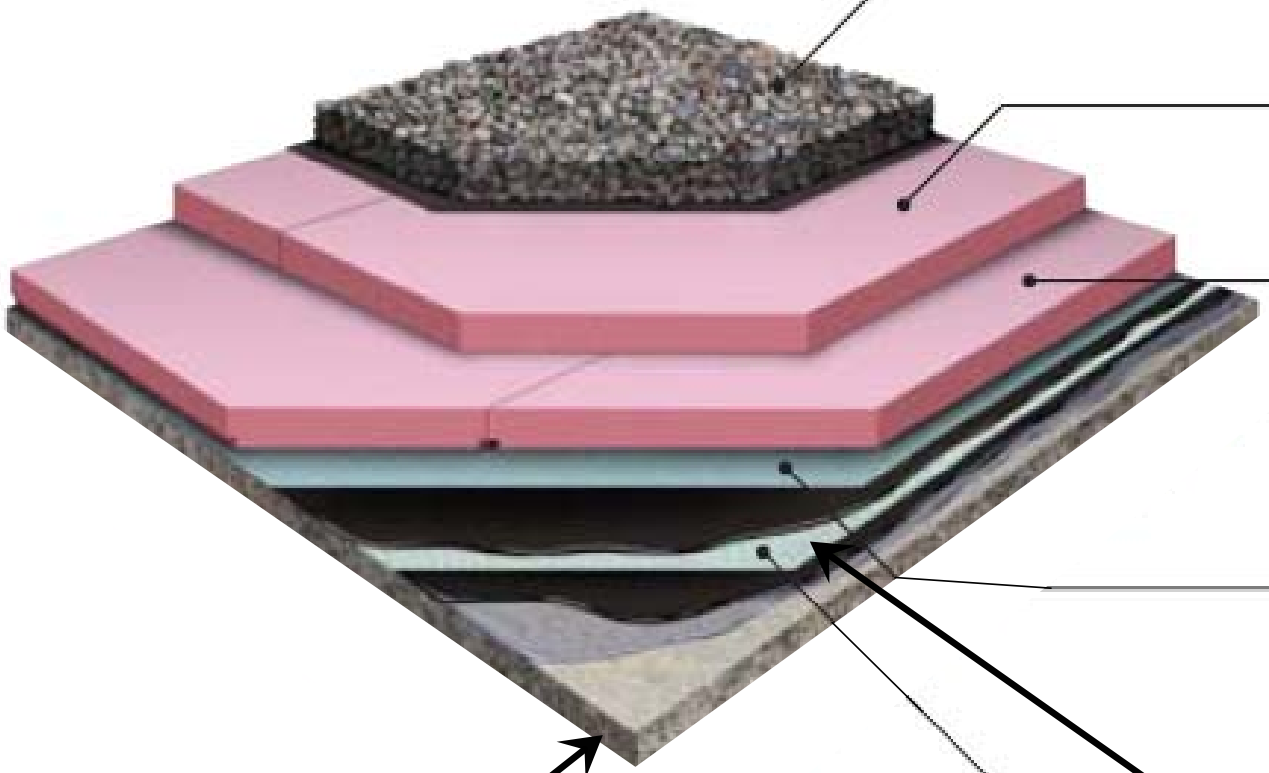
NOTE:
A LICENSED STRUCTURAL ENGINEER NEEDS TO PERFORM THE NECESSARY STRUCTURAL CALCULATIONS TO ASCERTAIN IF THE EXISTING ROOF DECK STRUCTURE IS CAPABLE OF SUPPORTING THE PROPOSED ROOF ASSEMBLY.



NOMINAL 1 1/2" ROUNDED WATER-WORN GRAVEL CONFORMING TO GRADATION #4 PER ASTM D 448

STONE BALLAST OVER FILTER FABRIC
(AT A RATE OF 10-12 LBS/SF)

FOAMULAR® 400 XPS INSULATION
(TOTAL THICKNESS OF FLAT XPS INSULATION IS 6" (R-5 PER 1")
R-30 TOTAL

FOAMULAR® 404 XPS INSULATION
(with rain channels on all 4 bottom edges)

DRAINAGE LAYER
(CARLISLE'S CCW MIRADRAIN G4 DRAINAGE COMPOSITE)
DRAINAGE LAYER

5" WIDE COVER STRIPS
OVER THE EXISTING LAP SEAMS

EXISTING SLOPED WOOD ROOF DECK STRUCTURE

EXISTING FIRESTONE'S EPDM ROOF SYSTEM (ASSUMED 2" OF EXISTING, MECHANICALLY ATTACHED POLYISO ROOF INSULATION;
AGED R-VALUE=R-10 (+/-)

Stone Ballasted Waterproofing System

BY:
ELVEDIN KRUPIC
SWBR
DEC. 19, 2018

PRMA, Vegetative and Plaza Deck
Insulated Roof Systems

Section Overview

PRMA, Vegetative and Plaza Deck Waterproofing

Protected roof membrane assemblies (PRMA) provide high value and long term durability on long life cycle buildings. PRMA roofs range in function from infrequently accessed stone ballasted systems, to paver/plaza deck walking surfaces, to fully landscaped vegetative roof gardens. PRMA extends the life of roofing components and reduces building maintenance costs by eliminating UV exposure and minimizing thermal cycling.

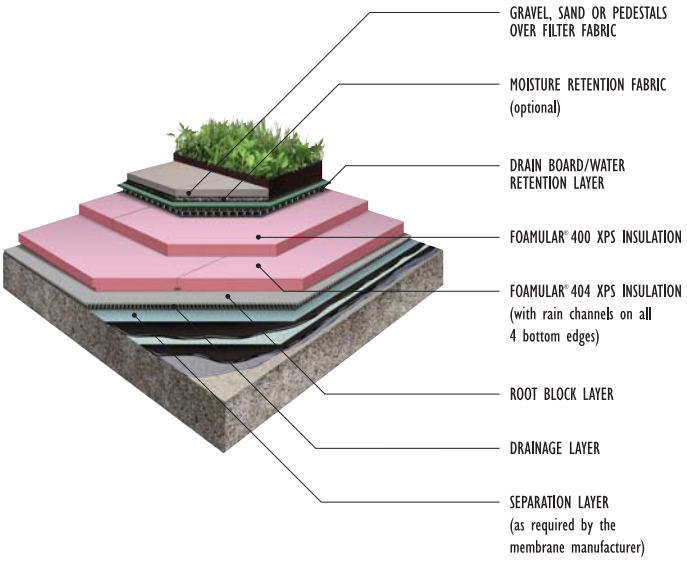
Vegetative roofs are gaining widespread acceptance due to the practical, financial, and environmental benefits they provide. In addition to creating more usable landscaped space in the form of rooftop terraces, walkways, plazas and gardens, a well insulated PRMA vegetative roof assembly improves energy efficiency and reduces heating and cooling costs. In some instances vegetative roofs receive financial funding incentives from government agencies responsible for reducing environmental impact. Vegetative roofs provide a number of important environmental benefits such as reduced storm water runoff and sewer fees, they help keep contaminants out of lakes and streams, they reduce the urban heat island effect, and they improve air quality by converting carbon dioxide to oxygen.

FOAMULAR® Extruded Polystyrene (XPS) Insulation for PRMA

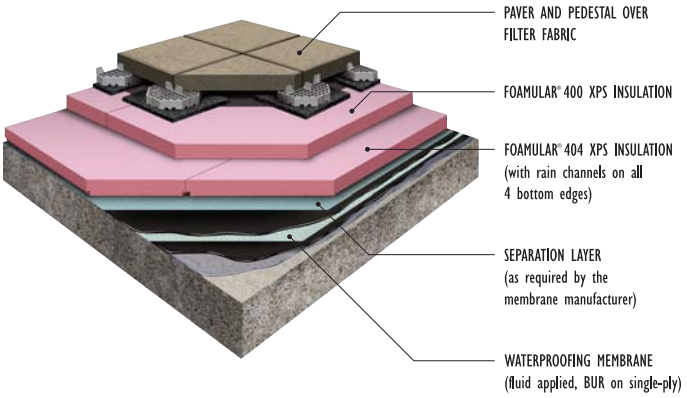
FOAMULAR® XPS insulation products 404, 604, 404RB and 604RB are used in PRMA applications. Extruded polystyrene is the only insulation used in PRMA roof systems due to its excellent resistance to water absorption compared to any other type of rigid board insulation. Because the insulation is installed above the waterproofing membrane and is exposed to water through its service life, resistance to water while maintaining physical properties is critical.

FOAMULAR® 404 and 604 have channels cut into the bottom edges on all four sides of the board to enhance drainage at the board/membrane interface. FOAMULAR® 404RB and 604RB have ribs cut into the top surface of the board in addition to the channels on the bottom. The ribs serve as drainage enhancement under pavers when the pavers are laid directly on top of the foam board.

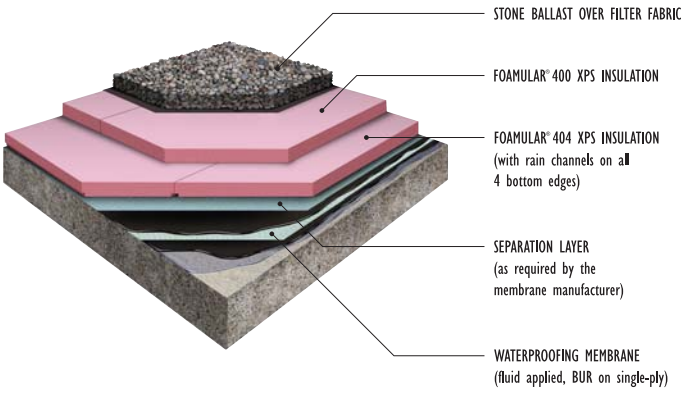
PRMA, Vegetative and Plaza Deck
Above Deck Roof Insulation



Vegetated Waterproofing System



Plaza Deck/Paver Waterproofing System



Stone Ballasted Waterproofing System

Section Overview

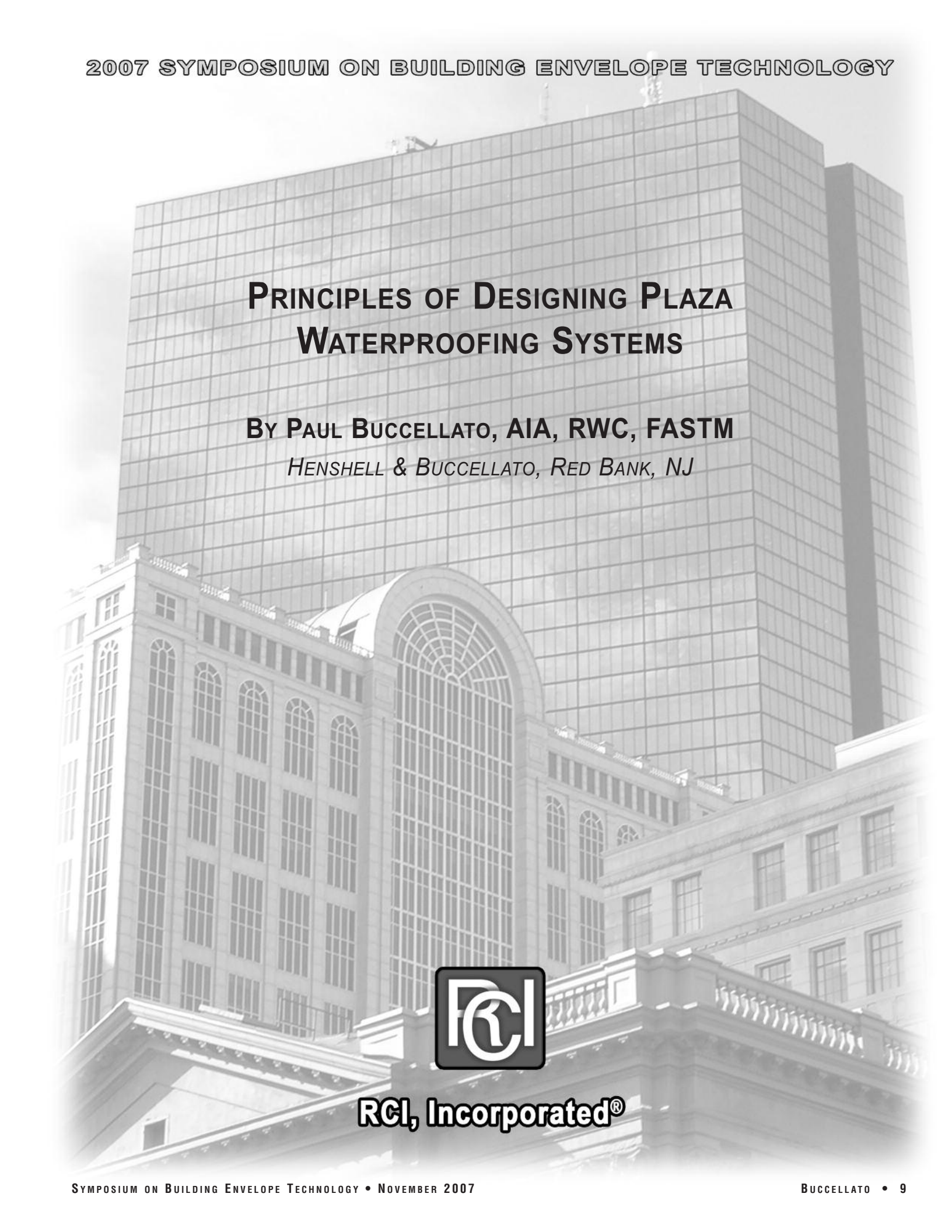
Sustainability

Owens Corning is committed to driving sustainability through greening our operations, greening our products and accelerating energy efficiency in the built environment. Owens Corning FOAMULAR® XPS products are GREENGUARD Indoor Air Quality Certified® and GREENGUARD Children and Schools Certified℠. FOAMULAR® XPS is also third party certified, to contain a minimum 20 percent recycled polystyrene content and is produced with a zero ozone depletion blowing agent formulation. FOAMULAR® XPS insulation products contribute to achieving credits in multiple LEED® categories including energy efficiency and recycled material content and carry a lifetime limited warranty[1] on all ASTM C578 physical properties for true long lasting value.

Notes

1. See actual warranty for complete details, limitations and requirements.

OWENS CORNING INSULATING SYSTEMS, LLC
ONE OWENS CORNING PARKWAY
TOLEDO, OHIO 43659
1-800-GET-PINK®
www.owenscorning.com



PRINCIPLES OF DESIGNING PLAZA WATERPROOFING SYSTEMS

BY PAUL BUCCELLATO, AIA, RWC, FASTM

HENSHELL & BUCCELLATO, RED BANK, NJ

RCI, Incorporated®

ABSTRACT

Plaza waterproofing differs from that of roofing systems because of the severe conditions under which it must perform. The waterproofing membrane is inaccessible for repairs, and its primary performance criteria are to resist the passage of water under continuous exposure to moisture. A plaza waterproofing system is covered by a wearing surface that can impede drainage at the membrane level. This makes any investigation and repair extremely difficult and expensive. Therefore, the anticipated service life of the membrane must approximate the predicted life of the building.

This paper will present design and installation fundamentals for plaza waterproofing systems. It will discuss drainage, insulation, waterproofing, and flashing details.

SPEAKER

Paul Buccellato, AIA, RWC, FASTM — Henshell & Buccellato, Red Bank, NJ

PAUL BUCCELLATO is a registered architect in four states and holds a certificate from the National Council of Architectural Registration Boards. He is also a Registered Waterproofing Consultant with RCI. Buccellato is a member of the American Institute of Architects, the New Jersey Society of Architects, the Construction Specifications Institute, RCI, and ASTM Committees D-08 Roofing and Waterproofing (chairman Subcommittee D08.20 Roofing Membrane Systems), C 15 Masonry Units, and C-24.

Mr. Buccellato has authored several technical papers on waterproofing and roofing, as well as three ASTM standards on roofing, and has lectured at Brookdale College, NJ. He wrote a column on roof design for *The Roofing Specifier* and is co-author of an NCARB monograph on built-up roofing. He has presented papers relating to waterproofing and roofing for RCI and ASTM.

Mr. Buccellato is a member of the RCI Education Committee and NRCA's Educational Resource Committee. He is also a member of RCI's Registered Waterproofing Examination Development Subcommittee.

Principles of Designing Plaza Waterproofing Systems

INTRODUCTION

The design of a plaza over occupied space must create a system that waterproofs and insulates the structural building deck while supporting pedestrian and/or vehicle traffic, including landscaping elements (*Figure 1*). Its design entails multiple component layers, including a waterproofing membrane, protection layer, drainage course, insulation, and wearing surface.

Earlier plaza designs did not incorporate a drainage layer within the system components. As a result, water that was trapped between the membrane and wearing surface caused them to deteriorate from freeze/thaw cycling or saturation. Since publication of Charles Parise's seminal paper in 1981, the accepted ASTM and industry standard requires the incorporation of a drainage course. The system must allow for the flow of water from the plaza wearing surface through the various components at the drains and sides. There are two basic categories of overburden on plazas over occupied spaces:

- Hardscaping with wearing surfaces, or
- Landscaping or softscaping with planting, fountains, etc.

Systems can be further divided into categories where the membrane is either accessible or inaccessible.

Accessible systems are those in which the wearing course is removable. Pavers that are installed on insulation, pedestals, or sand beds are classified as accessible systems. Landscaping or planting is considered to be an accessible system.

Inaccessible plaza systems are those in which the membrane is covered with a concrete protection slab or where the wearing surface units are installed in a solid, mortar-setting bed. Fountains and most vehicular wearing surfaces also fall into this category. These systems require demolition of the concrete protection slab or solidly grouted units for access to the membrane.

A waterproofed plaza system that

Figure 1A and 1B – Plaza with landscaping elements.

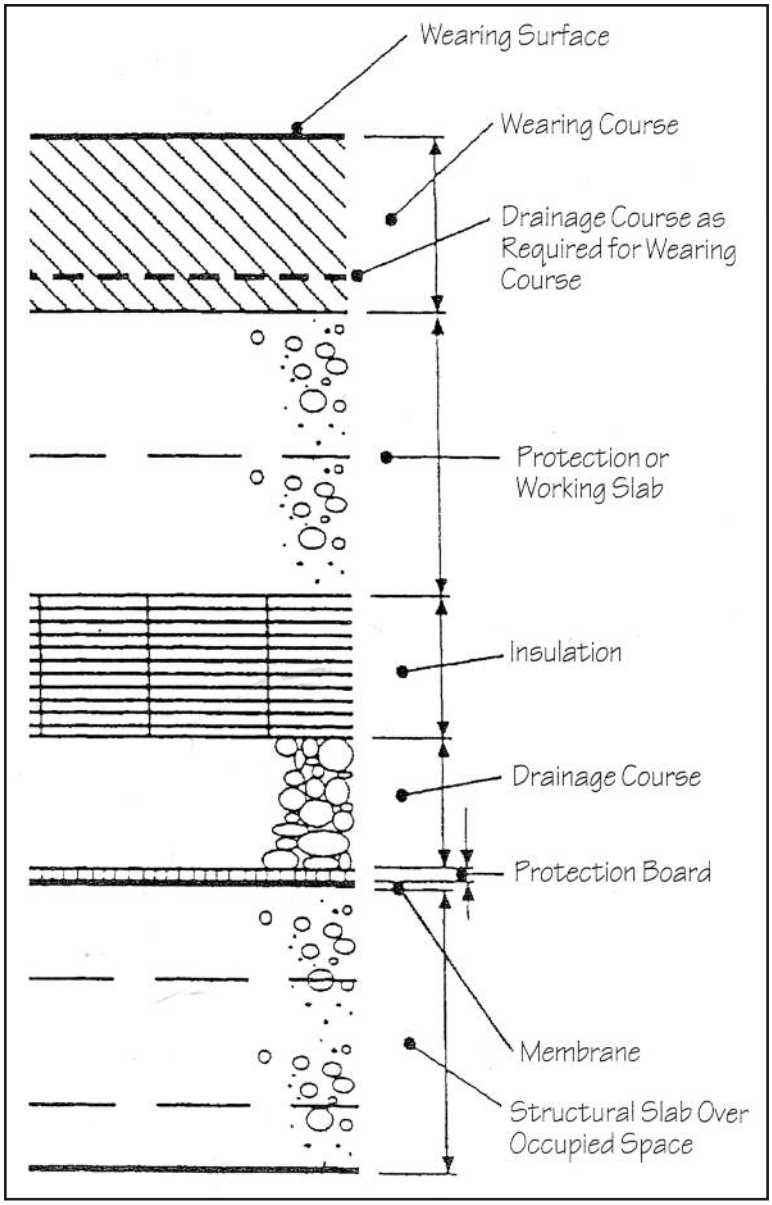


Figure 2 – Basic components of membrane waterproofing over a framed structural slab. (Courtesy of ASTM International.)

includes a separate wearing course contains some or all the following components (*Figure 2*):

- Structural deck
- Membrane
- Protection board or protection membrane
- Drainage layer or course
- Thermal insulation
- Concrete protection slab (optional)
- Flashing,
- Wearing surface

An earth-covered system consists of essentially the same, with the exception of the wearing surface, where the earth takes its place (*Figure 3*).

There are three ASTM International Standards that cover waterproofing under hardscaping:

C981 — *Standard Guide for Design of Built-Up Bituminous Membrane Waterproofing Systems for Building Decks*

C898 — *Standard Guide for Use of High-Solids Content, Cold, Liquid-Applied Elastomeric Waterproofing Membrane with Separate Wearing Course*

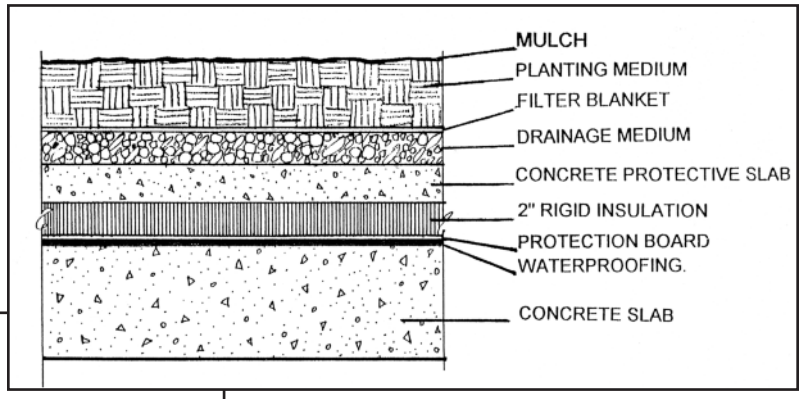
C1127 — *Standard Guide for Use of High-Solids Content, Cold, Liquid-Applied Elastomeric Waterproofing Membrane with an Integral Wearing Course*

Designers are advised to consult these standards when designing waterproofed plaza decks because they constitute the current body of knowledge on the subject.

STRUCTURAL BUILDING DECK

A structural plaza deck typically consists of reinforced concrete slabs, concrete topping over precast units, post-tensioned slabs, or composite concrete-and-steel decking. Reinforced structural concrete slabs are the most common and consist of framed or flat slabs. However, monolithic concrete slabs make a better substrate for waterproofing.

Joints between and at the ends of precast units and at



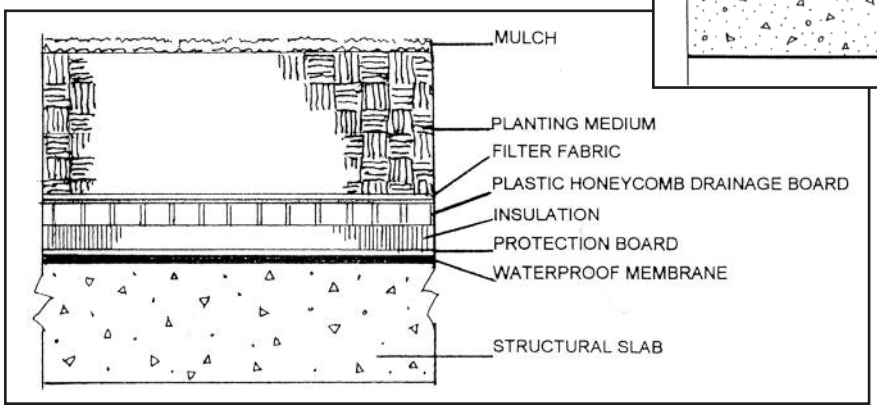


Figure 3 – Basic components of membrane waterproofing under earth.

their ends may not be in the same plane, and therefore they require a concrete topping to even out lippage and cover lifting rings and welded plates. However, the topping is prone to cracking along joints and, in particular, at the end joints, which may rotate between precast elements at supporting girders.

Post-tensioned slabs offer better control of deflection and cracking within the plaza deck. However, careful analysis of the deck deflection pattern and post-tensioning design is critical to achieve proper slope-to-drains after the plaza overburden has been placed.

Composite decking comprised of concrete-on-steel centering is more commonly used for terraces at higher floor levels than for plaza design near grade level. Provisions for venting moisture from the concrete must be made if a liquid membrane is applied to the concrete surface. This is typically achieved by using a slotted steel deck or additional curing time, which can be reduced by a low cement/water ratio.

Whichever structural system is selected, the waterproofing designer should assure himself that the structural engineer is informed as to the need for positive slope-to-drain. These discussions should include coordination among the waterproofing designer, landscape architect, and structural engineer to assure adequate load-bearing capacity and slab slope.

Figure 4 – Application of a coal tar pitch waterproofing membrane.

Figure 5 – Application of self-adhering modified bitumen membrane.

MEMBRANES

Membranes for waterproofed deck systems include:

- Conventional built-up bituminous
- Multi-ply modified bitumen sheets
- Single-ply sheets
- Liquid or fluid-applied elastomers

A built-up bituminous membrane consists of alternating multiple plies of saturated felts between applications of bitumen applied on-site (*Figure 4*). The plies include organic felt, glass mats or fabrics, and polyester mats or fabrics as reinforcement. Organic felts are preferred over glass. The bitumen can be asphalt or coal tar pitch. The bitumen of choice for waterproofing is coal tar pitch (ASTM D-450, Type I or II) because of its self-healing properties. Asphalt (ASTM D-449) has greater water absorption than coal tar pitch and is not suitable.

The felt plies can be shingled or phased (ply-on-ply). In a phased-type application, moisture that penetrates through a lap leads only to the next ply and not through the entire membrane.

Except for tarred felts, membranes constructed of organic felt have not performed well when exposed to standing water. Glass fiber felts are less absorbent than organic felt, but they tend to float or sink in coal tar pitch.

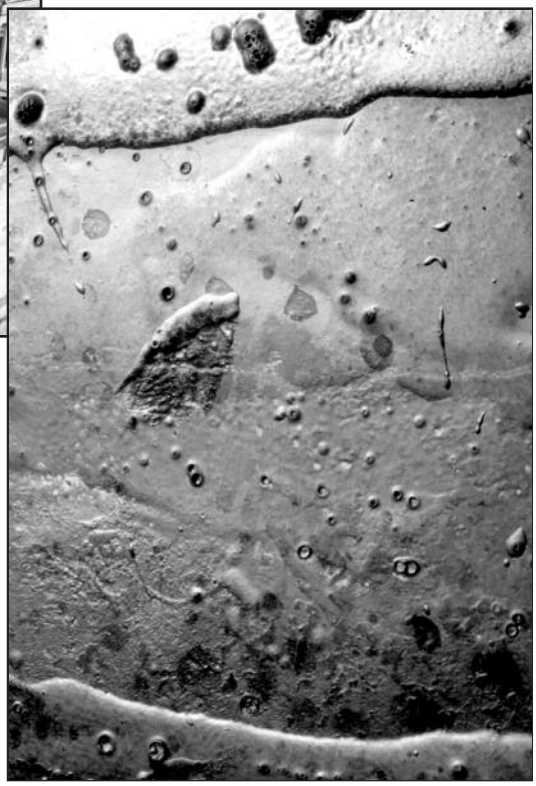
Modified bitumen sheets are modified with polymers to improve the sheets' flexibility and elasticity, as well as the cohesive strength of the bitumen. Some are self-adhering sheets, laminated to a high-density, polyethylene backing, and are often called "peel-and-stick" or rubberized asphalt (*Figure 5*). The sheets can be applied as a single- or multi-ply waterproofing membrane system. They must be protected from ultraviolet exposure within a few weeks of application.

Modified bitumen sheets used for roofing do not perform as well when used for waterproofing membranes because of the potential for wicking of the reinforcing as end-laps. These systems are fully adhered to the concrete substrate and are sensitive to site conditions, moisture, and deck surface quality.

Single-ply sheets include EPDM, butyl

Figure 6 – Compartmentalized installation of single-ply PVC membrane.

Figure 7 – Pinholing and air bubbles in liquid-applied membrane.



rubber, KEE, and PVC. Butyl rubber sheets have an advantage over EPDM sheets because of their lower moisture absorption. This benefit is more important for a waterproofing membrane than EPDM's greater resistance to ultraviolet resistance. PVC sheets offer improved puncture resistance and heat-welded seams.

These sheets are either fully adhered or loose laid. When loose laid, they should be compartmentalized by adhering the sheet in a 3-meter (10-foot) grid. This forms compartments that confine water migration if a leak occurs and also helps facilitate leak detection (*Figure 6*).

Liquid-applied membranes include hot and cold:

- Polymer-modified asphalt
- Single-blown asphalt
- Coal tar modified urethane
- Two-component urethanes
- Aliphatic polyurethanes
- Reinforced liquid polyester
- Two-component synthetic rubber
- Polymer-modified asphaltic emulsion.

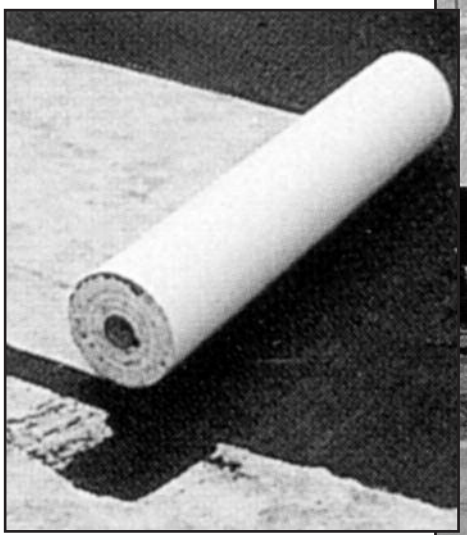
Proper performance of solvated or emulsion-type membrane systems requires that they contain a minimum of 65 percent solids to reduce pinholing. Problems associated with reflective cracking from the deck below can be addressed by proper dry mil thickness of the membrane (which is normally a minimum 60-dry-mil film thickness) and by reinforcement

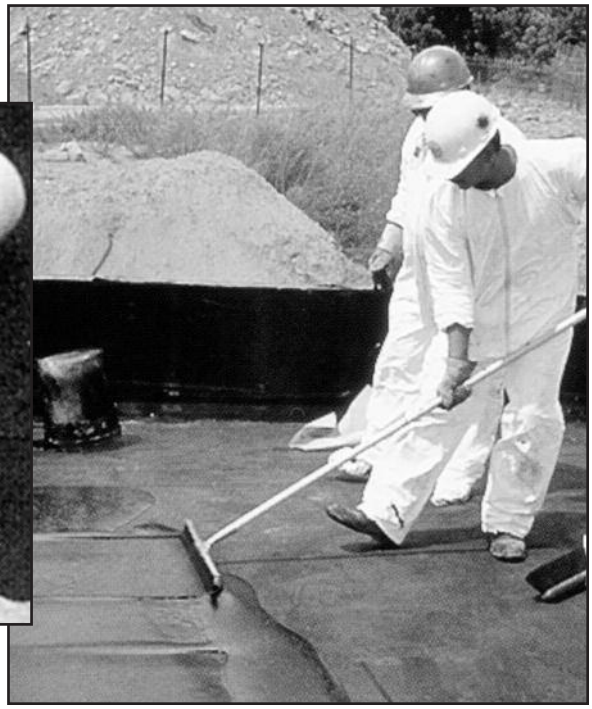
The advantage of adhered membrane systems is the localization of leaks. A disadvantage is the need for rigorous surface preparation of the substrate, which must be dry an dust-free, with a lightly broomed texture. Cracks must be detailed. Liquid-applied membranes should never be used to fill or level surface irregularities.

Moisture is the adversary of these systems. It causes urethanes to foam and hot-applied systems to froth. Dust can cause pinholing or entrained air bubbles in the coating film (*Figure 7*). Unsuitable curing agents such as waterglass can inhibit adhesion.

Hot-applied liquid systems are often reinforced with polyester or woven glass (*Figure 8*). This process requires two applications in order to prevent coincident pinholing and thin spots in the membrane.

Cold-applied liquid membranes are applied over concrete substrates by spray, squeegee, roller, brush, trowel, or other





Figures 8A and 8B – Hot-applied membrane application.

Figure 9 – Squeegee application of cold-applied liquid membrane.

method acceptable to the membrane manufacturer (*Figure 9*). Manufacturers claim that these products are sufficiently elastic to bridge cracks that occur in the concrete after the coating is in place. Reflected cracking is reduced by increased thickness.

The reinforced liquid polyester systems require exposure to ultraviolet light to cure. PMMA cures from contact with moisture in the air.

ASTM International Standard C-836, which was first published in 1976, is a non-generic performance specification that describes the required properties and test methods for cold-applied, elastomeric-type waterproofing membranes for both one- and two-component systems.

PROTECTION BOARD

Waterproofing membranes all require protection during construction as well as from ultraviolet radiation. This protection should be applied as soon as possible after the membrane is installed and flood testing is concluded.

The industry's most common material is an asphalt-core, laminated panel with polyethylene film on one side that prevents sticking. The panel or board is produced in 1.5-mm (1/16-inch), 3.1-mm (1/8-inch), or 6-mm (1/4-inch) thicknesses. One manufacturer produces a 2-mm (.085-inch), synthetic, fiber-reinforced, rubberized, asphalt-protection sheet in roll form for use with its waterproofing system.

Protection of the horizontal waterproofing membrane is mandatory after the membrane is installed and water testing is completed. The sequencing of these steps – membrane application, flood testing, and protection-board installation – must continue without interruption. If the protection-board installation is delayed, damage to the waterproofing membrane can occur from some of the following construction activities (*Figure 10*):

- Pipe scaffolding without proper protection
- Stockpiled masonry
- Reinforcing bars
- Welding rods
- Fasteners
- Loose aggregate

Any of the above items are hazards to the membrane's service life. A membrane is worthless after it is damaged or destroyed by careless construction operations. That is why it is important to have a qualified per-

Figure 10 – Construction activities over protection board.

son inspect the membrane and to ensure that the protection board is installed after the flood testing is completed. If the membrane fails the flood test, the protection application must be held until the membrane is repaired and re-tested.

DRAINAGE DESIGN

When a membrane waterproofing system is applied directly to the structural deck and then covered with a wearing surface or overburden, it is assumed that water will reach the membrane. If this were not the case, there would be no need for the membrane.

According to ASTM C-981, drainage of the waterproofed deck system should include all components, from the wearing surface down to the membrane. The structural deck and the supporting columns and walls should be properly designed to provide positive slope. Inadequate slope-to-drain is a common deficiency in plaza design.

Drainage at the membrane level is required for the following reasons:

- To avoid building up hydrostatic pressure due to collected water against the membrane
- To avoid freeze-thaw cycling of trapped water that could heave and disrupt the wearing surface
- To minimize the harmful effect that standing, undrained water may have on the wearing surface material and membrane
- To minimize thermal inefficiency of wet insulation or water below the insulation

A 2 percent (6-mm - 1/4-in per ft) slope is recommended for positive drainage. The substrate should slope away from expansion joints and walls. Gravel or plastic drainage panels (*Figure 11*) and grooved or ribbed insulation boards can provide the necessary medium to facilitate water flow to drains.

Waterproofed decks should incorporate multilevel drains capable of draining all layers (*Figure 12*). These drains must permit differential movement between the strainer located at the wearing level and the drain body that is cast into the structural concrete slab to prevent shearing.

The drainage of a waterproofing system at the wearing surface level can be accomplished through an open-jointed or closed-jointed system. The open-jointed system allows rainwater to quickly filter down to the membrane level and subsurface drainage system. A closed-jointed system is designed to remove most of the rainwater rapidly by sloping surface drains and allowing a minor portion to gradually infiltrate down to the membrane level.

Open-jointed systems include pavers on pedestals or pavers placed directly on ribbed polystyrene insulation boards (*Figure 13*). Joints should be less than 6 mm (1/4-in) wide to minimize catching high-heels and cigarettes. Advantages are:

- Elimination of the cost and maintenance of sealant joints
- Ease of adaptability to a dead-level wearing surface
- Faster and more efficient drainage
- Easier access for cleaning and repairs to subsurface components

The disadvantages are:

- Rocking of improperly set pavers due to pedestrian traffic
- Unpleasant reverberations from heel impact
- Possible hazards for pedestrians wearing high-heeled shoes

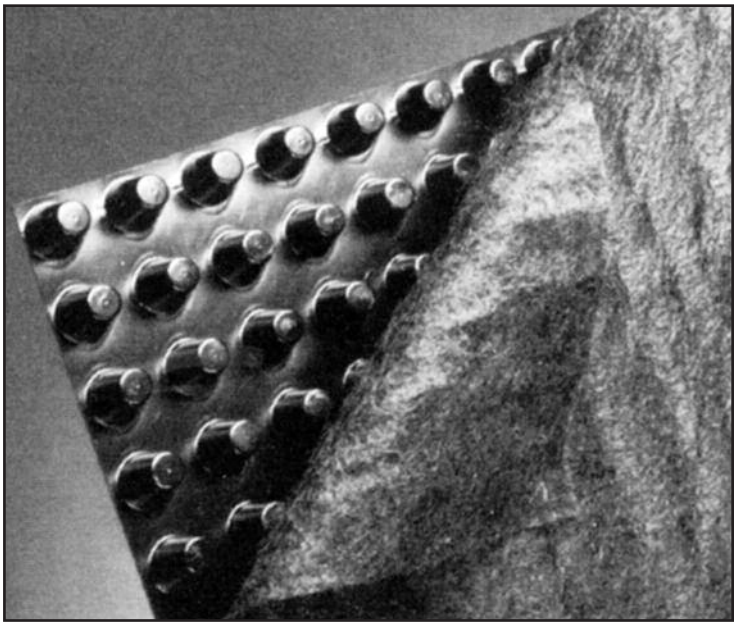


Figure 11 – Plastic drainage panel.

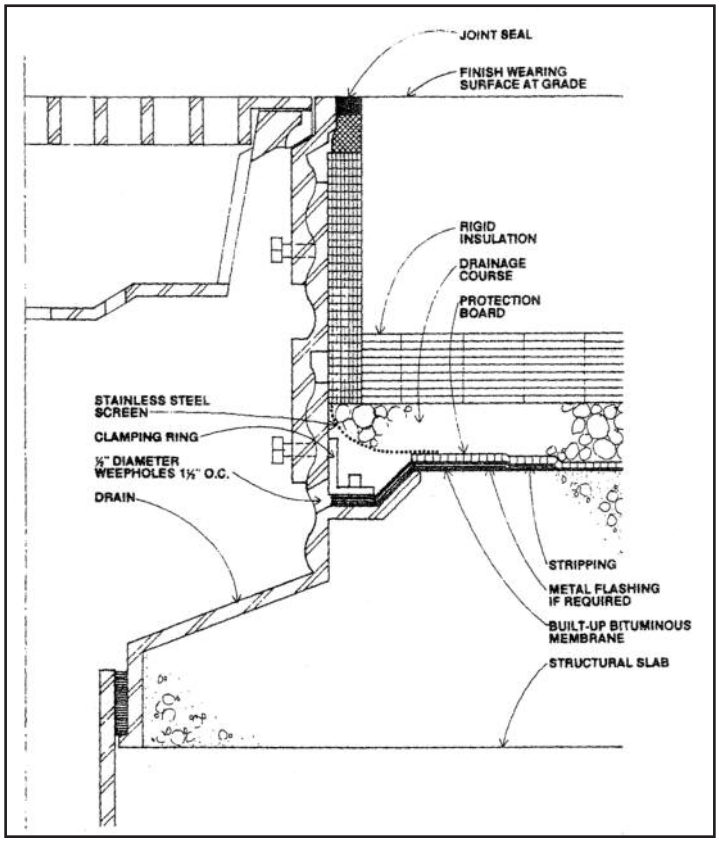
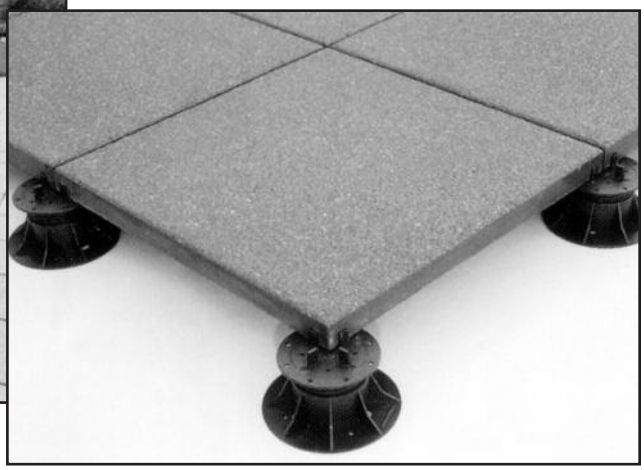


Figure 12 – Two-stage plaza drain. (Courtesy of ASTM International.)

Figure 13 – Open-jointed pavers on pedestals.



