ITRC Technology Information Sheet

Vapor Intrusion Mitigation Team | December 2020

Passive Vapor Intrusion Mitigation Systems Subgroup

Passive Barriers

This ITRC Technology Information Sheet provides a general technical overview of several common types of passive barrier technologies used to prevent and/or reduce the entry of vapors into a building. The information contained in this document is designed to provide guidance on the appropriate application of each passive barrier technology listed, as well as considerations for selecting, designing, and installing a passive barrier system.

Overview

Types of Passive Barriers

Passive barriers use one or more layers of materials installed below a building foundation to physically block or divert the entry of vapors into a building. While use of passive barriers in new construction is more common, passive barriers may be installed within existing buildings when site conditions allow. This document provides a general technical overview of several common types of passive barrier technologies used to mitigate buildings at sites with vapor intrusion (VI) risks. Most passive barrier technologies fall under two categories known as asphalt latex membranes (ALMs) and thermoplastic membranes (TMs). Advancements in TM technology have resulted in the creation of a third category known as composite membranes (CMs), which incorporate a combination of barrier materials to improve the performance of the passive barrier. Passive barriers are generally used in conjunction with passive venting systems to enhance their ability to prevent vapors from entering and accumulating beneath a building. When a passive barrier is used in conjunction with a passive venting system, the collective system is referred to as a passive VI mitigation system (VIMS). In some cases, passive barriers are used in conjunction with active venting systems or other building control technologies.

A brief technical overview of ALMs, TMs, and CMs is provided below. More information about passive venting systems can be found within the ***Passive Sub-slab Venting Systems Technology Information Sheet***. Additional information about active venting systems can be found within the ***Active Mitigation Fact Sheet*** and supporting technology information sheets.

Best Practices

Selection of Passive Barrier Technologies

Not all passive barrier system manufacturers provide performance data for their individual products or passive barrier technologies. Users should inquire with the passive barrier system manufacturer to request performance data and assess the appropriateness of individual products or systems for their project.

Pre-system Installation

Passive VIMS documentation should include drawings prepared by a qualified environmental professional, a site-specific quality assurance/quality control (QA/QC) plan consistent with manufacturer recommendations that addresses barrier inspection procedures and methods to prevent damage to the barrier during and after placement, and if required, an on-going monitoring plan. The ***Operations, Monitoring, and Maintenance***

Checklist provides recommendations of items to include in an operation, maintenance, and monitoring (OM&M) plan.

A properly trained or certified VIMS installation contractor should be selected. Manufacturers can provide lists of contractors that are certified to install their systems. Each member of the contractor's crew should be trained in the proper procedures for successful installation of the VIMS.

Installation Oversight

A qualified environmental professional properly trained and authorized by the manufacturer in the application and inspection of the passive VIMS should be selected and appointed as the QA/QC inspector by the appropriate party. Ideally, the inspector should always be present during the installation of the VIMS; however, this is usually not feasible. Typically, the more oversight the inspector can perform, the smoother the installation process will go because the inspector can prevent improper installation procedures or correct improper installation procedures shortly after they are performed. During installation, the inspector should confirm all aspects of proper installation of the VIMS.

System Installation Inspections

- QA/QC tests are commonly conducted during installation, including smoke, vacuum, or leak tests to confirm proper installation and material quality.
- Any deficient area of the installation should be properly documented and called to the attention of the applicator to address.
- Site inspectors should confirm and document required repairs.
- Site inspectors should prepare a final report verifying the VIMS installation.

Post-system Installation

After installation, a passive VIMS should be properly inspected and commissioned for use. The ***Post-Installation Verification Fact Sheet*** and associated checklist describe best practices for ensuring a passive barrier system is functioning as intended.

Asphalt Latex Membranes (ALMs)

Technology Description

The primary component of a passive ALM VIMS is a continuous seamless layer of spray-on asphalt latex material. ALM materials used for VIMS should be water based and free from volatile organic compounds (VOCs) and used in combination with other layers to create a barrier to VI. A typical ALM passive VIMS consists of a base layer, a continuous seamless layer of spray-applied ALM, and a cap sheet.

ALMs are applied to a carrier layer, referred to as a base layer, that consists of either a geotextile—a thin textile-backed plastic film—or a CM. The base layer serves as a carrier substrate for the spray-on membrane, increasing the tensile strength of the system and in some cases increasing the system's resistance to chemical attack or vapor diffusion.

