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Vapor Barriers under Concrete Slabs - How to Select and Locate

Course No: T01-001
Credit: 1 PDH

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VAPOR BARRIERS UNDER CONCRETE SLABS – HOW TO SELECT AND LOCATE

Introduction

Vapor barriers are traditionally specified by architects and engineers to limit the amount of moisture that migrates into and upward through concrete slabs. Moisture infiltration through concrete slabs has been known to cause flooring system failures, damage to the concrete slab, and growth of mold and mildew due to higher humidity levels within the building.

More recently, vapor barriers have been used at brownfields redevelopment sites. For sites where the source of soil or groundwater contamination cannot be completely eliminated, vapor barriers are used to prevent vapor intrusion of volatile organic compounds (VOCs) into newly constructed buildings.

Additionally, vapor barriers are used in high radon potential areas to prevent the migration and accumulation of radon gas in buildings and homes.

Given the many applications, a vapor barrier is one of the most critical building components used to prevent indoor air quality issues and minimize moisture-related concrete slab and flooring system failures. Additionally, installation of a vapor barrier may help to contribute to LEED credits for buildings seeking to be certified under the U.S. Green Building Council (USGBC) for Leadership in Energy and Environmental Design (LEED).

What is a Vapor Barrier?

A vapor barrier is an impermeable membrane primarily used to resist water vapor transmission from the soil to the concrete slab. The term ‘vapor barrier’ is often used interchangeably with the term ‘vapor retarder’ to describe all membranes used to resist water vapor transmission. However, vapor retarders only retard the transmission of water vapor, whereas, vapor barriers are impermeable to water vapor. Therefore, the most important criteria used when specifying a vapor barrier is resistance to water vapor transmission, also known as its permeance value.

Vapor Barrier Materials

For the purpose of this discussion, vapor barrier materials will be limited to sheets of membrane materials, though a vapor barrier can be any unbroken surface that is impermeable to water vapor such as spray-applied asphalt/latex. Membranes are most commonly made from high density polyethylene (HDPE) or other polyolefin-based resins. These materials have high tensile strength and high puncture resistance. HDPE tends to have the highest chemical resistance among polyolefin membranes.

Selecting a Vapor Barrier

Low water vapor transmission, high tensile strength, high puncture resistance, thickness, and chemical resistance are the primary selection and specification criteria. These characteristics will ensure that the vapor barrier not only performs as an effective barrier to moisture and other vapors, but will also maintain its physical integrity during the placement of the concrete slab.

Resistance to Water Vapor Transmission

Manufacturers typically use one of three terminologies to describe the water vapor transmission properties of their vapor membranes: (1) water vapor transmission rate, (2) permance, and (3) permeability. Of these terminologies, water vapor transmission rate and permeability are material properties, while permance is a performance indicator. Therefore, the permance value should be used to evaluate the effectiveness of vapor barriers to resist water vapor transmission. As per the standard definitions described in ASTM C 168, Standard Terminology Relating to Thermal Insulation, the water vapor transmission properties are described in the following paragraphs:

Water Vapor Transmission Rate

The water vapor transmission rate is the amount of water passing through a given area of material under specific conditions of temperature and humidity. The result is expressed in terms of grains/(hr•ft²) (SI units - g/24 hr•m²). The water vapor transmission rate equation is as follows:

Water Vapor Transmission (WVT) Rate = $G / (tA)$

Where:

G = amount of water vapor flow (grains),

t = time (hrs), and

A = test area (ft²).

Permeance

Permeance is the rate at which water vapor passes through a material under specific conditions of temperature and humidity. A material has a permeance of one perm if it allows the transmission of one grain of water vapor per square foot of area per inch of mercury (in Hg) of pressure difference per hour, expressed as grain/[ft²•in.Hg•hr] (SI units – ng/[Pa•s•m²]). The lower the permeance, the more effective the vapor barrier is to resisting transmission of water vapor. The permeance equation is as follows:

Permeance = $WVT / \Delta P = WVT / S(R_1 - R_2)$

Where:

ΔP = vapor pressure difference (in. Hg),

S = saturation vapor pressure at test temperature,

R₁ = relative humidity at the source expressed as a fraction, and

R₂ = relative humidity at the vapor sink expressed as a fraction.