Closed-joint systems consist of either a mortar-setting bed or caulked joints. This type of construction changes the waterproofing membrane to a secondary line of waterproofing defense, since the majority of rainwater is drained from the wearing surface level (*Figure 14*). The closed-joint system should slope away from adjoining walls and expansion joints to direct water away above and below the wearing surface level. The advantages of a closed-jointed system include:

- Protection of the membrane from deicing chemicals, dirt, and debris
- Its flexibility to a greater variety of paver types, designs, and sizes
- The feeling of solidity under pedestrian traffic

The main disadvantages are:

- Its slow drainage rate
- Its imposition of a hydrostatic head of pressure on the membrane.

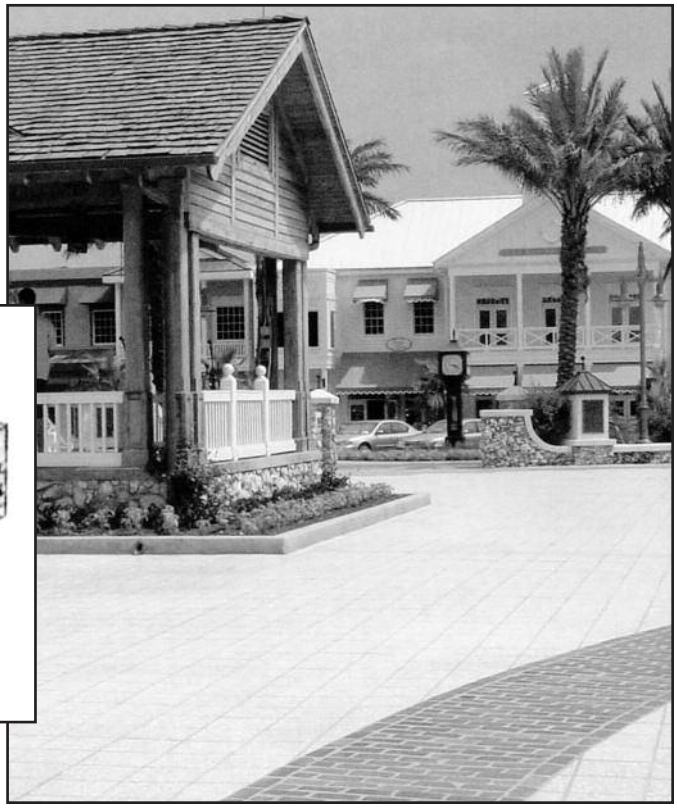
A third system that is better than a closed-jointed system, but not as good as an open-jointed system, is one that provides for brick or stone pavers in a sand-setting bed.

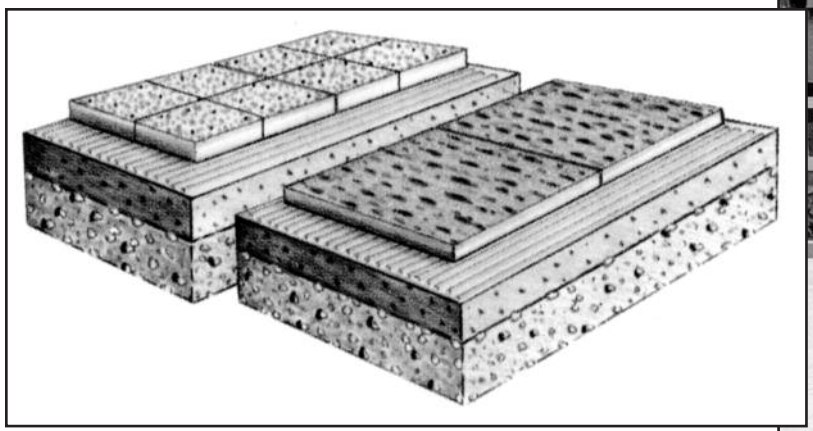
INSULATION

The selection of insulation and its location in the system is influenced by:

- Deck design
- The environment under which it may be functioning
- Its physical and chemical properties
- The characteristics of the wearing surface
- The loads to be supported

Insulation placed over the waterproofing membrane, protection, and drainage layer results in maximum system benefit. When insulation is placed in this location, the deck and membrane are insulated against





Figures 14A and 14B – Closed-joint pavers over mortar-setting bed.

extreme temperature cycles and the membrane can then function as a vapor retarder. The location of the insulation above the membrane also provides additional protection to the membrane.

The choice of insulation type is limited to extruded polystyrene (XPS) (ASTM International C-578 Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation). It must be able to accommodate the plaza's dead and live loads and be dimensionally stable and compatible with the waterproofing membrane. It must also be as nonabsorbent as possible and resistant to freeze/thaw deterioration

FLASHING AND EXPANSION JOINTS

Waterproofed deck systems, like roof systems, require flashings where the membrane terminates at walls, penetrations, and expansion joints. However, unlike roof systems where the flashing installation follows the membrane installation, flashing waterproofed deck terminations or penetrations must be installed first, prior to the membrane application.

Flashing Installation

Reinforce all intersections that occur at walls, corners, or any other location that may be subjected to unusual stress with one additional ply of membrane.

Extend flashing membranes above the wearing surface a minimum of 100 mm (8 in). This height is critical if the plaza design incorporates a wearing surface with closed joints. When the flashing extends above the wearing surface, it must be covered or protected against exposure to ultraviolet sunlight with sheet metal or vertical wall finishes such as stone or stucco. Some liquid-applied membranes (LAM) are self flashing.

When 100-mm (8-in) flashing heights are impractical–particularly at access doors that open onto the plaza at the same elevation for ADA accessibility–gutters with gratings are recommended (*Figure 15*).

Expansion Joints

Flashing at expansion joints located in the field of the plaza or at rising walls should be installed on a curb that is raised at minimum 37 mm (1-1/2 in) above the structural deck (*Figure 16*). This allows water to be directed away from the joint. This method is far superior in safeguarding against leakage.

A less costly method is to flash the joint at the membrane level. This method entails greater risk than the water shed concept, since it relies on positive sealing of materials at the membrane level, where the membrane is most vulnerable to water penetration. The materials used and their joining must be carefully considered and designed. The installation requires the highest degree of workmanship for success without any margin for error and is not advisable.

Figure 15 – Gutter drain at access door with ADA grating.

For moisture-sensitive occupancies, consider using a drainage gutter under the joint.

CONCRETE PROTECTION SLAB

A reinforced concrete protection slab that is a minimum of 75 mm (3 in) thick is an optional component in waterproofing systems for both plazas and earth-covered slabs. When a paved area is used for vehicular traffic, a concrete protection slab is mandatory to prevent damage and failure of the waterproofing membrane from braking loads, turning stresses, etc. Moreover, in a plaza system, a concrete protection slab will protect the membrane during subsequent construction activities. In earth-covered systems, it serves to protect the membrane from root damage that may penetrate the drainage course and protection board.

The inclusion or exclusion of a concrete protection slab is a major design decision in plaza waterproofing systems and balances accessibility against reliability. Gaining accessibility to the membrane by specifying removable components above the membrane is an enormous advantage. It can facilitate repairs and membrane replacement.

Accessibility to the membrane can sac-

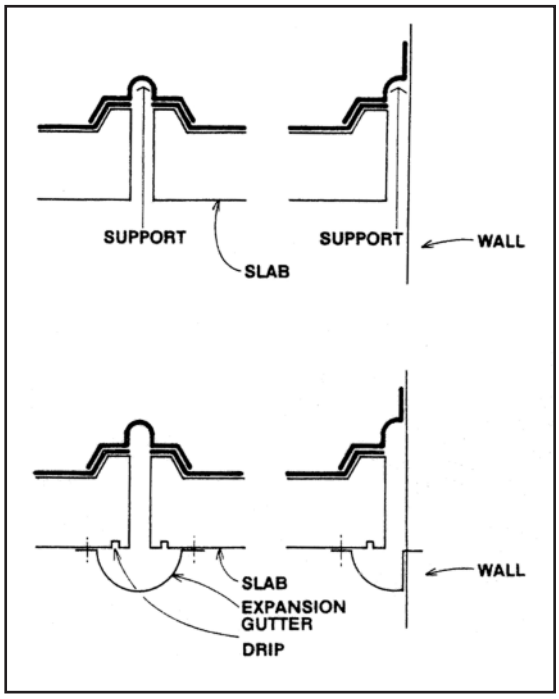


Figure 16 – Schematic section through expansion joints. (Courtesy of ASTM International.)

rifice reliability. Protection boards and drainage composite boards can provide resistance to root intrusion for earth-covered slabs. However, they can neither provide the level of resistance to root intrusion that a concrete protection slab can nor the protection from landscaping equipment. The decision to incorporate a concrete protection slab must be based on cost, which includes the initial cost of the slab and the potential cost associated with its removal to access the waterproofing membrane.

WEARING COURSE

As stated previously, wearing surfaces are generally divided into open-joint systems that are drained at the membrane level and closed-joint systems that are drained at the surface.

Waterproofing membranes in an open-joint system are infrequently subjected to hydrostatic pressure exceeding 5 psf (25 mm [1 in] depth of water). Closed-joint systems shed water at the surface and similarly protect the membrane from hydrostatic pressure.

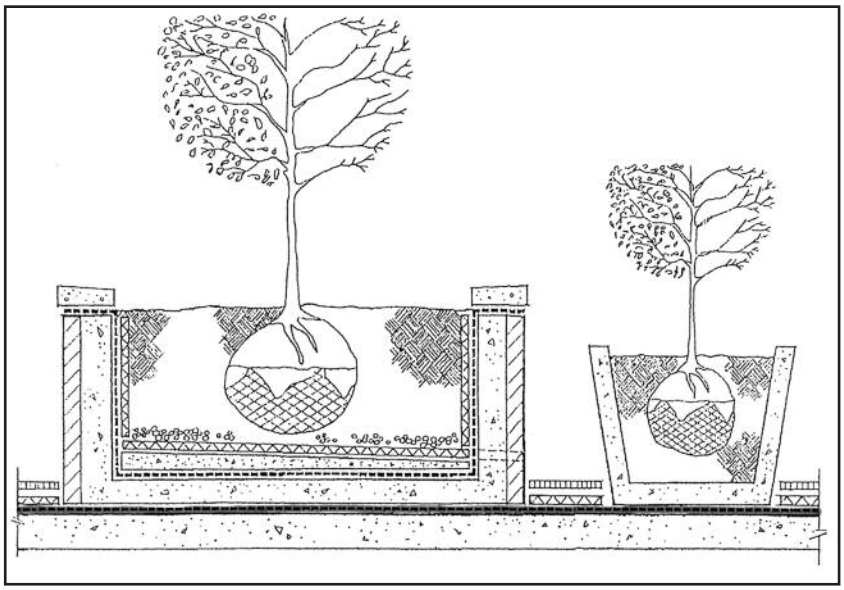


Figure 17 – Planter containers.

Any waterproofed plaza wearing surface must satisfy and meet the following criteria:

- Structurally sound to bear the intended traffic
- Durable under heavy wear and weathering
- Resistant to abrasion
- Aesthetically pleasing
- Heat reflecting

The first two items are mandatory, and the last two are optional.

EARTH-COVERED SLABS

Although beyond the scope of this paper, earth-covered slabs can be planted with groundcover, shrubs, and trees. Typically referred to as a green roof system, it is an extension of the existing roof that involves a high-quality waterproofing and root barrier system, a drainage system, filter cloth, a growing medium, and plants.

Green roof systems may be modular, with drainage layers, filter cloth, growing media, and plants already prepared in movable, interlocking grids; or each component of the system may be installed separately. A green roof involves the creation of "contained" green space on top of a man-made structure.

In today's environment, building owners and architects are embracing green roof technology. The two distinct types of green roofs are intensive and extensive.

Extensive green roofs are much lighter in weight, with engineered soil depths ranging from 75 mm (3 in) to 175 mm (7 in). Due to the shallow soils and the extreme environment on many roofs, plants are typically low-growing groundcover that are extremely sun and drought tolerant.

Extensive green roofs can be installed over existing roof decks, provided a structural engineer first inspects the structure to ascertain its load capacity. Although the focus of most extensive green roofs are their environmental benefits, extensive green roofs still require periodic maintenance and must be designed to resist wind uplift.

Intensive green roofs are characterized by thick soil depths (200 mm [8 in] - 1.2 m [4 ft]), heavy weights, and elaborate plantings that include shrubs and trees. Intensive green roofs are installed primarily over concrete roof decks to withstand the weight requirements. These park-like green roofs can be at or above grade and require considerable maintenance to sustain their aesthetic appearance.

PLAZA FURNITURE

If a plaza design includes planters, reflecting pools, foundations, benches, and other plaza "furniture," they should be installed over the waterproofing membrane. These items should be waterproofed individually and not part of the main waterproofing membrane. Trees should be planted in concrete containers (*Figure 17*) to avoid damage to the waterproofing membrane from root penetration or landscape shovels.

FLOOD TESTING

A failed waterproofing system is more destructive and expensive to correct than a failed roof. The replacement cost of a failed roof can be anywhere from $15 to $22 psf; a failed waterproofed plaza, between $75 and $125 psf, at a minimum.

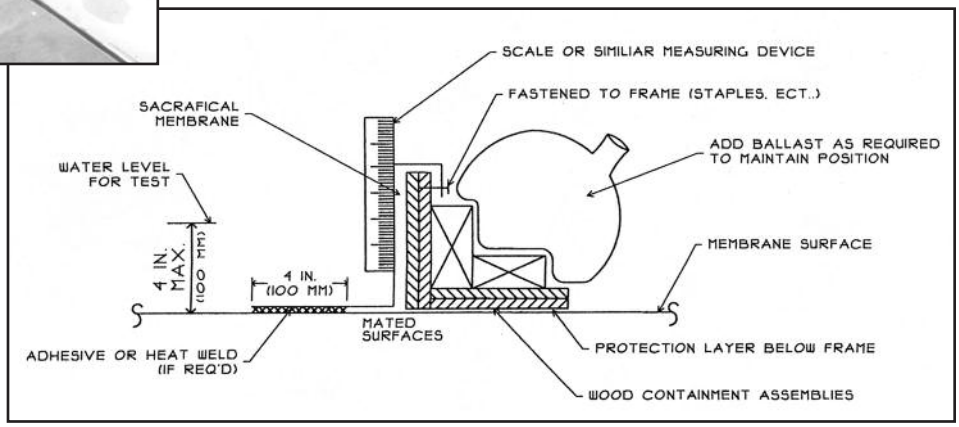
It is therefore advisable to flood-test a waterproofed deck after the flashing and membrane have been installed. ASTM D-5957, Flood Testing Horizontal Waterproofing Installations, first published in 1996, provides the necessary method for testing the watertightness of a waterproofed deck (*Figure 18*). Some limitations of this standard are:

- Slope-of-deck or membrane to be tested must not exceed 2 percent (6.25 mm [1/4 inch]) per foot.
- Membranes can be LAMs, adhered or loose-laid sheets, or built-up and modified.
- Do not test until 24 hours after the membrane has been installed. (This requirement increases to 48 hours if the membrane was installed at ambient temperatures below 50˚ F.)
- Inspect and repair flashing and membrane prior to testing.

If a leak occurs during the test process, the following provisions are to be followed:

- Drain water.
- Locate and repair leak.
- Retest area under the same initial conditions.

Electric field vector mapping (EFVM™) is a new tool for improving quality control of waterproofing systems. Although relatively new to the United States, it has achieved a



Figures 18A and 18B – Flood testing. (Sketch courtesy of ASTM International.)

long record of success in Europe. The system was pioneered in Germany. EFVM, unlike other leak-detection methods, can quickly and accurately locate the point of water entry.

EFVM uses water as an electrically conductive medium. A wire loop is installed around the perimeter of the area to be tested and introduces an electrical potential. The area within the loop is dampened and forms the upper electrical plate. The structural deck then becomes the lower plate. The membrane acts as separator and insulator between the two plates. If moisture enters a defect in the membrane, an electrical contact is established. The survey technician can then follow the direction of the electric field to the membrane defect. Advocates of EFVM state that the test method:

- Locates defects precisely, enabling efficient repairs
- Is able to re-test repairs immediately
- Can be used after cover systems are installed, especially with green roof landscapes
- Is less expensive than conventional flood testing
- Eliminates the hazard of overloading structural decks during testing
- Can be used on steeply sloped roof surfaces where flood testing is impossible

The suitability of EFVM depends on the electrical resistance of the waterproofing materials, and all membranes may not be compatible with this test method. Systems that employ a root barrier require special procedures, since the root barrier will act as an insulating layer. When root barriers are used, it is necessary to make small slits in the barrier to permit the establishment of electrical contact with the underlying waterproofing membrane. These cuts can be resealed after the leak is located.

SUMMARY

A plaza design over occupied spaces must create a system that waterproofs and insulates the structural building deck while supporting pedestrian and/or vehicle traffic, as well as landscaping elements.

The building deck must be reasonably smooth, be sound, and provide adequate slope to promote drainage. The waterproofing membrane selected and installed must be capable of withstanding long-term exposure to ponding water. Flashings at drains, penetrations, expansion joints, and other similar membrane terminations should be carefully detailed, since most leakage problems occur at these locations.

Insulation should be placed above the membrane to minimize temperature cycles of the membrane and deck and provide additional protection for the membrane. The insulation must have high compressive strength, low water absorption, and be resistant to freeze/thaw.

Drainage at the membrane level is an essential component of the system. Drainage at both the membrane level and below the wearing surface is particularly important to ensure water flow to drains and minimize freeze/thaw heaving or deterioration of the wearing surface.

The wearing surface should be aesthetically pleasing, durable, and able to accommodate loads associated with the plaza function. The wearing surface should consist of discrete components to facilitate removal and reinstallation and to allow for maintenance.

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Sarnafil
Plaza Deck Systems

▲ JFK Library and Museum, Boston, MA

Waterproofing. Protect your investment.

You are an architect, a designer or a building owner, and you have a building to protect. If this building is like most, it has critical areas inside the building that must be protected from the damaging effects of water, moisture or other contaminants. If these areas are covered with overburden such as earth, landscaping and pavers, it can be a challenge to remove the overburden and determine the cause should a leak occur. As a result, one of the most important decisions you have to make is the waterproofing system.

◀ **On the cover:**
H.H. Dow Academy
Midland, MI

Without proper waterproofing it is a question of when, not if, water infiltrates the structure. Structures move and settle with time. Structural movements or deficiencies cause cracks and openings in the structure. The cracks and openings create a pathway for water and moisture to enter the building. Water infiltration not only affects the usage and value of a building, but also has the potential to propagate mold and fungus growth. A building owner can be faced with future repairs and mitigation actions that could cost thousands. Because of this, it is important to not only waterproof your building, but to choose a waterproofing manufacturer whose performance history speaks for itself.

Sika Sarnafil. Waterproofing integrity.
Sika Sarnafil has earned the reputation as the most trusted name in waterproofing. Architects, specifiers and building owners choose Sika Sarnafil waterproofing systems for applications that demand absolute system integrity and watertight security. For over 40 years our waterproofing systems have provided protection against water infiltration on many of the world's most valuable building and civil engineering structures. With over 15 billion square feet of roofing and waterproofing membrane installed worldwide, you can depend on Sika Sarnafil for proven products and system performance.

Sika Sarnafil manufactures a variety of thermoplastic waterproofing membranes designed to provide long-term durability and watertightness for varying building and civil engineering applications and conditions. Our Sarnafil G476 membrane is the key component to the success of our waterproofing systems.

Sika Sarnafil has been using the same basic formulation in its manufacturing process for over 40 years. This durable thermoplastic membrane is designed to remain watertight in the extreme conditions of buried environments including constant dampness, ponding water, high and low alkaline conditions, exposure to plant roots, fungi and bacterial organisms.

Sarnafil G476 membrane is available in a range of thicknesses to match the application, overburden type and your specific project requirements. Highly puncture resistant, its bright orange surface color makes it easy to identify and inspect to maintain high levels of quality assurance and control during construction.

Sarnafil Milestone Management
The Sarnafil Milestone Management™ process is the key to a successful installation. From specification assistance to installation, our "hands on approach" is designed to make any project an easier task for you. Here's how we help make the process go smoothly:

Proven Materials
A high quality membrane is the key to any successful roofing or waterproofing project that demands absolute system integrity. With that in mind, Sika Sarnafil's manufacturing process uses only the highest quality materials to produce a monolithic, non-laminated membrane that offers excellent weatherablility and dimensional stability.

Expert Assistance
Our skilled technical experts make Sika Sarnafil stand apart from other manufacturers. We're involved at each major milestone – offering design assistance to architects and specifiers if needed, reviewing Notice of Award documentation, and training authorized applicators in the classroom and at the job site.

Skillful Workmanship
Unlike most other roofing and waterproofing manufacturers, Sika Sarnafil does not sell through distributors. Instead, we sell directly to a select group of trained, authorized applicators – only the best are invited to join our team. Maintaining strict control over the installation process means that Sika Sarnafil quality is carried through from start to finish.

Plaza Deck Waterproofing

Plaza decks are located at or above grade level. They are public areas accessible to pedestrians and in some cases vehicles. They may cover valuable commercial or office space, storage or mechanical areas, or parking.

Plaza decks are waterproofed to protect the structure, their occupants and the property beneath them from water and moisture penetration.

Plaza decks require special attention since they may hold water for a period of time after precipitation, and the waterproofing system is buried under the overburden making repairs challenging and costly.

Choosing the right waterproofing system is one of the most important decisions you will make on your project.

The right waterproofing system should:

- *Provide Factory Controlled Membrane Thickness* – Sheet waterproofing membranes are manufactured in a controlled environment, eliminating thickness variations found in field-applied systems. Thin spots can lead to a premature failure in the waterproofing system.
- *Accommodate Building Movement* – Waterproofing systems need to be flexible enough to withstand structural and thermal movement, and versatile enough to provide design options for each application.
- *Perform in Ponded Water Conditions* – Decks will hold water. The waterproofing membrane must withstand ponded water and constant damp conditions.

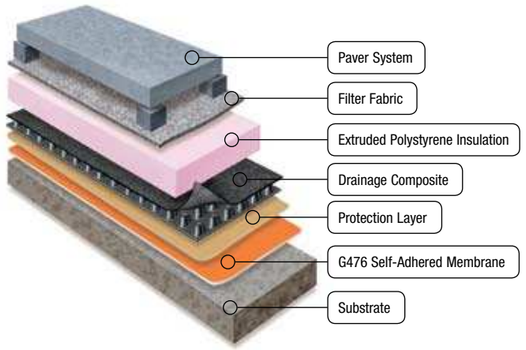
▲ Chase Tower Plaza, Dallas, TX

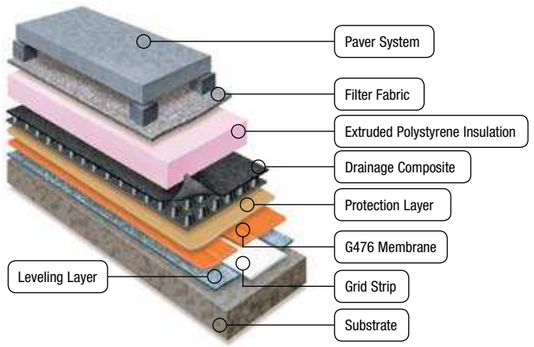
- *Resistant to Roots and Decay* – Roots are very aggressive and can penetrate some types of waterproofing materials. The waterproofing system must be resistant to roots and should not deteriorate in damp environments.
- *Puncture Resistance* – Waterproofing membranes must be tough and highly puncture resistant to withstand potential damage during and after installation. Protection layers will provide protection, but there will be times during the construction process when the waterproofing membrane will not be covered.
- *Secure Seams* – Sheet membranes are seamed together in the field to form a continuous waterproofing barrier. The seams must be the strongest part of the system, not the weakest.
- *Proven Performance History* – Make sure the company behind the waterproofing system has a history of proven performance on projects similar to yours.

Sika Sarnafil waterproofing systems meet and exceed these requirements. Sarnafil G476 membrane provides long-term durability and high puncture resistance. This durable thermoplastic membrane is compounded to remain watertight in extreme conditions including constant dampness, ponded water, high and low alkaline conditions, exposure to plant roots, fungi and bacterial organisms. It also is extremely flexible and able to conform to even the most difficult of details. Sarnafil membrane seams are hot-air welded, a key factor to the success of our waterproofing systems.

Sika®

Sarnafil®





Adhered System

When your building demands absolute system integrity with maximum watertight security, Sika Sarnafil's adhered system is for you. The system consists of the robust G476 Self-Adhered (SA) membrane, a composite sheet comprised of the heat-weldable G476 waterproofing membrane with a closed-cell foam backing. The foam backing is factory-coated with a pressure sensitive adhesive and is protected by a plastic release liner which is removed during installation.

Sarnafil G476 SA combines the time-tested, proven performance of Sarnafil G476 waterproofing membrane with the added security of an adhered sheet system. G476 SA provides 'peace of mind' for specifiers and owners who value the benefits of an adhered system and thermoplastic technology.

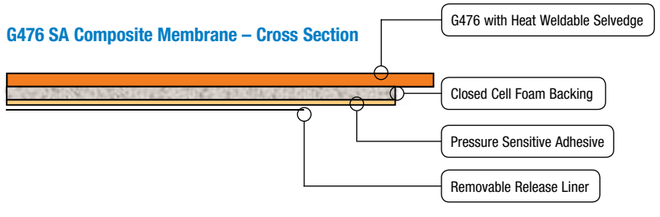
The flexible foam backing layer conforms to minor irregularities in the substrate and provides a cushion for the G476 waterproofing membrane. The pressure sensitive adhesive provides a tenacious bond to the substrate mitigating potential water migration under the membrane. The integration of G476 membrane with a foam backing layer and pressure sensitive adhesive eliminates the need for a field installed separation layer and adhesives. This 'all-in-one' product increases applicator productivity and helps keep the project on schedule. Sarnafil G476 SA also doesn't require hot asphalt kettles or flammable adhesives. This improves worker and job site safety.

Sarnafil G476 SA is best suited for new construction. It can also be used on certain renovation projects where the old waterproofing system can be removed completely, or where a new concrete topping slab is placed over the structural deck.

Advantages:

- Robust, factory-manufactured composite sheet
- Mitigates water migration under the sheet
- Reduces the risk of expensive removal and replacement of overburden
- Heat-weldable laps

G476 SA Composite Membrane – Cross Section



Grid System

For renovation projects where the substrate is contaminated or removal of the existing waterproofing is not practical, Sika Sarnafil offers the grid system. The grid system combines all of the advantages of a loose-laid membrane installation with the added security of adhered membrane grid strips. The grid strips compartmentalize the waterproofing system into smaller areas effectively limiting the scope of overburden removal if a problem develops.

Advantages:

- The adhered grid strips act as a sub-membrane waterstop to compartmentalize the waterproofed areas and limit overburden removal if a problem develops
- Optional control drains can be installed in each grid area as an active monitoring and alerting mechanism. The drain opening can be used as an injection port to facilitate repair without overburden removal
- The grid system can be installed economically over existing waterproofing with minimal deck preparation and removal of the existing waterproofing system

▲ St. Louis Children's Hospital, St. Louis, MO

More Sika Sarnafil Benefits

Partners Club

Sika Sarnafil sells directly to a limited group of authorized applicators assuring only trained, qualified contractors install our systems. Every applicator is trained on system installation and assisted as necessary during projects by our technical specialists. Only the best applicators are invited to join our team, your assurance of a quality installation.

Quality Assurance

Quality assurance is the key to a successful project. Sika Sarnafil offers on-site monitoring and inspection programs to building owners who want active involvement from the waterproofing system manufacturer. Sika Sarnafil has nearly 50 years experience in waterproofing applications and can assist the owner in achieving maximum performance.

Root Resistance

Many waterproofing membranes are not resistant to root penetration. They fail, often prematurely, due to root infiltration into the field seams and flashings.
Our Sarnafil membranes are inherently root and algae resistant and do not require additional root barriers. Sarnafil membranes have passed the most stringent European tests for root resistance including both the German FLL and the Swiss SIA 280 standards. The FLL standard test exposes the waterproofing membrane to 2 years of accelerated root growth.

Hot-Air Welded Seams and Flashings

Faulty seams and details are a common source of leaks in waterproofing systems. Some waterproofing membranes use sealants, adhesives or tapes to secure the seams, but because the Sarnafil membrane is thermoplastic, seams and flashings are welded together using Sika Sarnafil's automatic hot-air welder, the Sarnamatic. When welded together, the sheets of membrane become one monolithic layer of material impervious to water and moisture infiltration. In fact, hot-air welded seams are even stronger than the membrane itself and will last at least the duration of the system.

Warranty Options

Sika Sarnafil offers two types of warranties, consisting of 5, 10, 15 and 20 year durations:

- Waterproofing Membrane Only (Material)
- Waterproofing Labor and Material (Standard)

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Sika – Your Local Partner with a Global Presence

Sika is a globally active company in the specialty and construction chemicals business. It has subsidiary manufacturing, sales and technical support facilities in over 70 countries around the world.

Sika is THE global market and technology leader in waterproofing, sealing, bonding, dampening, strengthening and protection of buildings and civil engineering structures.

Sika has more than 10,000 employees worldwide and is therefore ideally positioned to support the success of its customers.

Quick Reference Guide

Sika Sarnafil Waterproofing Systems provide…	
Proven performance	• An industry veteran that has produced billions of sq. ft. of membrane since 1964
	• The same basic membrane formulation that has protected buildings for more than 40 years
	• Material that consistently ranks as the highest quality thermoplastic membrane in independent testing
Watertight integrity	• Permanent watertight flashings and details with hot-air welded seams
	• The Sarnafil G476 membrane is designed for buried environments such as constant dampness, ponding water, high and low alkaline conditions, exposure to plant roots, fungi and bacterial organisms
Milestone Management	• *Proven Materials* – Sika Sarnafil's manufacturing process uses only the highest quality materials to produce a monolithic membrane that offers excellent waterproofing and dimensional stability
	• *Expert Assistance* – We're involved at each major milestone, offering design assistance to architects and specifiers if needed
	• *Skillful Workmanship* – We sell directly to a select group of trained, authorized applicators—only the best are invited to join our team

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KEMPER SYSTEM

Plaza Waterproofing and Green Roofing Utilizing Liquid-applied Reinforced Polymeric Membranes

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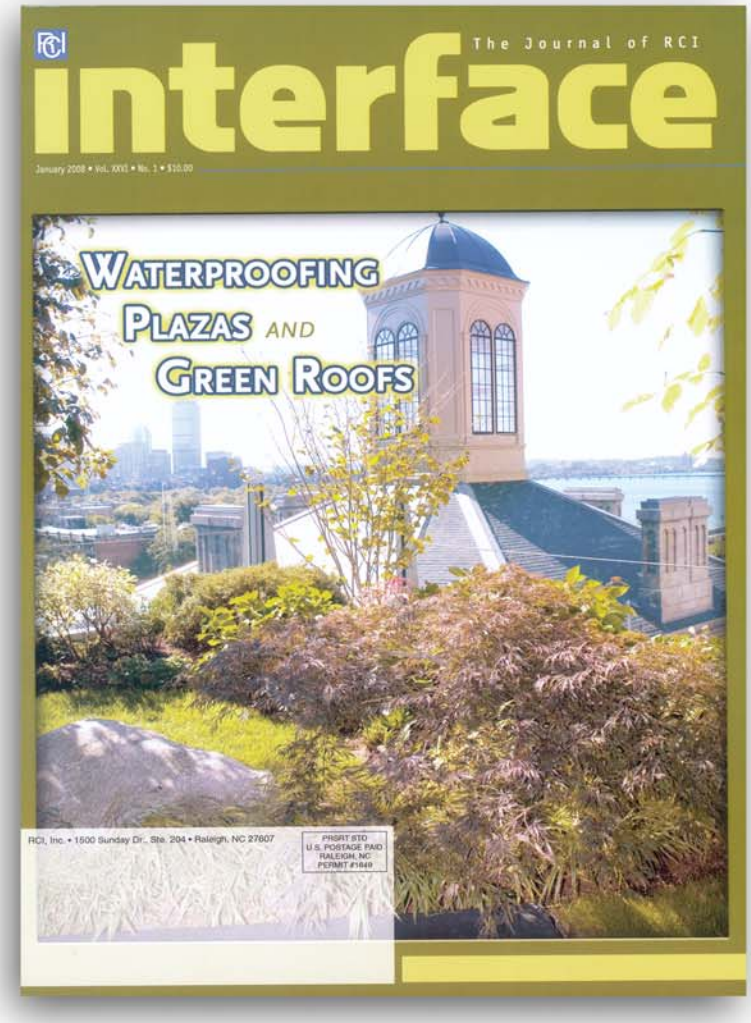


Plaza Waterproofing and Green Roofing Utilizing Liquid-Applied Reinforced Polymeric Membranes

By Paul Allenstein, PE

At first glance, plaza waterproofing and green roofing might not appear to have much in common. After all, most plazas are at grade level or, at most, a few stories above the ground, while green roofs (garden roofs, landscaped roofs, etc.) are way up on top of the building. Though these applications may appear opposite in concept, they end up achieving the same purpose.

Plaza waterproofing and green roofing both represent the need and desire to achieve multiple functions from the same space. Plazas create and allow the use of occupied space under an open public area. Green roofs create and allow the use of an open public area above an occupied space.

Relative elevations aside, plaza waterproofing and green roofing share many of the same challenges toward achieving a watertight condition, which is the fundamental requirement of both applications:

- The membrane will be inaccessible following application of overburden.
- The membrane will be subjected to moist and dark conditions, with the likelihood of standing water in some areas.
- The flashings will be subjected to long-term UV exposure.
- The membrane will be subjected to foot traffic and use as a staging area during overburden placement.
- The waterproofing/roofing membrane will be expected to accommodate elevation changes, dividing walls, planting wells, fountains and other water features, and various overburden materials.

The use of liquid-applied reinforced polymeric membrane systems allows designers and specifiers to satisfy these criteria.

Selecting the Membrane

Liquid-applied reinforced polymeric membrane is a 50-year-old technology that has only recently begun to enjoy more widespread recognition.

Briefly, liquid-applied reinforced polymeric membrane systems utilize a polymer-based resin (polyester, polyurethane, polymethylmethacrylate) to saturate a polyester or fiberglass reinforcing fabric. The advantages of this type of system are as follows:

- The reinforcing fabric is cut to fit tightly at perimeter conditions and around penetrations so that when the fabric is saturated with the resin, the flashings conform and bond directly to the walls, curbs, and penetrations. This eliminates the use of pitch pockets, preformed boots, termination bars, and other accessory products.
- Based upon laboratory testing, liquid-applied polymeric resins generally have an inherent resistance to deterioration from UV rays root penetration, and algae growth. This allows the use of the same resin and reinforcement at flashings as well as on the field membrane, providing a monolithic and continuous barrier to water penetration. This eliminates the need for the use of dissimilar flashing materials such as rubber sheets and metal accessories that can disbond from the primary waterproofing/roofing membrane. In addition, it eliminates the need for the use of a root barrier and UV barrier, typically required with asphalt-based membranes and representing an added expense to the installed system.

When the owners of Massachusetts General Hospital envisioned constructing a new landscaped green roof above their cancer wing in 2005, they had two chief concerns: safety and long-term durability. They chose a cold-liquid-applied waterproofing and roofing membrane by Kemper System, Inc. The landscaped roof design included four different gardens with extensive shrubbery, trees and grass designed to provide cancer patients with a haven for relaxation and meditation to aid in the healing process.

- Liquid-applied polymeric membrane systems are generally durable and resistant to scuffing, puncturing, and tearing. They do not soften significantly in hot weather and retain reasonable flexibility in cold weather. A simple aggregated surface utilizing kiln-dried sand broadcast into the wet resin will significantly improve resistance to damage related to foot traffic and staging operations. Of course, it is always a good idea to provide additional temporary protection in areas of heavy use.

Typical challenges of most applications where planters are involved are the numerous steel reinforcing bars that project upwards through the deck. Most systems don't have the ability to wrap those penetrations and treat each rebar as an individual flashing. The waterproofing and roofing membrane's ability to detail each individual rebar greatly reduces the possibility that water will seep through the planter walls and down to the existing plaza. This plaza is at 75 Henry Street, Brooklyn, NY.

- When properly installed, a polymeric membrane system provides a tightly bonded, custom-fitted membrane and flashing system that can seamlessly transition from through-wall flashing to base flashing to plaza deck membrane to parapet wall flashing to fountain lining to green roofing membrane to planter lining; all without mechanical transitions, system breaks, material changes, or other discontinuities.

For these reasons, a liquid-applied polymeric reinforced membrane system is often the system of choice for plaza deck waterproofing and green roofing applications.

Selecting the System

A design consideration related to the selection of membrane type is the design of a basic membrane system. This involves the following considerations:

- It is usually preferable to have the waterproofing/roofing membrane fully adhered, whether it is adhered directly to the structural deck substrate or to an underlying foam insulation/cement coverboard assembly. By nature, liquid-applied polymeric reinforced membrane systems are always fully adhered.

- There may be some system cost savings associated with the use of grid-adhered, mechanically attached, and loose-applied membranes, because adhesives can be expensive and less labor is required if adhesives and mechanical fasteners can be eliminated entirely. However, should there be a water penetration event, with mechanically attached and loose-applied systems, there is the certainty of uncontrolled lateral movement of water beneath the membrane. Grid-adhered systems are dependent on the integrity of their grid to provide some degree of water control. The cost savings compared to a fully adhered system is probably not sufficient to justify the increased risk and future expense associated with untraceable, buried leaks.

- It is usually preferable to have the waterproofing/roofing membrane placed directly over the structural deck, which is generally possible with concrete and wood decks. Again, this minimizes the potential for lateral movement of water beneath the membrane. If insulation is required in the system, extruded polystyrene insulation can be placed above the membrane in a manner similar in concept to a typical protected membrane assembly. Wherever possible, fully adhered membranes should be installed in plaza deck waterproofing and green roofing applications.

  If insulation must be installed beneath the waterproofing/roofing membrane (as is the case with steel decks), the use of a water- and rot-resistant foam insulation such as polyisocyanurate or extruded polystyrene is recommended. In addition, the installation of a water and rot-resistant, high-compressive-strength, cement-based cover board is recommended as well. In a 1/2-inch thickness, cement-based coverboards act almost like concrete decks, minimizing the potential for penetration through the membrane and into the heart of the insulated assembly, thereby limiting the potential for lateral movement of water beneath the membrane.

Selecting the Overburden Assembly

Plaza decks and green roofs both lend themselves to creative selection of overburden materials to create an environment that satisfies the overall design intent. This can range from an area for quiet, private reflection to something as completely different as an area for transient, public gatherings.

What follows is a short listing of commonly used overburden materials and some general comments on each.

Precast Concrete Pavers on Pedestals – This is the most common plaza-deck wearing course. Pavers are typically 24" x 24" x 2" thick. The use of a drainage mat, asphalt-protection board, or nonwoven polyester mat is often specified as protection between the pedestals and the waterproofing membrane. Sometimes pieces of extruded polystyrene insulation are substituted for pedestals as a cost-saving measure. This is not a good idea because the pieces of extruded polystyrene insulation tend to move around under the pavers and do not allow for accurate shimming and adjustment of paver heights.

Precast Concrete Pavers, Natural Stone Tiles, or Brick Paving Stones in a Sand Setting Bed – The use of a drainage mat is critical in order to have the sand-setting bed drain properly. Edge securement around the perimeter, at drain outlets, etc. is required to ensure that the paving units do not shift over time. The selection of the correct sand for the setting bed is important. Some specifiers prefer to mix a small quantity of asphalt into the sand. The use of bilevel plaza drains is required with this type of overburden, providing drainage at both the membrane level as well as at the overburden level.

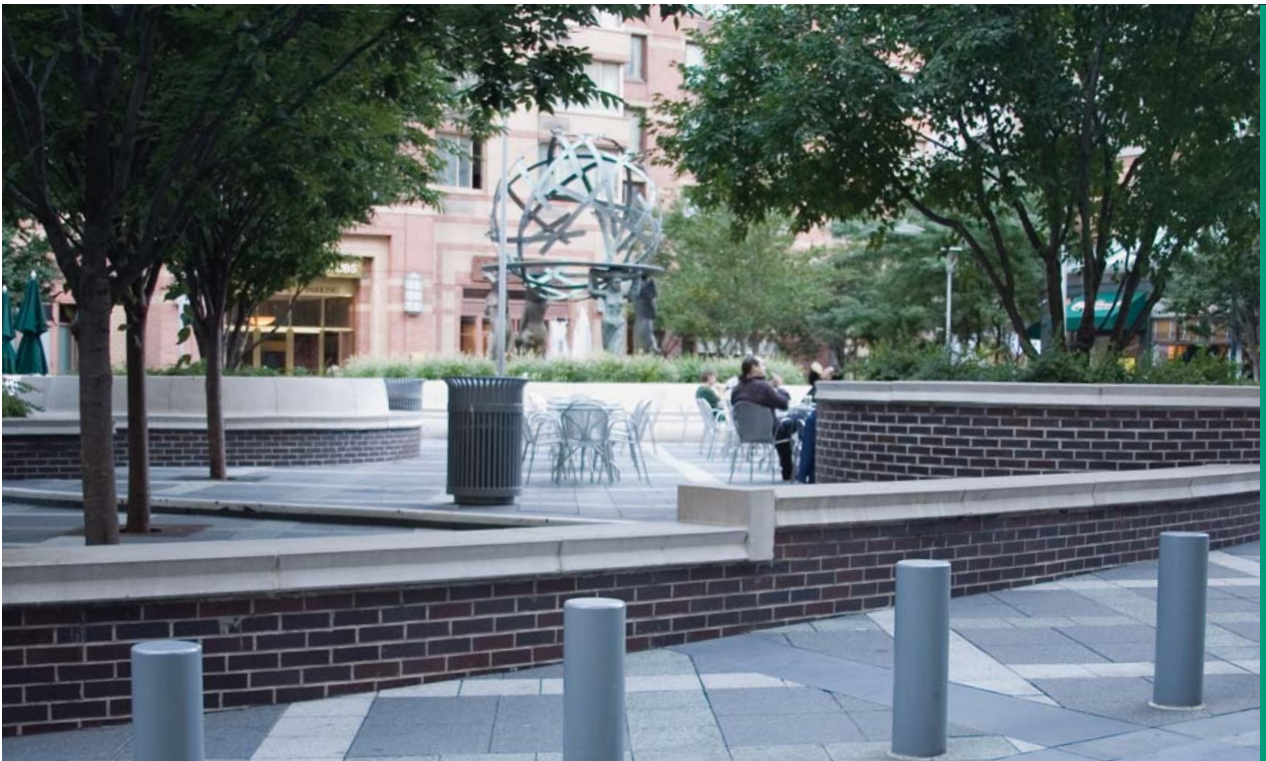
Quarry Tile or Natural Stone Tile in a Cementitious Setting Bed – The use of a drainage mat beneath the setting bed is preferred by many specifiers as a means of ensuring proper drainage of the setting bed, reducing the potential for freeze-thaw damage, and possibly limiting efflorescence in the grout joints. Typically, a 2" thick cementitious setting base bed is installed first, with the quarry or stone tile situated into a thin-set cementitious tile adhesive. The selection of a polymer-modified setting bed, tile adhesive, and grout intended for exterior application is important to achieve satisfactory performance. Interior-grade materials should not be used. The use of bilevel plaza drains is required with this type of overburden, providing drainage at both the membrane level as well as at the overburden level.