The ALM is applied at a specified mil thickness to the base layer. The asphalt emulsion and latex polymer blend is mixed with a catalyst material at the tip of a spray wand. This creates a reaction resulting in the instantaneous formation of a uniform seamless ALM. The membrane typically reaches 90 percent of its full properties within 15 minutes. After the ALM has been applied, a different geotextile is applied on top of the spray-on membrane. This is typically referred to as the cap layer or protective layer. The cap layer serves to protect the ALM from construction damage that might be caused by subsequent trades. Additionally, the nonwoven fibers of the cap geotextile get embedded into the concrete that is poured on top of the ALM. This allows for the ALM to be integrally bonded to the concrete, providing protection from VI even if the soils settle away from the bottom of the slab.

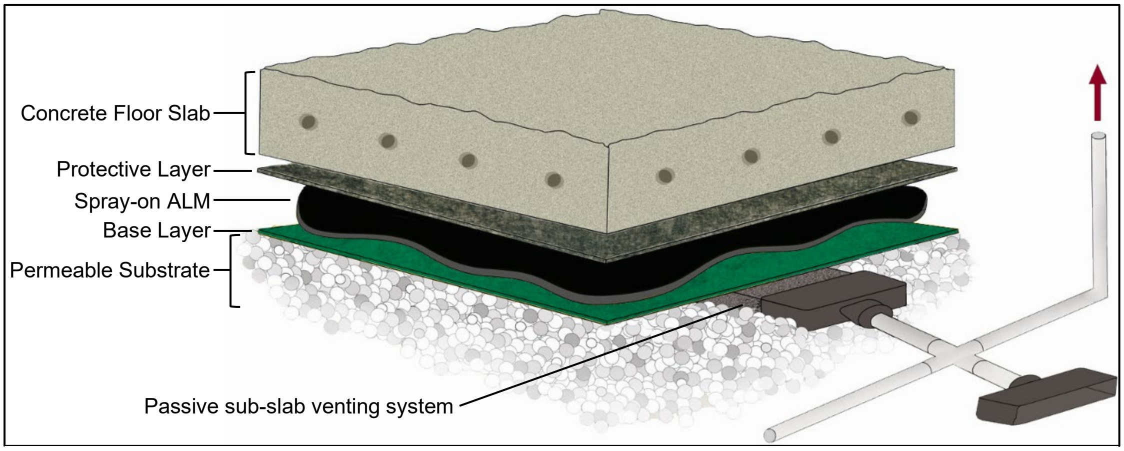

Figure 1. Illustration of a typical asphalt modified latex (ALM) passive barrier and passive venting system.
Source: Adapted from CETCO

When terminating the system to building footings, grade beams, stem walls, etc., the spray-on ALM adheres directly to concrete, thus removing the need for mechanical fastening. The spray-on ALM is also used to seal penetrations without the need for preformed boots. The ability of the membrane to adhere to typical substrates makes it ideal for sealing to penetrations such as polyvinyl chloride (PVC), steel, wood, and concrete terminations at its perimeter. This results in a fast installation by reducing the time spent on detailing.

Advantages

ALM VIMSs can be used for a wide range of chemicals of concern due to the variety of base and cap materials available.

- ALMs adhere to most surfaces, which eliminates mechanical fastening and caulking at penetrations and terminations.
- ALMs are spray-applied and cure in place, and therefore provide a seamless layer of protection. This reduces the risk of a membrane failure at seams, which tend to be the weakest points in seamed systems.
- ALMs that use a protective geotextile may bond to the concrete poured on top of them. This ensures protection even in the event of soil settling. The geotextile also protects the ALM from aggregate damage.
- ALMs are composed of very low permeability materials, which protect against diffusive and advective flow of vapors. If configured properly, an ALM can provide the additional benefit of moisture protection.
- ALMs can be combined with CMs. These combined systems can offer a higher level of protection from chemical diffusion.

Limitations

- ALMs are primarily limited to new construction or foundations that do not have an existing slab.
- ALMs should not be used if they are expected to be in direct contact with pure liquid-phase solvents.

Cost Considerations

Costs for passive ALM VIMSs are typically $2—$5 per square foot, including materials and installation. Cost will vary depending on the project location, size, complexity, and construction sequencing.

Design & Installation Considerations

Contaminant Types

Passive ALM VIMSs can be used for a wide range of contaminants because of the wide variety of base and cap materials that are used in conjunction with the spray-on membrane. Manufacturers generally provide suggestions for the contaminant classes that their systems may be appropriate for. An additional consideration is for the compatibility of the ALM with contaminants that are expected to contact the barrier in a separate liquid phase. These chemicals in their pure form may not be compatible with the ALM or the base and cap layers. If the barrier is expected to be in contact with these chemicals in their pure liquid phase, other remedial actions may be needed on site before redevelopment.