The American Society for Testing and Materials (ASTM) defines a vapor barrier as a material with a permeance rating of 0.1 perms or less. A vapor retarder is defined as a material with a permeance rating between 0.1 perms and 1.0 perm. Additionally, materials with a permeance rating greater than 1.0 perm are defined as vapor semi-permeable materials.

Permeability

Permeability is the time rate of water vapor transmission through a material under specific temperature and humidity conditions. Permeability is a property of a material and is the

arithmetic product of permeance and material thickness. It is commonly expressed in terms of perm-inches (SI units – $\text{g}/(\text{Pa}\cdot\text{s}\cdot\text{m})$). The permeability equation is as follows:

$$\text{Permeability} = \text{Permeance} \times \text{Thickness}$$

The units used to express the water vapor transmission properties depend on the manufacturer and/or the location. The conversion factors for these units are provided in Table 1.

Table 1 – Metric Units and Conversion Factors

| Multiply | By | To Obtain |
|---|---|---|
| Water Vapor Transmission | | |
| $\text{g}/(\text{hr}\cdot\text{m}^2)$ $\text{grains}/(\text{hr}\cdot\text{ft}^2)$ | 1.43 0.697 | $\text{grains}/(\text{hr}\cdot\text{ft}^2)$ $\text{g}/(\text{hr}\cdot\text{m}^2)$ |
| Permeance | | |
| $\text{ng}/(\text{Pa}\cdot\text{s}\cdot\text{m}^2)$ $\text{grains}/(\text{hr}\cdot\text{ft}^2\cdot\text{in.Hg})$ | 0.0175 57.2 | $\text{grains}/(\text{hr}\cdot\text{ft}^2\cdot\text{in.Hg})$ $\text{ng}/(\text{Pa}\cdot\text{s}\cdot\text{m}^2)$ |
| Permeability | | |
| $\text{g}/(\text{Pa}\cdot\text{s}\cdot\text{m})$ 1 Perm-inch | 6.88×10^8 1.45×10^{-9} | 1 Perm inch $\text{g}/(\text{Pa}\cdot\text{s}\cdot\text{m})$ |

Note: Table adapted from ASTM E96 / 96M-05

Therefore, when specifying a vapor barrier, the material should have a permeance of 0.1 perms or less. This may also be reported in technical data provided by manufacturers as less than 0.1 $\text{grains}/(\text{hr}\cdot\text{ft}^2\cdot\text{in.Hg})$ or less than $5.72 \text{ ng}/(\text{Pa}\cdot\text{s}\cdot\text{m}^2)$.

Strength and Durability Considerations

ASTM E 1745-09 defines three classes of vapor barriers. Each class has the same permeance, but different strength and durability properties. The current (2009) version lists a permeance of 0.1 perms for all three classes, where previous versions (1997 and 2004) listed a permeance of 0.3 perms. As shown in the properties list below, a Class A vapor barrier will be more resistant to tearing and punctures than Class B and C vapor barriers.

ASTM E 1745 Properties for Specified Performance Classes

Permeance

Class A – 0.1 perms (0.1 grains/[hr•ft²•in.Hg], 5.72 ng/[Pa•s•m²])

Class B – 0.1 perms (0.1 grains/[hr•ft²•in.Hg], 5.72 ng/[Pa•s•m²])

Class C – 0.1 perms (0.1 grains/[hr•ft²•in.Hg], 5.72 ng/[Pa•s•m²])

Tensile Strength

Class A – 45.0 lbf/in. (7.9 kN/m)

Class B – 30.0 lbf/in. (5.3 kN/m)

Class C – 13.6 lbf/in. (2.4 kN/m)

Puncture Resistance

Class A – 2200 grams

Class B – 1700 grams

Class C – 475 grams

When specifying a vapor barrier based upon the class system, consideration should be given to exposure to foot and equipment traffic, and cost. Generally, if the potential for damage to the vapor barrier is high, then a stronger and more durable vapor barrier is required. However, this also comes at a higher material cost.

Thickness of Vapor Barrier

The thickness of a vapor barrier is related to the tensile strength and puncture resistance properties. Generally, as the thickness of a vapor barrier increases, the strength and durability of the vapor barrier increases. Vapor barriers satisfying the requirements of ASTM E 1745-09 typically have a thickness of 10 mils (0.010 inch) or 15 mils (0.015 inch), but can be thicker depending upon the material and the manufacturer.