Wood Decking on Pedestals or Sleepers – Wood decking is often installed in residential applications. The use of a drainage mat is usually specified as a protection layer between wood sleepers and the waterproofing membrane because it facilitates drainage beneath the sleepers. Wood decking is sometimes constructed in sections to allow removal and reinstallation to provide access to the water-proofing membrane. Of interest is the recent introduction of wood deck tiles intended to be supported on pedestals commonly used to support concrete pavers. The selection of wood type is important; the current trend towards environmentally sensitive use of natural resources favors the use of naturally rot-resistant wood such as teak and ipâ that are part of a controlled harvesting program. Wood decking will require maintenance.

Sedum-Based Extensive Green Roofing – Many traditional green roof systems use hardy, low-lying sedum plants set in 2"–3" of a special growing medium. The sedum plants may not be particularly attractive compared to flower beds, shrubs, and turf, but the sedum plants require little maintenance and provide all of the environmentally important attributes of green roofing such as drainage retention, improved localized air quality, and protection of the waterproofing membrane.

A drainage and water-retention mat is usually installed between the growing medium and the waterproofing membrane. The special growing medium consists of mineral aggregates with a small amount of organic material. The idea is that the organic material fosters initial plant growth and establishment, while the mineral aggregate fosters development of a root mat that knits the planting layer together. The installation of concrete pavers in the corner and perimeter areas of the roof may be necessary to resist wind scour.

Intensive Green Roofing and Planting Beds – Most people expect green roofs to be garden-like, with flowers, perennials, shrubs, grasses, etc. The growing medium becomes thicker and more organic as larger plants are incorporated into the green landscape. This type of green



An 80,000-sq-ft open plaza area in New York City with difficult vertical flashing details required a seamless membrane, with many parts being covered with soil. The track record and ability of the waterproofing and roofing membrane to protect high-end businesses located below the plaza area were key factors in the product's selection.

roofing requires regular landscaping maintenance, supplemental irrigation systems, and periodic fertilizing, but it also allows for great design flexibility.

This type of green roofing is often combined with hardscape materials such as concrete pavers and with water features such as ponds and fountains. The most straightforward method of addressing the waterproofing requirements of such a varied design is often to install the waterproofing membrane throughout the roof area, followed by a drainage and water retention mat, and then the landscaping materials over this common base assembly.

Providing Positive Slope to Drain

Both plaza deck and green roof applications involve the use of overburden materials that can eliminate the appearance of ponding water. If a waterproofing/roofing system is used that is resistant to biodeterioration and is fully adhered directly to the structural substrate, the need for positive slope to drain may not be apparent. However, positive slope to drain is an important consideration that should not be ignored for the following reasons:

- Ponding water represents significant dead weight that must be taken into account when evaluating the structural adequacy of a deck to support all of the overburden materials, saturated soils, vehicular and pedestrian traffic, etc. The weight issue is always a structural concern.

- Ponding water represents a fertile breeding ground for mosquitoes. Positive slope to drain can limit the amount of standing water trapped beneath pedestal-supported concrete pavers. This is becoming more and more of an issue now that mosquito-borne diseases are experiencing a resurgence.

- When it comes to plants, providing the correct amount of water is critical to long life. Too much water will cause root rot to develop, while too little water will dry the roots out. Poorly draining soil can lead to underwatering just as readily as overwatering. Either way, the plants die. Therefore, achieving properly draining soil is the key to balancing moisture within the growing medium. Providing positive slope to drain allows excess water to make its way out of the assembly.

Approach Green Roofing with Caution

Plaza deck waterproofing is a relatively well-understood application when compared to green roofing. A green roof is a living environment, and in order for a green roof to be considered a success, it must be sustainable for 20 years or longer. It only seems like an easy proposition to roll out a drainage mat, spread some dirt, and install some plants, a walkway, and a koi pond. But that is only the beginning.

A green roof is much easier to maintain if it is properly designed. Achieving the correct balance among drainage, irrigation, growing medium composition, water retention, and plant types is an endeavor that requires careful consideration. The correct balance is going to be different, based upon geographic location as well. That is why the design services of a qualified landscape designer may be a smart investment in order to ensure the success of a green roof project.

This large penthouse terrace was designed as an outdoor environment to complement a multi-million dollar apartment high atop the New York City skyline, with multiple levels requiring exceptional waterproofing, especially around the flashings.

Paul Allenstein, PE

Paul Allenstein is the technical director for Kemper System, Inc., a manufacturer of cold liquid-applied reinforced waterproofing and roofing membrane systems. He is a professional engineer registered in New York and New Jersey. Allenstein has over 25 years of experience in construction materials, working in a technical capacity for Hilti Fasteners, Dynamit Nobel, Alkor-Hedwin, and GAF Materials Corp. before joining Kemper six years ago. He also worked for 10 years as a consulting engineer, specializing in building inspection and building exterior envelope evaluation.

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KEMP-3019

PRMA, Vegetative and Plaza Deck
Insulated Roof Systems

Section Overview

PRMA, Vegetative and Plaza Deck Waterproofing

Protected roof membrane assemblies (PRMA) provide high value and long term durability on long life cycle buildings. PRMA roofs range in function from infrequently accessed stone ballasted systems, to paver/plaza deck walking surfaces, to fully landscaped vegetative roof gardens. PRMA extends the life of roofing components and reduces building maintenance costs by eliminating UV exposure and minimizing thermal cycling.

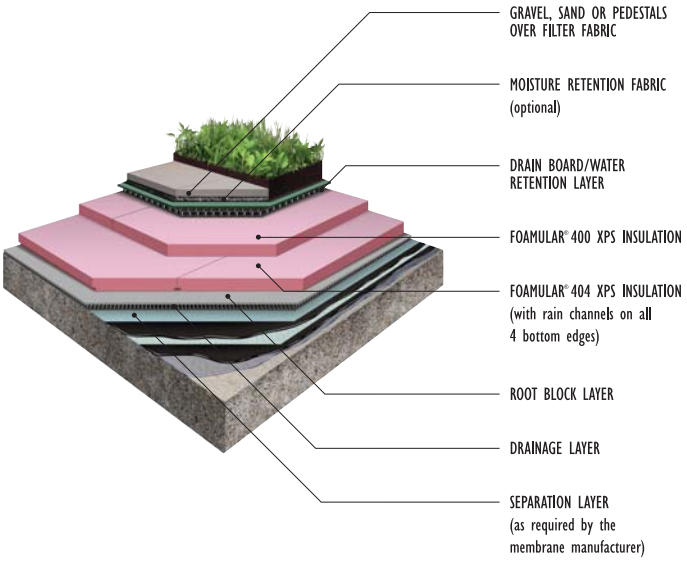
Vegetative roofs are gaining widespread acceptance due to the practical, financial, and environmental benefits they provide. In addition to creating more usable landscaped space in the form of rooftop terraces, walkways, plazas and gardens, a well insulated PRMA vegetative roof assembly improves energy efficiency and reduces heating and cooling costs. In some instances vegetative roofs receive financial funding incentives from government agencies responsible for reducing environmental impact. Vegetative roofs provide a number of important environmental benefits such as reduced storm water runoff and sewer fees, they help keep contaminants out of lakes and streams, they reduce the urban heat island effect, and they improve air quality by converting carbon dioxide to oxygen.

FOAMULAR® Extruded Polystyrene (XPS) Insulation for PRMA

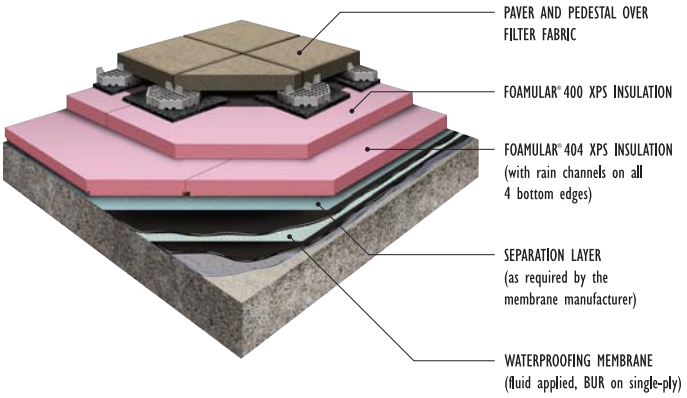
FOAMULAR® XPS insulation products 404, 604, 404RB and 604RB are used in PRMA applications. Extruded polystyrene is the only insulation used in PRMA roof systems due to its excellent resistance to water absorption compared to any other type of rigid board insulation. Because the insulation is installed above the waterproofing membrane and is exposed to water through its service life, resistance to water while maintaining physical properties is critical.

FOAMULAR® 404 and 604 have channels cut into the bottom edges on all four sides of the board to enhance drainage at the board/membrane interface. FOAMULAR® 404RB and 604RB have ribs cut into the top surface of the board in addition to the channels on the bottom. The ribs serve as drainage enhancement under pavers when the pavers are laid directly on top of the foam board.

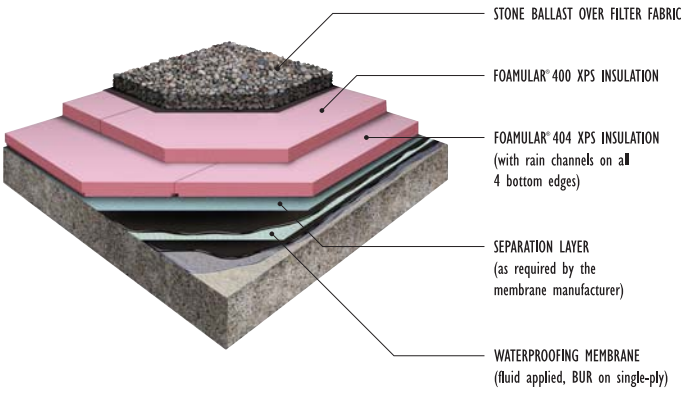
PRMA, Vegetative and Plaza Deck
Above Deck Roof Insulation



Vegetated Waterproofing System



Plaza Deck/Paver Waterproofing System



Stone Ballasted Waterproofing System

Section Overview

Sustainability

Owens Corning is committed to driving sustainability through greening our operations, greening our products and accelerating energy efficiency in the built environment. Owens Corning FOAMULAR® XPS products are GREENGUARD Indoor Air Quality Certified® and GREENGUARD Children and Schools Certified℠. FOAMULAR® XPS is also third party certified, to contain a minimum 20 percent recycled polystyrene content and is produced with a zero ozone depletion blowing agent formulation. FOAMULAR® XPS insulation products contribute to achieving credits in multiple LEED® categories including energy efficiency and recycled material content and carry a lifetime limited warranty[1] on all ASTM C578 physical properties for true long lasting value.

Notes

1. See actual warranty for complete details, limitations and requirements.

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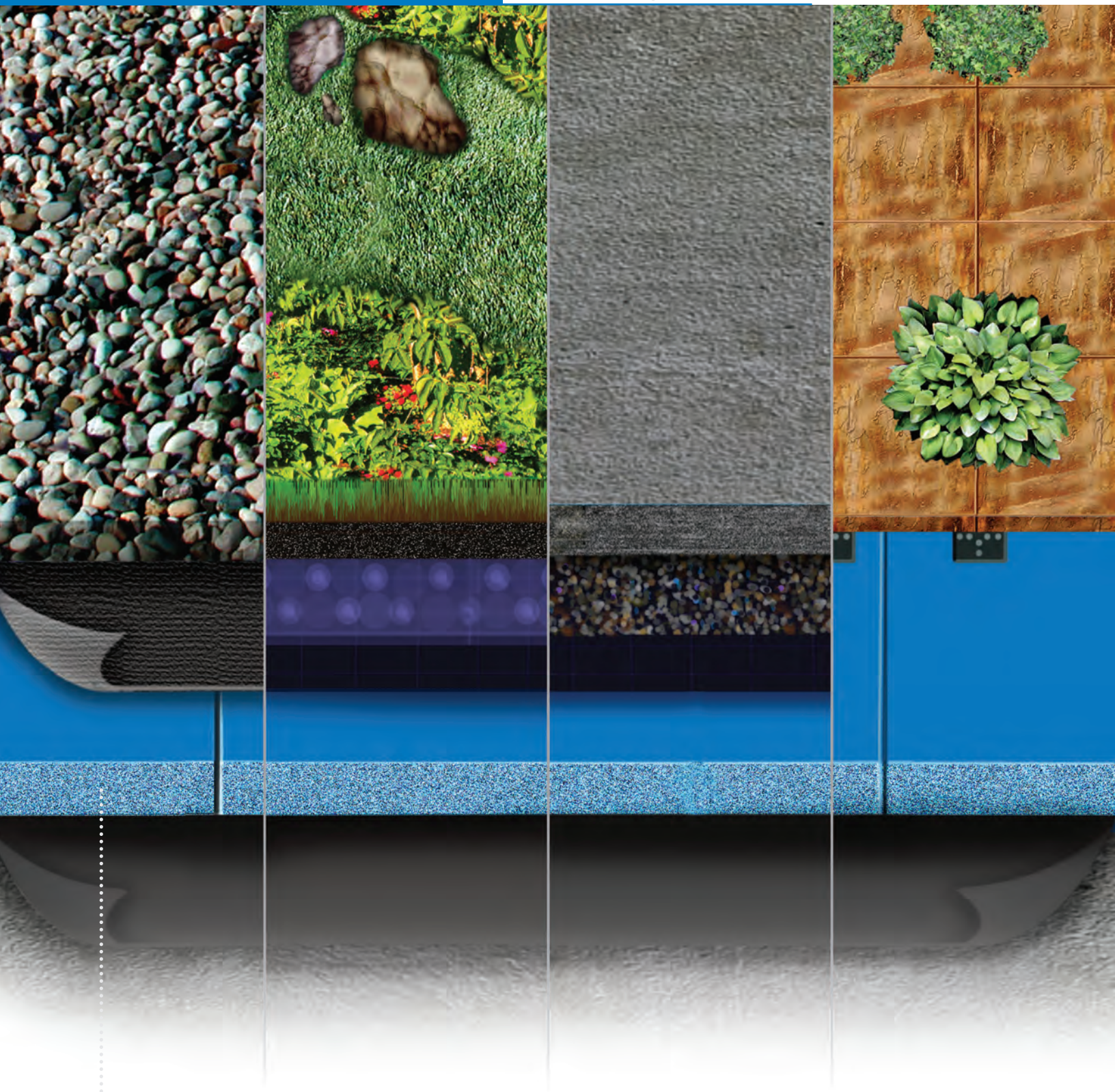


Protected Membrane Roof Installation Guidelines

PMR FIRST ... TO LAST.

Table of Contents

Overview

CHANGING THE SEQUENCE

Protected membrane roofing's breakthrough contribution to flat roof technology was the incorporation of an "upside-down" approach to insulating the roof: placing the insulation on top of the waterproof membrane to improve the membrane's effectiveness and the insulation's efficiency.

This advancement was made possible in large part by the use of STYROFOAM™ extruded polystyrene insulation, whose closed-cell, water-resistant qualities have proven to be a key component in protected membrane roof (PMR) systems.

A conventional roof places the membrane on top of the insulation, leaving the membrane vulnerable to extreme temperature changes, freeze-thaw conditions and physical abuse from heavy foot traffic (Figure 1).

The PMR system places the insulation on top of the membrane, protecting the roofing membrane from extreme temperature changes and physical abuse (Figure 2).

The main difference between PMR and conventional roofing is the sequence in which the materials are applied. The key to the PMR system is that the insulation is placed on top of the waterproofing membrane. This configuration protects the membrane, resulting in superior long-term performance and durability.

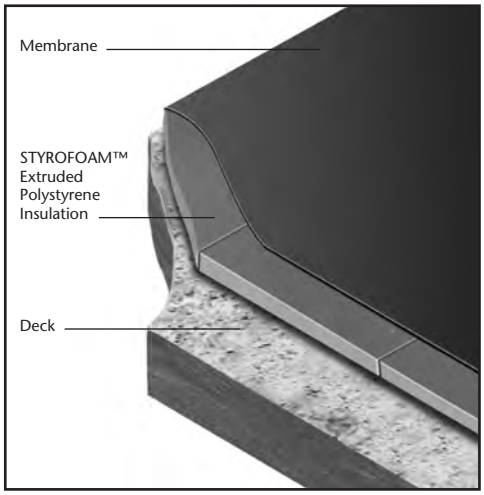


Figure 1: Conventional Roof With Membrane Above the Insulation (depending upon building and climate conditions, a vapor barrier may also be used)

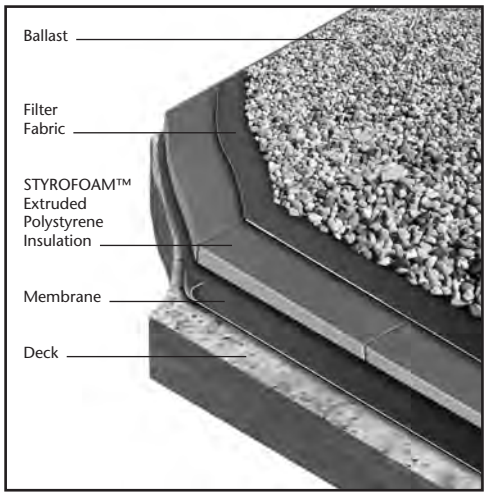


Figure 2: PMR With Membrane Below the Insulation

Overview

CHANGING THE SEQUENCE

Advantages of PMR

All flat roof assemblies consist of the same basic elements assembled in a seemingly logical order: a deck (composed of wood, metal or concrete), covered with insulation and topped with a waterproofing membrane. A protected membrane roof can employ the same elements, but the membrane is positioned *under* the insulation, offering superior long-term performance and durability.

PMR assemblies:

- Maintain the membrane at a nearly constant temperature, close to the temperature of the building's interior; this minimizes the stresses on the membrane by reducing the harmful effects of freeze-thaw cycling, thermal cycling and excessive heat
- Protect the membrane from weathering, foot traffic and other types of physical abuse – both during and after construction
- Allow year-round construction since the roof is waterproofed first, then insulated
- Permit easy removal and re-installation of the ballast and insulation for making repairs or for constructing additional stories. In addition, a protected membrane roof provides an environmentally preferred option to reuse the insulation
- Allow for a range of ballast options – stone, precast paving slabs, green roof, interlocking stone or concrete – depending on use and aesthetic considerations
- Are compatible with a range of membrane types
- Eliminate the need for a separate vapor retarder

PROVIDE DURABILITY AND PROTECTION

With the membrane positioned under the insulation, the choice of insulation becomes an important consideration. The insulation must be able to withstand wet environments (without sacrificing insulation performance) and foot traffic during and after construction, while continuing to perform over time.

Because of its durability and outstanding moisture-resistant qualities, STYROFOAM™ extruded polystyrene insulation delivers exceptional performance in roofing and plaza applications.

- Provides excellent moisture resistance and long-term R-value*
- Offers exceptional durability to extend the life of the plaza or roof
- Protects the membrane against weathering, physical abuse and damage
- Maintains the membrane at a relatively constant temperature
- Controls dew point location

*R means resistance to heat flow. The higher the R-value, the greater the insulating power.

Glossary

Absorption: the ability of a material to absorb quantities of gases or liquids, such as moisture.

Accelerated Weathering: an experimental test where a material is exposed in a controlled environment to various elements (heat, water, condensation or light) to magnify the effects of weathering. The material's physical properties are measured before and after the process to identify any detrimental effects of weathering.

Aggregate: rock, stone, crushed stone, crushed slag or water-worn gravel used for ballasting a roof system.

Aging: the effect on materials exposed to an environment for a defined time.

Alligatoring: the cracking of the exposed bitumen on a built-up roof, producing a pattern of cracks similar to an alligator's hide.

Asphalt: a dark brown or black substance left as a residue when processing crude oil or petroleum. Asphalt may be further refined to conform to various roofing grade specifications.

Asphalt Emulsion: a mixture of asphalt particles and an emulsifying agent, such as bentonite clay and water.

Ballast: an anchoring material, such as stone or precast concrete pavers, used to hold insulation and/or roof membranes in place.

Base Ply: the bottom ply of roofing in a roof membrane or roof system.

Base Sheet: an impregnated, saturated or coated felt placed as the first ply in some multi-ply built-up and modified bitumen roof membranes.

Blocking: sections of wood built into a roof assembly, usually attached above the deck and below the membrane or flashing, used to stiffen the deck around an opening, act as a stop for insulation, support a curb or to serve as a nailer for attachment of the membrane and/or flashing.

Built-up Roof (BUR) Membrane: a continuous, semi-flexible multi-ply roof membrane, made up of plies or layers of saturated felts, fabrics or mats with bitumen in between.

Cant Strip: a beveled or triangular-shaped strip of wood or other suitable material used to transition from the horizontal surface of a roof deck or rigid insulation to a vertical surface.

Caulking: sealing and making weather-tight the joints, seams or voids between adjacent units using a sealant.

Compatible Materials: two or more substances that can be mixed, blended or attached without separating, reacting or affecting the materials adversely.

Condensation: the conversion of water vapor or other gas to liquid state as the temperature drops or atmospheric pressure rises. (Also see Dew Point.)

Counterflashing: formed metal sheeting secured on or into another surface used to protect the upper edge of the membrane or underlying metal flashing and associated fasteners from exposure to the weather.

Curb: a raised roof location relatively low in height.

Dead Load: permanent non-moving load that results from the weight of a building's structural and architectural components, mechanical and electrical equipment, and the roof assembly itself.

Deck: a structural component of the roof of a building designed to safely support the design dead and live loads, including the weight of the roof systems, and the additional live loads required by the governing building codes. Decks are either non-combustible (e.g., corrugated metal, concrete or gypsum) or combustible (e.g., wood plank or plywood) and are the substrate used to apply the roofing or waterproofing system.

Design Load: load specified in building codes or standards published by federal, state, county or city agencies, or in owners' specifications to be used in the design of a building.

Dew Point: the temperature where water vapor condenses in cooling air at the existing atmospheric pressure and vapor content. Cooling at or below the dew point will cause condensation.

Dynamic Load: any load that is non-static, such as a wind load or a moving live load.

Glossary

Fabric: a woven cloth or material of organic or inorganic filaments, threads or yarns. Can be used as a reinforcement in certain membranes and flashings or used in a protected membrane roof application to reduce the ballast requirements.

Flashing: materials used to weatherproof or seal the roof system edges at perimeters, penetrations, walls, expansion joints, valleys, drains and other places where the roof covering is interrupted or terminated.

Gravel Stop: a low profile, upward-projecting metal edge flashing with a flange along the roof side, usually formed from sheet or extruded metal. Installed along the perimeter of a roof to provide a continuous finished edge for roofing material.

Humidity: the amount of moisture contained in the atmosphere. Generally expressed as percent relative humidity (% RH). It is the ratio of the amount of water vapor actually present in the air, compared to the maximum amount that the air could contain at the same temperature.

Inverted Roof Membrane Assembly (IRMA): same as protected membrane roof (PMR) assembly, where a closed-cell insulation (e.g., STYROFOAM™ insulation) and ballast are placed over the roof membrane.

Live Load: temporary load that the roof structure must be designed to support, as required by governing building codes. Can include people, installation equipment, vehicles, wind, snow, ice or rain, etc.

Loose-laid Membrane: membrane that is not attached to the substrate except at the perimeter of the roof and at penetrations. Typically, a loose-laid membrane is held in place with ballast.

Mechanically Fastened Membrane: membrane that is attached at defined intervals to the substrate, using various fasteners and/or other mechanical devices.

Membrane: a flexible or semi-flexible material that waterproofs (excludes water) a roof.

Parapet Wall: that part of a perimeter wall immediately adjacent to the roof, which extends above the roof.

PMR: protected membrane roof.

Positive Drainage: the drainage profile of a deck, considering the roof slope and loading deflections to ensure the roof deck drains within 48 hours of rainfall during ambient drying conditions.

Ridge: highest point on the roof where two roof areas intersect.

Roof Assembly: an assembly of interacting roof components (includes the roof deck, vapor retarder [if present], insulation and roof covering).

Roof Slope: the angle a roof surface makes with the horizontal. Typically expressed as a ratio of rise to run, such as 4:12, or as a percent.

Square: 100 square feet of roof area.

Substrate: the surface on which the roofing or waterproofing membrane is applied (e.g., the structural deck or insulation).

Vapor Retarder: a material that restricts the movement of water vapor.

Wind Uplift: the force caused by the deflection of wind at roof edges, roof peaks or obstructions, causing a drop in air pressure immediately above the roof surface (e.g., suction). Uplift may also occur from air movement from underneath the roof deck, causing the membrane to balloon and pull away from the deck.

Components

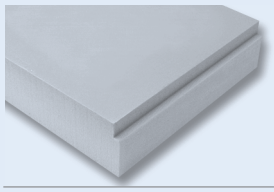
STYROFOAM™ EXTRUDED POLYSTYRENE INSULATION

Description

STYROFOAM™ extruded polystyrene insulation is a rigid, closed-cell insulation, ideally suited and designed for PMR installations. Because of the properties imparted during the extrusion process combined with the hydrophobic nature of polystyrene, STYROFOAM insulation has a high resistance to both water and water vapor, providing demonstrated long-term mechanical and thermal performance.

The boards are available in a range of thicknesses, densities, and edge and surface treatments.

STYROFOAM™ ROOFMATE™



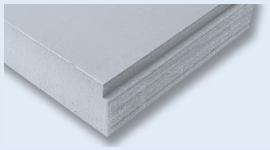
An extruded polystyrene foam insulation providing excellent moisture resistance, durability and long-term R-value. Ideal for installation above waterproofing or roofing membranes in PMR applications.

STYROFOAM™ Ribbed ROOFMATE™

An extruded polystyrene foam insulation board with 1/4" x 1/2" drainage channels on the bottom long edge of each board. The top surface of the board has ribs that form corrugations in the long dimension of the board.

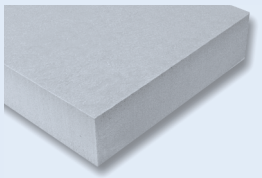
Designed for installation above waterproofing or roofing membranes in PMR applications that use pavers as ballast. Pavers can be installed directly over the ribbed foam surface without needing pedestals.

STYROFOAM™ PLAZAMATE™



A high-density extruded polystyrene foam insulation board designed to be installed above waterproofing or roofing membranes in most plaza deck applications.

STYROFOAM™ Highload 40, 60 and 100



An extruded polystyrene foam insulation board with high compressive strength developed specifically for in-ground application and freezer floors. The products are also well-suited for plaza decks and protected membrane roofs that must withstand heavy traffic.

Components

STYROFOAM™ EXTRUDED POLYSTYRENE INSULATION

Function

Provide thermal properties: STYROFOAM™ extruded polystyrene insulation has a high aged thermal resistance (R-value) when compared with competitive roof insulations.

Provide membrane protection: By installing the insulation over the membrane, the membrane is kept at a relatively constant temperature year-round and protected from weathering, mechanical damage and abuse.

Specification

The insulation shall meet ASTM C578-05 (Type V, VI or VII depending on the required properties) or CAN/ULC S701 Type 4.

Install required thickness of STYROFOAM™ extruded polystyrene insulation unbonded over the roof membrane. Install a slip or separation sheet over the membrane if the membrane is coal tar or Type 1 or 2 asphalt, or if required by the membrane manufacturer.

Butt boards tightly together with a maximum 3/8" gap between boards, staggering end joints. The recommended stagger between each board is 2'. However, in cases where boards have been cut to fit, try and maximize the stagger where possible. At a minimum, each board should have at least an 8" stagger.

When using STYROFOAM insulation with pre-cut drainage channels, ensure that the drainage channel edges are face down (i.e., on the membrane side).

Bevel edges to fit closely to cant slopes.

Fit around protrusions and obstructions with a maximum 3/4" gap to minimize heat loss.

Multi-layer foam installation:

- The bottom layer of insulation (the layer directly on the membrane) must be at least 2" thick.
- The bottom layer must be the thickest or, at minimum, equal to the top layer (e.g., 3" bottom and 3" top).
- Lay successive layers of insulation unbonded or unadhered.
- Stagger or offset all joints from those of the underlying layer.

Installation Notes

Protect insulation from physical damage.

Handle boards carefully to prevent damage during installation.

Always wear protective eyewear and gloves when handling and cutting insulation.

Always store insulation away from direct sunlight, particularly when storing for an extended time. Cover with a light-colored opaque tarp for protection from solar radiation. The surface degradation caused by ultraviolet (UV) light will have no measurable effect on the insulating value unless the deterioration is allowed to continue until actual thickness is lost.

Always check the compatibility with other products that may come in direct contact with the insulation, particularly those containing solvents. Preventive care must be taken, such as allowing the solvents to evaporate, providing a slip sheet or painting the surface of the insulation with white latex paint. Always brush off any surface dust before applying white latex paint on the insulation.

STYROFOAM™ extruded polystyrene insulation is combustible and may constitute a fire hazard if improperly used or installed. The insulation contains a flame-retardant additive to inhibit ignition from small fire sources. During shipping, storage, installation and use, this material should not be exposed to open flames or other ignition sources.

Components

FABRIC

Description

Ballast reduction fabric, commonly known as filter fabric, is used in PMR installations between the ballast and insulation. This water-permeable material must have proven long-term weather resistance, be strong enough to withstand traffic abuse and prevent displacement of the insulation under flotation conditions.

Function

- Prevent fines from penetrating between insulation boards
- Raft the insulation together to reduce ballast requirements
- Reduce mechanical damage to insulation
- Allow easy stone removal if access required to flashings, insulation and/or membrane

Specification

Apply fabric unbonded and shingle fashion over the installed insulation (Figure 3).

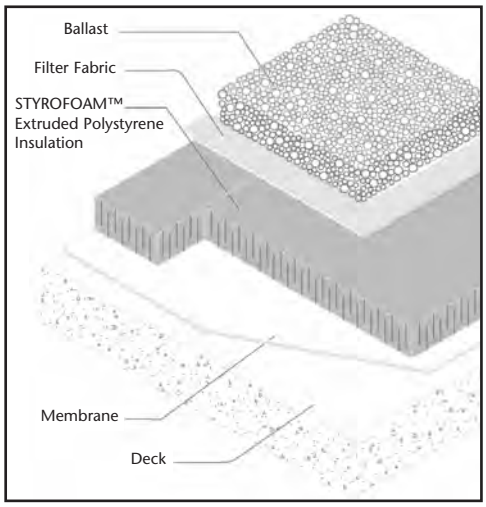


Figure 3: Fabric Placement**

Overlap all edges a minimum of 12". If a small piece has to be used, minimum size should be 8' x 8'.

Slit fabric to fit over any roof penetrations. Cut around roof drains and other openings (Figure 4).

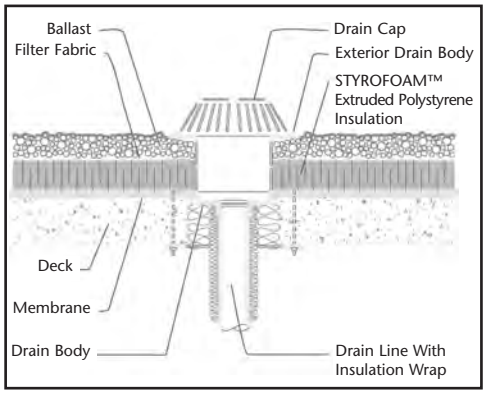


Figure 4: Drain Detail With Fabric**

®™Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow
**This is an illustration of a typical detail. Responsibility for actual design remains that of the designer.

Components

FABRIC

Extend the fabric up the roof perimeter cants and roof protrusions by at least 3" above the top level of the ballast (typically about a 6" upturn) and place it loose under the metal counterflashings (Figure 5).

Fabrics, such as Fabrene V.I.E.,† should meet or exceed the guidelines listed in Table 1.

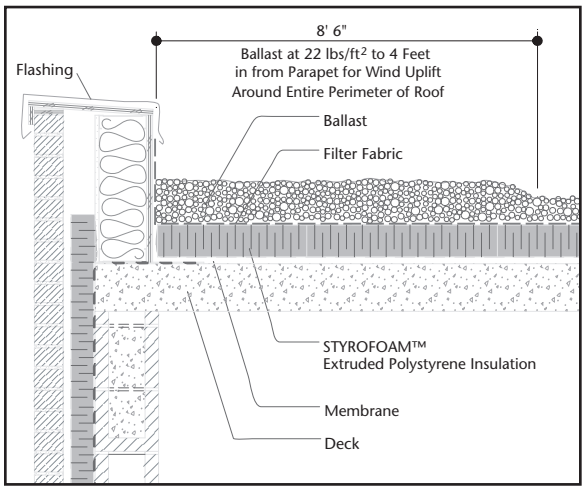


Figure 5: Parapet Detail With Fabric**

TABLE 1

Specification Guidelines			
Criteria	**Test Method**	**Units**	**Value**
Unit Weight	ASTM D1910	oz/yd²	4.0 (max)
Notch Tear MD CD	ASTM D2262	lb	 7.0 (min) 7.0 (min)
Tensile Grab MD CD	ASTM D1682	lbf	 70 (min) 60 (min)
Elongation @ break	ASTM D1682	%	15 (min)
UV Resistance			Approved for outdoor use
Material			Woven polyolefin preferred to promote run-off

Installation Notes

Store all materials in dry, protected areas in an upright position.

Dow experience has shown that when the STYROFOAM™ extruded polystyrene insulation is exposed to both direct sunlight and an outdoor air temperature over 90°F, distortion of the foam can occur in as little as 30 minutes when a heavy, dark-colored fabric is over the insulation. To prevent this phenomenon during hot weather, temporarily place white opaque polyethylene film on the fabric until the ballast is laid.

Install the fabric unadhered directly over the foam insulation. Wetting the fabric sometimes helps secure it until the ballast can be applied.

Supporting Documentation

TechNote 501a: "Protecting STYROFOAM Brand Insulation Below Dark Roofing Membranes and Fabrics"

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BALLAST

Description

Crushed stone or washed, rounded riverbed rock, ASTM D448 Gradation #2, 4, 5 or 57 depending on membrane type, building height, wind zone and parapet height (Table 2).

Depending on the ballast design, the range of ballast is 10 to 15 lb/ft^2 with additional ballast around perimeters and penetrations (15 to 20 lb/ft^2). In some cases, pavers can be used. See "Pavers" on page 12 for additional details.

Function

Prevent uplift and prevent flotation: The amount and placement of ballast is based on the following considerations:

- Design wind speed – Refer to the ANSI/ASCE 7-95 wind speed map, contact the local code authority for the design wind speed for the building location or refer to TechNote 508: "Ballast Design Guide for IRMA Roofs"
- Roof height – Use the worst-case elevation (e.g., from ground level to the highest point of the roof)
- Parapet height – Measured from the top of the ballast to the top of the parapet, use the shortest parapet height in any variation
- Membrane type – Adhered, loose-laid or mechanically attached

Areas of extra ballasting: Extra ballast, required to overcome high wind loads and restrain insulation during heavy rainstorms, should be considered in the following locations:

- Perimeter edge – 8.5' wide band running along the perimeter edge of the roof insulation. As an alternate to additional ballast, 1 to 4 rows of concrete pavers may be installed along the perimeter edge (see TechNote 508).
- Penetrations through the insulation – 4' wide band around any roof penetration greater than 4' in any direction (e.g., skylights, equipment pads, etc.).
- Corners – Concrete pavers may be required with steel strapping and anchors for certain designs (see TechNote 508). See "Pavers" on page 12 for details about concrete pavers.
- Building exposure – Consider the surrounding terrain and its potential effect on the overall wind exposure (e.g., nearby woods versus shorelines).
- Membrane type – Adhered, mechanically fastened or fully ballasted. For additional details, see "All Other Components" on page 13.

Prevent wind scouring: The wind performance of stone ballasted PMRs has been excellent. Only a few isolated minor scouring problems have occurred, typically limited to small areas in a corner. In these few cases, the ballast has blown inbound by about 4' and piled up on the filter fabric, creating additional weight.

Prevent UV degradation of the insulation: Most PMR applications use a filter fabric that typically incorporates a UV stabilizer. However, if no fabric is used, the insulation must be totally covered by the ballast to prevent UV degradation. The quality of the ballast is very critical in these types of applications. Too small (fines not more than 10 percent of mix) and the stones may work into the insulation joints or be moved by the wind; too large and the ballast may not provide adequate cover to protect from UV light.

Provide a Class A fire-resistant roof cover: Class A roof covering, as defined by ULC S107, ULI 790 and ASTM E108. (See "Fire and Wind Ratings" on page 20 for additional details.) The requirements for Class A roof construction cover the performance of roof assemblies and roof covering materials when exposed to a fire originating from sources outside a building. The stone ballast or pavers provide the Class A fire rating.

TABLE 2

Standard Sizes of Coarse Aggregate (Weight % Finer Than Sieve Openings)										
ASTM D448 Gradation	**Nominal Size Square Openings**	**3"**	**2-1/2"**	**2"**	**1-1/2"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**3/16"**
2	2-1/2" to 1-1/2"	100%	90-100%	35-70%	0-15%		0-5%			
4	1-1/2" to 3/4"			100%	90-100%	20-55%	0-15%		0-5%	
5	1" to 1/2"				100%	90-100%	20-55%	0-10%	0-5%	
57	1" to No. 4				100%	95-100%		25-60%		0-10%

Components

BALLAST

Design Approach

Refer to TechNote 508 for the recommended amount and placement of ballast. The ballast design depends on:

- Type of membrane (adhered, loose-laid or mechanically attached)
- Building height
- Design wind speed
- Site exposure
- Parapet height
- Gravel stop height

Specification

ASTM D448 Gradation #2, 4, 5 or 57 washed free of fines or stones.

Spread stone ballast uniformly over installed insulation to provide minimum weight or thickness.

Spread additional ballast around the roof perimeter for a width of 8.5' to increase ballast weight or thickness.

Spread additional ballast around any penetration for a width of 4' around any penetration that exceeds 4' in any direction.

Installation Notes

Make sure that proper provisions have been specified to seal off openings in the roof deck and any perimeter blocks. This will prevent air from getting below the roofing membrane and billowing it.

For PMR installations without a fabric, ensure that the ballast does not contain too many small stones (fines not more than 10 percent of mix) as they may work into the insulation joints or be moved by the wind. Conversely, too many large stones may not provide adequate cover to protect the insulation from UV light where a fabric is not used.

If ballast has been moved by wind scour, repair is simple. Just replace the insulation (if necessary), re-lay the filter fabric and replace the ballast. A small paver can be added, if required.

If a gravel stop is required, the height of the gravel stop at a building perimeter should be at least 2" from the top of the ballast.

Supporting Documentation

TechNote 508: "Ballast Design Guide for IRMA Roofs"

National Research Council of Canada report by Kind and Wardlaw. Report on PMRs using a 30' x 30' wind tunnel, with various ASTM gradation/sizes of ballast. (See reports NRC LTR-LA 269, NRC LTR-LA 234, NRC No. 15544.)

ANSI/SPRI RP-4 Wind Design Standard for Ballasted Single-Ply Roofing Systems (for mechanically attached and loose-laid PMR)

ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction

ANSI/ASCE 7 Minimum Design Loads for Buildings and Other Structures (includes Basic Wind Speed Map)

Components

PAVERS

Description

Concrete slab pavers or interlocking pavers can be used to supplement or replace conventional stone ballast requirements and create a surface for rooftop decks, walkways, terraces, gardens and similar applications.

Note: *For structural plaza deck design, such as for parking decks and other high-traffic areas, the design is the responsibility of an architect and/or structural engineer.*

Function

Note: *For additional information, see "Ballast" on page 10.*

Narrow roof walkways for access: Pavers can be placed to facilitate access to rooftop equipment.

Prevent wind scouring: In exposed areas or areas of high winds, pavers may be required. In certain conditions, the pavers should be strapped together using galvanized or stainless steel straps, mechanically fastened to each paver.