Performance

Performance of an ALM is a function of the materials that it is made from and the quality of the installation. Selection of the most appropriate ALM, based on the contaminant types, concentration, and risk, should consider the performance of the ALM. Chemicals move through a barrier by advection and diffusion. Advective flow is dominated by imperfections in the barrier that coincide with cracks or other openings in the slab, illustrating the importance of the installation of the barrier. The rate of chemical diffusion through the barrier is dependent on the material type. Certain types of materials are better at controlling diffusion. An ALM that incorporates CMs in the base provides higher reductions in chemical diffusion through the barrier.

QA/QC

A QA/QC plan should be implemented on all ALM applications. This may include destructive testing or coupon samples cut at a predetermined frequency. Coupon sampling is the collection of samples cut from the ALM to verify that the membrane thickness meets the project requirements. Areas that are cut for sampling should be repaired with the appropriate methods.

Additionally, a smoke test should be used to inspect the ALM for imperfections. Nontoxic theatrical smoke may be pumped below the membrane prior to placement of concrete to allow for visual identification of holes in the membrane. This allows the entire ALM to be inspected for imperfections that are not visible to the naked eye. Manufacturers can provide standard procedures for conducting these tests. Reports documenting the QA/QC testing should be part of the project records.

Thermoplastic Membranes (TMs)

Technology Description

TMs are composed of plastic resins formed into uniform membranes. They can also be referred to as geomembranes or plastic liners. TMs most commonly consist of high-density polyethylene (HDPE), but variations such as linear low-density polyethylene (LLDPE) and other materials are also available. The physical characterizes of TMs can vary between manufacturers as resin blends are specific to each manufacturer and each type of resin blend provides unique physical and chemical resistance properties.

Since most passive barrier applications also require the use of a sub-membrane vapor collection system, TMs are commonly installed over a gravel substrate. To prevent damage during the installation process it is common to install a non-woven geotextile (between 6 and 12 ounces per square yard in weight) under the TM.

A welding device is used to thermally seal the seams of the TM together. Heat welding methodologies can vary depending on the thickness of the TM. Thicker TMs will require more robust equipment to achieve the goal of a uniform and continuous welded seam. Prefabricated “boots” made of the same TM material are used to seal around pipe penetrations and protrusions. Steel clamps and sealants are used to create a compressive seal between the penetration and the TM.

When terminating the TM to building footings, grade beams, stem walls, etc., a termination bar is mechanically fastened over the edge of the liner and onto the concrete substrate. The termination bar's purpose is to create a compressive seal between the desired substrate and the TM because TMs have no adhesive properties. Proper compression between the termination bar and the termination substrate is required to create an effective seal. Stainless steel termination bars are generally specified due to their longevity, physical strength, and resistance to moisture and chemicals. To promote and maintain uniform adhesion, the lag bolts and washers should be the same material as the termination bar.

Additional considerations must be taken if the geotechnical report indicates that settling may occur underneath the structure. Soil settlement will compromise the integrity of a TM at seams and terminations by no longer providing support for the TM. Manufacturers of TMs provide modifications to TMs to mechanically bond (anchor) the TM to the concrete slab.

Thickness and installation procedures differentiate TMs from common vapor barriers. "Vapor barrier" is the term most associated with thin mil plastic liners (e.g., 6–15 mils) that are used to mitigate moisture transmission through concrete. Vapor barriers used in standard construction practices are not typically designed to mitigate chemical vapor transmission (DNREC-SIRB, 2007).

Advantages

- TMs may provide factory QA documentation, ensuring uniform quality of the base material.
- The material cost for a TM can be low when compared to the material cost of ALM.
- Puncture resistance can be increased by using thicker membranes.
- Independent testing demonstrates that HDPE has a relatively high level of chemical resistance compared to other geomembrane materials.
- ATSM standards provide a standard for field QA/QC.

Limitations

- The use of TMs is primarily limited to new construction projects.
- TMs typically require heat-welded seams and mechanical fastening and sealing at penetrations and terminations, which are the areas more prone to develop leaks.
- While the material cost of a TM may be relatively low, the labor to install the TM is relatively high, when compared to ALMs.
- Thicker TMs decrease the likelihood of damage during the construction process; however, they are more difficult to install properly. Generally, large flat open areas are more conducive to TM installation.
- TMs can be susceptible to thermal expansion and contraction, thus potentially compromising penetration and termination seals.
- TM effectiveness can be compromised if proper compression is not achieved between the termination bar, the TM, and the substrate.