The minimum building code requirement for a vapor barrier is 6 mils (0.006 inch). However, a 6 mil vapor barrier may not have the tear and puncture resistance necessary to withstand normal construction activities. ACI 302.1R-04 recommends that vapor barriers be a minimum of 10

mils in thickness. If heavy equipment will be operating on the vapor barrier or if the vapor barrier will be installed over an angular subbase, a minimum of 15 mils is recommended.

Chemical Resistance Consideration

If a vapor barrier is being used under a slab to control vapors at a brownfields site, the chemical resistance of the vapor barrier must be considered. Typically, these sites are former industrial facilities, gasoline stations, and dry cleaners. Contaminated soils and groundwater beneath the site may contain petroleum hydrocarbons and chlorinated solvents. The vapor barrier, therefore, should be chemically-resistant to the soil vapors encountered on site to reduce the potential for chemical degradation of the vapor barrier. Since this information is not typically provided by the manufacturer in the vapor barrier product description sheets, it is recommended that the architect or engineer obtain a letter from the manufacturer stating that the vapor barrier is chemically-resistant to the contaminants encountered beneath the site.

Guide Specification for Vapor Barrier

A guide specification for vapor barriers is provided after the References section of this course. The template should be revised to meet the project requirements and coordinated with other specification sections.

Location of Vapor Barrier

Studies have shown that vapor barriers can affect the behavior of the concrete slab and significantly influence finishing time, cracking, and strength. Architects, engineers, and contractors therefore often disagree on whether concrete should be placed directly on the vapor barrier or on a granular base placed over the vapor barrier. There are risks and benefits associated with both options, and they depend primarily on the water-cement ratio of the concrete mix.

Arguments for Placing Granular Base over the Vapor Barrier

Increased Finishing Time and Surface Defects

Placing concrete directly on a vapor barrier increases the amount of bleedwater that rises to the top surface, since it cannot pass through the bottom of the concrete into the subsurface. As a

result, it prolongs the waiting time between floating the concrete and finishing because the extra bleedwater must evaporate before final troweling. If the finishing work is done while the bleedwater is still on the concrete surface, it could lead to surface defects. These problems can be alleviated by choosing a concrete mix with a low water-cement ratio to reduce the amount of potential bleedwater.

Increased Cracking of the Concrete Slab

Studies have shown that extensive cracking can occur in slabs placed on vapor barriers and little cracking in slabs placed over sand. The reduction in cracking was attributed to absorption of concrete mix water into the sand bed. However, it should be noted that the concrete mixes used in the study had high water-cement ratios of 0.7 to 0.8 and slump from 8 to 9 inches. A lower water-cement ratio would decrease the likelihood for cracking.

Reduced Strength

Studies have shown that concrete placed over a sand bed was 30% stronger than concrete placed over a vapor barrier. However, the concrete mix used in the studies had high water-cement ratios. The difference in strength between concrete placed on a sand bed versus concrete placed on a granular base should be less significant at lower water-cement ratios.

Arguments against Placing Granular Base over the Vapor Barrier

The primary argument against using a granular base between the vapor barrier and the concrete slab is that when concrete is placed on a granular base overlying a vapor barrier, the granular base absorbs the excess water creating a moisture reservoir beneath the slab. This then provides a large source for moisture migration through the concrete slab and can lead to moisture-related flooring and health problems in the building.

Summary

Since the risks and benefits are project and site dependent, the decision of where to place the vapor barrier should be considered on a project-specific basis. ACI 302.1R-04 recommends that the location of the vapor barrier should be evaluated based upon the moisture sensitivity of

subsequent floor finishes, anticipated construction and completed project conditions, and the potential effects of cracking.

ACI 302.1R-04 provides a decision flow chart to determine if a vapor barrier is required and where it is to be placed. To summarize, the concrete should be placed directly on the vapor barrier if the concrete slab will be covered with a moisture-sensitive covering or if the slab will be exposed to the elements (i.e., precipitation) during curing. If these conditions do not exist, then a granular base can be placed on top of the vapor barrier prior to the concrete pour.

