce moisture condensation within floor, wall, and ceiling cavities. The lower the perm rating, the better a material prevents moisture diffusion. In addition to low water-vapor permeance and resistance to environmental attack, an effective under-slab vapor retarder must possess high tensile strength and puncture resistance to withstand certain job-site abuses such as penetration of rocks and falling objects and abrasions due to high traffic during installation.

The vapor barriers are typically multiple-ply semi-flexible bituminous boards. These barriers provide a positive, easy to install, economical, true vaporproofing and waterproofing system for horizontal applications. Properly applied, these membranes stop moisture migration in footings, concrete floors, and structural slabs. The bituminous vapor barriers offer a virtually impermeable system with perm ratings of 0.002 or less.

The vapor retarders are typically made of extruded blends of different types of polyethylenes. As the water vapor diffusion is dependent on the size of the permeant molecule and the amorphous configuration of the polyethylene, the perm rating of polyethylene is dependent on the densities. The lowest possible perm rating of polyethylene is 0.3 perms/mil thicknesses.

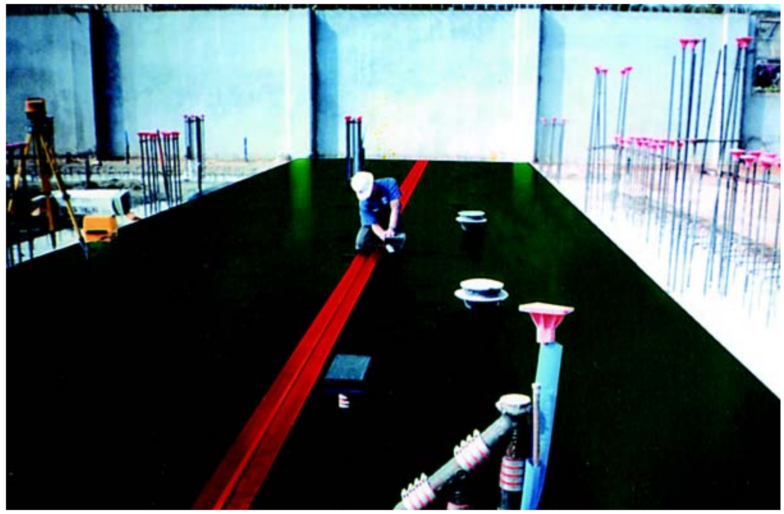

Figure 5: Installation of plastic vapor retarders

Figure 6: Installation of bituminous vapor barriers

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