Cost Considerations

- Costs for TMs are typically $5–$10 per square foot, based on HDPE, PVC, or other field-constructed thermoplastic liner systems (Kilmer et al., 2016).
- Cost will vary depending on the project location, size, complexity, and construction sequencing.

Design & Installation Considerations

TM should be designed considering foundation complexity, contaminants of concern, and weather conditions at the anticipated time of installation. The most common ASTM QA standards are:

- ASTM D5820—Conductive Geomembrane Spark Test
- ASTM D4437—Air Lance Test
- ASTM D4437—Vacuum Box Test

- ASTM D5820—Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

Other forms of quality control include:

- smoke test—the process of injecting nontoxic smoke underneath the membrane, checking for any smoke penetrating the membrane, and then patching the membrane to ensure no more smoke penetrates the membrane. Care should be taken when using a smoke test of a passive VIMS with taped seams. Pressure from the smoke test can cause the seams to separate.
- mechanical point stress test—testing the integrity of each seam using a handheld seam probing tool.

Composite Membranes (CMs)

Technology Description

Advancements in TM technology have led to the development of CMs. These CMs incorporate a variety of materials that can reduce diffusion rates of chemical vapors from VOCs, petroleum hydrocarbons, methane, and radon. CMs use a variety of different passive barrier materials to create a multilayered system designed to improve chemical resistance, constructability, and durability.

Examples of materials used in CMs include ethylene vinyl alcohol (EVOH) embedded between layers of polyethylene. These systems combine the functionality of polyethylene with improved chemical resistance of EVOH (McWatters and K. Rowe, 2018). Other advanced CMs may include metallized films or foils made of metals, such as aluminum, to achieve improved chemical resistance. The inner barrier of CMs may be protected by multiple layers.

Multiple layers provide redundancy and improved diffusion rates for a variety of chemicals, including various VOCs and petroleum hydrocarbons. The redundancy of multiple layers also provides improved durability against construction traffic. Seams may be sealed using various methods, such as heat welding, taping, or spray-on emulsions. Terminations and penetrations are typically sealed using either mechanical fastening and caulking, tapes, or spray-on emulsions.

Advantages

- Using a combination of barrier materials can offer improved chemical resistance.
- Multiple layers may improve long-term durability.
- CMs may provide protection against a broad range of chemicals.
- CMs can provide greater protection and improve installation times using thinner mil systems.
- CMs can be combined with ALMs. Combined systems can offer a high level of protection from chemical diffusion.

Limitations

- New technologies may require regulatory approval. Some CMs may not meet minimum mil thickness regulatory requirements.
- Smooth CMs may pose challenges during installation due to lack of adhesion to concrete and may require mechanical fasting around penetrations and perimeter terminations.
- Taped-based CMs may be subject to delamination in high moisture environments and may have difficulty passing a smoke test.

Cost Considerations

Installed costs for CMs typically range from $1 to $5 per square foot, depending on building type, building size, and warranty requirements. Cost will vary depending on the project location, size, complexity, and construction sequencing.

Design & Installation Considerations

Design and installation considerations for CMs are similar to other passive barriers. The primary methods for design evaluation should focus on chemical resistance, constructability, and cost. The evaluation for chemical resistance should include diffusion testing for representative chemical contaminants. In addition, other testing methods should be used in combination with chemical resistance testing to evaluate the following parameters of CMs:

- composite mil thickness
- tensile strength
- tear strength
- puncture resistance
- elongation

These physical properties should be used in combination with diffusion testing to create a better understanding of the overall robustness of the CM. These barriers will be installed in construction traffic environments and must demonstrate sufficient durability to prevent punctures and/or tears prior to concrete slab pour. Installation is best completed by certified installers who are familiar with the application of the CM. In addition, it is best practice to have third-party inspectors present during installation to ensure the installation is performed per the designed technical specification.

Typical Barrier Selection Considerations

Thickness

The barrier material, properties, and application affect the appropriate thickness and these factors should be considered when selecting a barrier for any particular purpose. It should also be noted that some VI guidance documents do not specify an appropriate minimum thickness, but state that passive barriers should be thick enough to withstand construction and diffuse the chemicals of concern. State and federal VI guidance documents that do suggest an acceptable minimum thickness vary from 30 to 100 mils. A thickness of 40 mils is commonly referenced for TMs and 60 mils for ALMs. A 30-mil minimum thickness is referenced in some guidance (USEPA, 2008). Vapor barriers less than 30 mils are more prone to puncture, tearing, and incomplete seals, thus limiting their effectiveness. However, membranes less than 30 mils may be appropriate when combined with active systems.