If the concrete will be poured directly on top of a vapor barrier, choosing a high-quality, low-shrinkage concrete with a low water-cement ratio, properly finishing the concrete, and reducing joint spacing will minimize potential problems with the concrete slab. In all cases, do not allow the contractor to poke holes in the vapor barrier to drain out the excess water since this will reduce the effectiveness of the vapor barrier.

LEED Credits

Vapor barriers may contribute to several LEED credits for buildings seeking certification as a U.S. Green Building Council LEED for New Construction projects. The following is a list of potential points that vapor barriers may help to achieve for such projects.

Sustainable Sites – SS Credit 3: Brownfield Redevelopment (1 point)

This credit encourages the rehabilitation of environmentally contaminated land for redevelopment. Vapor barriers maintain a low permeance to protect buildings and its inhabitants from vapor intrusion of harmful soil gases found in brownfields sites.

Energy and Atmosphere – EA Credit 1: Optimize Energy Performance (1-19 points)

The intent of this credit is to achieve increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with increased energy use. Vapor barriers prevent significant amounts of water vapor from entering into a building envelope. This reduced moisture transmission can significantly reduce the latent moisture load, and the power required by an HVAC system to maintain indoor humidity and

temperature levels. A vapor barrier may not reduce the power consumption by itself, but it can contribute to an overall energy optimization strategy.

Indoor Environmental Quality – EQ Credit 4.1 & 4.3: Low-Emitting Materials (1-2 points)

EQ Credit 4.1 and EQ Credit 4.3 require low VOC content adhesives and low VOC emitting flooring systems, respectively. However, low VOC flooring adhesives and flooring systems are susceptible to moisture related damage and mold growth due to water vapor migration. The use of a vapor barrier will protect low VOC adhesives and carpets from moisture related damage.

Course Summary

A vapor barrier is one of the most critical building components used to prevent indoor air quality issues and minimize moisture-related concrete slab and flooring system failures. Proper selection of a vapor barrier based upon the criteria of low permeance, high tensile strength, high puncture resistance, and chemical resistance will ensure that the vapor barrier not only performs as an effective barrier to moisture and other vapors, but will also maintain its physical integrity during the placement of the concrete slab.

Problems with the concrete slab can potentially occur if the concrete is poured directly on top of the vapor barrier. If the concrete will be poured directly on top of a vapor barrier, choosing a high-quality, low-shrinkage concrete with a low water-cement ratio, properly finishing the concrete, and reducing joint spacing will minimize potential problems with the concrete slab.

Finally, vapor barriers may contribute to several LEED credits for buildings seeking certification as a U.S. Green Building Council LEED for New Construction projects.

References

ACI 302.1R-04, “Guide for Concrete Floor and Slab Construction,” American Concrete Institute.

ASTM C 168-08b, “Standard Terminology Relating to Thermal Insulation,” American Society for Testing and Materials.

ASTM E 96 / E96M-05, “Standard Test Methods for Rating Water Vapor Permeance of Materials,” American Society for Testing and Materials.

ASTM E 1745-09, “Standard Specification for Water Vapor Retarders used in Contact with Soil or Granular Fill Under Concrete Slabs,” American Society for Testing and Materials.

M. Phalguni, K. Kumaran, J. Lackey, and D. van Reenen, “Water Vapor Transmission Measurement and Significance of Corrections,” *Journal of ASTM International*, Vol. 4, No. 8, 2007.

B. Suprenant, “Vapor Barriers Under Concrete Slabs”, *Concrete Construction*, Publication #C920292, 1992.

U.S. Green Building Council, “LEED 2009 for New Construction and Major Renovations Rating System”, 2009.

ATTACHMENT A
GUIDE SPECIFICATION FOR BELOW GRADE VAPOR BARRIERS

DIVISION 7 – THERMAL AND MOISTURE PROTECTION

SECTION 07 26 16 – Below Grade Vapor Barriers

Specifier Notes: This guide specification is written according to the Construction Specifications Institute (CSI) Format. The section must be carefully reviewed and edited by the Architect or Engineer to meet the requirements of the project. Coordinate this section with other specification sections and the drawings.

PART 1 – GENERAL

1.01 Section Includes

- A. Surface Preparation
- B. Application of underslab vapor barrier

1.02 Related Sections

Specifier Notes: Edit the list of related sections as required for the project. List other sections dealing with work directly related to this section.