Perimeter ballast: Additional ballast is required around the building perimeter in a PMR design. Depending on the design, pavers can be installed instead of conventional stone ballast.

Plaza-deck design: For light traffic requirements, the stone ballast can be replaced with concrete pavers completely. In many cases, the pavers must be raised from the surface of the fabric and insulation. See "Installation Notes" for details.

Specification

PAVERS

Concrete pavers shall be manufactured from minimum 3,000 lb/in^2 concrete with a minimum weight of 18 lb/ft^2.

When ribbed insulation is not used and the total area to be covered by pavers is more than 10 percent and the location has more than 3,000 heating degree-days, pavers should be raised from the surface of the fabric and insulation using spacers to maintain at least a 3/16" ventilating air space ("diffusion open" design). The spacer can be:

- 1" thick insulation cut into 6" square blocks and placed under the four corners of the paver (limited to 108 lb/in^2 live loading)
- Preformed pavers with at least a 3/16" foot in each corner or ribbed undersurface
- Paver pedestal of injection molded, weathering-grade plastic, installed under each corner (e.g., PAVE-EL by Envirospec Inc., Terra-Tabs by Wausau Tile, etc.)
- Layer of pea gravel 1" (min.) free of fines

Note: *This air space is not required if the pavers are covering only a limited area (less than 10 percent of roof area), such as corners or narrow roof walkways.*

PAVER STRAPPING AND FASTENERS (IF REQUIRED):

Straps shall be of 22 gauge galvanized or stainless steel, 3" wide and 12' long.

Fasteners shall be 1/4" x 1-1/4" corrosion-resistant metal anchors, expanded in pre-drilled holes (e.g., Zamac Nailin #2814 by Powers Fasteners, Inc).

Installation Notes

When pavers cover more than 10 percent of the insulation surface and are located in climates with more than 3,000 heating degree-days, create a 3/16" space between the insulation and the underside of the pavers. In colder climates, the air space will minimize any freeze-thaw spalling on the concrete and moisture build-up in the insulation due to vapor drive from the inside.

Components

ALL OTHER COMPONENTS

Description

MEMBRANES

The membrane is the flexible or semi-flexible waterproofing layer on the roof deck. In a PMR application, the membrane is sandwiched between the roof deck and the insulation.

Membranes fall into three general categories: built-up roof (BUR), two-ply modified bitumen, single-ply (sheet) or liquid membranes.

Note: *PMR assemblies should be installed with adhered membranes only.*

BUR membranes are semi-flexible, multi-ply roof membranes, consisting of plies or layers of saturated felts, coated felts, fabrics or mats between alternate layers of bitumen, either asphalt or coal tar based.

Modified bitumen membranes are similar to BUR membranes, but instead are manufactured in a production facility, using asphalt modified with various additives. The membrane is fully adhered and the seams overlap to provide an uninterrupted waterproof layer.

Sheet or single-ply membranes are prefabricated sheets of polymer-based material, such as thermoplastic (e.g., PVC), elastomeric (e.g., EPDM) or modified bitumen with polymer modifiers. Single-ply roofs can be:

- *Fully or partially adhered:* The membrane is fully or partially adhered to the underlying substrate with a flood coat.
- *Loose-laid:* The membrane is not attached to the substrate except at the perimeter and at penetrations. In a PMR assembly, the loose-laid membrane is held in place with full ballast. (See "Ballast" on page 10 for details.) Care must be taken to ensure that air infiltration underneath the membrane is prevented.
- *Mechanically fastened:* The membrane is attached at defined intervals to the substrate. Mechanical fastening may use various fasteners and/or other mechanical devices, such as plates or battens.
- *Self-adhering:* The membrane is adhered to a substrate and to itself at overlaps without the use of an additional adhesive. This is usually accomplished with a surface adhesive protected by a release paper or film that prevents the membrane from bonding to itself during shipping and handling.

Note: *With some membranes, manufacturers may recommend a slip sheet (e.g., 4-mil polyethylene film) over the membrane to prevent adhesion of the foam to the membrane or plasticizer migration (e.g., chemical attack) to the STYROFOAM™ extruded polystyrene insulation. Consult the membrane manufacturer for recommendations.*

Liquid membranes are applied in-situ as a liquid that hardens or sets into a continuous, monolithic membrane over the substrate. These liquids are generally applied by spraying or with rollers and include:

- Hot-applied rubberized asphalts, a blend of asphalt, mineral fillers, elastomers, virgin or reclaimed oil. Some versions consist of two coats of rubberized asphalt with a polyester mat in between (fully reinforced or two-ply system).
- Cold-applied liquid compounds consist of emulsions and solutions of resins, elastomers (e.g., polyurethanes, silicones, acrylics, etc.) and bitumens and/or modified bitumens.

FLASHINGS

Flashings are materials used to weatherproof or seal the roof system edges at perimeters, penetrations, walls, expansion joints, valleys, drains and other places where the roof covering is interrupted or terminated. For example, membrane base flashing covers the edge of the field membrane, and cap flashings or counterflashings shield the upper edges of the base flashing.

ROOF DECK

The roof deck (including drains and gutters) is the structural component of a building's roof. The deck must be capable of safely supporting the design dead and live loads, including the weight of the roof systems and the additional live loads required by governing building codes.

Decks are either non-combustible (e.g., corrugated metal, concrete or gypsum) or combustible (e.g., wood plank or plywood), and provide the substrate to which the roofing or waterproofing system is applied.

Components

ALL OTHER COMPONENTS

Function

The **roof deck** should:
- Provide structural support to accommodate both live and dead loads without significant deflection.
- Provide dimensional stability by forming a stable substrate not affected adversely by cyclical thermal- and moisture-induced movement.
- Provide fire resistance as determined by the building type and intended use.
- Provide a substrate for the roof system.
- Accommodate building movement. Where necessary, building expansion joints and roof area dividers should be designed and installed.
- Provide for drainage (either by sloping the roof deck or using tapered insulation or both). The roof surface should be sound and should drain water freely within 48 hours following a rain. Every effort should be made to isolate and correct the causes of any standing water or ponding on the roof. CRCA and NRCA recommend a minimum slope of 1/4" per foot (2 percent). The International Building Code (IBC) also requires a slope of 1/4", except for coal tar membranes that require 1/8" slope. However, if the roof is designed to allow ponding, ensure the insulation is *not* adhered to the membrane and a filter fabric is used.
- Provide suitable roof drains and gutters. Care should be taken to prevent ballast from entering the drains and/or gutters by using perforated collars or paving stones. When concerns exist, a drainage assessment should be conducted per SMACNA guidelines.

The **membrane** should:
- Provide a continuous waterproofing barrier to protect the interior environment.
- If the membrane is tacky, use a slip or separation sheet (e.g., 4-mil polyethylene) to minimize adhesion between the membrane and insulation.
- If there are compatibility issues with the membrane, such as with certain PVC or coal tar membranes, refer to the manufacturer's or supplier's recommendations. In some cases, a slip or separation sheet (e.g., 4-mil polyethylene) may be required.

The **flashing** should:
- Provide a continuous waterproofing barrier when tied into the membrane to protect the interior environment.
- Extend well above the expected high water level (typically 8" minimum).

Specification

General: The overall system (including membrane and insulation) should be designed so that the dew point is located above the membrane. The system should be designed so that freezing will not occur at the membrane level.

Where required, an adequate thermal barrier should be provided between the insulation and the interior of the building. The thermal barrier may consist of the deck, a ceiling assembly or an underlayment board equivalent to 1/2" gypsum board.

Membrane: Refer to membrane manufacturer's literature for details. The manufacturer or supplier of the membrane shall be responsible for determining compatibility of the membrane with STYROFOAM™ extruded polystyrene insulation.

Roof deck and flashing: Refer to general roofing specification for details.

Installation Notes

See the NRCA Roofing and Waterproofing Manual – Fifth Edition. Online edition available at: http://www.nrca.net/rp/technical/manual/manual.aspx

See the CRCA Roofing Specification Manual. Details available at: http://www.roofingcanada.com/ItemsForSale.asp

Cold Rain Phenomenon

THE ISSUE

"Cold rain phenomenon" (or "cold water wash") occurs during periods of cold rain and/or melting snow or when the ambient condition is 33°F to 50°F. In these conditions, the deck temperature may be temporarily reduced. The issue is that there may be additional heat loss, and in buildings with high humidity, such as pulp and paper mills, the likelihood of condensation increases.

DISCUSSION

Increased heat loss: Heat loss studies have shown that extra heat loss in PMR systems during periods of "cold rain" is a temporary phenomenon, occurring only during the short time of cold rain in a heating season. In fact, cold rain in the cooling season creates a cooling advantage for a PMR system. Studies comparing a conventional versus PMR assembly show only a 3 percent overall heat loss disadvantage for the PMR assembly.

High temperature/high humidity buildings: According to NRCA, a building with 45 percent RH is considered high moisture occupancy. Other buildings, such as pulp and paper mills, textile mills and natatoriums, can have an even higher internal humidity. Combining high humidity with a higher than normal operating temperature results in a "high temperature/high humidity" building environment that requires special design consideration.

The severe operating conditions of high temperature/high humidity buildings are particularly problematic for conventional roof systems. The high temperatures drive the high humidity up into the roof system, resulting in severe condensation and premature deterioration of the insulation and roof deck.

A PMR system offers an inherent design solution for this moisture problem. The waterproof roof membrane is an excellent vapor retarder. With the membrane directly on the roof deck and the insulation above the membrane, the membrane effectively blocks water vapor from reaching the insulation. Also, the membrane is maintained at a temperature near that of the interior, dramatically reducing the probability of condensation on the membrane and minimizing the possibility of premature roof failure.

The "cold rain phenomenon" can change this situation. Cold rain, filtering past the insulation to the membrane, can cool the membrane and the deck below, resulting in a temporary condensation condition on the underside of the deck. For some businesses, like pulp and paper mills, this dripping condensation can create problems with the manufacturing processes and products, causing decreased productivity and increased production costs.

To solve this problem, a thin layer of insulation can be placed below the membrane. This layer keeps the roof deck warm during brief cold rain periods – maintaining the inherent advantages of a PMR system while mitigating the problem of the "cold rain phenomenon."

See TechNote 507: "STYROFOAM™ Insulation in the Optimum Design System for Pulp & Paper Mill Roofs" for additional details.

CONCLUSION

The effect of "cold rain phenomenon" is temporary and does not have a significant overall effect on the performance of a PMR assembly. Generally, thicker amounts of insulation are not required to counteract the negative effects of cold rain.

In high humidity and high temperature applications, sandwiching the membrane between two layers of insulation, coupled with a vapor retarder on the roof deck will address condensation problems in high humidity roofing systems. Remember that the thicker insulation layer should be *above* the membrane to ensure the dew point is *above* the membrane.

Conditions, Issues and Ratings

SPECIAL CONDITIONS AND ISSUES

Moisture Absorption

THE ISSUE

STYROFOAM™ extruded polystyrene insulation will absorb water and the insulation value will be reduced.

DISCUSSION

In a PMR design, it is critical that any insulation installed *above* the membrane can perform in a wet environment without any detrimental effects on its long-term performance. STYROFOAM™ extruded polystyrene insulation has a unique closed-cell structure that provides excellent moisture resistance and long-term R-value.

Nine PMR systems were monitored over a period of 22 years and the insulation properties assessed. The average moisture content of the insulation was 0.9 percent on a percent by volume basis, with a retained R-value of 96 percent.

In plaza deck designs, it is important that a drainage layer be created *above* the insulation, allowing precipitation to drain off the top surface of the insulation, creating a "diffusion open" assembly. If the insulation is sandwiched between a vapor barrier (e.g., pavers) and the roof deck, vapor cannot escape so it is driven back into the insulation. To create a "diffusion open" layer, ensure impermeable roof coverings (such as pavers) have a ventilating air space. This could be a layer of fine-free gravel or a 3/16" minimum air space. See "Pavers" on page 12 for additional details. In addition, if the wearing surface is installed in direct contact with the insulation, moisture may become trapped and freeze-thaw cycling could cause spalling on the bottom of the wearing surface.

Always ensure that the roof deck has proper drainage; if the PMR system has significant ponding (e.g., standing water), the insulation will not be "diffusion open." Follow roofing association guidelines for drainage recommendations.

CONCLUSION

STYROFOAM™ extruded polystyrene insulation offers demonstrated long-term performance in a PMR assembly.

Dimensional Stability

THE ISSUE

STYROFOAM™ extruded polystyrene insulation "shrinks" over time, leading to increased heat loss.

DISCUSSION

All building materials will experience dimensional change due to temperature fluctuations. STYROFOAM™ extruded polystyrene insulation is no different.

For example, the coefficient of expansion of STYROFOAM extruded polystyrene insulation is 3.5 x 10^{-5} in/in/°F. A 2' x 8' sheet of insulation exposed to a temperature swing of 75°F could result in a maximum change of just 1/4" in the 8' direction. Once the temperature is reduced, the insulation will return to its original cut dimension. In addition, this theoretical change does not account for the temperature profile across the insulation. For example, while one side may see a large temperature swing, the underside may see only a small change.

This relatively small gap between the boards does not significantly increase the heat loss through the board joints. In heat loss studies comparing PMR versus conventional roofs, there was no significant difference between the two systems. The findings showed that the PMR system used 3 percent more energy per year.

In addition to addressing the coefficient of expansion, another consideration is the "creep" of materials. Creep is the permanent deformation resulting from continuous, long-term dead (or non-moving) loads. Creep is generally only an issue for STYROFOAM insulation used in pavements, airport runways, parking decks, floors, etc. – installations where the insulation is used to carry a significant load for a long time. In these applications, higher compressive strength insulation may be required.

CONCLUSION

All building materials have a coefficient of expansion that results in dimensional change with temperature fluctuations. The dimensional change that occurs in STYROFOAM™ insulation in a PMR assembly does not significantly impact the system's thermal performance.

Green Roof Design

THE ISSUE

Can PMR assemblies be used for "green roof" designs?

DISCUSSION

In a "green roof" design, the ballast in a PMR assembly is essentially replaced with green material – usually soil and plantings – plus a drainage layer directly on top of the insulation (Figure 6). Replacing conventional ballast with vegetation can limit storm water runoff and, by filtering the runoff through the plants, also improve the quality of the runoff. The plantings not only ballast the insulation, they can, depending on the configuration, also add additional R-value to the roof assembly. Green roofs provide habitat for insects and other wildlife and often are considered in buildings applying for LEED†† (Leadership in Energy & Environmental Design) certification.

Many materials may be suitable as ballast, provided they are compatible with the insulation, prevent flotation, shield ultraviolet light and provide a Class A fire-resistant roof finish.

The roof structure must also be designed to accommodate the dead load from the additional weight of the plantings (including when they are fully saturated by rainfall and covered in several feet of snow), plus any live load from traffic, if applicable. It is also important to design the roof slope and drainage system to accommodate rain runoff.

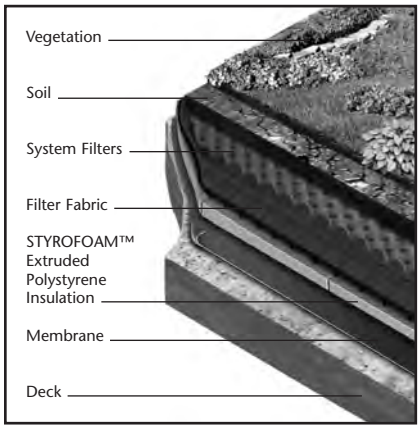

Figure 6: Green Roof Design

PMR assemblies are ideal for green roof designs:

- The membrane is protected under the insulation.
- Because STYROFOAM™ extruded polystyrene products come in a range of compressive strengths, the insulation layer can be designed to withstand the higher dead loads.
- STYROFOAM insulation is proven to outperform in a moist environment.
- STYROFOAM insulation has a high modulus of elasticity, allowing it to perform under long-term live or cycle loading. Maximum recommended dynamic (live) load is 1/10 of the rated compressive strength for 1,000,000 repetitions to address creep and fatigue guidelines.

Typically, a drainage layer is placed over the insulation to direct runoff to the drains, as well as keep the top surface of the insulation "diffusion open." (See "Moisture Absorption" on page 16 for details.) This drainage layer usually includes a fabric over the insulation to protect the joints and keep them open for drainage. Any stone used for this drainage layer must be clean and have a low percentage of fines. In some cases, a drainage mat combined with a filter fabric has also been used successfully to create the necessary air space.

For additional information on green roof design, see:

Design Guidelines for Green Roofs, by Steven Peck and Monica Kuhn, B.E.S., B. Arch., OAA, an OAA and CMHC publication, available at http://www.cmhc-schl.gc.ca

CONCLUSION

PMR assemblies are ideally suited to green roof designs.

Conditions, Issues and Ratings

SPECIAL CONDITIONS AND ISSUES

Finding Leaks in a PMR

THE ISSUE

Is it more difficult to locate a leak with a PMR or conventional roof assembly?

DISCUSSION

Building upon years of in-field experience, the majority of roof leaks in PMR systems occur at flashing as opposed to the interior field area. The field area is protected from physical abuse, UV attack and thermal cycling – all factors that are the primary causes of roof failures – by both the insulation and ballast over the membrane. However, sometimes interior field leaks do occur.

Concrete decks: For PMR installations on concrete decks, generally the membrane is fully adhered to the deck. This simplifies leak detection because the leak is localized. For example, the leak in the interior will be exactly where the hole in the membrane is located. If the membrane is not adhered, the water can run under the membrane for many feet before entering the building – just like in a conventional roof.

Steel decks: For PMR installations on steel decks, a layer of insulation or other substrate (e.g., drywall) is placed first to provide a base for the membrane – exactly the same as in a conventional roof. The same type of leak detection effort is required for both PMR and conventional roofs on steel decks.

Wood decks: On wood decks with a PMR installation, the membrane is typically a felt layer and two or three plies mopped on top. In a conventional installation, the insulation is fastened to the deck and then the membrane is applied. Both of these approaches will allow the water to run to the deck joints prior to entering the building.

CONCLUSION

Not only do PMR assemblies have fewer leaks in the first place, PMR assemblies over concrete decks with bonded membranes have definite advantages when isolating any leaks that do occur. Both conventional and PMR roofs over steel or wood decks require the same leak detection strategies. In addition, because PMR roofs are easier to repair and typically all of the original materials can be reused (ballast and insulation), this environmentally friendly feature can save money.

Low Temperature Applications

THE ISSUE

PMR assemblies should not be used in low temperature applications because of the potential adverse effect on the STYROFOAM™ extruded polystyrene insulation.

DISCUSSION

In a low temperature application (e.g., freezers), the interior space has a low temperature and low water vapor pressure (humidity). In contrast, the warm outside temperature and higher water vapor pressure causes a vapor drive toward the interior space. Unless addressed, this vapor can condense in the insulation and lower the R-value of the system. It can also condense on the membrane and freeze, gradually forming a layer of thick ice.

Typically in low temperature applications, the membrane is placed on the "warm side" – or the exterior in a conventional roofing application.

CONCLUSION

In low temperature applications (e.g., freezers), a conventional roof may offer performance benefits.

High Temperature Installation

THE ISSUE

In high temperature locations, PMR assemblies should not be covered with a dark fabric prior to laying the ballast because of the potential adverse effect on the STYROFOAM™ extruded polystyrene insulation.

DISCUSSION

Like many insulations, higher temperatures may cause permanent distortion and/or long-term creep. The maximum use temperature for STYROFOAM™ extruded polystyrene insulation is 165°F for continuous use, with short-term exposure up to 190°F.

Typically, this concern arises in warmer locations (e.g., southern U.S.) when STYROFOAM insulation is placed underneath a dark fabric prior to laying the ballast. Given the right conditions, the temperature on the top of the insulation may reach close to the upper limits for polystyrene insulation and cause some distortion. Experience has shown that when the STYROFOAM insulation is exposed to both direct sunlight and an outdoor air temperature over 90°F, distortion of the foam can occur in as little as 30 minutes when a heavy fabric is over the insulation. To prevent this phenomenon during hot weather, temporarily place white opaque polyethylene film on the fabric until the ballast is laid.

CONCLUSION

In high temperature locations, the temporary use of white opaque polyethylene film laid on the fabric until the ballast is laid will prevent any distortion of the insulation.

SPECIAL CONDITIONS AND ISSUES

Membrane Seam Failure

THE ISSUE

Failures at the seams in thermoset membranes may be worse with PMR because the membrane stays damp.

DISCUSSION

Thermoset membranes (such as EPDM and neoprene) were historically seamed with a contact adhesive. Seam failure due to moisture intrusion or other contaminant was a concern for this type of membrane because the membrane stays damp in a PMR, potentially resulting in an increase in seam failure. In fact, Dow never received a complaint about this perceived concern.

In today's EPDM system, a seam tape is used. This tape has exhibited excellent performance and this is no longer an issue.

CONCLUSION

There are no documented cases of seam failure related to the PMR application.

Plant Growth on PMR Assemblies

THE ISSUE

Periodically, plant growth will occur on PMR and other low-sloped roofs. Can this be avoided?

DISCUSSION

At times, grass, weeds or small trees may grow on both PMR and conventional roofs. Good roofing practice should include a maintenance program that includes periodic inspection for this type of growth. Any plant growth should be pulled out and, if required, the area treated with a weed killer.

Roots from plant growth can sometimes damage the membrane if left unchecked. With a PMR system, there is less chance of this happening since the membrane is protected by the insulation, fabric and ballast.

CONCLUSION

A preventive maintenance and inspection program should include inspection and removal of any plant growth.

Conditions, Issues and Ratings

FIRE AND WIND RATINGS

Overview

Fire and wind ratings are required to meet building code requirements. Typically, a PMR assembly, including roof deck, membrane, insulation and ballast, is tested in exactly the same configuration as would be constructed in the field. No deviation from the component specification is allowed.

Underwriters Laboratories Inc. (ULI), Underwriters Laboratories Canada (ULC) and Factory Mutual (FM) have developed test methods to rate the fire and wind properties of assemblies.

For the most current listings, contact Dow at 1-866-583-BLUE (2583).

Test Methods

FIRE RESISTANCE RATINGS – FIRE WITHIN A BUILDING

Both ULI and ULC test roof assemblies based on the type of fire exposure. For fires originating within a building, roof assemblies are assessed using either ANSI/UL 263 or CAN/ULC S101-M.

When testing for fires originating within a building, a full-scale roof system is exposed to a controlled fire in order to assess a construction/assembly that can contain a fully developed fire. The Fire Resistance Rating represents the time it takes for the temperature on the unexposed side of the assembly to increase by 250°F.

A sample measuring approximately 14' x 17' is used, including the decking material, any suspended ceiling, hangers, insulation, etc. The sample is then exposed to a fire with temperatures reaching 1,000°F at five minutes and then 1,700°F for a specified time. During the test, a load is applied to the floor to represent the maximum load the joists are designed to support.

EXTERNAL FIRE PERFORMANCE OF A ROOF ASSEMBLY

The fire resistance performance of roof coverings exposed to simulated fire source originating outside a building is conducted in accordance with UL 790 (ASTM E108) or CAN/ULC S107-M. Three classifications are available.

Class A roof covering:
- Effective against *severe* fire test exposures
- Provides a *high* degree of fire protection
- Not expected to produce flying embers
- Does not slip from position during the test

Class B roof covering:
- Effective against *moderate* fire test exposures
- Provides a *moderate* degree of fire protection
- Not expected to produce flying embers
- Does not slip from position during the test

Class C roof covering:
- Effective against *light* fire test exposures
- Provides a *light* degree of fire protection
- Not expected to produce flying embers
- Does not slip from position during the test

***Note:** PMR assemblies ballasted with a minimum of 9 lb/ft² of stone ballast (or pavers installed with a maximum gap of 1/4") achieve a Class A rating.*

FM TESTS FOR WIND PERFORMANCE

Factory Mutual approved roof assemblies are *only* required when the building is insured by FM Global. Building code authorities may recognize some FM standards; however, they do not require the use of FM approved or accepted products and systems.

FM 4450, "Approval Standard for Class 1 Insulated Steel Deck Roofs," and FM 4470, "Approval Standard for Class 1 Roof Covers," are two recognized laboratory test methods for determining the wind-uplift resistances of roof assemblies. FM 4450 and FM 4470 are the basis of FM's 1-60, 1-90, 1-120, etc., approvals. For example, a Class 1-60 design resists a 60 lb/ft² uplift pressure for one minute without loss of pressure.

Dow has a PMR system rated FM 1-90 that adheres STYROFOAM™ extruded polystyrene insulation to a BUR roof assembly with asphalt. This system can be used on both steel and concrete roof decks. Loose-laid single-ply roof membranes with ballast are not listed in the FM approval guide since there are not methods to test these systems for wind uplift. Loose-laid systems can be "accepted" by FM if the assembly is ballasted in accordance with FM Loss Prevention Guide 1-29 and reviewed by the local FM engineering office.

IBC REQUIREMENTS FOR BALLASTED ROOF ASSEMBLIES

The International Building Code (IBC) requires that ballasted roofing assemblies, including PMR assemblies, be ballasted in accordance with ANSI/SPRI RP-4. This standard can be downloaded (free of charge) at www.spri.org

ULI Hourly Fire Resistance Ratings for PMR – Steel Deck

Assembly #	Rating (hrs)	Description
P-225, P-226, P-235 (New PMR)	1, 1-1/2	Steel deck 1/2" or 5/8" Type X gypsum (varies) Bar joists Suspended ceiling
P-404 (New PMR)	1-1/2	Steel deck 1" mineral or fiberboard Bar joists Plaster ceiling
P-801, P-805 (Retrofit PMR)	1, 1-1/2, 2	Steel deck Mineral or fiberboards Spray fiber fireproofing Beam construction
P-803 (Retrofit PMR)	1, 1-1/2	Steel deck Mineral or fiberboards Spray fiber fireproofing Bar joists
P-811 (New PMR)	1, 1-1/2, 2, 3	Steel deck 5/8" Type X gypsum Spray fiber fireproofing Beam construction Suspended ceiling (optional)
P-813 (New PMR)	1, 1-1/2	Steel deck 5/8" Type X gypsum Spray fiber fireproofing Bar joists
P-908	2	Steel deck 3-5/6" vermiculite concrete Beam construction

Note: *Always refer to the actual listing for complete details, including maximum thickness of insulation allowed. For details, call Dow at 1-866-583-BLUE (2583).*

FIRE AND WIND RATINGS

ULI Hourly Fire Resistance Ratings for PMR – Concrete Deck

Assembly #	Rating (hrs)	Description
P-904, P-909, P-912, P-915 (Retrofit PMR)	2	Precast concrete units Mineral fiberboard
P-904, P-909, P-912, P-915 (New PMR)	2	Precast concrete units 1" gypsum board

ULI Hourly Fire Resistance Ratings for PMR – Other

Assembly #	Rating (hrs)	Description
P-229, P-505, P-507 (New PMR)	1, 1-1/2	2' poured gypsum deck Bar joists Suspended ceiling

FIRE AND WIND RATINGS

ULC Hourly Fire Resistance Ratings for PMR – Metal Deck

Assembly #	Rating (hrs)	Description
R-202, R-217 (New PMR)	1	Steel deck 1/2" gypsum Beams or bar joists Suspended ceiling
R-702, R-703 (New PMR)	1, 1-1/2	Steel deck 5/8" gypsum Spray cementitious mixture Beams or bar joists
R-804 (New PMR)	3/4, 1, 1-1/2, 2, 3	Steel deck 5/8" Type X gypsum Spray fiber fireproofing Beam construction
R-805, R-806 (New PMR)	1	Steel deck 1/2" or 5/8" Type X gypsum (varies) Spray fiber fireproofing Beams or bar joists

Conditions, Issues and Ratings

FIRE AND WIND RATINGS

ULC Hourly Fire Resistance Ratings for PMR – Concrete Deck

Assembly #	Rating (hrs)	Description
P-229, P-505, P-507 (New PMR)	1, 1-1/2	2' poured gypsum deck Bar joists Suspended ceiling

FM Hourly Fire Resistance Ratings for PMR

Assembly #	Rating (hrs)	Description
RC-227 (New PMR)	1	Steel deck 1/2" Type X gypsum Gypsum board ceiling
RC-264 (New PMR)	1	Steel deck 1/2" Type X gypsum Suspended ceiling

FM Class 1 Fire and Wind Uplift

Class	Description
1-60, 1-90	Steel deck 1/2" StrataGuard[§] or 5/8" DensDeck[§§] (mechanically fastened) 3-ply BUR

Note: *Current FM wind tests cannot be used to evaluate loose-applied roofing systems. FM Loss Prevention Guide 1-29 provides accepted ballasting requirements.*

IN THE U.S.:

- **For Technical Information: 1-866-583-BLUE (2583)**
- **For Sales Information: 1-800-232-2436**

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• Building Solutions • 200 Larkin • Midland, MI 48674 • **www.dowstyrofoam.com/architect**

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Building and/or construction practices unrelated to building materials could greatly affect moisture and the potential for mold formation. No material supplier including Dow can give assurance that mold will not develop in any specific system.

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Form No. 179-05051-0713MCK
McKAY219202

ISSUE 2/2009 ▪ VOLUME 26 ▪ NUMBER 2

Hoffmann Architects

Journal of architectural technology published by Hoffmann Architects, Inc., specialists in the rehabilitation of building exteriors.

Journal

Fundamentals of Plaza Design

Craig A. Hargrove, AIA LEED AP and Stephanie L. Dillon, Assoc. AIA

Plaza investigation by an experienced architect or engineer uncovers the causes of water damage or deterioration.

A plaza can be an attractive amenity, especially in an urban area where open space is at a premium. But when age, deferred maintenance, design defects, or faulty construction lead to unsightly weed growth and pooling water, dangerous tripping hazards and ice buildup, or costly maintenance demands, it might be prudent to protect that amenity by rehabilitating it.

The question is, "how?" (And, reasonably, "how much?") The answer depends on the type of system that's in place, the type you opt to install, the use of the plaza space, and the complexity and requirements of planters, stairs, fountains, seating, and other features. To begin, a team of architects and/or engineers should evaluate the existing plaza or terrace and help establish a realistic rehabilitation budget. Then, the design team should guide you in balancing project variables to achieve the desired look while meeting cost objectives.

A well-designed plaza or terrace not only reduces upkeep costs, it also attracts tenants, increases property value, and enhances outdoor space. With reductions in energy and maintenance expenses afforded by "green" design principles and sophisticated water movement strategies, plaza or terrace rehabilitation can provide excellent return on investment.

Plaza Use and Configuration

When considering options for plaza or terrace design, an architect or engineer will first assess the function and composition of the space. A plaza over which vehicles routinely drive demands a different type of assembly than does a roof terrace that sees only maintenance foot traffic.

Similarly, a private terrace for the exclusive use of building tenants has different design considerations than does a plaza classified as "privately owned public space" or one in a busy campus setting. Access, circulation, furniture, decorative elements, and plantings must be coordinated to facilitate intended usage. Paving assemblies and materials, as well as any waterproofing systems, are thus dictated not only by the form of the plaza or terrace space, but also by its function. Historic planning regulations may place further restrictions on surfacing options.

Types of Paving Assemblies

The surfacing system needs to accommodate the volume and type of anticipated traffic, while meeting

Craig A. Hargrove, AIA LEED AP directs Hoffmann Architects, Inc.'s New York City office. As Senior Vice President and Director, Architecture, he is responsible for the integrity, coordination, and oversight of diverse plaza and terrace rehabilitation projects. Stephanie L. Dillon, Assoc. AIA, Project Coordinator, has experience in all phases of plaza evaluation, waterproofing, design, and construction.

Plazas Over Occupied Space

Waterproofing is the central concern for a terrace or plaza that is also a roof.

The membrane. Once the waterproofing has been installed on a plaza or terrace, it is buried beneath tons of overburden, making it virtually impossible to access should problems arise. In all horizontal waterproofing applications, choosing and correctly applying the membrane is critical, but plazas and terraces demand a more conservative approach than do roofs or parking structures. Generally speaking, the options are:

Comparison of Waterproofing Systems for Plazas and Terraces					
Membrane system	Installation	Puncture resistance	Crack bridging	Strong suit	Weak spot
Single-ply	Sheets adhered to deck, with glued, taped, or welded seams.	Poor	Fair	Cold, low-odor application.	Seam quality depends on skilled installation. No redundancy.
Multi-layer and combination	Multiple sheets bonded in layers by flame or by cold adhesive.	Excellent	Moderate	Redundancy, via layered materials.	Height restrictions may preclude use in some retrofit applications.
Fluid-applied	Liquid binder applied to deck, with embedded reinforcing.	Good	Poor	Seamless, with smooth transition from horizontal to vertical.	Poor adhesion or uneven coverage if prepared or applied incorrectly.

Choice of membrane is situation-specific, and demands holistic consideration of the entire plaza. Only by analyzing all variables, from weather to traffic to load limits to space constraints, can a design professional determine the appropriate assembly.

The substrate. The deck should be cleaned of debris and properly prepared to facilitate adhesion. A fully adhered system prevents moisture that does penetrate the membrane from travelling underneath it. Spot repairs can then be completed without tearing up the entire plaza in search of the water entry point.

The protection. Drainage mats atop the membrane system direct water to drains, and protection boards can provide additional coverage in high-wearing areas. Insulation helps control energy costs.

The paving. Structural analysis must confirm that the building can accommodate the chosen paving system, as well as additional loading from snow, ice, wind, pedestrians, and plantings.

The result. Waterproofing concerns shouldn't undermine a plaza's allure. A well-designed, properly installed plaza or terrace creates usable outdoor space above a built structure, a valuable asset in a dense urban setting. ■

Installation of a paver-on-pedestal system. Pavers are supported only at corners, with fully open joints.

design goals for drainage, loading, siting, and usage. What are the benefits, drawbacks, and appropriate applications for each type of system? Here are the basics:

Light Duty

If the plaza or terrace is designed to function as an extension of the building interior, with space for dining, seating, or entertaining, then the finish surface will need to be nearly level, while still allowing for the effective removal of water. For light pedestrian traffic, there are two basic options: a **paver-on-pedestal** or **sand-set** system.

Features. *Paver-on-pedestal:* Waterproofing membrane adheres to substrate, which slopes to drains. Columnar pedestals are individually set, at graduated heights, atop the insulation or a protection board, to create a level support. Pavers are then supported by a pedestal at each corner. Open joints allow water to flow directly down to the sloped surface below and on to drains. *Sand-set:* Pavers are set atop compacted sand, with small butt joints (approx. 1/16 of an inch), into which additional sand is swept. Walking surface is pitched to bi-level drains.

Benefits. Quick and easy to install. Depending on material selection, light-weight systems can also be the

least expensive. Should any problems develop, the loose-laid pavers can be readily removed for maintenance, investigation, and repair.

Drawbacks. Open joints are notoriously problematic for high-heeled shoes, and they can create tripping hazards should pavers become displaced. Snow removal must be done with a blower or shovel, as plows can dislodge pavers. Weight limitations may preclude not only snowplows but also, in the case of a plaza at the front entrance to a building, emergency vehicles. It is possible to accommodate occasional vehicular access with an open-joint system, but at a significantly greater construction cost.

Medium Duty

Frequent and heavy foot traffic, such as on a college campus or in a shopping mall, demands a more resilient system. An **asphalt-set system** with sand-swept joints can provide a landscaped pedestrian setting while holding up to the abuses of shoes and occasional light vehicles, like golf carts.

Features. Modular brick, stone, or concrete pavers are set on an asphalt/sand composite bed, atop asphalt or cast-in-place concrete slabs separated by expansion joints. Drainage takes place predominantly at the surface level, although bi-level drains should be used to remove any water that does penetrate below the pavers.

Benefits. The asphalt-set paver system can accommodate much greater loads without cracking or displacement than can a paver-on-pedestal system, because the load is supported across the entirety of each paver, rather than only at corners. Although the setting bed is still 90% sand, the addition of asphalt creates a more durable paving assembly than the simple sand-set system. Application of a neoprene tack coat adds further resilience.

Drawbacks. As the frequency and weight of traffic increases, so do costs. Medium duty plazas are more expensive to install than are light duty plazas, and the level of traffic demands more vigilant maintenance. Because asphalt-set pavers are more secure than are their light-duty counterparts, removal and replacement present challenges, as does accessing underlying waterproofing membranes.

Heavy Duty

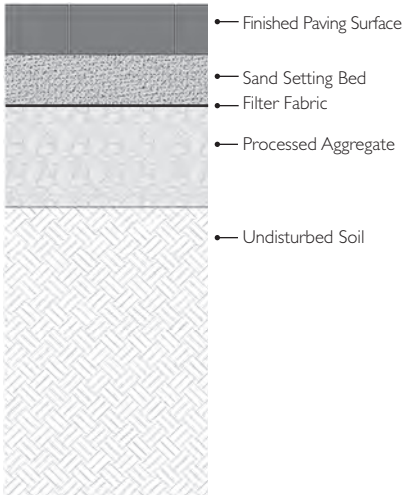
Plazas can also be designed to withstand heavier vehicle traffic. The two options for durable support of cars and trucks are **cast-in-place concrete** or **closed-joint paving systems**.

Features. Where the plaza is set on grade, the subgrade must be well compacted. Insufficient compaction can result in cracking, heaving, and premature deterioration of the paving assembly. To withstand the rigors of vehicle traffic, hard joints, with mortar or sealant, are preferred. A cementitious setting bed adds durability.

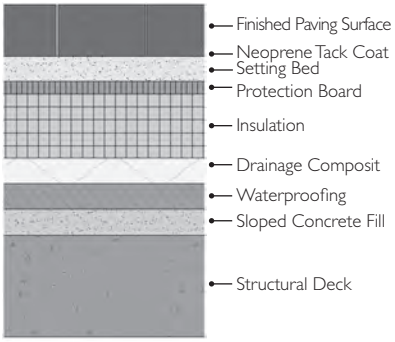
Benefits. Aggressive resistance to traffic. Closed-joint systems can be designed to support 40 tons or more without damage.

Drawbacks. Material costs for high-traffic plazas are greater than for other plaza types. Maintenance, particularly of joints, can be demanding, and replacement of pavers is difficult. Overly aggressive cleaning can blow out joints. Mortar or sealant lifespan should be considered as part of the cost equation, as joint material may need replacement every 7-10 years.

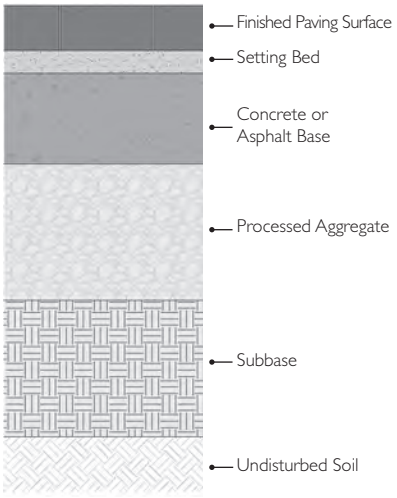
Representative Illustrations of Paving Assemblies



Light-Duty on grade



Medium-Duty over suspended slab



Heavy-Duty on grade

Drawings not to scale. Components can vary.

THE REHABILITATION PROCESS
Columbia University, College Walk

The existing plaza.

Construction of concrete retaining walls.

Installation of granite curbs.

Asphalt setting bed, ready to receive hexagonal asphalt pavers.

The reconstructed pedestrian street. The redesigned paving system can withstand frequent, heavy pedestrian traffic, as well as vehicle use, while preserving the aesthetic character of the original plaza.

Code Compliance

When a plaza retrofit project is already underway is not the time to discover that building codes have changed, and that the seating for 20 must now be increased to 200, or that the plan needed to incorporate wheelchair access ramps. Local regulations stipulate when a plaza rehabilitation is significant enough to demand updated code compliance. Plazas classified as "privately held public spaces" are generally subject to fairly rigid parameters governing occupancy, circulation, and hours of use, all of which will necessarily impact design.

Federal, state, and municipal regulations incorporate evolving "green" building codes, including provisions for plaza and terrace lighting, energy conservation, and water use. Security measures may also be dictated by local law. The design team can coordinate lighting, signage, access pathways, and landscape elements to maximize safety while meeting ecological building standards.

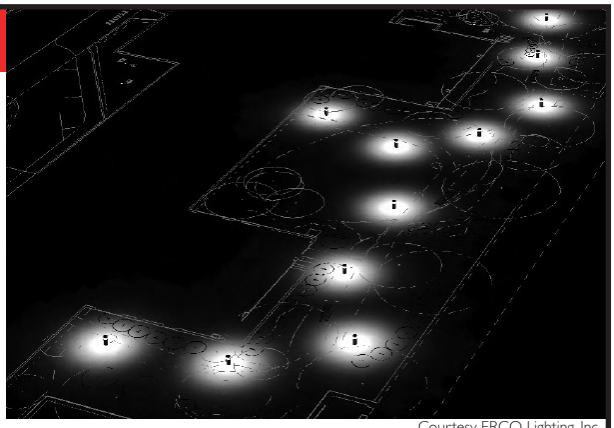
Weight Limits

A plaza or terrace must support the weight of pavers, landscaping elements, seating, fountains, pedestrians, and, in some cases, vehicles. Grade-level terraces may also need to bear fire equipment, in an emergency. Retrofitting an existing plaza or terrace requires consideration of structural load-bearing capacity, especially when a new type of system is being installed that carries significant load beyond that of the existing assembly.

To avoid serious structural failure, the project architect or engineer should assess load-bearing capacity before plaza rehabilitation is undertaken.