Chemical Resistance and Diffusion

Universally accepted standards do not exist for the chemical resistance to chemical vapor or diffusive properties of passive barrier materials. Existing ASTM standards used to evaluate water vapor barriers (ASTM E96) or short-term free product chemical exposure do not adequately address the intended use of VI barrier systems, and may differ due to the molecular size and attraction of the solvent vapor barrier material (Wilson et al., 2014). Manufacturers of VI barrier products publish chemical vapor resistance testing and/or diffusion results. These tests should be evaluated on their own merits. While testing methodologies can vary between manufacturers, there are independent laboratories and universities, such as Geokinetics of Irvine, California, and Queens University in Ontario, Canada, using standard protocols to determine chemical diffusion rates for various commercially available passive barriers.

Puncture and Tensile Strength

Testing the strength of a membrane system helps predict a membrane's ability to resist damage during the construction process. Damage to membranes after they are installed often occurs when small objects (hand tools, rebar, etc.) are dropped onto the membrane. Puncture resistance by ASTM D1709, which measures the amount of force required to fully penetrate the membrane material, is commonly used (NJDEP, 2018).

Tensile strength (ASTM D882) is a measure of a material's resistance failure due to stretching (NJDEP, 2018). Tensile strength can be used to evaluate a membrane's ability to resist failure due to tension that may be caused by differential settlement of the underlying soil.

Constructability

Constructability of a passive barrier system is a subjective term that attempts to convey to users how easy a passive barrier is to install versus its ability to withstand the construction process as well as its usability in a wide variety of situations. TMs are typically provided in large rolls. The material's stiffness and thickness make it more difficult to work with in areas requiring a lot of detail work. However, the large rolls facilitate a fast installation in open areas not requiring detailing. ALMs are efficient for use in areas that require detail work because they are spray-applied and rapidly seal to the substrate. In large open areas ALMs typically take longer to install than TMs.

Special Circumstances

The presence of a high water table or perched aquifer may adversely affect the performance of both passive and active mitigation systems installed within structures constructed below grade. While slab-on-grade structures are not often affected unless they are built in a flood zone, below-grade structures will need protection against both water and VI. Local building code requirements will dictate a building owner's ability to artificially lower the water table to an elevation that does not affect the foundation or mitigation system; however, in many cases this is not economically feasible when contaminated groundwater is encountered. When dewatering systems are used, a passive barrier with waterproofing capabilities should still be used in the event of dewatering system failure, and to prevent the migration of nuisance water. Water intrusion into the structure indicates that a potentially complete VI pathway exists. Waterproofing materials used on contaminated sites must also demonstrate effectiveness to contaminated vapor.

Settlement of soils beneath structures may occur for a variety of reasons. Therefore, passive barriers should demonstrate their ability to adhere directly to the concrete slab, as this will prevent the barrier from settling with the soil. Likewise, peel adhesion and tensile stress on the passive barrier material and its seals and seams may compromise the system.

Occupant, Community, and Stakeholder Considerations

Occupants of buildings with existing passive barriers should be made aware of potential VI risks and that the barrier provides a level of protection designed to prevent VI from occurring. Occupants should be instructed to avoid modifying the concrete slab to prevent affecting the function of the passive barrier. When planning modifications to a building with a passive barrier, consideration should be given to whether the modifications will affect the integrity of the barrier.

It is essential to develop and implement a site-specific community involvement plan that addresses, among other things, how to win trust and gain access to properties, communicate risk to potentially exposed individuals, and minimize the disruption of people's lives and businesses. For more details see ITRC's ***Public Outreach During Vapor Intrusion Mitigation Fact Sheet***.

Resources

- ASTM. 2016. Standard Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method. American Society for Testing and Materials. 2016. ASTM D1709-16ae1

- ASTM. 2017. Standard Specifications for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs. American Society for Testing and Materials. 2017. ASTM E-1745-17
- ASTM. 2018. Standard Test Method for Tensile Properties of Thin Plastic Sheeting. American Society for Testing Materials. 2018. ASTM D882-18
- ASTM. 2018. Standard Practice for Nondestructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes. American Society for Testing and Materials. 2018. ASTM D4437 / D4437M-16(2018)
- ASTM. 2018. Standard Practice for Pressurized Air Channel Evaluation of Dual-Seamed Geomembranes. American Society for Testing and Materials. ASTM 5820-95(2018)
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- Wisconsin Department of Natural Resources. 2018. "Addressing Vapor Intrusion at Remediation & Redevelopment Sites in Wisconsin". Wisconsin Department of Natural Resources.

For more information and useful links about VI pathways and mitigation technologies, go to http://www.itrcweb.org/

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