- A. Section 03 30 00 – Concrete
- B. Section 07 10 00 – Dampproofing and Waterproofing

1.03 References

- A. American Society for Testing and Materials (ASTM)
 - 1. ASTM E96 – Standard Test Methods for Water Vapor Transmission of Materials
 - 2. ASTM E154 – Standard Test Methods for Water Vapor Retarders Used in Contact with Earth Under Concrete Slabs
 - 3. ASTM E1643 – Standard Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs
 - 4. ASTM E1745 – Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill Under Concrete Slabs

5. ASTM F1249-01 – Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor

B. American Concrete Institute (ACI)

1. ACI 302.1R-04 – Guide for Concrete Floor and Slab Construction

1.04 Submittals

A. Comply with Section 01 33 00 – Submittals

B. Submit manufacturer’s product data and application instructions.

1.05 Delivery, Storage, and Handling

A. Deliver materials to site in manufacturer’s original, unopened containers and packaging, with labels clearly identifying product name and manufacturer.

B. Store materials in a clean, dry area in accordance with manufacturer’s instructions.

C. Protect materials during handling and application to prevent damage.

1.06 Environmental Requirements

A. Product not intended for permanent exposure to the elements.

B. Do not apply on frozen ground.

PART 2 – PRODUCTS

2.01 Manufacturer

Specifier Notes: This is an incomplete list of vapor barrier manufacturers. Edit the list of manufacturers to those available to work site location.

A. GSE Lining Technology, Inc., (800) 435-2008. www.gseworld.com

B. Grace Construction Products, (800) 354-5414. www.na.graceconstruction.com

C. Insulation Solutions, Inc., (866) 698-6562. www.insulationsolutions.com

D. Raven Industries, Inc., (800) 635-3456. www.ravenind.com

- E. Reef Industries, Inc., (800) 231-6074. www.reefindustries.com
- F. Stego Industries LLC, (877) 464-7834. www.stegoindustries.com
- G. Tremco, Inc., (800) 321-7906. www.tremcosealants.com
- H. W.R. Meadows, Inc., (800) 342-5976. www.wrmeadows.com
- I. Approved Equal.

2.02 Materials

- A. Plastic Vapor Barrier – Performance Based Specification

Specifier Notes: Specifier to revise based upon performance requirements.

Vapor barrier shall have the following characteristics:

1. Minimum Permeance: 0.1 perms
2. Minimum Tensile Strength: 30 lbf/in.
3. Minimum Puncture Resistance: 1700 grams
4. Minimum Thickness: 10 mils
5. ASTM E 1745-09 Class: B

- B. Plastic Vapor Barrier – Proprietary Based Specification

Specifier Notes: Specifier to identify manufacturer and product name / model.

2.03 Accessories

- A. Seam Tape – Adhesive or pressure-sensitive tape must have the same qualities as the vapor barrier and supplied by the same manufacturer. Minimum width: 4 inches.

PART 3 – EXECUTION

3.01 Examination

- A. Examine surfaces to receive vapor barrier. Notify Architect / Engineer / Owner's Representative if surfaces are not acceptable. Do not begin surface preparation or application until acceptable conditions have been corrected.

3.02 Surface Preparation

- A. Prepare surfaces in accordance with manufacturer's instructions.

3.03 Application

- A. Installation shall be in accordance with manufacturer's instructions.
- B. Unroll vapor barrier with the longest dimension parallel with the direction of the pour.
- C. Lap vapor barrier over footings and seal to foundation walls.
- D. Overlap joints minimum of 6 inches and seal with manufacturer's tape.
- E. Seal all penetrations (including pipes) with vapor barrier material and seal tape.

3.04 Field Quality Control

- A. Testing and Inspecting: Contractor will engage a qualified testing and inspecting agency to perform field tests and inspections and to prepare test reports.
- B. Inspections: Installation of vapor barrier including sealing of joints and penetrations.

3.05 Repair

- A. Repair vapor barrier damaged with vapor barrier material or as instructed by the manufacturer.
- B. Lap beyond damaged areas a minimum of 6 inches and seal as prescribed for seam joints.

END OF SECTION 072616