Fields of Green

As green building initiatives are prompting federal, state, and local mandates on efficiency and sustainability, building codes and regulations change to reflect evolving ecological guidelines. Relevant requirements for efficient water use, storm water runoff management, light pollution reduction, and energy conservation should be researched as part of the plaza or terrace design process. Some green ideas:



Courtesy ERCO Lighting, Inc.

- ***Reuse pavers,*** where possible, after replacing a waterproofing membrane, both to reduce waste and save on material expenses.
- ***Use "dark sky" technology,*** which employs strategically positioned, low-radiance lighting, low-angle spotlights, and low-reflectance surfaces to cut down on light pollution. See sample plaza lighting diagram, *above*.
- ***Choose materials that reduce the "heat island effect."*** Heat-trapping materials like asphalt, tar, and non-pigmented concrete raise air temperatures in cities. Besides plantings, which dissipate heat through evapotranspiration, certain building materials, like light-colored pavers, can help moderate temperature differences.
- ***Select native or adaptive plantings*** to conserve water and provide a habitat for bird and insect populations. Limit sod and turf grasses, which demand copious irrigation, mowing, and pest/weed control.
- ***Use efficient drip systems*** or subsurface sprinklers, in conjunction with reclaimed water, wherever irrigation is needed.
- ***Install "smart" controllers*** that vary light and water use by season, time of day, and weather.
- ***Employ mulching, alternate mowing, and composting,*** low-tech solutions that protect the environment and cut upkeep costs.

Above all, correct design and installation is the best way to build an environmentally sound plaza. When poor construction shortens a plaza's lifespan, resources are wasted on rebuilding. The most ecological plaza is the one built to last. ■

The Final Design

Drainage

Once owner's expectations, usage, weight limitations, applicable building codes, and traffic exposure have been considered and a plaza system selected, it's time to prepare the deck slope. Some original concrete decks were constructed dead level, leading to standing water and leaks. To correct the problem, slope fill may need to be added, which can create waterproofing challenges during construction, as well as raise load-bearing concerns. For areas that will contain tables and chairs, a 1/4 inch per foot slope is generally sufficient and maintains a suitable walking surface. However, a 1/4 to 1/2 inch per foot slope or more provides better drainage.

Drains should allow for water removal not only at the surface, but at the membrane or deck level, as well. Bilevel drains prevent trapped water from pooling atop the membrane, leading to premature deterioration. A combination of *trench drains*, which collect water from a larger area but are not designed for subsurface drainage, and *area drains*, which are smaller but both efficient and bilevel, is often the best strategy for optimal drainage.

Appearance

Materials. Plaza design must integrate the aesthetics of the outdoor space with those of the structure and surrounding area. Pavers of natural stone, brick, or concrete are the most common options, and care must be taken to balance appearance of these materials with their durability.

To avoid slippery surfaces, the coefficient of friction of various finishes must be considered, as well. Ice and snow removal approaches will also need to vary depending on the material selected, as some pavers respond better than others to deicing chemicals and snowplows.

Landscaping. Caretaking demands for landscaping can vary widely. Some plantings will demand daily mowing, weekly pruning, or monthly replacement, as well as costly irrigation systems, while many native or adaptive plants can get by with only natural rainfall and minimal attention. Ecologically conscious landscaping design therefore saves not only on natural resources, but on costs.

Additionally, planters require special waterproofing considerations, including root barriers and other extra protection over the membrane to avoid puncture. Structural load capacity may also be an issue when selecting plantings; beyond the weight of the plants themselves, growing media ranges in density and can add significant load.

Water features. Fountains and pools demand extra attention to waterproofing, especially over occupied space. Generally, a continuous waterproofing system is preferred, which can smoothly accommodate transitions from horizontal to vertical surfaces. Size and position of water features may also be dictated by traffic patterns, drainage sloping, and structural capacity, as well as aesthetics.

Furniture. Seating can rest atop pavers, as with dining chairs and other temporary furniture, or it can be anchored to the plaza. Waterproofing and paving system options therefore may be dependent on the quantity and design of any furniture or ornamental elements.

Lighting. Safety and appearance of a plaza or terrace at night depend on the quality and positioning of illumination. A plaza which sees significant nighttime traffic will need thoughtfully designed lighting, including within fountains and around planters, to preserve the ambiance and protect pedestrians. More is not necessarily better: indiscriminate use of bright lights casts stark shadows and can actually diminish visibility, and it also contributes to light pollution.

Budget

Initial installation and materials costs play a role in plaza design, but so do maintenance expenses. Be sure to understand up front what upkeep will be required for any systems under consideration. Some paving assemblies, such as sand-set systems, can be significantly cheaper to install, but demand vigilant maintenance to keep overgrown weeds from making the plaza look ragged and unkempt.

For elevated plazas or terraces over occupied spaces, it can be tempting to cut costs by going with a less pricey waterproofing option, as the membrane lies below the surface, out of view. However, scrimping on waterproofing can cost more than it saves if the membrane fails prematurely, and the entire paving overburden must be ripped up to replace it.

Accessibility

Local building codes, as well as the Americans with Disabilities Act (ADA), dictate the incorporation of ramps, elevators, railings, and other accessibility provisions. Substantial rehabilitation of a plaza provides an opportunity to upgrade entrance and egress pathways to admit wheelchairs, strollers, or walkers, without compromising on aesthetics.

Schedule

All rehabilitation projects for plazas over occupied space are, by necessity, on a tight schedule, as removal of the waterproofing system for any period of time opens the building up to water entry. Even plazas on grade may need to remain operational during construction, because of local government requirements, building access issues, or both. Organizing a plaza or terrace project into well-orchestrated phases can permit continuous usage while accomplishing rehabilitation objectives.

The time of year at which a given waterproofing assembly can be

(continued on page 8)

Maintaining Your Investment

You've invested in rehabilitating your plaza or terrace, and it looks great. How do you keep it up?

A little prevention goes a long way. By catching small problems before they become big ones, you can extend the lifespan of your plaza and avoid the undue expense of major repairs.

Daily. Sweep and remove trash and debris. Check for and treat ice and snow accumulation and clear tripping hazards.

Weekly. Wash down plaza. Clean joints and check drains and sump pumps. Trim and weed plantings and check for proper operation of irrigation systems. Do a safety check of railings, stairs, and lights.

Monthly. Replace dead plantings. Repair deteriorated mortar or sealant in joints.

Seasonally. Inspect sprinkler systems. Perform checks of the deck for deterioration, leaks, cracks, or rust. Repair rust spots on railings, conduits, and other metal.

Annually. *Fall:* Drain irrigation and sprinkler systems for winter. *Spring:* Conduct a structural inspection to plan for summer repairs.

Every 3-5 years. Replace sand in sand-swept butt joints.

If any leaks are reported, inspect and repair the waterproofing system as soon as possible to avoid further damage. Know your rights within the waterproofing warranty. If the problem persists, a design professional experienced in plaza remediation may need to conduct a more thorough investigation. ■

representative projects

Plaza and Terrace Rehabilitation

Hoffmann Architects focuses exclusively on the outsides of existing buildings. A substantial portion of our practice involves diagnosing and correcting problems within plazas, terraces, roof setbacks, and courtyards.

For plazas and terraces over occupied space, Hoffmann Architects solves recurrent water infiltration by treating these areas as roofs that need extra protection, rather than as platforms for traffic on which waterproofing is merely an afterthought.

We create aesthetically appealing, technically appropriate plaza and terrace solutions by locating the sources of deterioration and developing targeted programs of replacement or repair. Project oversight and guidance for ongoing maintenance see the rehabilitation through to a successful outcome, now and in the long term.

Among Hoffmann Architects' plaza and terrace projects are:

College Walk
Columbia University
New York, New York
Plaza Reconstruction

Phoenix Life Insurance Company
One American Row
Hartford, Connecticut
Plaza Investigation

The World Bank
Washington, District of Columbia
Terrace Waterproofing System Design

The George Washington University's Eye Street Pedestrian Mall in Washington, DC.
Plaza Design and Rehabilitation

Royal Bank of Scotland
Greenwich Capital Building
Greenwich, Connecticut
Plaza Rehabilitation

Purchase Campus Center
State University of New York (SUNY)
Purchase, New York
Plaza Reconstruction

Franklin & Marshall College
Keiper Hall/Green Room Theatre
Lancaster, Pennsylvania
Plaza and Stair Rehabilitation

The Ford Foundation
New York, New York
Plaza Rehabilitation

The Schering-Plough Corporation
Kenilworth, New Jersey
Plaza Investigation and Design

Paul Rudolph Hall
Yale University
New Haven, Connecticut
Terrace, Exterior Stair, Roof, and Skylight Rehabilitation and Reconstruction

Babbidge Library, White Building, and Bousfield Hall
University of Connecticut
Storrs, Connecticut
Investigation and Rehabilitation of Plazas and Exterior Stairs

Manhattan House
O'Connor Capital Partners
New York, New York
Roof Garden and Terrace Rehabilitation

State of Connecticut Office Building
25 Sigourney Street
Hartford, Connecticut
Plaza Rehabilitation

Hoffmann Architects, Inc.
2321 Whitney Avenue
Hamden, CT 06518

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(continued from page 6)

This multi-level plaza over occupied space coordinates temporary and fixed furniture and planters with high- and low-traffic areas to achieve a practical, aesthetically appealing outdoor space.

installed may also affect a rehabilitation project's scheduling. For example, adhesives and fluid-applied membranes must generally be applied when air temperatures are above approximately 40°F and below 80°F, which may mean scheduling installation for late spring or early fall. Coordinating seasonal restrictions with building usage demands and weather events can pose significant logistical challenges.

When to Rehabilitate: Cost-Benefit Analysis

Plazas and terraces are appealing features that attract tenants, raise property values, and provide aesthetically pleasing outdoor public spaces. Unfortunately, many suffer from poor design, inappropriate materials selection, faulty installation, or simply the effects of time and the elements. If your plaza or terrace evidences the following or other burdensome conditions, rehabilitation might prove cost-effective:

- Deterioration
- Decreased usage
- Rising maintenance expenses
- Increased liability

Facing an ailing plaza can be daunting. But those who brave a plaza overhaul with forethought and care are rewarded with a functional, pleasant open space that demands little attention or resources once it's in place. ■

JOURNAL is a publication of Hoffmann Architects, Inc., specialists in the rehabilitation of building exteriors. The firm's work includes investigative and rehabilitative architecture and engineering services for the analysis and resolution of problems within roofs, facades, glazing, and structural systems of existing buildings, plazas, terraces and parking garages.

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www.hoffarch.com

Editor: Alison Hoffmann
Production: Cari Tate

Printed on 50% recycled paper:

Tech Spec 14

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Segmental Concrete Paving Units for Roof Decks

Introduction

An increasing amount of new and rehabilitated roof decks use segmental concrete paving units to support pedestrian and vehicular applications. The units provide an attractive, durable walking surface for pedestrian plaza decks. They can be used to create outdoor space, usable exterior living environments at commercial and residential buildings e.g. next to offices, hotels, hospitals, universities, observation areas on commercial buildings and at cultural centers. See Figure 1. Parking structures and the roof decks of underground buildings use concrete pavers to support vehicular traffic as shown in Figure 2.

Segmental concrete paving units protect roofing materials from damage due to foot traffic, equipment, hail and vehicles. Concrete provides a heat sink that reduces the thermal stress and deterioration of waterproofing materials. The units flex with the movement of the structure as well as with vehicular and seismic loads. Additionally, the units provide a slip-resistant surface and are especially attractive when viewed from adjacent buildings. They can exhibit high durability under freeze-thaw and deicing salt conditions.

A primary role of segmental concrete units is ballast for roofing materials to prevent uplift from high winds. When caught by high winds, gravel ballast on roofs can shift and distribute unevenly. This leaves roof materials exposed to winds, thereby increasing the risk of their uplift. In some cases the gravel can be blown from roofs creating a hazard for glass, pedestrians and vehicles. Concrete units are preferred over gravel ballast because they provide a consistent, evenly distributed weight for protection from wind uplift and damage. Furthermore, concrete unit paving is required by many building codes as roof ballast for high-rise buildings.

This Tech Spec provides guidance on the design and construction of roof assemblies using precast concrete pavers or concrete paving slabs using with various setting methods for pedestrian and vehicular applications. There are many kinds of roof assemblies placed under these types of paving units. The compatibility of paving units and setting methods with the components of roofing assemblies such as waterproof membrane, protection board and insulation should always be verified with the manufacturers of such components.

Vegetated, low-slope roof surfaces or "green roofs" are receiving increased attention from designers and clients interested in reducing building energy costs and the urban heat island. This trend is changing the aerial view of our cities. Furthermore, sustainable building rating systems such as LEED® recognize green roof technology as well as highly reflective roof surfaces. Concrete unit paving offers designers a reflective surface that can be easily integrated into green roof projects while earning LEED® credits. *ICPI Tech Spec 16-Acheiving LEED® Credits with Segmental Concrete Pavement* provides additional information on how to integrate green roofs with concrete unit paving.

Figure 1. Concrete pavers provide a durable and attractive roof plaza deck surface. At left is the observation deck on the 86th floor of Empire State Building in New York City. At center is a hotel plaza deck constructed with concrete paving slabs.

Figure 2. Concrete pavers serve vehicular traffic and parking over a concrete parking structure next to a residential development.

Figure 3. Concrete paver (right) and a concrete paving slab (left): similar paving products with varying applications for roof decks.

Figure 4. Some ballast-type slabs for roof decks are made with lightweight concrete materials. They can be joined with tongue-and-grooves and/or with connectors to resist wind uplift. This is one of several designs available.

Plaza Deck Components

Concrete pavers and slabs—There are two categories of segmental concrete deck materials for roofs, concrete pavers and slabs. See Figure 3. Concrete pavers are units that are a minimum thickness of 2 3/8 in. (60 mm) and whose length to thickness (aspect ratio) does not exceed 4 to 1. They conform to the requirements of ASTM C 936 (1) in the U.S. or CSA A231.2 (2) in Canada. These units can be used in pedestrian and vehicular applications. Concrete pavers 2 3/8 in. (60 mm) thick are commonly used in pedestrian plaza or terrace applications. When the capacity of the structure is limited to additional weight, units as thin as 1 1/2 in. (40 mm) have been used in pedestrian applications. For vehicular uses, the recommended minimum thickness of units is 3 1/8 in. (80 mm).

Precast concrete paving slabs range in nominal size from 10 x 10 in. (250 x 250 mm) to 48 x 48 in. (1200 x 1200 mm). These products should conform to CSA A231.1 (3) in Canada ASTM C1782 (4) in the US. Like pavers, concrete paving slabs can be manufactured with a variety of colors, special aggregates and architectural finishes to enhance their appearance. Surface finishes include shot-blasted, hammered and ground or polished. They differ from pavers in that slabs typically require at least two hands to lift and place them, and the length to thickness (aspect ratio) is 4 to 1 or greater. Paving slabs generally range in thickness from 1 1/2 in. to 2 in. (40 to 50 mm) and thicker units are also applied to roofs. Slabs are only for pedestrian plaza applications and are not recommended for vehicular use. Slabs risk tipping, cracking from bending forces, and shifting under repeated forces from turning and braking tires.

In ASTM and CSA paving slab product standards, flexural (rather than compressive strength) is used to assess unit strength since the larger slabs are exposed to bending and cracking. Compressive strength is excluded from these standards because it is not a true measure of the performance of the concrete. It can increase as the thickness of the tested unit decreases. Therefore, a high compressive strength test result required from a thin slab gives a false indication of a slab's resistance to bending since thinner slabs will break in bending more readily than thicker ones.

Unit dimensions are measured on samples and compared to the dimensions of the manufacturer's product drawings. Allowable tolerances for length and width in ASTM C1782 and CSA A231.1 (3) are –1.0 to +2.0 mm from the manufacturer's product drawings. Height should not vary ±3.0 mm. Units should not warp more than 2 mm on those up to 450 mm in length and/or width. For units over 450 mm, warping should not exceed 3 mm. Tighter dimensional tolerances may be required for pedestal-set, bitumen-set and some sand-set applications. Recommended tolerances are typically ±1.5 mm for length, width, height and no greater than 1.5 mm for warpage. These tolerances are needed for precision required in these construction assemblies and management of tripping hazards. These tolerances are often met through grinding the units, also called gauging.

There are some lightweight, low-flexural strength ballast slabs (mistakenly named roof pavers) manufactured with a tongue-and-groove or bevels along their sides to increase their interlock. Other designs include plastic fasteners to connect one unit to the next. These methods of joining the sides to one another provide greater resistance to uplift from wind. Figure 4 illustrates one type of unit with tongue and grooved sides (not visible) and connecting tabs between each unit. Some of these types of units are made with lightweight concrete, or are thinner in order to reduce the dead load on the roof structure. Some designs have grooves on their bottom surface. When installed, these follow the roof slope to help remove water. These types of units offer limited architectural enhancement from patterns, colors, or surface finishes.

ASTM has issued C1491, *Standard Specification for Concrete Roof Pavers* (5). This product specification is appropriate for ballast-only type paving units (pavers or slabs) used

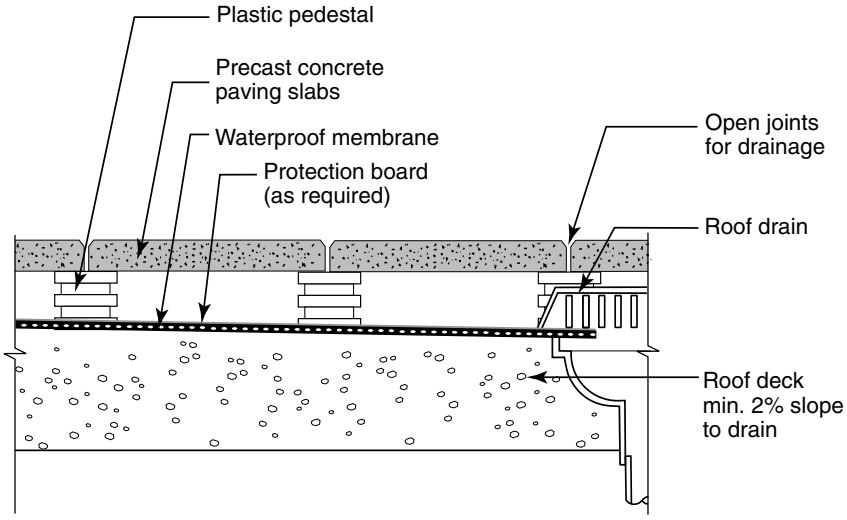

Figure 5. Paving slabs on pedestals

Figure 6. Foam pedestal system

Figure 7. Concrete pavers on geotextile over plastic grids

only in direct contact with roof materials and only for limited pedestrian use such as walkways for maintenance personnel. Products that meet this standard should not be subject to constant pedestrian use, not placed on pedestals and never be subject to vehicles. Specifiers and contractors are advised to use roof paving products for vehicular and pedestrian applications that meet the previously mentioned ASTM or CSA standards. ICPI takes a conservative approach by not recognizing differences among shapes with respect to structural and functional performance. Certain manufacturers may have materials and data that discuss the potential benefits of shapes that impact functional and structural performance.

Setting materials

Pedestals—Paving slabs for plaza decks are often placed on plastic or fiberglass pedestals. The result is a level deck, concealment of slope and drains and water storage space under the units during very heavy rainfalls. Pedestal-set paving units install quickly and enable fast removal for repair of waterproofing materials and for maintenance of deck drains. The units can be reinstated after repair with no visible evidence of movement. Damaged paving units can also be easily removed and replaced. Figure 5 shows a diagram of a pedestal system with paving slabs.

In most pedestal-set applications, units are 18 x 18 in. (450 x 450 mm) or larger but can be configured to support nearly any unit dimensions. The corners of paving units rest on plastic pedestals. These units usually require shimming after placement. Shims are inserted under the corners of a nonaligned paving unit until its surface is even with adjacent units. Some plastic pedestals have a built-in leveling device to reduce the amount of labor involved with shimming. Some are telescoping cylinders whose length can be changed by rotating an adjustable sleeve within another. Other designs have a base that tilts slightly to compensate for the slope of the roof.

Vertical spacers are often molded in the plastic pedestals to ensure uniform joint widths among the paving units. The open joints allow runoff to pass through them onto the waterproof membrane and into roof drains. The joint created by the spacer should not exceed $^{3}/_{16}$ in. (5 mm) and this will minimize the likelihood of tripping.

Another type of pedestal system consists of 8 in. (200 mm) square extruded polystyrene blocks (typically 2 in. or 50 mm thick) glued together, spaced on a grid across the deck and adhered to a polystyrene insulation board that rests on the waterproof membrane. Many contractors use 60 psi (0.4 MPa) polystyrene blocks to support the paving units. To support heavier loads, 100 psi (0.7 MPa) extruded or expanded polystyrene foam can be used. The bottom block of foam may have grooves in contact with roofing materials to facilitate drainage. The grooves should point toward drains.

A patented leveling system trims the tops of the polystyrene blocks to the required height. Shimming is not necessary except for the occasional paving unit that might be slightly out of dimension. Spacing is typically maintained with neoprene rubber spacer tabs adhered to the corners of the paving units, although plastic pedestals can be used. This pedestal system supports units up to 36 x 36 in. (910 x 910 mm). The foam pedestals can extend as high as 5 ft (1.5 m). Figure 6 shows the foam pedestals in place and receiving the paving slabs (6).

Another approach to creating roof decks is placing a plastic or fiberglass grid system, geotextile, pavers and jointing sand.

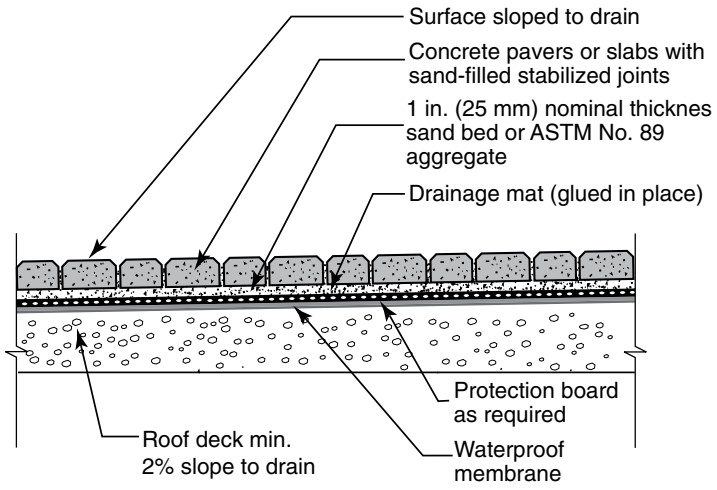

Figure 8. Sand-set concrete pavers or slabs for a pedestrian roof plaza deck. Units no larger than 12 x 12 in. (300 x 300 mm) length and width are recommended for sand-set applications to avoid tipping.

Gradation for Bedding Sand			
ASTM C33		CSA A23.1 FA1	
Sieve Size	Percent Passing	Sieve Size	Percent Passing
3/8 in.(9.5 mm)	100	10.0 mm	100
No. 4 (4.75 mm)	95 to 100	5.0 mm	95 to 100
No. 8 (2.36 mm)	80 to 100	2.5 mm	80 to 100
No. 16 (1.18 mm)	50 to 85	1.25 mm	50 to 90
No. 30 (0.6 mm)	25 to 60	630 µm	25 to 65
No. 50 (0.3 mm)	5 to 30	315 µm	10 to 35
No. 100 (0.15 mm)	0 to 10	160 µm	2 to 10
No. 200 (0.075 mm)	0 to 1	80 µm	0 to 1

Note: Bedding sands should conform to ASTM C33 or CSA A23.1 FA1 gradations for concrete sand. For ASTM C33, ICPI recommends the additional limitations on the No. 200 (0.075 mm) sieve as shown. For CSA A23.1 FA1, ICPI recommends reducing the maximum passing the 80 µm sieve from 3% to 1%.

Gradation for Joint Sand			
ASTM C144		CSA A179	
Sieve Size	Percent Passing	Sieve Size	Percent Passing
No. 4 (4.75 mm)	100	5.0 mm	100
No. 8 (2.36 mm)	95 to 100	2.5 mm	90 to 100
No. 16 (1.18 mm)	70 to 100	1.25 mm	85 to 100
No. 30 (0.6 mm)	40 to 75	630 µm	65 to 95
No. 50 (0.3 mm)	10 to 35	315 µm	15 to 80
No. 100 (0.15 mm)	2 to 15	160 µm	0 to 35
No. 200 (0.075 mm)	0 to 5	80 µm	0 to 10

Table 1. Bedding and Joint Sand Gradation for Concrete Pavers and Paving Slabs for Roof Decks

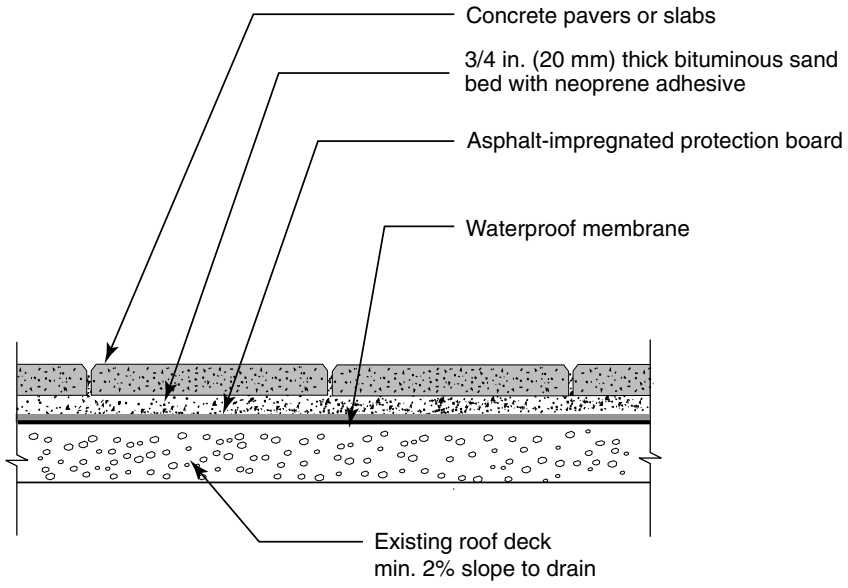

Figure 9. Neoprene adhesive on an asphalt-stabilized sand setting bed

With any segmental paving system, the final, installed result should provide a smooth, stable, and even surface. For pedestrian plaza deck applications, lipping tolerances among adjacent paving units should be no greater than 1/8 in. (3 mm). Surface tolerances of the finished elevations should be no greater than ±1/8 in. (±3 mm).

Figure 8 shows this application as overlay onto an existing concrete roof deck. This assembly is for pedestrian applications only.

Bedding and Joint Sand for Pedestrian Applications—Sand-set pavers and slabs (up to 12 x 12 in. or 300 x 300 mm) are common options for pedestrian applications. The typical sand thickness is nominal one inch (25 mm). Figure 8 illustrates a sand-set application for pedestrians.

A key design consideration is not allowing the bedding sand to become saturated. Continually saturated sand and joints can support moss or vegetation that eventually clogs roof drains. Saturated sand can increase the potential for efflorescence that might exist in some concrete paving units. While not attractive, efflorescence will eventually disappear and it is not detrimental to structural performance.

The risk of saturated bedding sand is reduced by adequate slope of the roof structure and correct sand gradation. Sand requires at least a minimum deck slope of 2% to drain. Gradation of the bedding sand for pedestrian applications should conform to ASTM C33 (7) or CSA A23.1 "FA 1" (8). It is important that no material (fines) pass the No. 200 (0.075 mm) sieve as the presence of this size of material will greatly slow the movement of water through the bedding sand.

Grading Requirements for ASTM No. 9 and ASTM No. 89 Bedding Materials		
Sieve Size	ASTM No. 9 Percent Passing	ASTM No. 89 Percent Passing
1/2 in. (12.5 mm)	–	100
3/8 in. (9.5 mm)	100	90 to 100
No. 4 (4.75 mm	85 to 100	20 to 55
No. 8 (2.36 mm)	10 to 40	5 to 30
No. 16 (1.18 mm)	0 to 10	0 to10
No. 50 (0.300 mm)	0 to 5	0 to 5

Table 2. ASTM No. 9 or 89 materials for the bedding material may be an advantageous alternative to some sands for vehicular and pedestrian applications

Recommended gradations for pedestrian applications are provided in Table 1. Limestone screenings or stone dust should not be used since they typically have fines passing the No. 200 (0.075 mm) sieve. It is accepted construction practice to use bedding sand for joint sand. Additional effort in sweeping and compacting joint sand may be required to work the larger particles down the joints. The sand should be dry when applied so that it flows freely into the joints.

Bedding and Joint Materials for Vehicular Applications—As with pedestrian plaza or terrace applications, bedding materials for vehicular applications need to freely drain water so that they do not become saturated. Again, an essential roof structure requirement is a 2% minimum slope. Parking decks with saturated bedding sand subjected to constant wheel loads will pump sand laterally or upward and out of the paving assembly. Joint sand is carried out as well, and loss of interlock follows. An unstable surface results where loose pavers receive damage (chipping and cracking) from continued wheel loads. Loss and lateral movement of bedding sand can result in damage to and leaks in the waterproof membrane from loose paving units.

In a few older, vehicular roof deck applications, there have been instances of bedding sand becoming clogged with fines over several years. The source of fines is likely from a combination of a lack of adequate slope, dirt deposited from vehicles and sometimes from degradation and wearing of the sand into finer material under constant traffic. The fines eventually accumulate in the bedding sand and slow drainage.

To help prevent the bedding layer from becoming saturated or becoming clogged, bedding material with a coarser gradation than that shown in Table 1 may be advantageous for vehicular or pedestrian applications. An example is material conforming to the gradation of ASTM No. 9 or No. 89 aggregate (9). See Table 2. The void space in this aggregate can allow for movement and removal of fines.

Joint sand should have sufficient coarseness such that it does not vacate the joints by working its way down and into the bedding material. The bedding material gradation should overlap with that of ASTM C33 or CSA A23.1 joint sand to help prevent it from working into the bedding sand.

Joint Sand Stabilization—Joint stabilization materials are recommended in sand-set roof applications for pedestrian and vehicular use. They are applied as a liquid or mixed dry with the joint sand and activated by moistening the joints with water. These materials reduce infiltration of water and ingress of fines brought to the surface by vehicles, and they achieve early stabilization of joint sand. Stabilization can help prevent the joint sand from being washed out by rainfall or blown out by winds. *ICPI*

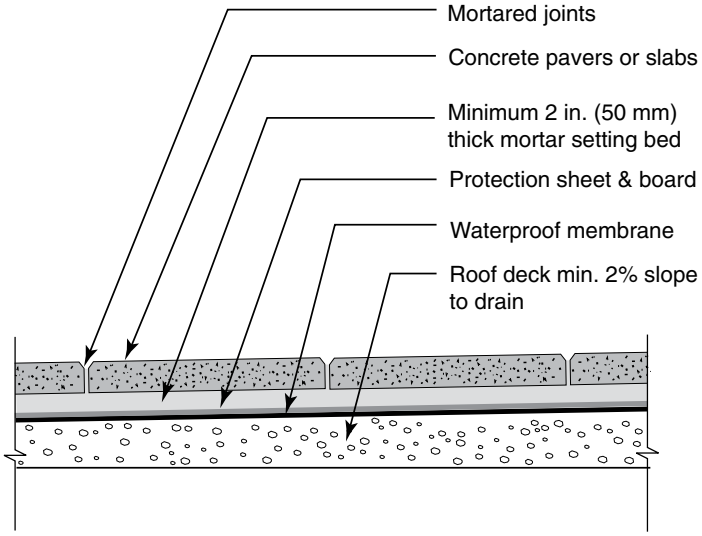

Figure 10. Mortar bed under paving units

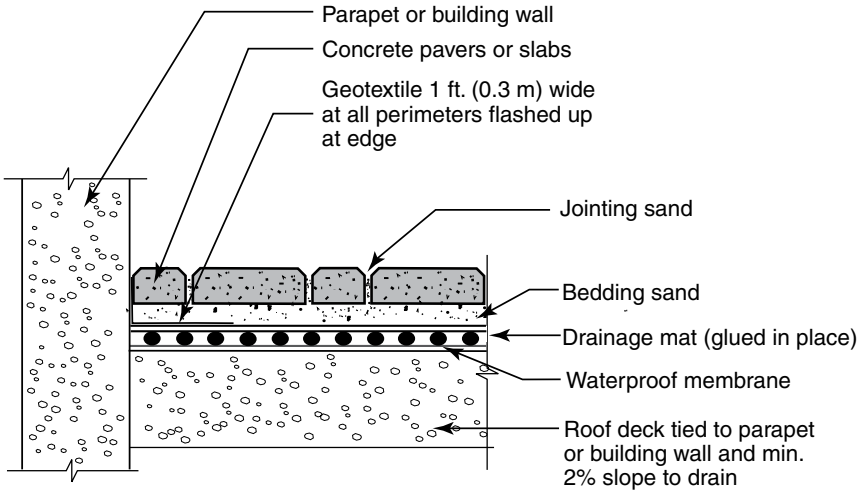

Figure 11. Detail showing geotextile at all edges of sand and aggregate bedding courses for a pedestrian application.

Tech Spec 5– Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavements offers further guidance on the types of joint stabilizers and their applications.

Neoprene adhesive with bitumen-sand bed—This setting method typically involves applying an asphalt primer to the substrate and then placing a 3/4 in. (20 mm) (1 in. or 25 mm maximum) thick asphalt-stabilized sand layer over it, followed by a neoprene adhesive. The sand asphalt mix is applied hot and compacted. The units are set into the adhesive after a dry skin forms and the joints are then filled with sand. Figure 9 provides a schematic cross-section. The waterproof membrane manufacturer should confirm compatibility of the primer, asphalt setting bed and adhesive with the membrane. Joint sand stabilizer can provide early stabilization of the joint sand. Cement mixed with sand to stabilize it in joints is not recommended since the cement can stain the surface of the paving units.

Drainage for roof applications should use bi-level drains which provide surface and bedding layer drainage. Bi-level drains include holes in the sides of roof drains to remove water that collects below the paving units. Details on drains are discussed later.

Mortar—While it is not a common setting material, a mortar bed (approximately 3:1 sand to cement) may be used to level and secure pavers or slabs. This setting method is not used over drainage mats. See Figure 10. Like a bitumen setting bed, mortar is costly to remove and replace should there be a need for roof maintenance. In addition, mortar deteriorates in freeze-thaw climates, and especially when exposed to deicing salts. In ASTM C270, *Standard Specification for Mortar for Unit Masonry,* the Appendices include a table on the Guide for the Selection of Masonry Mortars. While Type S is recommended, the guide states caution in selecting mortar for horizontal applications. While they are not foolproof, latex or epoxy modified mortars can reduce the onset of deterioration from freeze-thaw and salts making them acceptable for some pedestrian applications. However, loading and environmental factors preclude the use of mortar-set paving units for vehicular applications, and this setting method is better suited for non-freezing areas.

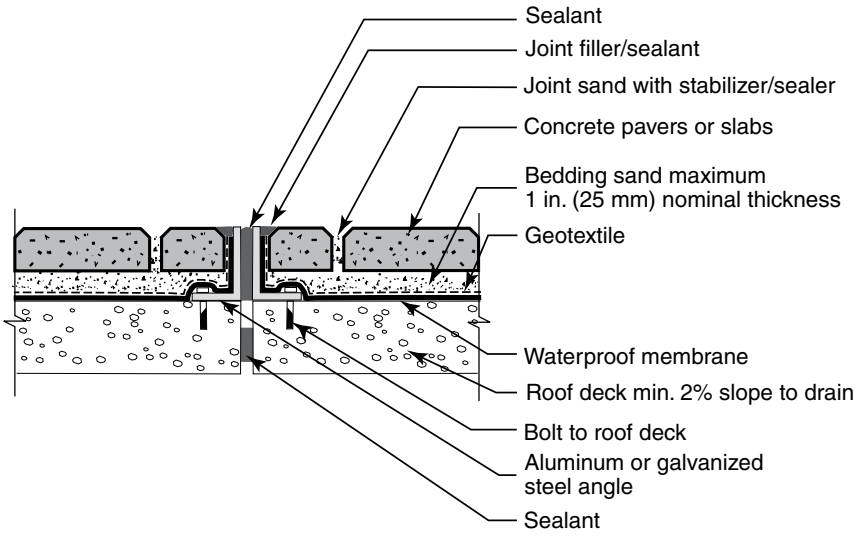

Figure 12. Edge restraint detail at a roof construction joint for pedestrian roof applications (14)

Geotextiles, Protection Board, Insulation and Drainage Mats

Geotextiles—With sand or aggregate bedding materials, geotextile will be needed to contain them and keep them from migrating into deck drains or through wall drains such as scuppers. In addition, sand or aggregate requires geotextile under it to prevent loss into the protection board and insulation (if used). Geotextile manufacturers should be consulted on geotextile selection. The fabric should be turned up against drains, vents and other protrusions in the roof and along parapets and walls.

To contain sand and aggregate bedding materials, the geotextile should extend up the side. Figure 11 shows this detail which will help prevent loss of bedding materials from a deluge of rainfall that causes temporary ponding around the drains. A separate piece of geotextile is wrapped around the roof drain to prevent loss of bedding sand or aggregate.

Protection board—Most waterproofing systems require a protection board over them to prevent damage to the waterproofing from paving units and to reduce thermal stresses from temperature changes. This can be an asphaltic protection board or other materials. The manufacturers of waterproofing systems can provide guidance on the use of protection layers and they can recommend specific materials when this option is required. Protection board is generally not used in vehicular applications.

Insulation—If a pedestrian plaza deck covers an inhabited space, insulation may be required. Insulation typically consists of foam or fiber boards placed over the waterproofing. Sometimes they are adhered directly to the waterproofing. Insulation may be tapered to roof drains to facilitate movement of water into the drains. Insulation board in contact with the waterproof membrane should have drainage channels to facilitate drainage of water under it. Insulation under pavers in vehicular applications requires careful design and execution. As with other engineered pavements, consult an experienced designer familiar with these applications. A secure location for insulation is sandwiched in place inside the concrete deck.

Drainage mats—Drainage mats are generally placed under bedding sand and over waterproof membranes to accelerate drainage of water from the sand. Drainage mats are typically 1/4 to 3/8 in. (6 to 10 mm) thick. They consist of a plastic core, called a geonet, covered by geotextile. Some geonets are a "dimpled" plastic sheet, which will have limited ability to support load. Geonets that have a lattice like structure are capable of carrying greater loads. The geonet and geotextile support and contain the bedding sand under the paving units while allowing water to move into it and laterally to roof drains. They are recommended in pedestrian applications under a sand setting bed. They should be placed at a minimum of 2% slope.

Installation of drainage mats for pedestrian applications should start at the low-

est slope on the roof with the work proceeding upslope. Flaps on each should go under the next (in a manner similar to placing roof shingles) so that the water drains from one section to the next. This helps prevent water from leaking under the mats. While mats reduce the amount of water reaching the waterproof membrane, they are not a substitute for deck waterproofing. The paving installation contractor should install mats.

Drainage mats are typically supplied in rolls making them difficult to flatten, and they often don't remain flat during installation. An adhesive between the mat and waterproof membrane will likely be required to maintain flat drainage mats during their installation. Before using an adhesive, confirm that it will not harm the other materials oand in particular the waterproof membrane.

Drainage mats can be used under foam or plastic pedestal systems. While drainage mats may be tested according to the compressive strength test method in ASTM D1621 (10), they may require additional testing by pre-loading to ensure that they will not crush under loads from the pedestals.

Drainage mats should not be used under vehicles. Mats deflect under wheel loads, eventually fatiguing, compressing and deforming. Repeated deflection tends to shift the pavers, bedding and joint sand, making interlock difficult to maintain. The deflection causes the joint sand to work its way into the bedding and the bedding sand shifts under loads, especially when saturated. The loss of joint and bedding sand, with possible eventual crushing of the mat, retains water and this can saturate the bedding sand.

Waterproof Membranes

The choice of waterproofing is influenced by the application, the project budget, the deck materials under it and the type of structure supporting the roof. There are three broad types of waterproofing materials used under concrete paving units. They are single-ply, liquid membranes, built-up or modified bitumen roofing. A brief description of these materials follows with their compatibility to segmental paving (11,12).

Single-ply roofing is strictly for pedestrian applications and it is the most widely used waterproofing. It is typically made from vulcanized (cured) elastomers such as ethylene propylene diene monomer (EPDM), neoprene, or butyl. These flexible sheets have excellent weathering properties, high elongation and puncture resistance. When assembled on a roof, the sheets are spliced together at the job site with an adhesive. The entire assembly of sheets can be loose-laid and ballast provided by paving units. They also can be partially or fully adhered, or mechanically fastened to the roof deck.

Another type of single-ply membranes includes non-vulcanized elastomers such as polyisobutylene (PIB), chlorinated polyethylene (CPE), chlorosulfanated polyethylene (CSPE). These materials are usually reinforced with a polyester mat laminated between two plies. Thermoplastics such as polyvinyl chloride (PVC) sheets are heat welded in the field. Like the elastomers, PVC is loose-laid with ballast paving units, partially or fully adhered, or mechanically fastened to the deck material.

Rubberized asphalt membranes and polyethylene laminates have been used extensively to waterproof pedestrian plaza decks. Prefabricated sheets are made in small sheets and are spliced together in field. They generally are fully adhered to the concrete deck, so their longevity is highly dependent on the quality of the workmanship in splicing and on the smoothness and quality of the concrete.

Manufacturers of single-ply membranes should be contacted about the extent of warranties on the field splices under paving units. Additional measures may be necessary to protect the splices from the paving. This can include installation of a second, sacrificial membrane layer directly under the paving units.

Liquid applied membranes are installed either hot or cold depending on the materials. Rubberized asphalt membranes are hot applied to the concrete deck to form a continuous coating with no seams. These are for pedestrian plaza decks only. Cold-applied liquid resins and elastomers such as polyurethane are generally suitable as waterproofing on concrete decks subject to vehicular use. Sprayed-in-place polyurethane foam acts as an insulator and as waterproofing. The material is soft and is not recommended for use with concrete paving units.

Built-up roofing is made from paper, woven fabric or glass fiber mats, polyester mats or fabrics adhered together in alternating layers with bitumen or coal tar. The exterior surface of the layers is covered with bitumen or coal tar. Built-up roofs use concrete pavers or slabs as a walking surface to prevent wear and puncture of the membrane, especially around mechanical equipment. The use of pedestal systems should be avoided in built-up roofing due to the likelihood of indentations in the layered waterproofing materials.

Modified bitumen consists of plastic or rubber additives pressed into asphalt sheets. They are installed by heating the sheets with a torch and applying them to the deck substrate, or by mopping bitumen and securing them to the substrate with it. Some systems use cold cement or mastics to adhere the sheets to the substrate. Some modified bitumen waterproofings create overlap "bumps" every yard (meter) or so. There can be an additional construction cost to avoid these when using a pedestal system. These systems do not require segmental paving ballast unless insulation needs to be secured in place. While these systems are generally compatible with concrete paving units in pedestrian applications, manufacturers should be contacted for verification of use with paving units under vehicular traffic.

Each of these waterproofing systems has advantages and disadvantages on speed of installation, costs, durability and

Figure 13. An absence of edge restraints and use of a sealant in this construction joint caused the pavers to shift and open their joints on both sides of the sealant.

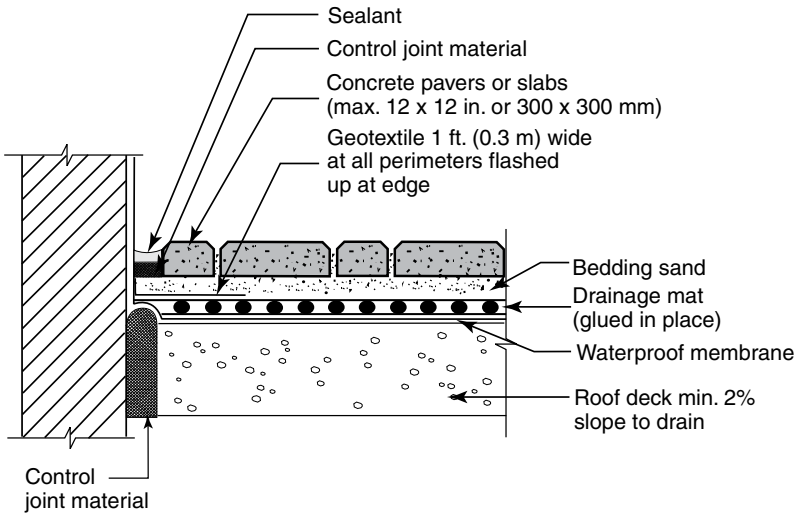

Figure 14. Detail at building wall not joined to decking using paving units and bedding sand with a drainage mat for pedestrian applications only

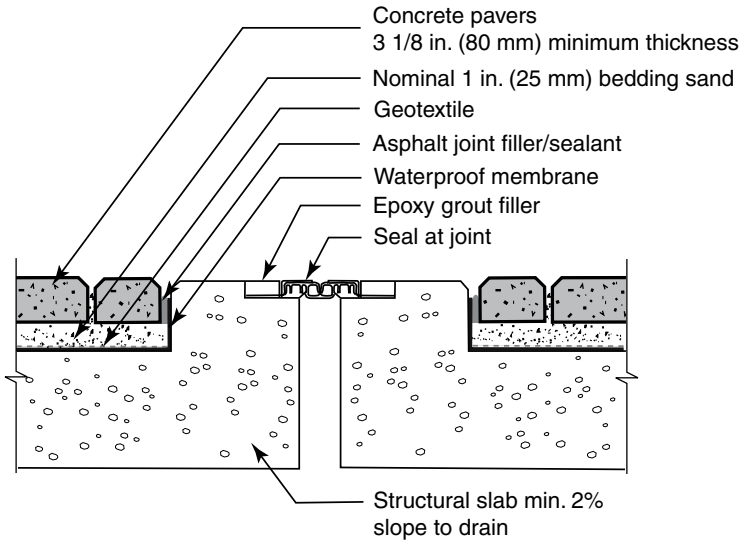

Figure 15. Edge restraint detail at a roof expansion joint for vehicular applications

manufacturer warranties. Many waterproof membrane manufacturers require the use of roofing contractors that have been certified to install a particular manufacturer's roofing system. The subject of roof waterproofing is large and outside the scope of this publication. There are many references on roofing and waterproofing systems. An overview is provided in *Roofing—Design Criteria, Options, Selection* (12). Other resources are publications by the National Roofing Contractors Association at http://www.nrca.net and the Roof Consultants Institute at http://www.rci-online.org.

Deck Structure Systems

Concrete—There are four types of concrete deck structural systems (11). They are reinforced concrete slabs, post-tensioned slabs, prestressed precast elements such as "T" beams with a concrete topping, and concrete poured onto and formed by steel decks. Each type responds to waterproofing differently. For example, volumetric changes in reinforced concrete slabs can cause reflective cracking in liquid-applied membranes and some fully adhered bituminous systems. Post-tensioned slabs are generally suited for liquid applied membranes because the slabs have a low amount of deflection and cracking. Loose-laid waterproofing systems are suited for over precast elements because they can accommodate the many joints in the deck, whereas liquid-applied and fully adhered membranes are prone to reflective cracking and splitting at joints.

In lighter, less expensive roofs, the concrete deck is poured onto and formed by a corrugated steel deck. In some cases the concrete is lightweight, i.e., weighing less per cubic foot or cubic meter than ordinary ready-mixed concrete. The weight of lightweight concrete is reduced by using lighter aggregates and by air-entraining the concrete mix. Lightweight concrete reduces loads on the columns and beams, thereby reducing their size and expense. (See Reference 13 for further information on lightweight concrete.) Steel decks topped with concrete should be vented so that moisture can escape if waterproofed with liquid-applied or fully adhered materials. Some waterproofing manufacturers do not recommend use of their materials over lightweight concrete.

Steel—Corrugated steel decks are generally covered with insulation and loose-laid single-ply membranes. This inexpensive assembly often uses ballast made with lightweight concrete paving units. These assemblies typically do not use heavier precast concrete pavers or paving slabs.

Design Considerations

Detailing for movement for pedestrian applications—Roof joints should be located when there is a change in roof direction, dimension, height, material, or when there are extreme differences in humidity or temperature within a building. Most roof structures have joints that allow each part of the structure to move independently due to settlement, seismic activity and thermal expansion/contraction. There is

Figure 16. An absence of holes in the sides of this roof drain led to ponding.

usually a flexible sealant in the joint to prevent water from entering and leaking into the space below. The sealant can be a compression seal squeezed into the joint, or a more expensive and durable strip seal. A strip seal is a length of flexible material fastened to metal clips secured to the concrete deck. The strip seal flexes with the movement of the adjacent structures.

Figure 12 illustrates a joint in a concrete structure and with sand-set paving units over it. Expansion joints should be treated as pavement edges. As with all segmental pavement construction, an edge restraint is required to hold the units together. Figure 12 shows steel angle restraint on both sides of the joint and secured to the concrete deck. There should be a compression seal at the top against the steel edge restraints, as well as one between the concrete decks. This detail is recommended at roof expansion joints for pedestrian applications.

This detail shows the paving pattern stopping at a joint in the deck and resuming on the opposite side. The sealant is joined to the edge restraint and not to the sides of the paving units. The use of a sailor or soldier course of pavers on both sides of the joint will present a clean visual break in the pattern. Figure 13 shows the consequences of not stopping the pattern with an edge restraint at an expansion joint. The pavers separated and exposed the bedding sand and waterproof membrane.

Parapets or building walls can typically serve as edge restraints. For sand-set paving assemblies, expansion material should be placed between the outside edge of the pavers and vertical walls of buildings when functioning as separate structures from the deck on which the paving units rest. Figure 14 shows this detail with expansion material. It should not adhere to the paving units or the wall, but should independently expand and contract with their movement. Expansion materials at the perimeter of the pavers are not necessary to place against walls or parapets when the pavers are resting on the same structure as the walls. Figure 11 illustrates this condition.

Detailing for movement for vehicular applications—Figure 15 details an expansion joint in a roof application subject to vehicles such as a parking structure. Although compression seals can be used, this assembly uses a strip seal for bridging the joint. The ends of the concrete deck are formed as edge restraints to hold the concrete pavers in place.

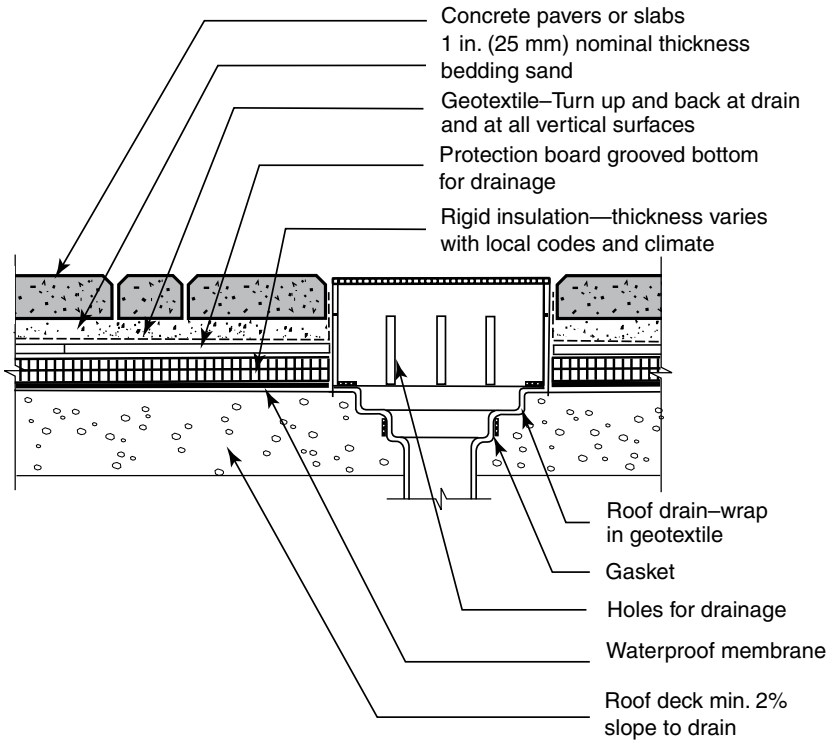

Figure 17. A bi-level drain detail for a pedestrian plaza deck over habitable space.

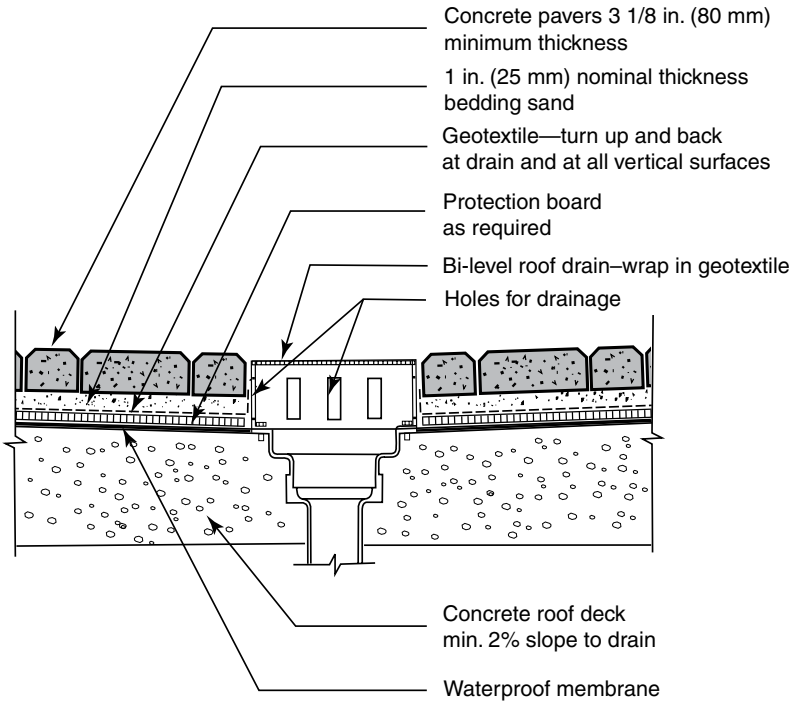

Figure 18. A bi-level drain detail on a vehicular roof application.

2 3/8 in. (60 mm) vs. 3 1/8 in. (80 mm) thick pavers for vehicular applications—Most vehicular applications with pavers are supported by a concrete structure. The support from such a structure is often used as rationale for using pavers that are less than 3 1/2 in. (80 mm) thick. Thicker units render greater vertical and rotational interlock. Using concrete pavers less than 3 1/2 in. (80 mm) thick in vehicular of applications increases the risk of reduced surface stability by reducing horizontal and rotational interlock under turning and braking vehicles.

Weight—Concrete pavers, slabs and bedding materials exert

substantial weight on roof structures. The structure supporting these materials should withstand dead and live loads. The advice of a structural engineer should be sought to assess the capacity of the roof and tolerable deflections from paving-related loads especially when units are added to an existing roof deck structure. The weight of paving units can be obtained from manufacturers for the purposes of calculating loads. Bedding sand (1 in. or 25 mm thick) weighs approximately 10 lbs. per sf (49 kg/m^2).

Resistance to wind uplift—The designer should consult *Loss Prevention Data for Roofing Contractors* Data Sheets published by Factory Mutual (FM) Engineering Corporation (15). Data Sheets 1-28 and 1-29 provide design data including the minimum pounds per square foot (or kg/m^2) of paving unit weight required for resistance to wind uplift. The FM charts consider wind velocity pressure on roofs at various heights in different geographic locations. Design pressures are then compared to the type of roof construction, parapet height and the whether the paving units have tongue-and-groove, beveled joints, or are strapped together. Some high wind regions may have local building codes with additional weight requirements for paving units, especially on high-rise buildings.

Slope for drainage—A flat or "dead level" roof, i.e., one with no pitch, should never be designed. A dead level roof does not drain, creating a high risk of leaks in the waterproofing, as well a potential saturation of bedding sand (when used). The membrane will be exposed to continual standing water and ice that accelerates its deterioration and increases the potential for leaks. Likewise, paving units and bedding materials in constantly standing water subject to many freeze and thaw cycles will experience a decrease in their useful life.

Regardless of the deck substrate, it should be built with a minimum 2% slope to drain. This may be difficult to achieve with certain decks sloping toward area drains and some decks are built flat and then a topping applied to achieve slopes. The designers should take every opportunity to use deck systems that enable construction of a minimum 2% slope as some toppings are not waterproof and flat roofs will eventually leak.

Slopes for pedestrians and vehicles —The maximum slope is constrained by the need for a comfortable walking surface and the maximum percentage is typically 8% (4.5°). For driving surfaces, the maximum recommended slope should not exceed 20% (11°) and ideally should not exceed 8% as such surfaces will often see pedestrian use. For slopes exceeding 4% with exposure to vehicles, consideration should be given to using bituminous-set rather than sand set systems.

Roof drains—Depending on the design, roofs are drained at their edges and/or from the interior with roof drains. When roofs decks are loaded with dead and live loads, they will deflect. Continual deflection over time results in deformation of the roof. This movement can make drain inlets or scuppers adjacent to columns or on frame lines at the perimeter of the highest points of the roof. Therefore, sufficient pitch to the roof that accounts for such deflections is essential to continual drainage. In addition, the surface of the paving should be a minimum of $^3/_{16}$ in. (5 mm) above the inlet of roof drains.

When sand or aggregate is used for bedding or fill, it is essential that holes be in the sides of drains to allow water to escape the bedding sand. The bottom of the holes should be at the same elevation as the top of the waterproof membrane. As previously noted, drains should be wrapped in geotextile or fiberglass screen to prevent loss of bedding material through the drain holes.

Figure 16 illustrates ponding around a parking deck roof drain that didn't have drain holes in its sides to drain subsurface water. Figures 17 and 18 illustrate a possible drain solution with holes for a pedestrian roof and parking deck. For paving slabs with pedestals, the slabs generally are located over roof drains, or are cut to fit around drains (see Figure 5). Bitumen-set assemblies require holes in the sides of the drains to remove water that may collect below the paving units. Bitumen and neoprene must not be allowed to clog roof drains or holes on their sides during installation.

Raising elevations—New and rehabilitated roofs may require fill material for raising the paved surface so it conforms to adjacent elevations. The deck surface receiving the fill material should slope a minimum of 2%. Fill materials are typically concrete, asphalt, or open-graded base. The structure should be evaluated first by a structural engineer for its capability in taking the additional load. Lightweight concrete may be considered if there are load limitations. These fill materials are often placed over a water-proof membrane. Consideration should be given to using insulation and protection board over the waterproof membrane. Attention in detailing and during construction should be given to how the fill materials will meet vents, skylights and other protrusions in the roof without damage to them, their flashing, or to their waterproofing.

Open-graded bases will require geotextile under them to contain them. The fabric should cover all sides of the base.

Dense-graded aggregate base fill materials without drains are not recommended since water can collect at the bottom of the base and soften it. Over time, this condition can increase the potential for deformation of the base under repeated vehicular wheel loads. In addition, aggregate base materials can shed fine particles that, over time, can clog geotextiles and drains. Concrete, asphalt, or open-graded

Figure 19. A mechanical screed used to level bedding sand on a roof parking deck project.

Figure 20. Mechanical equipment used to install concrete pavers on a roof deck.

bases are preferred as fill materials since they do not deform when continually exposed to water. In addition, they seldom shed particles into the roof drains so they present a much lower risk of clogged geotextile and drains.

Due to its high temperature at application, asphalt may not be compatible with some waterproof membranes, insulation, or protection board. All fill materials should be reviewed with the manufacturer for compatability with these components. Other important considerations are the minimum thickness to which the fill materials can be applied without cracking and deterioration from freeze-thaw cycles and salts. The design and selection of fill materials should address movement from temperature changes, vibration (if exposed to vehicles) and seismic activity.

Figure 21. Vacuum assisted mechanical equipment for installing paving slabs.

Construction Considerations

Low slope roofs and waterproofing systems are generally installed by a specialty roofing subcontractor. A second subcontractor specializing in the installation of segmental paving supplies and installs bedding materials, pedestals, pavers or slabs after the waterproofing is placed by the roofing contractor. Installation of protection board and/or drainage mat may be by the paving contractor or roofing contractor depending on the project specifications. Testing of the waterproofing for leaks and any repairs should be completed prior to starting the paving.

Job Planning—Roof jobs are typically built in a very limited space. There will be an additional expense of moving the paving units from the ground to the roof. Most roofs may not have space to store cubes of pavers and stockpiled sand, and if they did, they most likely do not have the structural capacity to withstand their concentrated weight. The advice of a structural engineer should be should be sought on assessing the maximum load capacity of the roof to safely support the weight, packaging and distribution of all materials delivered to the roof, or a crane used to lift them from the exterior.

Forecasting delivery time for moving pavers to the roof, as well as sand, pedestals, saw(s), tools, geotextile and crew to the roof is critical to accurately estimating roof projects. Labor functions and costs must be tracked on each project for use in future bids. For example, additional time and expense may arise from the need for the paving contractor to place temporary protection on the waterproof membrane to prevent damage during construction. A one-story parking garage may allow all materials to be driven onto and delivered quickly to the roof. A multi-story parking garage with pavers on the top floor may have a 6 ft - 6 in. (2 m) ceiling height that will not allow delivery of pavers and sand in large trucks. Trucks with a low clearance will be needed to move materials through the structure and to the roof, or craned to the roof.

The packaging of most concrete pavers and slabs allows their transport to the roof via elevator or crane during construction.

Figure 22. The plaza area around Scope Center in Norfolk, Virginia, (left) and one side of the Alamo Dome (right) in San Antonio, Texas, include roof plaza decks surfaced with concrete pavers.

Roof access, construction scheduling, the capacity of the roof to withstand loads from packaged materials, and reduction of labor costs will dictate the economics of using a crane to transport materials to the roof. The roofing contractor often handles this.

In some cases, an elevator may be the only means of transport. An example of using only an elevator to move crews, tools and materials was to the observation deck on the 86th floor of the Empire State Building in New York City (Figure 1) where the deck was rehabilitated with concrete pavers.

The layout of paving slabs can be more demanding than the layout of interlocking concrete pavers. Some designers prefer joint lines to be located in particular places such as centered at columns or staircases. Careful planning of the layout will spare wasted cuts and adjusting the pattern on site to conform to the drawings and design intent.

Sometimes railing posts along the perimeter of a roof may require coring holes in paving slabs to fit around them. In addition, paving units may need to be cut to fit against moldings and other protrusions from parapets. The location of the pattern and cutting should be anticipated in advance of the construction.

Installation of bedding sand—After placing the geotextile, the bedding sand is screeded using screed bars and a strike board to 1 in. (25 mm) thickness. Mechanical screeders may be used on large deck jobs as shown in Figure 19. This shows 40,000 sf (3,715 m^2) of pavers on a concrete parking deck next to a condominium housing project. Once the bedding sand is screeded, the pavers are compacted into the bedding sand. Sand is spread, swept and vibrated into the joints with at least two passes of a plate compactor. Excess sand is removed upon completion of compacting.

For larger than 12 in. x 12 in. (300 mm x 300 mm) slabs, bitumen or pedestals are recommended as the preferred setting methods rather than a sand bed. If placed on bedding sand, larger slabs tend to tip and tilt when loads are placed on their corners. Pedestals and bitumen are more stable assemblies for pedestrian applications. When compacting paving slabs with a plate compactor, using "add-on" rollers on this equipment should be considered to help eliminate risk of damage.

Some jobs may require slabs to completely cover the roof right up to the parapets and protruding vents. If full slabs do not fit next to vents and parapets, the slabs are saw cut and placed on pedestals next to them.

Mechanical installation—Roof decks can be built by mechanically placing the paving units. Figure 20 shows a parking deck being installed with mechanical equipment. Slabs can be installed with vacuum equipment that relies on suction to grab and place each unit. See Figure 21. For most jobs, these kinds of equipment can not run directly on the waterproofing. They must run over installed concrete pavers. Therefore, a starting area of pavers may need to be placed by hand and the equipment placed on it to continue the paving. Further information on mechanical installation is found in *ICPI Tech Spec 11—Mechanical Installation of Interlocking Concrete Pavements.* Regardless of the installation method, all federal, provincial, state and local worker safety rules should be followed for fall protection of crews working on roofs.

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BOD Approved: August 2016

PAVING SYSTEMS OVER PLAZA WATERPROOFING MEMBRANES:

The Importance of Membrane-Level Drainage

By Greg Doelp, PE and Phil Moser, LEED AP

Introduction

Subsurface drainage in any paving system is critical to its long-term performance, particularly in freeze-thaw climates. "Paving" is a broad term that includes both continuous (i.e., asphalt or Portland cement concrete) and unit paving systems (i.e., brick, stone, or precast concrete pavers, installed either in an open-joint configuration or with filled joints). While each of these systems performs differently, they all allow some water to seep through cracks or joints. Where the paving is installed on grade, this incidental water typically seeps down into the ground, aided by gravel layers and/or perforated pipes where appropriate. However, when paving is installed over a waterproofing membrane, moisture that penetrates it can become trapped in the paving and cause drainage and durability problems. Paving installed over waterproofing membranes can be found on pedestrian or vehicular plaza decks over below-grade parking garages or occupied space, and also on rooftop terraces and bridge decks. These applications require membrane-level drainage (see *Figures 1A* and *1B*). Designers mus make provisions for water that infiltrates the paving and collects on the membrane to travel laterally to a drainage outlet.

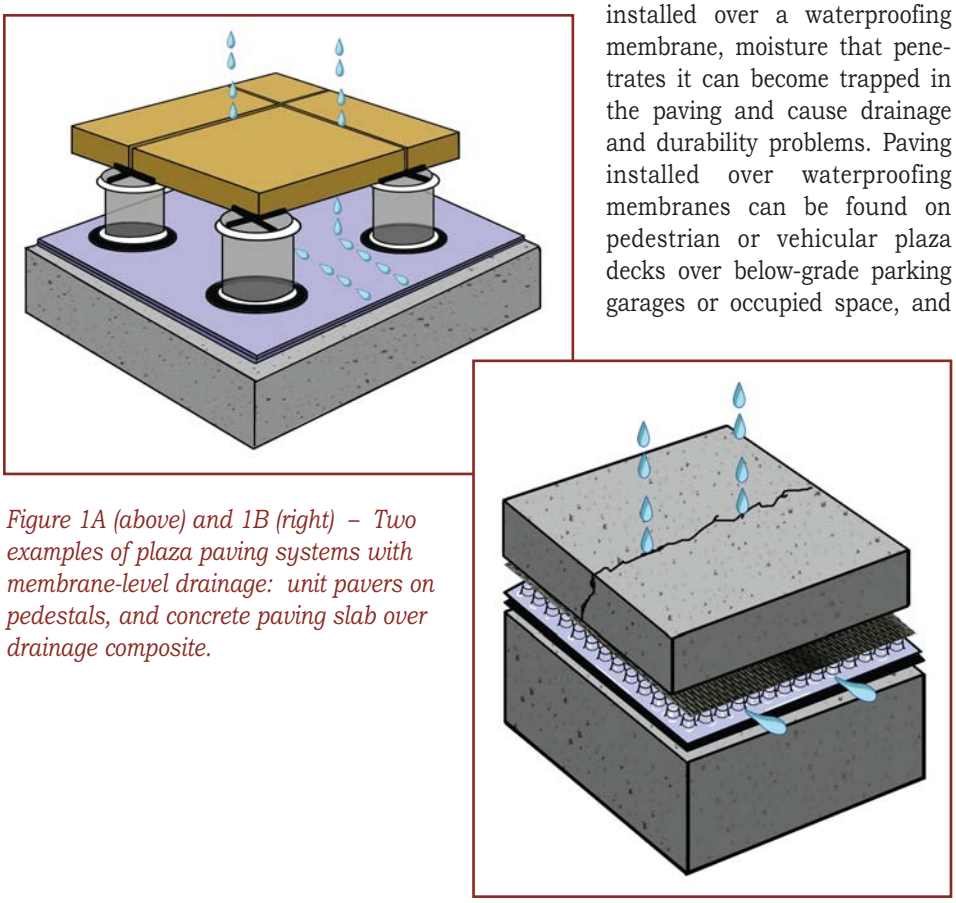


Figure 1A (above) and 1B (right) – Two examples of plaza paving systems with membrane-level drainage: unit pavers on pedestals, and concrete paving slab over drainage composite.

Plaza drainage systems such as paver-pedestals, prefabricated drainage composites, and bilevel drain fixtures have long been available, but we continue to see failures in paving systems over waterproofing where membrane-level drainage was not provided. This article presents examples of problems the authors have observed on existing plaza decks, and it reviews principles for designing successful membrane-level drainage in new or remedial designs to prevent premature deterioration of the paving.

Problems Caused by Poor Membrane-Level Drainage

Moisture trapped in the paving system due to poor membrane-level drainage can create numerous problems, such as the following:

- Freeze-thaw cycles can cause paving materials, such as the stone shown in *Photo 1*, to flake and crumble. These pavers were installed on a thin peastone setting bed over waterproofing membrane, and the internal drains on this plaza have only small, slow-flowing seepage holes at the membrane level. The concrete paving slab in *Photo 2* is another example of freeze-thaw

Photo 1 – Freeze-thaw damage to stone pavers.

Photo 2 – Freeze-thaw damage to concrete paving slab.

damage caused by poor drainage. This slab was poured directly on top of the waterproofing with no drainage layer, and the plaza drains are typical roadway storm drains with no path for water on the membrane level to get into the drain. It is important to note that some paving materials have a greater ability to resist freeze-thaw cycles than others, but material selection is outside the scope of this article.

- Frost heaving is also a concern in cold climates and can create tripping hazards, such as the brick shown in *Photo 3*. This closed-joint (mortar joint) brick paving system was installed in a mortar-setting bed directly over the waterproofing (no drainage layer), and the plaza drains had no seepage holes to drain water at the membrane level. Water that soaks through the joints between pavers becomes trapped in the setting bed material, creating frost heaves in the winter months.

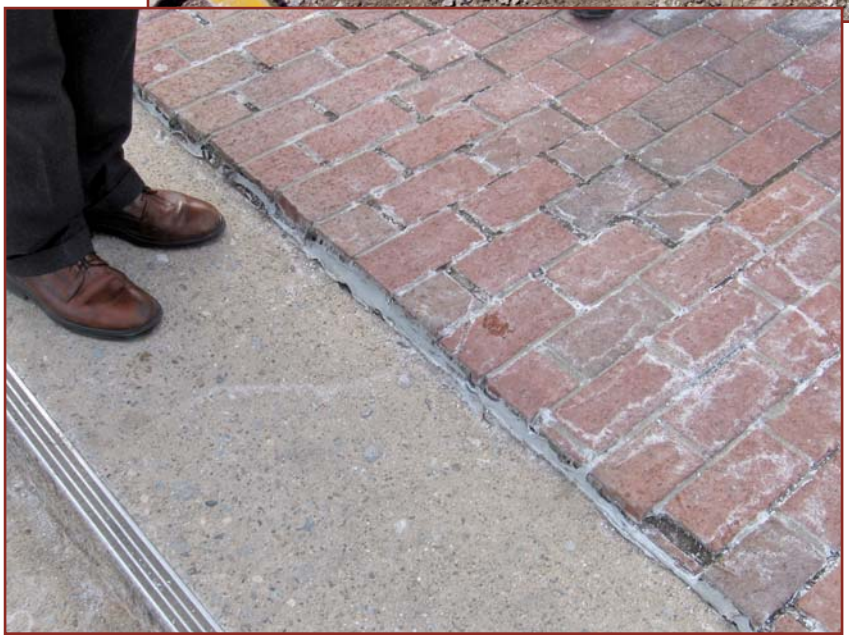


Photo 3 – Frost heaving of brick pavers.

Photo 4 – Efflorescence on brick pavers at the base of stairs.

Photo 5 – Leakage to interior spaces below a plaza.

- Efflorescence on paving can be caused by moisture migrating to the surface and depositing salts in the form of white stains. Efflorescence is particularly common at the bottom of stairs and other transitions where water can exit the system (*Photo 4*), but it can also occur in stagnant areas of flat paving where moisture wicks to and evaporates from its surface.
- Leakage through the waterproofing (*Photo 5*) is not directly a paving problem but is important to note because leakage is often exacerbated by drainage problems, and it can reduce the lifespan of a plaza where the paving has to be removed to replace the waterproofing. Many of the severe plaza leakage problems that we have seen were in instances where membrane-level drainage was not provided under the paving. Rather than flowing past, water was trapped against the waterproofing, exerting constant hydrostatic pressure on any holes in the waterproofing. (Waterproofing system selection, flashing details, and workmanship also play a major role in the prevention of leakage, but these issues are outside the scope of this article).

Use Membrane-Level Drainage to Avoid Paving Problems

The three design features described below can help provide good membrane-level drainage and avoid premature deterioration of the paving.

Slope

Provide positive slope-to-drain at the waterproofing membrane level. An inverted diamond pattern (four-way slope to an internal drain – *Figure 2*) is generally the most efficient layout. The slope on the waterproofing should be a minimum of one-quarter in per ft (approximately 2%). Lesser

slopes will drain slowly and increase the likelihood that localized areas of unevenness in the deck surface will result in ponding on the membrane (particularly in valleys, where the slope is already less). All decks have some natural unevenness due to construction tolerances and will experience deflection when loaded.

On a recent waterproofing reconstruction project, the existing concrete deck (a two-way slab with 28-ft column bays) in a large planter area had midspan deflections ranging from three-quarter to two inches, which caused water to pond on the membrane. Positive slope is needed to overcome the unevenness and deflection. For new construction, locating the plaza drains near the midspan of the deck (as opposed to near the columns – see *Figure 2*) will allow future deflection to complement the intended slope (as the low point at the drain deflects even lower), rather than working against it. If a drain cannot be located at the center of each span, provide sufficient slope to counteract the anticipated deflection and maintain good slope-to-drain on the waterproofing membrane. The structural engineer can estimate the deflection of the plaza deck. When reconstructing an existing plaza, a simple, level survey of the structural deck can determine existing slopes and locate low points.

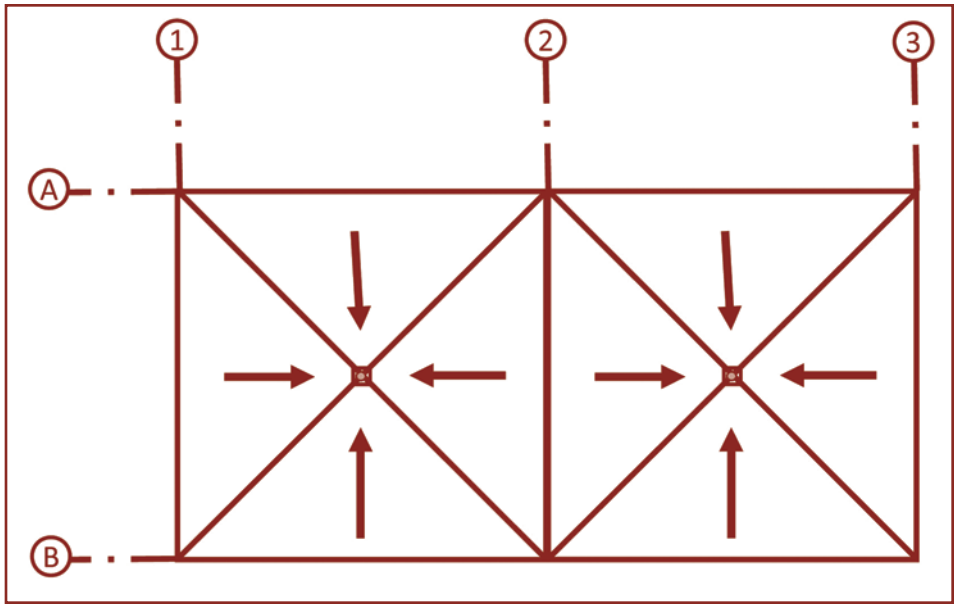


Figure 2 – Example drainage plan showing four-way drainage coordinated with the structural column layout.

Reconstruction of existing plazas with little or no slope may require adding tapered concrete to improve drainage prior to installing the waterproofing. A structural engineer must confirm that the existing structure can safely support the additional weight of tapered concrete. Improvements to existing slope may also be limited by the height of perimeter conditions. When

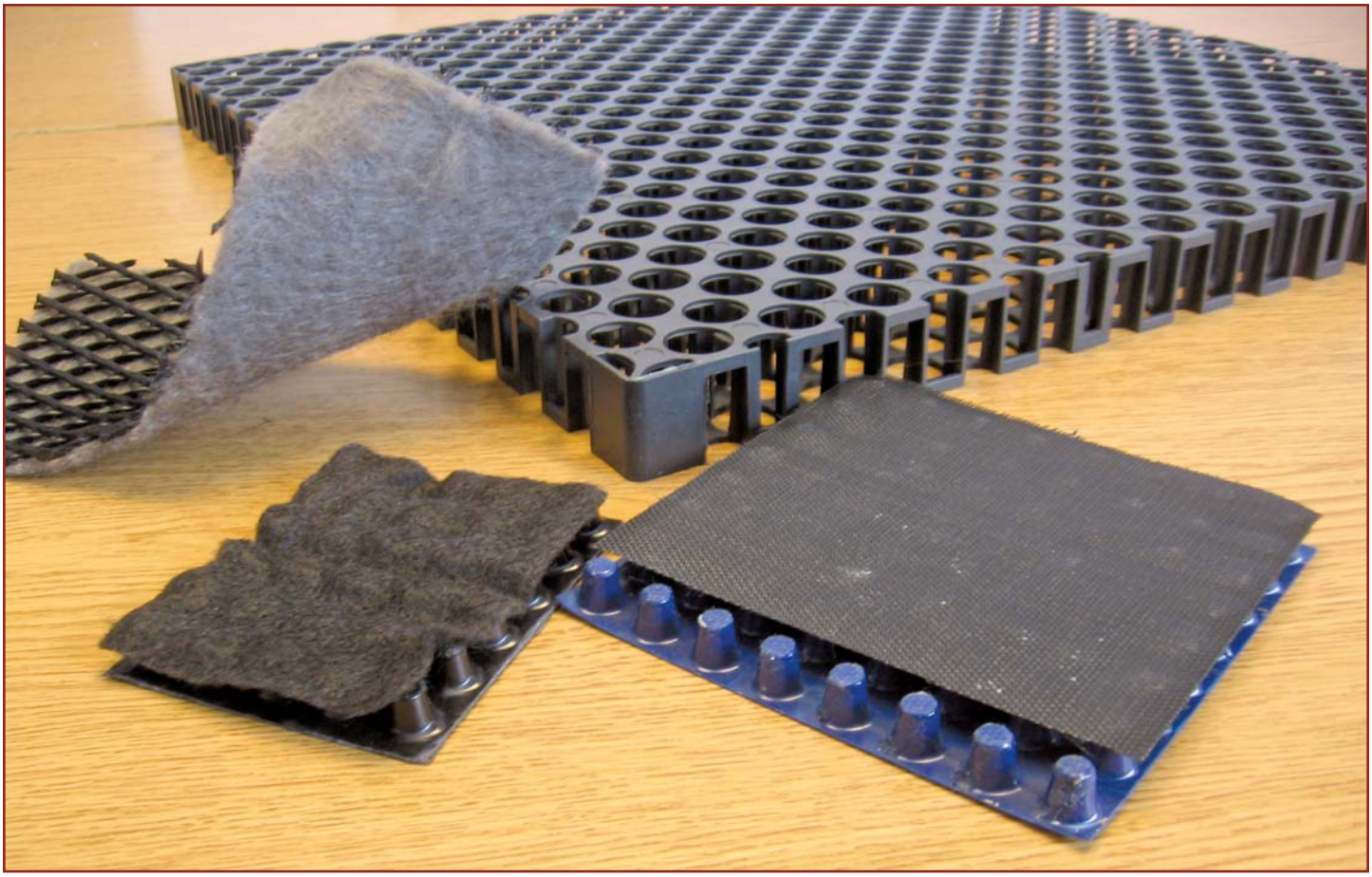


Photo 6 – Various examples of geosynthetic drainage cores.

designing a drainage layout, coordinate slope on the paving surface with slope on the membrane level, and space drainage outlets (discussed below) closely enough to accommodate desired slopes without exceeding the available thickness at the high point between drains. Coordinate the drainage layout with curbs, expansion joints, and other elements that could interfere with drainage.

Drainage Layer

Most paving materials have such low permeability that, even with proper slope, they will block the flow of subsurface water and become saturated if installed directly on the membrane. Therefore, a drainage layer should be provided between the waterproofing and the paving whenever possible.

The best way to promote free drainage under the paving is to use a system of pavers on pedestals (*Figure 1A*). Pedestals keep the paving up out of the water that collects on the membrane and provide an open space underneath the paving so water can flow freely to a drain. Paver-on-pedestal systems also allow easy removal and reinstallation of the paving for inspection and maintenance of the waterproofing membrane. However, pedestals are not applicable to small-unit pavers (i.e., brick) or continuous paving. Also, most prefabricated paver and pedestal products have limited load-bearing capacity and are intended for pedestrian traffic only. Custom paving systems can be designed to accommodate vehicular traffic using reinforced concrete "paver slabs" set on concrete piers for drainage. These systems work similarly to pedestrian pedestal-paver systems, but the custom paver slabs are generally thicker and require special lifting equipment.

On decks where other paving finishes or traffic-bearing properties are desired, a geosynthetic drainage core (*Figure 1B*) placed under the paving can provide more uniform support for the paving and still allow drainage. Drainage cores consist of plastic that is molded into a dimpled sheet or woven into an open grid (*Photo 6*) and are used to support overlying materials while maintaining a path for drainage between dimples or strands. Drainage cores are more easily clogged than a paver-on-pedestal system because the drainage area is generally smaller; and soil, concrete, or mortar placed over them can run or be washed into the drainage area where the filter fabric is not continuous or properly installed. Designs using a geosynthetic drainage core should consider the following:

- Flow capacity is published for most drainage cores. A product with capacity exceeding the expected flow rate should be selected. For low-permeability paving systems where most of the water drains off the surface, the expected flow rate at the membrane level is very small. However, thicker drainage cores with higher drainage capacity are still preferred, because the larger open spaces for drainage are less susceptible to clogging. Drainage cores up to 1¼ inch thick in one layer are available.
- Filter fabric is needed to keep debris from clogging the drainage core. Prefabricated products known as drainage composites include a filter fabric already laminated to the drainage core, but additional fabric will be needed to wrap the edges and cut ends of the drainage panels. Careful detailing and installation is needed to prevent debris from washing through the filter fabric at joints

or terminations and potentially clogging the drainage composite.

- Coordinate the use of drainage cores with support requirements for the paving system (both during installation and in service). While drainage cores are available with overall compressive strengths high enough for most applications, the drainage core will not lie perfectly flat until loaded, resulting in uneven support. For example, a thin, sand-setting bed for unit pavers may be difficult to compact when installed over drainage cores. The drainage core can also act as a slip plane, preventing the transfer of in-plane shear loads from the paving to the structural deck. For example, traffic-bearing asphalt paving installed over drainage cores may be more prone to rutting due to the slip plane created by the drainage layer.
- Continuity of drainage path is imperative. The drainage cores must extend all the way to the drainage outlet. Depending on the drainage layout and paving design, this may require the drainage cores to be continuous underneath curbs and other features that would otherwise block drainage.
- Gravel can also be used as a drainage layer in plaza paving systems, but is generally less desirable than either pedestal systems or drainage cores, because it can have slower drainage capacity and adds more weight to the structure.

Drainage Outlet

Drainage outlets at the low points of the waterproofing membrane are needed to receive and carry away water that collects in the drainage layer; these outlets are in addition to the outlets at the surface of the paving. Drainage at both levels can be achieved via "bilevel" drains or by separate systems of surface and subsurface drains. In some cases, water on the membrane level drainage can be drained off the edge of the foundation wall, but this requires providing a drainage system at the foundation wall to receive this runoff and exposes the foundation wall to additional water and potential leakage. Designers of internal drains should consider the following:

- Many drain assemblies promoted as "bilevel" plaza drains have only a small number of tiny weep openings to collect water on the membrane level. These openings are prone to clogging with debris or minerals that seep out of the paving and cannot be relied upon to provide membrane-level drainage over the long term. When relying solely on these weep openings for bilevel drainage, use drains that contain a large number of substantial-sized openings or modify the drain to enlarge or supplement the openings provided by the manufacturer.
- Many plaza drains are available with stainless steel perforated extensions, which increase the number and size of the openings to receive water that has infiltrated the paving (*Figure 3*). These extensions are generally not traffic-bearing by themselves; traffic-bearing applications require a separate, heavy-duty frame and drain grate or a manhole cover embedded in the paving and spanning over the membrane-level drain to protect it from traffic loads.

- Trench drains are generally not effective for bi-level drainage applications such as waterproofing below paving; most do not have membrane-clamping hardware or subsurface weep slots. Those that have these features generally have only small, clog-prone weeps that need to be enlarged and/or supplemented. Membrane-level trench drains also require coordination with the structural design, because they require forming a continuous slot in the deck to receive the trench drain. Due to these difficulties, unit drains are generally preferred for plaza paving and waterproofing systems. Where trench drains must be used for surface drainage, a secondary system of subsurface drains may be needed to drain away water at the membrane level.

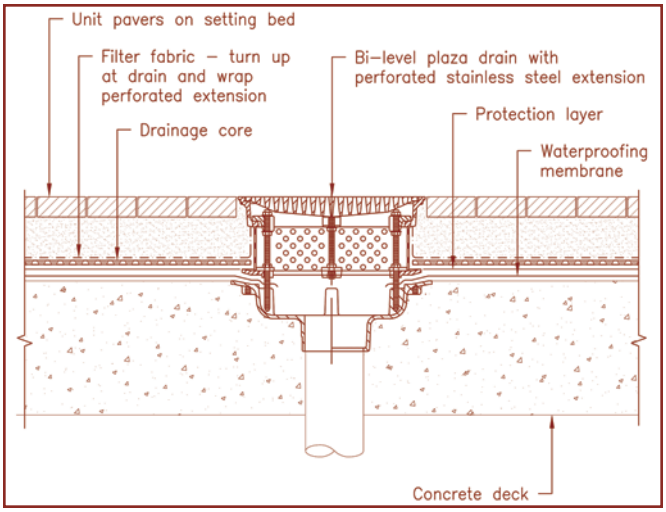


Figure 3

Summary

Many problems with paving systems installed over waterproofing membranes can be avoided with a basic understanding of drainage issues and careful detailing. The following strategies will help improve the long-term performance of both the paving and the waterproofing:

- Slope the deck a minimum of ¼ in per ft at the waterproofing membrane level using a four-way drainage pattern that is coordinated with the structural supports and anticipated deflection.
- Maintain a free-flowing, continuous drainage layer at the membrane level, coordinated with the support requirements for the paving system.
- Select drain hardware that provides an adequate drainage outlet on the waterproofing membrane level and is not prone to blockage.

Greg Doelp, PE

Greg Doelp, PE, is a principal at Simpson Gumpertz & Heger Inc. (SGH) and has 24 years of experience as a consulting engineer. He specializes in investigating and designing plaza waterproofing, below-grade waterproofing, and roofing systems. His projects have also included analyzing building moisture problems and leakage problems as well as repairing and renovating structures. Mr. Doelp is a member of RCI and the American Society of Civil Engineers. He can be reached at grdoelp@sgh.com and at 781-907-9217.

Phil Moser, LEED AP

Phil Moser, LEED AP, is on the building technology staff at SGH and specializes in investigating and designing plaza waterproofing, below-grade waterproofing, and roofing systems. His projects have also included evaluating and designing repairs to window systems and to masonry and concrete façades. Mr. Moser can be reached at psmoser@sgh.com and at 781-907-9281.

Montante SOLAR

System Size **101 kW**

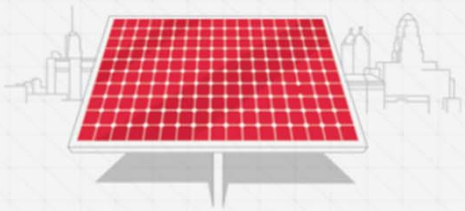
Prepared For:
Scott Dueker
Conifer Realty, LLC
90 S. Main Street
Portville, NY14770

Proposal Date:
August 24, 2018

conifer
REAL ESTATE DEVELOPMENT, CONSTRUCTION & MANAGEMENT

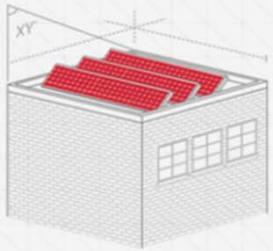
Buy the System

and enjoy a quick payback



1. Purchase your system

Investing in a solar energy system for your business is the best way to save money while going solar. Solar energy systems typically pay for themselves within 5-7 years, due to the energy cost savings, federal tax credits, and state incentives. Each system is designed to be turn-key and the team at Montante Solar will make the transition to solar easy. Buying your system will grant your business the ability to maximize the savings and other financial benefits of going solar.



2. We will design your solar energy

Our experts evaluate your facility and devise an installation plan that will suit your facility. Our team will also secure all the required state and local permits, along with completing the applicable financial documentation for any financial incentives, if applicable.

3. Generate your own power.

Once your solar energy system has been installed, inspected by the applicable municipality and utility company, and turned on, you will begin immediately harnessing the sun to power your business. Sit back, relax and watch your energy costs fall.

 Pricing valid for 30 days from Proposal Date

About Montante Solar

Full Service Solar Installation

Montante Solar is a full-service installer of commercial solar energy systems.

Our team of experts is experienced in both solar installation and commercial real estate development, which enables us to provide our clients with a wide range of solar energy services including construction, solar panel installation, maintenance, financing, and consulting. Our talented professionals work closely with our clients to develop solarenergy systems that are optimized for each client's unique facilities and budget requirements

Headquartered in Buffalo, NY, Montante Solar was established in 2009 by Daniel Montante and Matthew Montante as a consulting firm to affiliate TM Montante Development, a family-owned, LEED accredited real estate development company. The initial mission was to enhance the value of TM Montante Development's real estate portfolio through the integration of solar technology into their properties. Daniel and Matthew's passion for real estate and solar development helped fuel the creation of New York State's first solar ready business park, Riverview Solar Technology Park, located in Tonawanda, NY. The solar park is a 200 acre Shovel Ready site that harnesses the power of the sun to provide electricity to all of its buildings and common areas. Montante Solar experienced rapid growth due to a great deal of outside demand for their solar services, which made it necessary to expand the solar operation into a full service NYS certified solar installer, servicing clients throughout Western New York. Montante Solar is now the region's second largest solar installer and the only regional integrator of Advanced Solar Architecture.

 Pricing valid for 30 days from Proposal Date

The Benefits

With solar power comes great benefits: both fiscal and environmental

 Pricing valid for 30 days from Proposal Date

and that's not all…

Give Back... To the Grid

In the event that your solar energy system generates more power than your business consumes, the excess power will be sold to the utility company and you will receive a credit for the power on your monthly utility bill, which will save your organization even more money.

Clean Energy Source

IUtilizing solar energy can help offset energy generated by fossil fuels, which are harmful to the environment. The sun is a free, renewable source of energy that generates electricity cleanly and safely.

Attracting Great Employees

Powering your business with solar energy shows that your company is a forward-thinking leader in both technology and community involvement. This will attract high quality candidates to apply for positions at your business.

Increase Property Value

A solar energy system is an opportunity for your business to invest in its own future and will generate a positive return on investment quickly. You are not just installing solar panels, you are installing a secure investment vehicle with a superior return on capital.

Green Identity

Companies with a "green" reputation are held in high regard by their customers, as it demonstrates your business's commitment to creating a cleaner community.

Easy to Access

The rays of the sun surround us each and every day. Sunlight is a plentiful resource that is readily available to everyone on a daily basis.

Endless Source of Power

Sunlight will continue to be available for billions of years and in ample quantities.

Receive a Free T-Shirt

When you sign up with Montante Solar, you will receive a complimentary t-shirt.

 Pricing valid for 30 days from Proposal Date

Key Solar Array Specs and System Monitoring

Your System Description and Its Environmental Impact

Your Solar Array Specifications	
System Size:	100.8 kW
Area Required (ft^2)	10,000
Annual Electricity Production:	117,936 kWh
Reduction in CO2 Emissions	168,524 lbs
Lifetime CO2 Reduction	4,213,135 lbs

Features Tailored for Commercial Solar Users

- Easy to view graphs and metrics
- Performance stats by day, week, month or lifetime
- Automated Reports & Alerts
- Customize elements, colors, branding
- EPA energy equivalencies
- Kiosk / Touchscreen ready

 Pricing valid for 30 days from Proposal Date

Quantifiable Benefits & Incentives

Energy Savings Add Up!

Solar Energy Production & Value			
Year	**Production (kWh)**	**Rate ($/kWh)**	**Value**
1	117,936	0.085	**$10,025**
2	117,346	0.087	**$10,174**
3	116,760	0.088	**$10,326**
4	116,176	0.090	**$10,479**
5	115,595	0.092	**$10,636**
6	115,017	0.094	**$10,794**
7	114,442	0.096	**$10,955**
8	113,870	0.098	**$11,118**
9	113,300	0.100	**$11,284**
10	112,734	0.102	**$11,452**
11	112,170	0.104	**$11,622**
12	111,609	0.106	**$11,796**
13	111,051	0.108	**$11,971**
14	110,496	0.110	**$12,150**
15	109,943	0.112	**$12,331**
16	109,394	0.114	**$12,515**
17	108,847	0.117	**$12,701**
18	108,303	0.119	**$12,890**
19	107,761	0.121	**$13,082**
20	107,222	0.124	**$13,277**
21	106,686	0.126	**$13,475**
22	106,153	0.129	**$13,676**
23	105,622	0.131	**$13,880**
24	105,094	0.134	**$14,086**
25	104,568	0.137	**$14,296**
	2,778,095		**$300,990**

A Brief Explanation

Solar electricity production will decline about 0.5% per year. This is normal and we ensure our financial models reflect this factor.

We also assume that electricity rates will increase at 2.0% per year - or roughly the rate of long-term

Multiplying your solar electricity production by your rate gives you the value of your electricity

Your Project Financial Benefits	
NYSERDA Grant	$45,360
Federal 30% Tax Credit	$71,064
Depreciation Benefit	$84,566
Value of Electricity	$300,990
TOTAL	**$501,980**

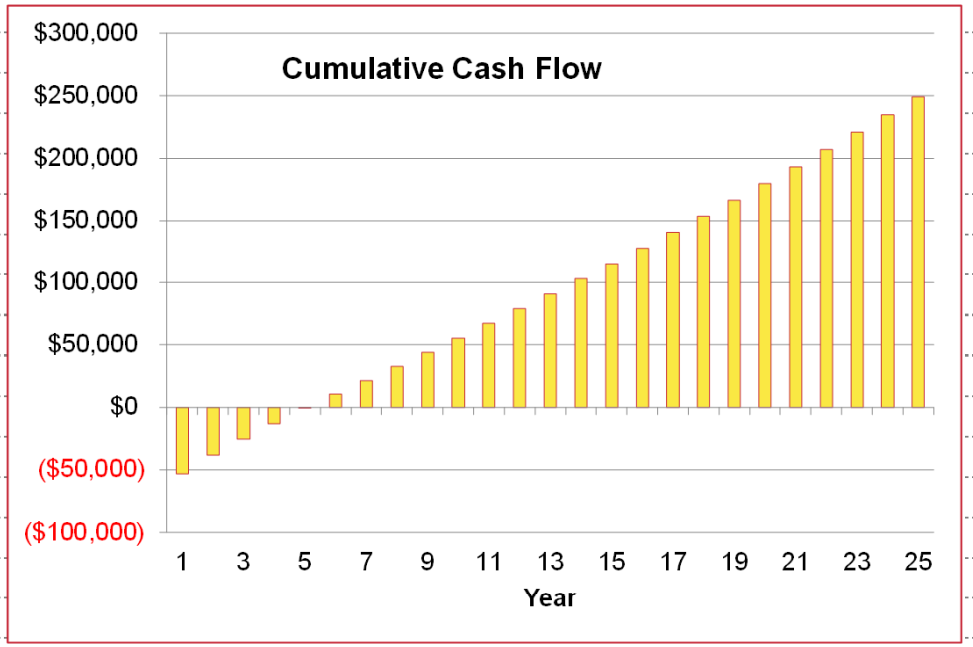
 Pricing valid for 30 days from Proposal Date

Total Solar Ownership

Putting It All Together

Project IRR: 24%

Year	System Cost	NYSERDA Grant	Taxes on NYS Grant	Federal Tax Credit	Depreciation Benefit (Fed+NY)	Value of Solar Electricity	Cumulative Cash Flow
1	($236,880)	$45,360	($15,876)	$71,064	$73,291	$10,025	($53,017)
2					$4,510	$10,174	($38,333)
3					$2,706	$10,326	($25,301)
4					$1,621	$10,479	($13,201)
5					$1,621	$10,636	($944)
6					$817	$10,794	$10,667
7						$10,955	$21,622
8						$11,118	$32,740
9						$11,284	$44,024
10						$11,452	$55,475
11						$11,622	$67,098
12						$11,796	$78,893
13						$11,971	$90,865
14						$12,150	$103,015
15						$12,331	$115,345
16						$12,515	$127,860
17						$12,701	$140,561
18						$12,890	$153,451
19						$13,082	$166,533
20						$13,277	$179,811
21						$13,475	$193,286
22						$13,676	$206,962
23						$13,880	$220,841
24						$14,086	$234,928
25						$14,296	$249,224



 Pricing valid for 30 days from Proposal Date

Additional Quantifiable Benefits - Depreciation

Depreciation Tax Rules Support Solar!

Federal Depreciation Schedule

Year	Depreciable Basis[1]	Depreciation Schedule	Non Cash Expense	Tax Benefit [2]
1	$201,348	100%	$201,348	$70,472
2	$201,348	0%	$0	$0
3	$201,348	0%	$0	$0
4	$201,348	0%	$0	$0
5	$201,348	0%	$0	$0
6	$201,348	0%	$0	$0
			$201,348	**$70,472**

New York State Depreciation Schedule

Year	Depreciable Basis[1]	Depreciation Schedule	Non Cash Expense	Tax Benefit [2]
1	$201,348	20%	$40,270	$2,819
2	$201,348	32%	$64,431	$4,510
3	$201,348	19%	$38,659	$2,706
4	$201,348	12%	$23,155	$1,621
5	$201,348	12%	$23,155	$1,621
6	$201,348	6%	$11,678	$817
			$201,348	**$14,094**

THE FINE PRINT

[1] *Cost basis is reduced by 50% of the value of the Federal Investment Tax Credit*

[2] *Assumes Fed marginal tax rate of 35% , and NY marginal tax rate of 7%*

 Pricing valid for 30 days from Proposal Date

Total Solar Ownership

System Cost and New York State & Federal Incentives

Your Investment	
Gross System Cost	**$236,880**
LESS: NYSERDA Grant	**($45,360)**
Contract Cost . . .	**$191,520**
ADD: Taxes on Grant	**$15,876**
LESS: Federal 30% Tax Credit †	**($71,064)**
LESS: 1st Yr Fed Depreciation Benefit	**($70,472)**
LESS: 1st Yr NY Depreciation Benefit	**($2,819)**
LESS: 1st Yr Energy Savings	**($10,174)**
NET INVESTMENT	**$52,867**

Montante Solar handles all the paperwork, permitting, installation work, and interconnection to provide you with a simple, hassle-free experience!

THE FINE PRINT

† The tax credit must be initially claimed in the tax year that the solar system commences operation. This does not constitute tax advice. Consult your tax advisor to understand how these credits apply to your specific situation.

 Pricing valid for 30 days from Proposal Date

Montante SOLAR

System Size **126 kW**

Prepared For:
Scott Dueker
Conifer Realty, LLC
90 S. Main Street
Portville, NY14770

Proposal Date:
August 24, 2018

conifer
REAL ESTATE DEVELOPMENT, CONSTRUCTION & MANAGEMENT

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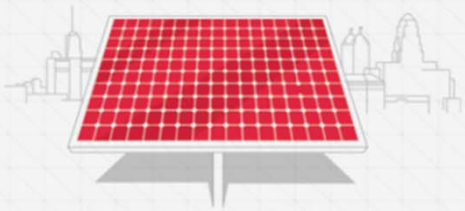

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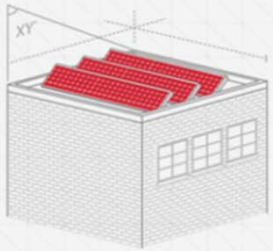

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Receive a Free T-Shirt

When you sign up with Montante Solar, you will receive a complimentary t-shirt.

 Pricing valid for 30 days from Proposal Date

Key Solar Array Specs and System Monitoring

Your System Description and Its Environmental Impact

Your Solar Array Specifications	
System Size:	126 kW
Area Required (ft^2)	13,000
Annual Electricity Production:	147,420 kWh
Reduction in CO2 Emissions	210,656 lbs
Lifetime CO2 Reduction	5,266,419 lbs

Features Tailored for Commercial Solar Users

- Easy to view graphs and metrics
- Performance stats by day, week, month or lifetime
- Automated Reports & Alerts
- Customize elements, colors, branding
- EPA energy equivalencies
- Kiosk / Touchscreen ready

 Pricing valid for 30 days from Proposal Date

Quantifiable Benefits & Incentives

Energy Savings Add Up!

Solar Energy Production & Value			
Year	**Production (kWh)**	**Rate ($/kWh)**	**Value**
1	147,420	0.085	**$12,531**
2	146,683	0.087	**$12,717**
3	145,949	0.088	**$12,907**
4	145,220	0.090	**$13,099**
5	144,494	0.092	**$13,294**
6	143,771	0.094	**$13,492**
7	143,052	0.096	**$13,694**
8	142,337	0.098	**$13,898**
9	141,625	0.100	**$14,105**
10	140,917	0.102	**$14,315**
11	140,213	0.104	**$14,528**
12	139,512	0.106	**$14,745**
13	138,814	0.108	**$14,964**
14	138,120	0.110	**$15,187**
15	137,429	0.112	**$15,413**
16	136,742	0.114	**$15,643**
17	136,059	0.117	**$15,876**
18	135,378	0.119	**$16,113**
19	134,701	0.121	**$16,353**
20	134,028	0.124	**$16,597**
21	133,358	0.126	**$16,844**
22	132,691	0.129	**$17,095**
23	132,027	0.131	**$17,349**
24	131,367	0.134	**$17,608**
25	130,710	0.137	**$17,870**
	3,472,618		**$376,237**

A Brief Explanation

Solar electricity production will decline about 0.5% per year. This is normal and we ensure our financial models reflect this factor.

We also assume that electricity rates will increase at 2.0% per year - or roughly the rate of long-term

Multiplying your solar electricity production by your rate gives you the value of your electricity

Your Project Financial Benefits	
NYSERDA Grant	$56,700
Federal 30% Tax Credit	$86,940
Depreciation Benefit	$103,459
Value of Electricity	$376,237
TOTAL	**$623,336**

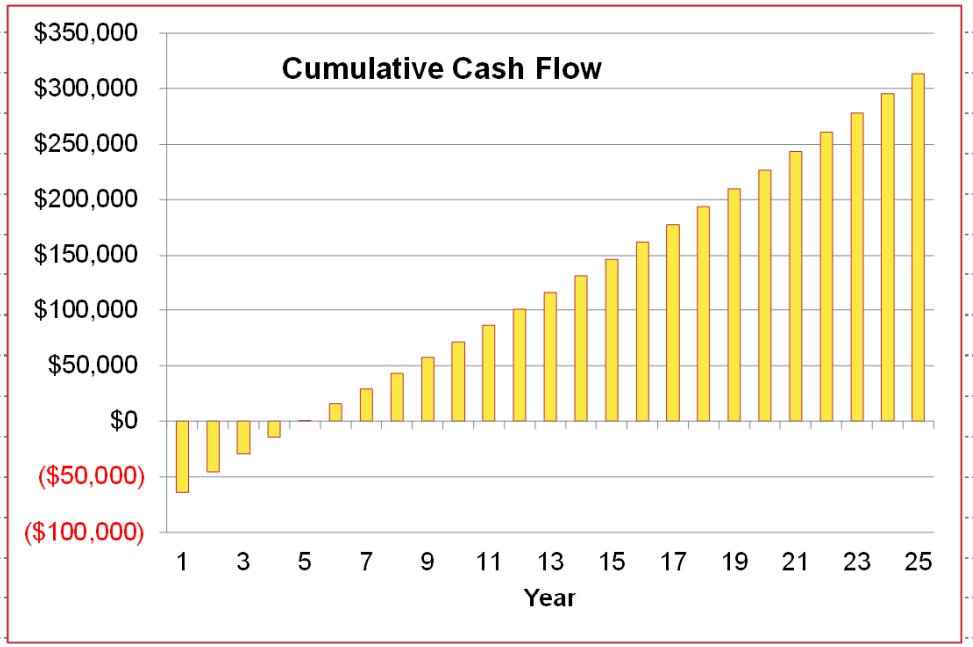
 Pricing valid for 30 days from Proposal Date

Total Solar Ownership

Putting It All Together

Project IRR: 24%

Year	System Cost	NYSERDA Grant	Taxes on NYS Grant	Federal Tax Credit	Depreciation Benefit (Fed+NY)	Value of Solar Electricity	Cumulative Cash Flow
1	($289,800)	$56,700	($19,845)	$86,940	$89,664	$12,531	($63,810)
2					$5,518	$12,717	($45,575)
3					$3,311	$12,907	($29,357)
4					$1,983	$13,099	($14,275)
5					$1,983	$13,294	$1,002
6					$1,000	$13,492	$15,495
7						$13,694	$29,188
8						$13,898	$43,086
9						$14,105	$57,190
10						$14,315	$71,505
11						$14,528	$86,033
12						$14,745	$100,778
13						$14,964	$115,742
14						$15,187	$130,929
15						$15,413	$146,343
16						$15,643	$161,986
17						$15,876	$177,862
18						$16,113	$193,975
19						$16,353	$210,328
20						$16,597	$226,924
21						$16,844	$243,768
22						$17,095	$260,863
23						$17,349	$278,212
24						$17,608	$295,820
25						$17,870	$313,691



 Pricing valid for 30 days from Proposal Date

Additional Quantifiable Benefits - Depreciation

Depreciation Tax Rules Support Solar!

Federal Depreciation Schedule

Year	Depreciable Basis[1]	Depreciation Schedule	Non Cash Expense	Tax Benefit [2]
1	$246,330	100%	$246,330	$86,216
2	$246,330	0%	$0	$0
3	$246,330	0%	$0	$0
4	$246,330	0%	$0	$0
5	$246,330	0%	$0	$0
6	$246,330	0%	$0	$0
			$246,330	**$86,216**

New York State Depreciation Schedule

Year	Depreciable Basis[1]	Depreciation Schedule	Non Cash Expense	Tax Benefit [2]
1	$246,330	20%	$49,266	$3,449
2	$246,330	32%	$78,826	$5,518
3	$246,330	19%	$47,295	$3,311
4	$246,330	12%	$28,328	$1,983
5	$246,330	12%	$28,328	$1,983
6	$246,330	6%	$14,287	$1,000
			$246,330	**$17,243**

THE FINE PRINT

[1] *Cost basis is reduced by 50% of the value of the Federal Investment Tax Credit*

[2] *Assumes Fed marginal tax rate of 35% , and NY marginal tax rate of 7%*

 Pricing valid for 30 days from Proposal Date

Total Solar Ownership

System Cost and New York State & Federal Incentives

Your Investment	
Gross System Cost	**$289,800**
LESS: NYSERDA Grant	**($56,700)**
Contract Cost . . .	**$233,100**
ADD: Taxes on Grant	**$19,845**
LESS: Federal 30% Tax Credit †	**($86,940)**
LESS: 1st Yr Fed Depreciation Benefit	**($86,216)**
LESS: 1st Yr NY Depreciation Benefit	**($3,449)**
LESS: 1st Yr Energy Savings	**($12,717)**
NET INVESTMENT	**$63,623**

Montante Solar handles all the paperwork, permitting, installation work, and interconnection to provide you with a simple, hassle-free experience!

THE FINE PRINT

† The tax credit must be initially claimed in the tax year that the solar system commences operation. This does not constitute tax advice. Consult your tax advisor to understand how these credits apply to your specific situation.

 Pricing valid for 30 days from Proposal Date

Neopor®
Innovation in Insulation

Neopor® GPS Energy Savings Guide for Existing Homes

Insulated Vinyl Siding • Fanfold Underlayment • Continuous Insulation Sheathing

Neopor® is Smart Insulation

BASF Neopor® GPS is a graphite polystyrene (GPS) rigid thermal foam insulation that gives builders maximum efficiency, cost-effectiveness and sustainability on construction projects. It's unique silver-gray color and exceptional insulation characteristics are a result of high-purity graphite that reflects and absorbs radiant energy, decreasing the materials thermal conductivity and increasing its R-value.

- Excellent insulation value of R-5 per inch enabling the use of thinner boards
- Exceptional moisture resistance with maximum water absorption by volume of less than 1%
- New polymeric flame retardant (PolyFR) with a better environmental profile

This means that Neopor® can result in serious annual energy savings for you when used as your preferred insulation material.

Flip the page to learn the potential savings from using Neopor® Insulation

Existing Homes

BASF
We create chemistry

Neopor Potential Energy Savings Chart

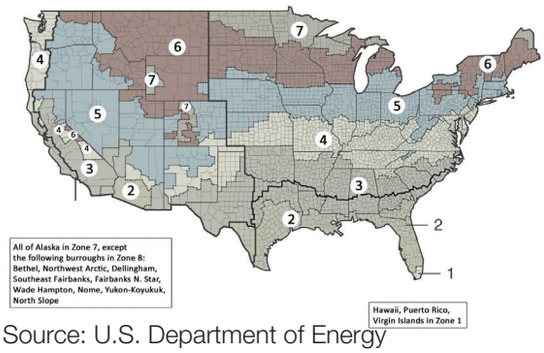
You can determine the money **Neopor insulated vinyl siding, wall underlayment** and **insulated wall sheathing** will potentially save you on your annual energy bills by using the table to the right. Just follow these steps:

1. Find the city nearest to you in the first column.

2. Use the All Electric or Gas/Electric columns, depending on what type of energy your home uses.

3. Scan across to the thickness of Neopor that you will be using. This is your potential savings!

U.S. Climate Zone Map



Source: U.S. Department of Energy

Methodology

Energy and cost savings were determined using RESNET REM software (V14.6.1). New Home savings were based on the current IECC (International Energy Conservation Code) requirements in each state for building envelope and mechanical equipment construction. New Home potential annual savings were based on the current IECC (International Energy Conservation Code) requirements in each state for building envelope and mechanical equipment construction. U.S. Department of Energy data was used to determine the relevant climate zone as well as the heating and cooling degree days for each location. A representative 2200 ft2, 2-story home with 3-bedrooms, slab-on-grade, 2x4 walls, truss roof, and worst-case solar orientation was defined using U.S. Bureau of the Census and U.S. DOE Energy Information Administration data.

BASF Corporation
1609 Biddle Avenue
Wyandotte, MI 48192 USA
Web: neopor.basf.com
Phone: 1-800-543-1747
Email: neopor-us@basf.com

Existing Homes

State-MSA	Climate Zone	Potential Annual Energy Savings based on Neopor Thickness ($)							
		All Electric				Gas/Electric			
		1/4"	1/2"	3/4"	1"	1/4"	1/2"	3/4"	1"
AL-Birmingham	3	55	93	113	130	38	65	78	89
AK-Anchorage	7	306	508	609	692	101	170	206	236
AZ-Phoenix	2	44	73	89	102	52	86	105	120
AR-Little Rock	3	61	100	122	139	44	71	86	107
CA-Los Angeles	3	20	33	40	46	19	32	38	44
CA-San Diego	3	18	31	37	42	15	26	32	38
CA-San Francisco	3	35	58	69	80	26	44	53	61
CO-Denver	5	142	236	282	321	57	97	117	134
CT-Hartford	5	131	216	259	295	55	92	112	128
DE-Dover	4	102	169	203	230	52	88	106	121
FL-Miami	1	17	29	35	39	24	40	48	55
FL-Orlando	2	19	31	38	43	22	37	44	51
FL-Tampa	2	22	39	47	54	28	47	57	64
GA-Atlanta	3	54	93	114	131	37	62	75	86
HI-Honolulu	1	21	36	43	50	30	51	62	71
ID-Boise	6	128	212	253	288	58	98	119	135
IL-Chicago	5	165	272	327	371	60	101	122	140
IN-Indianapolis	5	136	226	271	308	55	94	113	129
IA-Des Moines	5	174	289	346	394	62	104	126	145
KS-Wichita	5	111	185	221	252	53	91	110	126
KY-Louisville	4	94	155	187	211	47	78	94	108
LA-New Orleans	2	35	58	70	81	32	55	66	76
ME-Portland	6	179	296	354	401	64	109	132	152
MD-Baltimore	4	91	152	182	206	49	84	101	115
MA-Boston	5	114	190	228	258	53	88	107	123
MI-Detroit	5	154	253	304	344	0	100	120	138
MN-Minneapolis	6	229	381	457	520	72	124	149	171
MS-Jackson	2	49	86	103	119	38	66	80	91
MO-St. Louis	4	111	184	221	252	52	88	106	122
MT-Billings	6	192	318	382	434	65	109	131	151
NE-Omaha	5	167	277	333	377	60	102	124	142
NV-Las Vegas	3	59	99	121	138	55	93	113	129
NH-Manchester	6	132	218	262	297	55	95	114	131
NJ-Trenton	5	96	160	191	217	49	83	101	115
NM-Albuquerque	4	78	133	161	185	50	85	102	117
NY-New York	4	90	151	182	207	50	84	101	116
NC-Charlotte	3	60	102	124	142	42	71	85	98
NC-Raleigh	4	64	106	128	147	41	69	83	95
ND-Fargo	7	278	465	560	637	85	144	173	199
OH-Cincinnati	5	107	178	213	242	51	86	104	120
OK-Oklahoma City	3	75	124	150	170	45	75	92	105
OR-Portland	5	68	116	140	160	42	70	85	98
PA-Philadelphia	4	96	161	192	219	50	85	103	118
RI-Providence	5	122	203	244	277	54	91	111	126
SC-Columbia	3	49	85	104	119	36	61	74	84
SD-Sioux Falls	6	225	374	450	511	72	122	148	168
TN-Nashville	4	76	125	151	172	44	74	90	102
TX-Dallas	3	52	88	108	123	44	73	88	100
TX-Austin	2	44	74	88	100	40	67	80	92
TX-Houston	3	37	63	76	88	34	57	69	78
TX-San Antonio	2	44	72	86	98	40	66	79	90
UT-Salt Lake City	5	116	192	231	261	59	99	120	137
VA-Charlottesville	4	73	121	145	166	44	74	90	102
VT-Burlington	6	213	354	424	482	70	118	142	163
DC-Washington	4	85	142	171	195	49	83	101	115
WA-Seattle	5	66	111	134	152	39	66	79	91
WV-Charleston	4	95	158	190	216	46	79	94	108
WI-Milwaukee	6	187	310	371	421	66	111	134	155
WY-Cheyenne	6	172	286	342	389	65	109	132	151

* Please consider that annual savings potential varies with climate zone, heating degree days and also local energy code.

Neopor®

Performance You Can Rely On

Smart Insulation by Neopor® Plus GPS.

BASF

We create chemistry

www.neopor-insulation.com

CONTENTS

GOOD REASONS TO CHOOSE NEOPOR® PLUS GPS

THE S.M.A.R.T. INSULATION

Neopor Plus GPS – the next generation of insulation

Neopor Plus GPS is a graphite polystyrene (GPS) rigid foam insulation that gives maximum efficiency, cost-effectiveness and sustainability on construction projects. Planners, architects, contractors and builder-owners benefit from insulation made of Neopor Plus GPS because of the special advantages this material offers.

Grey Neopor Plus GPS is comprised of many small pockets of air within a polymer matrix containing graphite. The graphite reflects radiant heat energy like a mirror, increasing the material's resistance to the flow of heat, or R-value.

Most polymer-based foams exhibit a greater ability to slow the movement of heat as the temperature decreases. Neopor Plus GPS is in a unique class because it increases in R-value as the temperature outside drops.

Neopor Plus GPS is S.M.A.R.T. Insulation:

Stability and Durability

Neopor Plus GPS is adaptable in size, thickness, shape and density, providing maximum flexibility and durability. And, Neopor Plus GPS is stable as it consistently delivers the highest consistent R-value performance over time.

Moisture-management

Neopor Plus GPS is a breathable and semi-permeable high performance insulation that helps reduce the risk of mold, rot and structural damage associated with moisture condensation and long-term water retention.

Adaptable to all climate zones

Neopor Plus GPS powers up when it gets cold outside. Insulating external walls with Neopor Plus GPS increases the temperature of their inside surfaces which helps create a better indoor climate. And, Neopor Plus GPS boards are thinner than others so the same effect is achieved with less material.

Resource-efficient

Neopor Plus GPS uses up to 30% less material than other rigid foam insulation to achieve the same R-value, saving on building materials and installation labor.

Third-party validated and certified

Neopor Plus GPS earned GREENGUARD Gold Certification and has been referenced by both The Collaborative for High Performance Schools (CHPS) and the Leadership in Energy and Environmental Design (LEED®) Building Rating System.

STABILITY AND DURABILITY

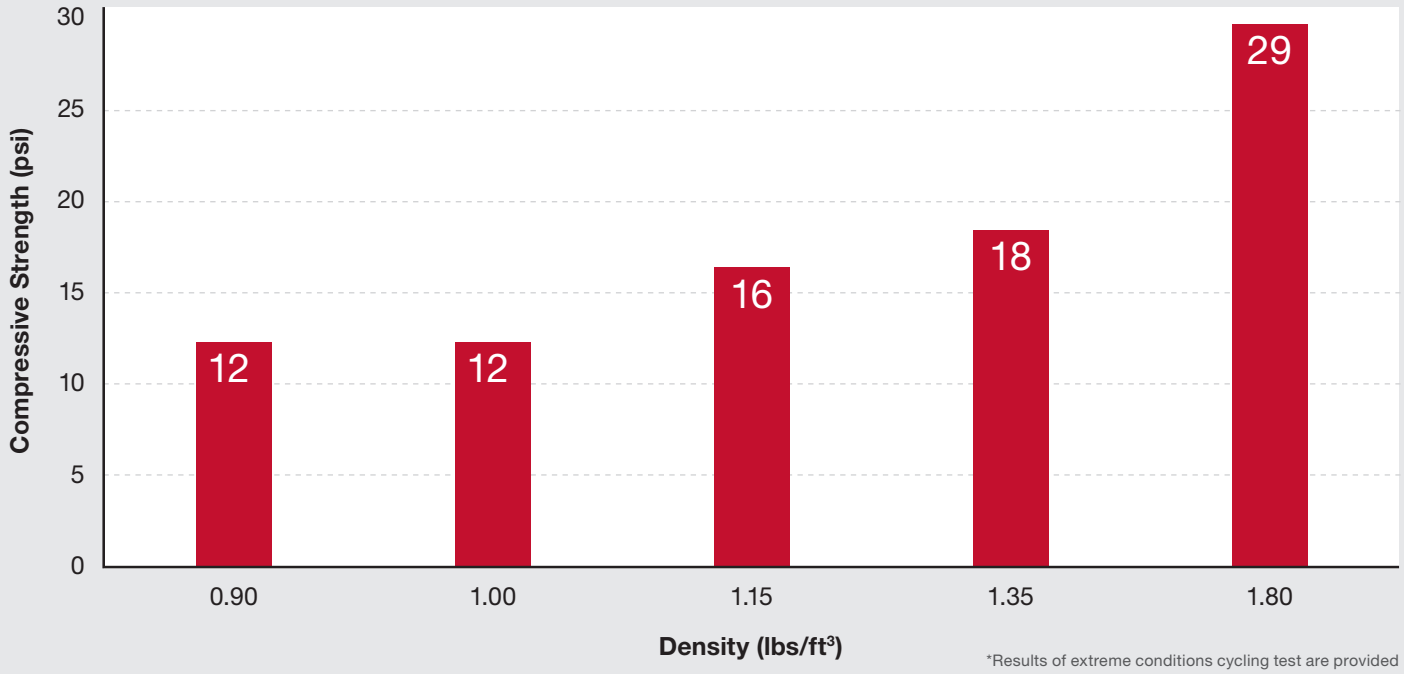
NEOPOR® PLUS GPS STANDS FOR STRENGTH

Neopor Plus GPS is adaptable in size, thickness, shape and density. This means you can specify the thickness you need.

Neopor Plus GPS is versatile. It has numerous applications in building and construction, packaging, cold storage, and more. The material can be shaped or formed to the design needed. It can be wire-cut to incorporate water drainage channels or precisely manufactured for insertion into window frames. Neopor Plus GPS can also be shape molded with corners, bulk-water management grooves and interlocking features "built-in" such as the interlocking features of ICF's made of Neopor Plus GPS.

And, since Neopor Plus GPS can be produced in any density between 0.9 to 2.0 lbs/ft^3, Neopor Plus GPS lets insulation manufacturers select the density that affords them the strength and the R-value they need.

Density and Compressive Strength – the designer is in charge

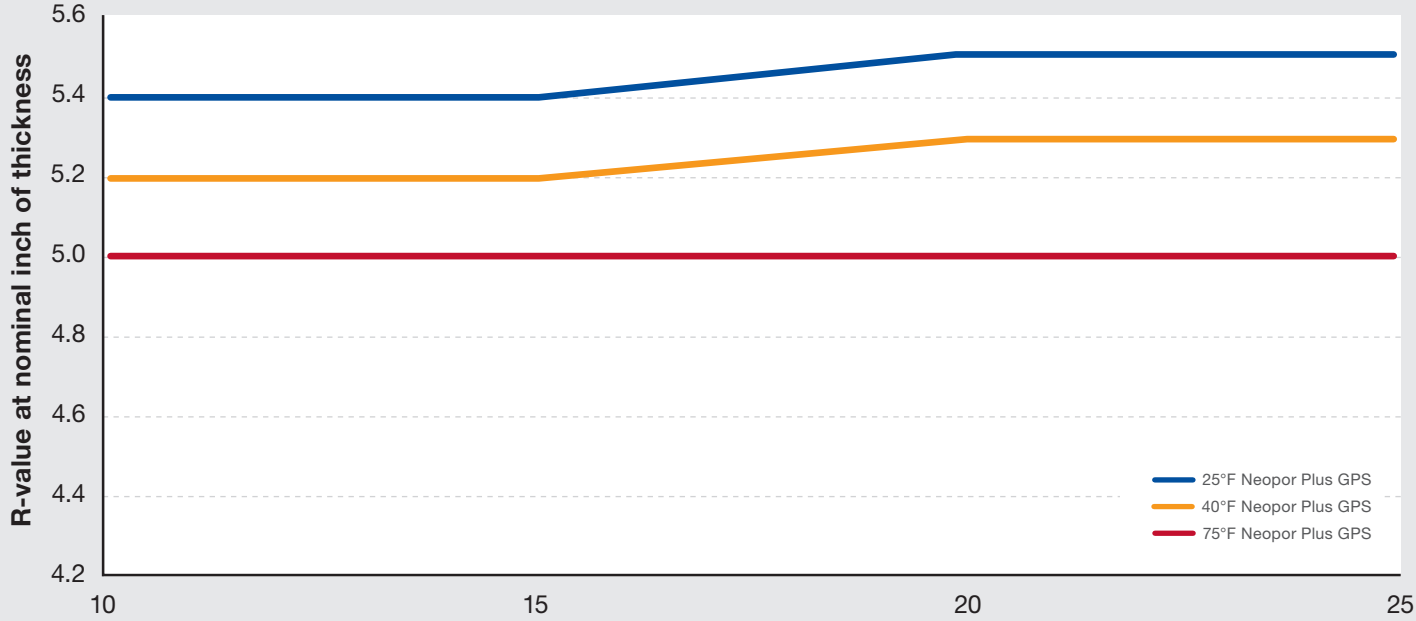


*Results of extreme conditions cycling test are provided by Intertek, Evaluation Center, June 26, 2015.

In fact, Neopor Plus GPS maintains its ability to slow the movement of heat energy, year after year because it sustains its R-value. Compared to polymer-based foams like extruded polystyrene that use fluorocarbons as an expansion agent and insulating gas, Neopor Plus GPS uses air. This means Neopor Plus GPS maintains its R-value performance at its original level and does not deteriorate over time, a phenomenon called 'Thermal Drift'.

This, and the material's other unique attributes, leads to its choice as a specified ingredient in a variety of higher efficiency insulation products and highly engineered components.

Neopor Plus GPS Thermal Resistance (R-value)



R means resistance to heat flow.
The higher the R-value, the greater the insulating power.
The R-value properties are based on 1-1/16 in thickness.

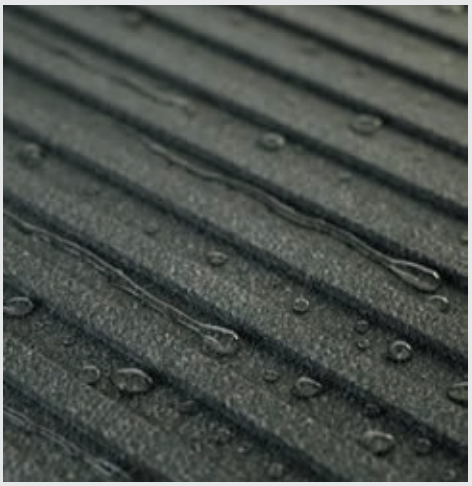
MOISTURE MANAGEMENT

DRYING POTENTIAL OF NEOPOR® PLUS GPS

An ideal insulation material has both the ability to shed bulk water and allow water to pass through it. Neopor Plus GPS does both—and maintains a significant proportion of its original R-value even after extensive contact with water.

Neopor Plus GPS is a breathable and semi-permeable material. As an assembly component or stand alone application, it provides an opportunity for moisture to 'dry out'. Neopor Plus GPS starts dry and stays dry.

For panels of the same thickness, Neopor Plus GPS (unfaced or faced with a material of equal or higher vapor permeability), supports conveyance of water vapor at a rate greater than XPS or EPS can demonstrate.



Neopor Plus GPS	Compression ASTM D1621 (lbs/in²)	Moisture Content After Cycling (%)	Retained R-value (%)
Type I	12	0.03	99.7
Type VIII	16	0.02	100
Type II	18	0.04	100
Type IX	24	0.04	100

Neopor results of extreme conditions cycling test (Freeze Thaw Study ASTM C1512) are provided by Intertek, Evaluation Center, 2015.

ADAPTABLE TO ALL CLIMATE ZONES

NEOPOR® PLUS GPS 'POWERS UP' WHEN IT GETS COLD OUTSIDE

Good insulation ensures a pleasant indoor climate

Thermal comfort in a room depends on two factors: the temperature of the air and the surface temperature on the insides of external walls. Insulating external walls increases the temperature of their inside surfaces, which helps create a better indoor climate. Insulation made of Neopor Plus GPS provides two benefits at once, because of its greater insulating performance, thinner boards achieve the same effect.

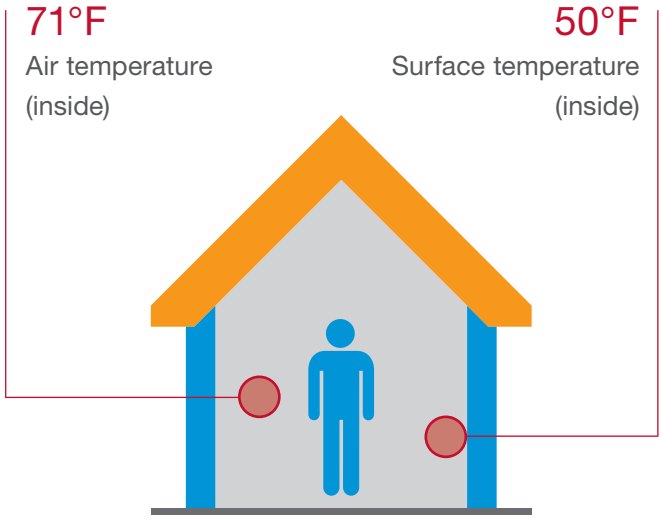
Good insulation is also essential for ensuring good hygiene indoors. Mildew can thrive in moist spots inside a house. These can result when condensation forms on cold surfaces. When walls are properly insulated with boards made of Neopor Plus GPS, they are warm on the inside and free of thermal bridges. The risk of mildew developing is therefore much smaller than on the insides of uninsulated and cold external walls.

Professional insulation protects the house

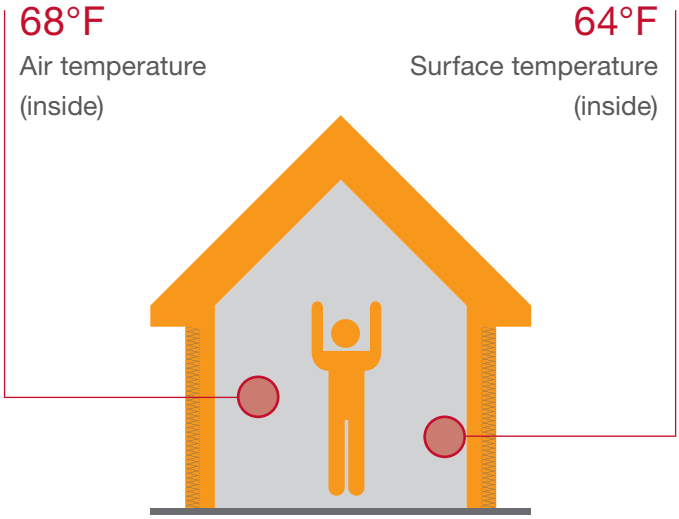
Insulation made of Neopor Plus GPS offers a lot of possibilities when planning new buildings and renovating existing ones. To make sure that insulation has the desired effect of keeping a building in good shape for many years – and, ideally, even increasing its value – it is absolutely essential for the work to be planned and executed by experienced experts.

Thermal comfort – a comparison:

Building **WITHOUT** thermal insulation



Building **WITH** thermal insulation

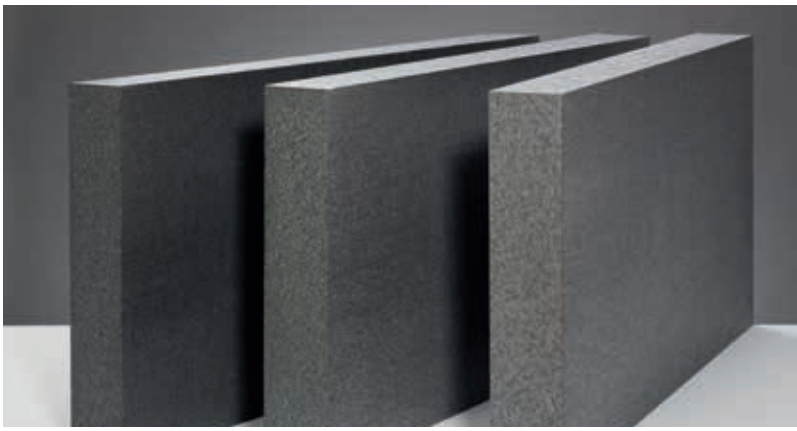


Source: Forschungsinstitut für Wärmeschutz e.V. München, FIW

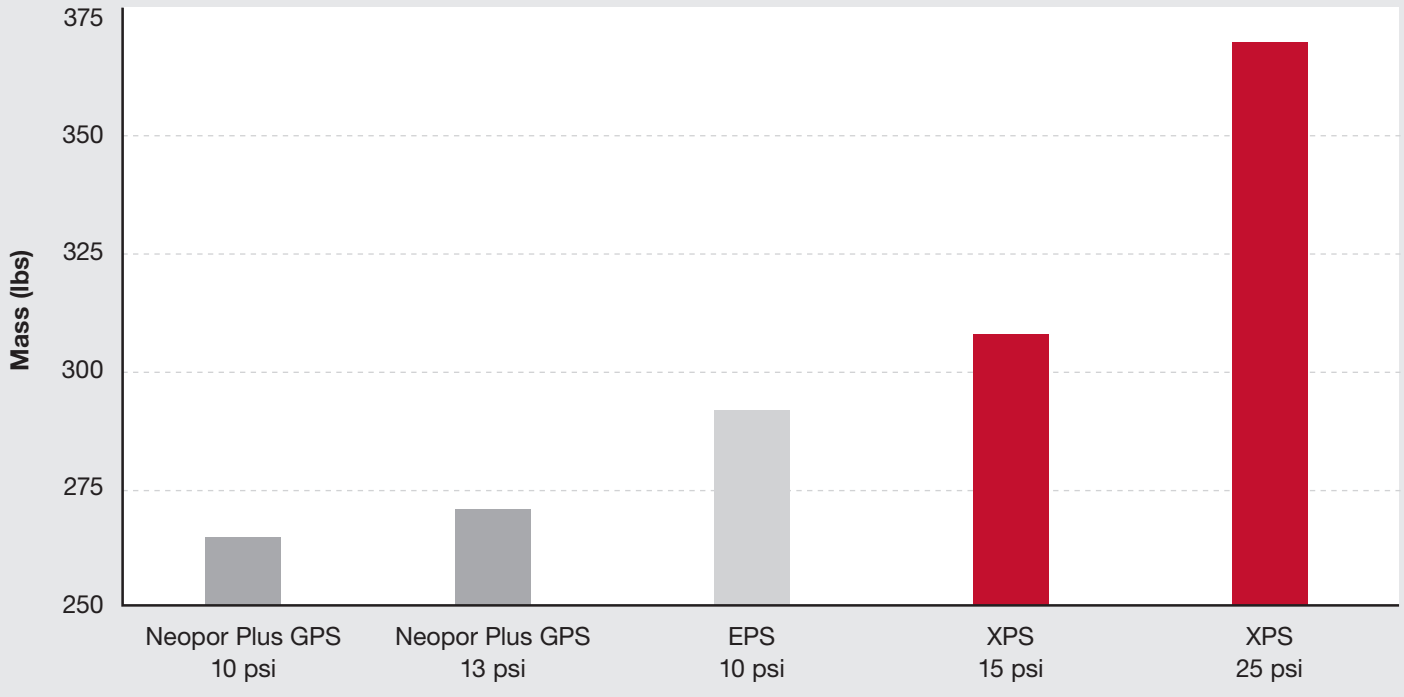
RESOURCE-EFFICIENT

SPECIFYING NEOPOR® PLUS GPS MEANS USING RESOURCES MORE WISELY

Specification of Neopor Plus GPS can lead up to 30% material savings compared to conventional EPS and XPS. The chart below illustrates the mass (lbs) of various R-5 rigid insulation materials required for a typical 2,000 sq.ft. building (continuous insulation, 75% of exterior surface with 9 ft. tall exterior walls).



Mass of R-5 continuous insulation required using rigid foam in a typical residence.



NEOPOR® PLUS GPS – A STRONG CONTRIBUTION TO SUSTAINABLE CONSTRUCTION

Insulating for the future with Neopor Plus GPS

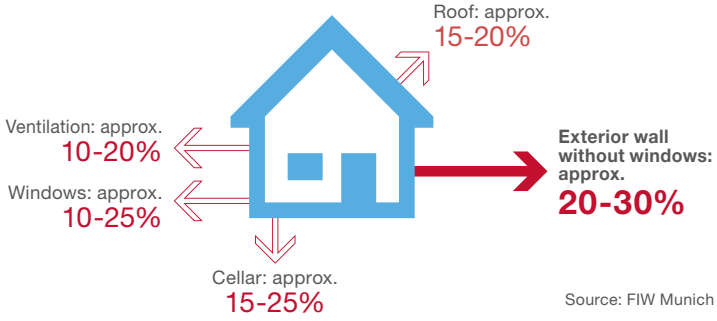
To tell whether a building qualifies as sustainable, it has to be assessed in its entirety. The exemplary eco-efficiency of Neopor Plus GPS greatly improves overall sustainability assessments.

Houses mainly lose energy through their outer envelope. In the case of a single-family home, an uninsulated external wall without windows can account for between 20 and 30% of the total energy loss. To achieve energy-saving targets, whether they are prescribed by law or voluntary, Neopor Plus GPS provides solutions to this challenge as numerous reference projects have shown.

Properly executed and installed insulation made of Neopor Plus GPS lasts for many years and greatly contributes to reducing heating costs.

Especially in the context of integrated concepts for increasing the energy efficiency of new or renovated older buildings, insulation made of Neopor Plus GPS makes good economic sense.

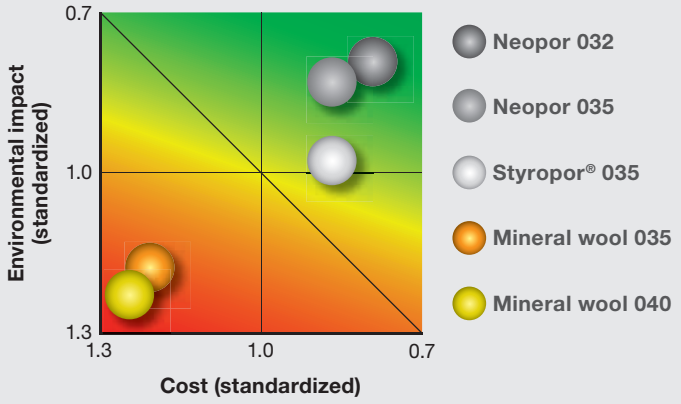
Shares of heat loss in a typical unrenovated single-family home



Source: FIW Munich

Exemplary Eco-efficiency

BASF's patented Eco-efficiency Analysis evaluates efficiency from both an economic and an environmental standpoint. Compared with alternative products, Neopor Plus GPS insulating materials offer greater benefits at lower costs with less environmental impact. The advantage is in its performance: its higher R-values means as much as 50% less raw material is needed. This lowers costs, saves resources and reduces the environmental effects of construction. Neopor Plus GPS materials also achieve the same insulation effect at up to 30% thinner profiles, making it a highly eco-efficient insulation for modern thermal protection.



This graphic orders different insulating materials in terms of their cost-effectivness and environmental impacts:

- For 10 sq.ft. of CIFS
- Considering their entire life cycle (raw materials, production, logistics, processing, useful life, disposal)

Source: Eco-efficiency analysis for average CIFS insulated house in Germany by BASF in 2013, validated by TÜV Rheinland.

NEOPOR® PLUS GPS DEMONSTRATES LOW GLOBAL WARMING POTENTIAL (GWP)

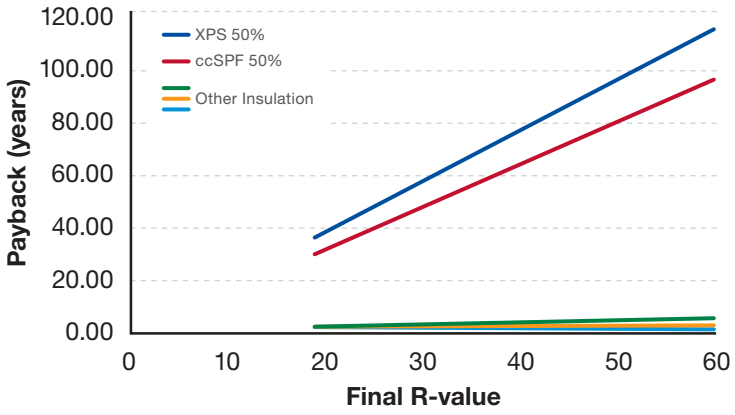
Insulation is key to reducing carbon emissions and global warming potential from buildings by saving energy consumption. On the other hand, all insulation materials take energy to manufacture and transport—something the industry refers to as embodied energy.

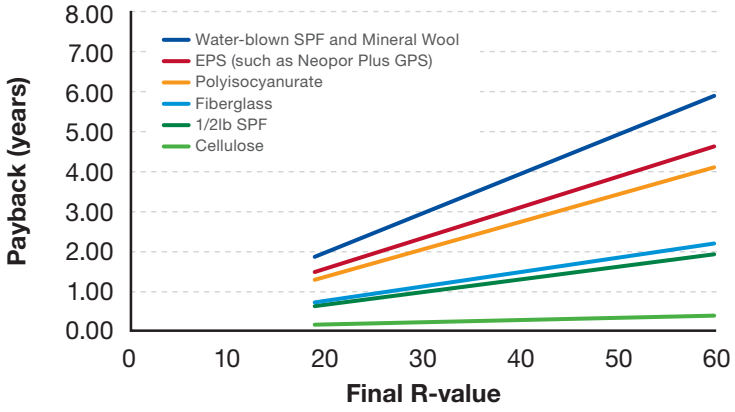
The amount of embodied energy depends to a great extent on the blowing agent in insulation material. Designers, architects and builders aiming to minimize the global warming impacts of their buildings should choose non-HFC (hydrofluorocarbon) foam insulation.

Two common foam insulation materials are produced with HFC blowing agents: Extruded polystyrene (XPS) and standard closed-cell spray polyurethane foam (ccSPF). Neopor Plus GPS is a non-HFC foam insulation and complies with the latest requirements published as part of the Significant New Alternatives Policy (SNAP, 2015) by the Environmental Protection Agency (EPA).

Payback (years) of insulation materials

The graphs below show the payback period (years) of different insulation materials based on their R-value. Payback refers to how many years of energy savings will be required to neutralize the global warming potential of the insulation. Neopor Plus GPS, listed under EPS, with an R-value of 40 will be fully covered after 3 years. In comparison to XPS that will need almost 80 years for the same R-value.





Building Science Corporation at NESEA Building Energy Conference, 2010.

THIRD-PARTY VALIDATED AND CERTIFIED

NEOPOR® PLUS GPS MEETS STRINGENT PERFORMANCE STANDARDS

GREENGUARD Gold Certified for indoor air quality

Neopor Plus GPS has achieved GREENGUARD Gold Certification by UL Environment for products with low chemical emissions.

Products used to build indoor environments can have a significant impact on indoor air pollution levels. Those that have achieved GREENGUARD Certification are scientifically proven to meet some of the most rigorous, third-party chemical emissions standards—helping reduce indoor air pollution and the risk of chemical exposure while aiding in the creation of healthier indoor environments.

Neopor Plus GPS is proven to perform

Neopor Plus GPS meets ASTM C578 Type I, VIII, II, II (1.45 lbs/ft^3), IX and CAN/ ULC S701 Type 1,2,3 requirements, complies with ASTM C1512, UL-723, UL S102.2 and is listed in NFRC 101 for use in fenestration products. Neopor Plus GPS is described in ICC-ES ESR 3463, listed with UL and UL Canada under UL ER 5817-02 and listed on the QAI Laboratories Material Directory. The product is fire and code approved by UL and ICC for ASTM E84, NFPA 286 and NFPA 285 for use in commercial cavity wall with a wide range of cladding approvals (i.e. multiple masonry veneer finishes over steel stud frame). The use of Neopor Plus GPS can earn points under the LEED® Energy Performance Process.

U.S. GREEN BUILDING COUNCIL MEMBER

CLASSIFIED UL

See complete UL Classification Marking on the product, product packaging or UL Certificate that accompanies the product.

c UL ®

QAI US

ICC ES™

ESR 3463
ESR 2784

UL GREENGUARD
PRODUCT CERTIFIED FOR LOW CHEMICAL EMISSIONS
UL.COM/GG
UL 2818
GOLD

REFERENCE PROJECTS MADE OF NEOPOR® PLUS GPS

BRUNCKVIERTEL DISTRICT IN LUDWIGSHAFEN, GERMANY

FACTS & FIGURES:

Continuous Insulation Finish System (CIFS), roof insulation and basement insulation made of Neopor Plus GPS

- Originally built in 1930 to accommodate workers
- Work to revitalize the district began in 1996
- Germany's first "three-liter houses"
- Development of innovative system solutions
- Residents involved in planning phase
- Long-term monitoring results in 2013: insulation system intact, reduction in heat consumption even greater than predicted in some cases, high level of tenant satisfaction

"In our climate zone, it's always a good thing when the heat stays inside. And we hardly ever have to turn on the heating, only on a few really cold days in the winter. We've benefitted enormously from the insulation and the ventilation system."

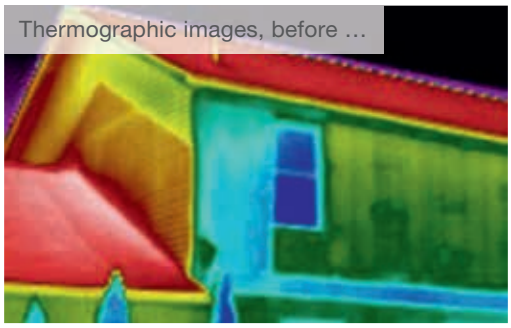
***Peter Doland**, Tenant*

EXTERIOR REMODEL IN BOLIVAR, OHIO

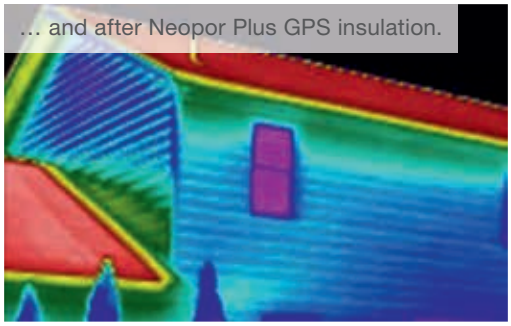
Location: Bolivar, Ohio
Size: 2,500 sq.ft. home
Completed: Summer 2013
Builder: Kraiger Construction Co.

The remodel project in progress.

Thermographic images, before …



… and after Neopor Plus GPS insulation.



FACTS & FIGURES:

Exterior remodel features three products made of Neopor® Plus GPS, forming an integrated, highly effective insulation envelope around the exterior of the home

- Halfback H_2O by Progressive Foam Technologies as continuous insulation, which significantly improved the performance of the existing wall insulation
- CraneBoard 7-inch clapboard vinyl siding by Royal Building Products, backed by Solid CoRe insulation — an R-3 insulated siding product that integrates Neopor Plus GPS to further mitigate thermal bridging through the existing wall structure
- Fiberglass entry door by JELD-WEN, which features an insulating core made of Neopor Plus GPS

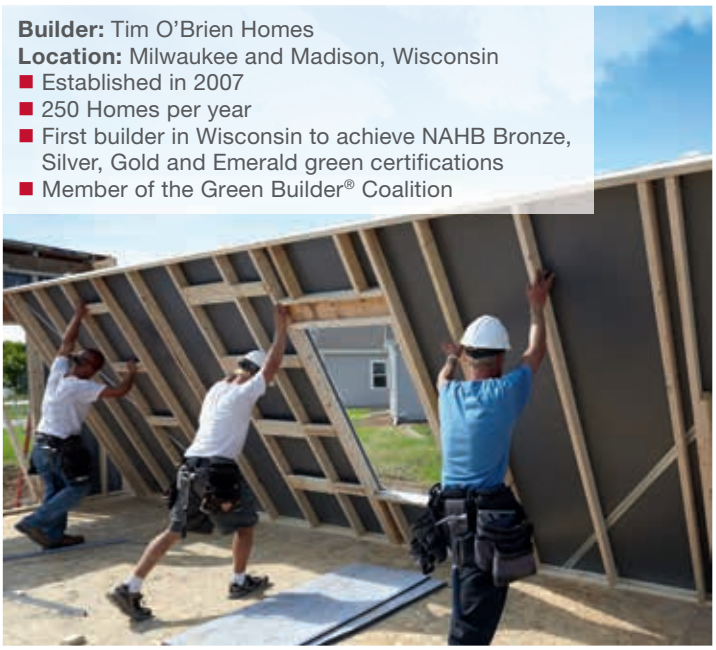
"We are so pleased with how our project turned out. Our home used to be drafty in the winter, and in the summer we had some rooms that were too warm to enjoy. We have already noticed a difference in the comfort level of our home."

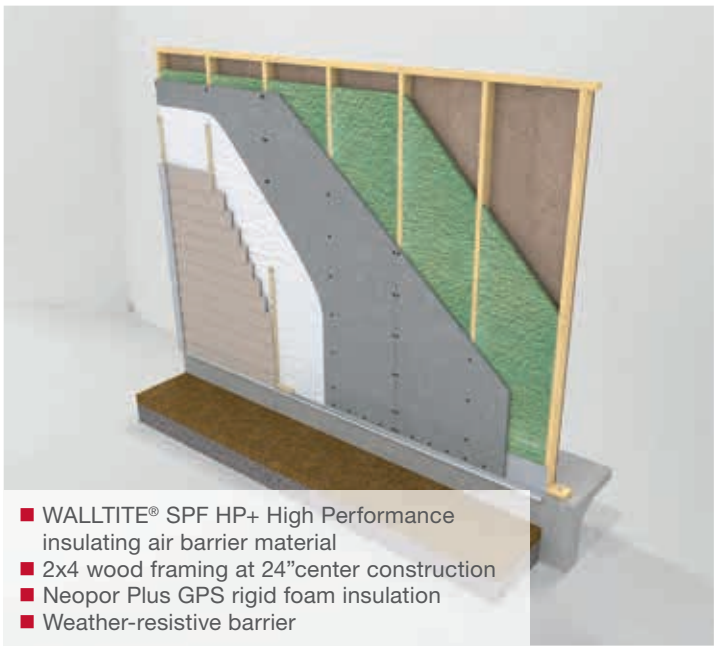
Ben and Kathy Higl, Homeowners

TIM O‘BRIEN HOMES IN MILWAUKEE, WISCONSIN

Builder: Tim O’Brien Homes
Location: Milwaukee and Madison, Wisconsin

- Established in 2007
- 250 Homes per year
- First builder in Wisconsin to achieve NAHB Bronze, Silver, Gold and Emerald green certifications
- Member of the Green Builder® Coalition





- WALLTITE® SPF HP+ High Performance insulating air barrier material
- 2x4 wood framing at 24”center construction
- Neopor Plus GPS rigid foam insulation
- Weather-resistive barrier

FACTS & FIGURES:

BASF HP+™ Wall System made of Neopor® Plus GPS

- The builder participated in the HP+ Wall System, which featured advanced framing and incorporated four control layers in a single-wall design to deliver integrated control of heat, air, moisture and vapor flow
- The home achieved a significantly lower HERS score
- The process also enabled the builder to allocate costs in an extremely efficient manner, in some areas reducing both materials and labor
- Plus, since the HP+ Wall System’s design capacity has been demonstrated to be 35% greater than the design capacity of a wall built with standard framing and OSB with full sheathing, its installation also positively impacted the home’s structural integrity

“Overall, I have to say that it was a wonderful experience from which we learned a great deal that will allow us to achieve higher performance at a price point that delivers outstanding value to our customers. We are proud of the homes we build, and now, with BASF, they’re even better.”

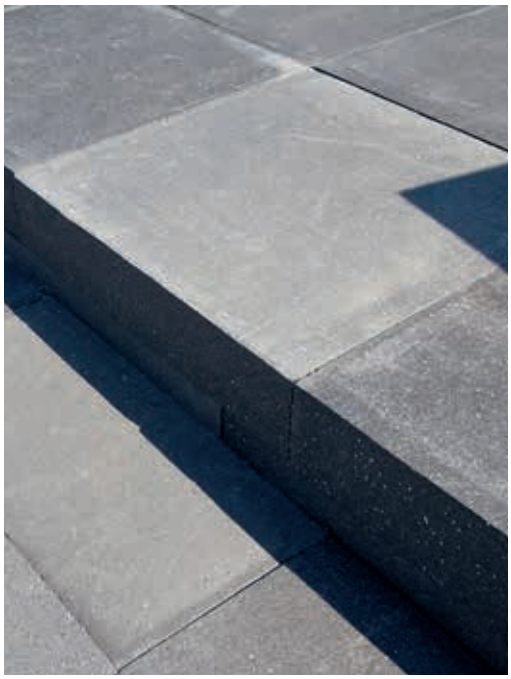
***Tim O’Brien**, President, Tim O’Brien Homes*

WÄLDERHAUS IN HAMBURG, GERMANY

FACTS & FIGURES:

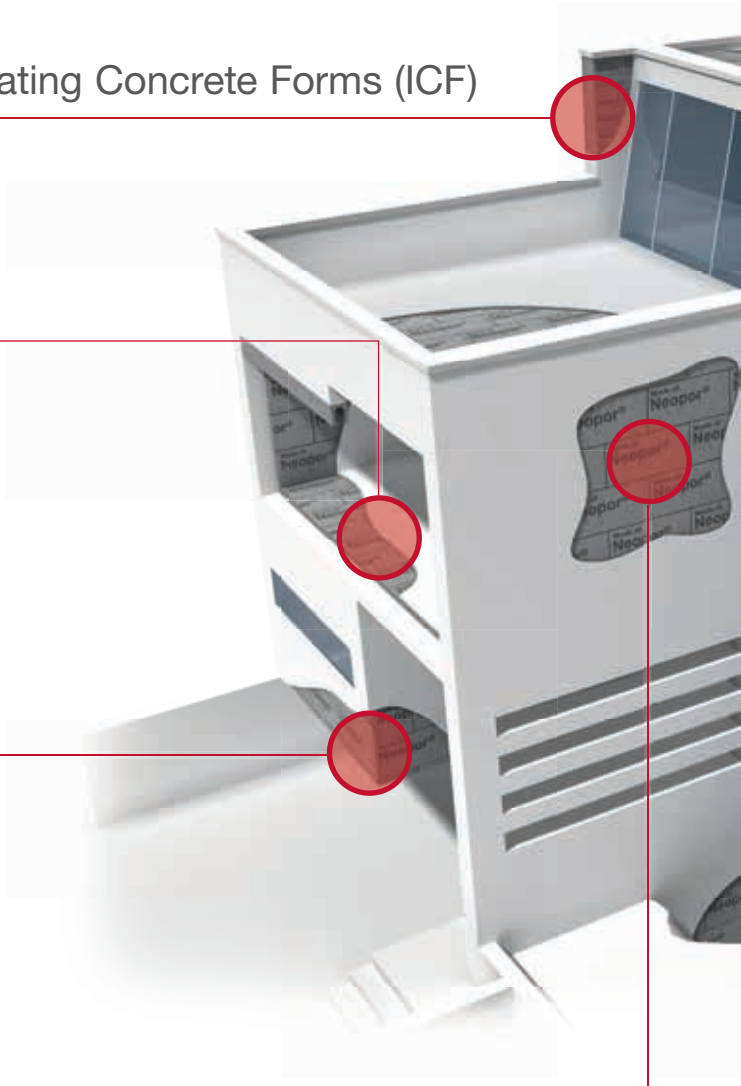
Commercial Roof (Flat Roof) made of Neopor® Plus GPS

- Award-winning project at the 2013 International Building Exhibition in Hamburg
- Builder-owner: Association for the Protection of German Forests, which has the motto “Learning About, Understanding, and Practicing Sustainability”
- The proven excellent eco-efficiency of Neopor Plus GPS supports the goal of sustainability
- Its ease of use enables quick and simple installation on flat roofs
- Its very good insulating properties yield considerable energy savings



NEOPOR® PLUS GPS – FROM TOP TO BOTTOM

ONE INSULATION, MANY USES

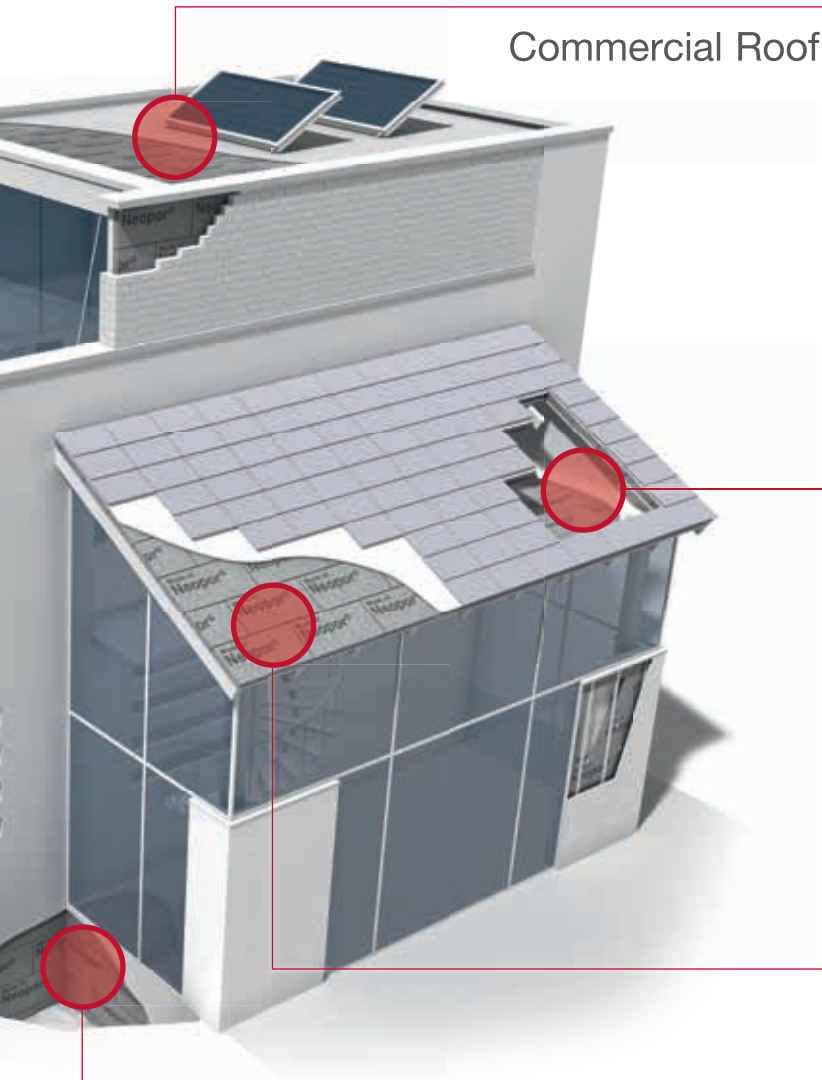


Insulating Concrete Forms (ICF)

Under Slab

Basement Wall / Ceiling

Continuous Insulation Sheathing (CIS) /
Continuous Insulation Finish System (CIFS)


Commercial Roof (Flat Roof)
Attic
Pitch Roof (Vented / Unvented)
Perimeter and Foundation

Continuous Insulation Finishing System (CIFS)

Basement Wall

Basement Ceiling

APPLICATIONS WITH NEOPOR® PLUS GPS

CONTINUOUS INSULATION SHEATHING (CIS)

Advantages

- Efficient thermal insulation
- Uncomplicated and economical
- Excellent for facade renovations

Heat lost through wall surface thermal bridging can add up to annual energy losses of 40%, Continuous Insulation Sheathing (CIS) made of Neopor Plus GPS is the practical way to help reduce such losses. It has excellent structural-physical properties for thermal insulation of residential and commercial exterior walls. By using CIS made of Neopor Plus GPS, builders can meet the latest energy codes and home owners can benefit from energy savings as well.

BASEMENT WALL

Advantages

- Rooms heat up quickly
- Simple and cost-effective implementation
- Improved thermal insulation

Internal thermal insulation achieves very good insulation results for new construction or renovation projects wherever external thermal insulation is not an option. Spaces that have to be heated up quickly or only for brief periods of time definitely benefit from interior thermal insulation.

Because of the outstanding thermal insulation properties of Neopor Plus GPS insulating boards, better insulation performance is achieved with smaller thicknesses than other insulation materials. This means less valuable interior space is lost.

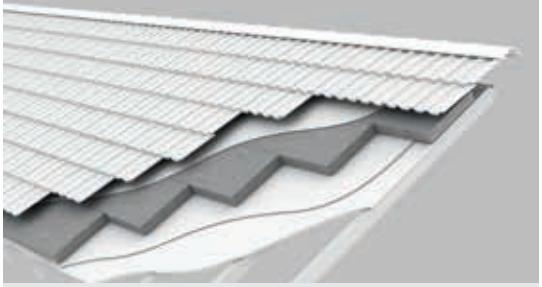
BASEMENT CEILING

Advantages

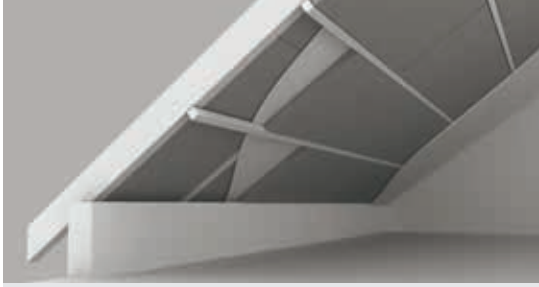
- Improved insulation performance
- Low installation height
- Cool basements, warm living spaces

Basement ceilings can be optimally insulated with insulation boards made of Neopor Plus GPS. The existing ceiling height is only minimally reduced, and as a result, the heating energy consumption is lowered.

Commercial Roof (Flat Roof)



Above-rafter Insulation



Between-/Under-rafter Insulation

COMMERCIAL ROOF (FLAT ROOF)

Flat roofs are subject to high thermal stress and the resulting strains, which has an effect on the roof waterproofing and the building construction. Insulation boards made of Neopor® Plus GPS protect the construction from the effects of temperature fluctuations and ensure reliable thermal insulation. Insulation boards made of Neopor Plus GPS are used for warm roof constructions. They are suitable for almost all conceivable sealing materials, as well as protective and top layers. Environmentally friendly and economical flat roofs are realized with insulation boards made of Neopor Plus GPS. An additional thermal insulation layer with insulation boards made of Neopor Plus GPS is used for roof renovations. This modernizes the flat roof to meet today's thermal insulation standards.

Advantages

- Reliable thermal insulation
- Economical constructions
- Installation independent of weather conditions

PITCH ROOF (VENTED / UNVENTED)

Above-rafter insulation

From a structural-physical point of view, above-rafter insulation is an optimal construction, since the insulating layer is installed virtually without gaps above the roof construction. In doing so, the visible rafters are integrated as a decorative element in the interior design of the rooms. In order to optimally fulfill the thermal insulation requirements, insulation materials made of Neopor Plus GPS are installed efficiently in the form of panels or roof elements for above-rafter insulation. Professionally renovated areas under steep roofs offer valuable living space. The sufficiently dimensioned insulation layer made of Neopor Plus GPS is of special importance in this regard: In the summer, living spaces under the roof can stay cooler and in the winter, the thermal insulation can restrict the loss of expensive heating energy.

Advantages

- Complete insulation layer
- Water-repellent and open to diffusion
- Easy handling

Between-/Under-rafter insulation

Slotted thermal insulation boards made of Neopor Plus GPS are ideal for between-rafter insulation. Special longitudinal slits make the insulation board flexible and elastic, which enables a perfect fit of the panels between the rafters. The combination of between- and under-rafter insulation with insulation boards made of Neopor Plus GPS provides increased thermal insulation with minimal installation height. The energetic restoration of the attic with insulation boards made of Neopor Plus GPS provides a healthy and cozy living space and contributes to the conservation of and increase in value of the building.

Advantages

- Dust-free and fast laying
- No skin-irritant effects
- Firm and dimensionally stable

Under Slab

Perimeter and Foundation

UNDER SLAB

Advantages

- Low water uptake
- Resistant to aging and decay
- High compression strength and bulk density

Floor insulation is important for preventing heat loss to the soil substrate. Due to their high compression strength, Neopor® Plus GPS boards are excellently suited for distributing loads when used for this application. Because it insulates more effectively than other insulation materials, thinner boards can be installed. This reduces construction costs in addition to delivering other benefits.

PERIMETER AND FOUNDATION

Advantages

- High resistance to normal soil moisture
- Perfect supplement to thermal insulation composite systems

Heat loss from heated basements to the surrounding ground can be significantly reduced by installing technically approved Neopor Plus GPS perimeter insulation panels on the exterior of basement walls.

Perimeter insulation panels made of Neopor Plus GPS have good R-values and therefore strong thermal insulation properties. In addition, they are stable under pressure at different installation depths and pressure loads, and are highly resistant to normal soil moisture.

During installation, it is important to follow the specifications of local building codes for the relevant area of application.

Neopor Plus GPS insulation panels also provide the base of a building with effective protection against heat loss.

Perimeter and Foundation insulation panels do not assume functions such as providing drainage or sealing buildings against moisture.

Attic

Insulating concrete forms (ICF)

ATTIC

Regardless of building code requirements, it is recommended for all owners to check the thermal insulation in the attic, which may help to significantly save costs. In many homes, the ceiling of the top floor is poorly insulated or not insulated at all. The attic can be optimally insulated using insulation boards made of Neopor® Plus GPS.

Advantages

- Optimal insulation
- High energy cost savings
- Recommended for older buildings

INSULATING CONCRETE FORMS (ICF)

Insulating concrete forms made of Neopor Plus GPS are suitable for all types of building elements, particularly for those requiring thermal insulation and a simple design. They are used as wall and ceiling elements for single-family homes as well as high-rise buildings. They offer enormous potential savings for do-it-yourself builders.

Formwork elements made of Neopor Plus GPS make it possible to build and insulate exterior walls at the same time. The elements are available in various wall thicknesses and designs – for example, lintel elements that are free of thermal bridges, floor surrounds, roller shutter housings, or cantilevers. Thanks to their good thermal-insulating propties, for work elements made of Neopor Plus GPS are well-suited for the construction of low-energy and passive houses.

Advantages

- No thermal bridges
- High degree of thermal insulation
- Simple and fast handling

NEOPOR® PLUS GPS TECHNICAL PROPERTIES

Neopor Plus GPS rigid foam is today's energy-efficient and cost-effective insulation solution for architects, builders and contractors.

Property	Unit	Neopor Plus GPS				
ASTM C578 Classification		Type I	Type VIII	Type II	Type II+	Type IX
Compressive Resistance	at yield of 10% deformation in psi (min)	10.0	14.0	15.0	20.0	25.0
Thermal Resistance (R-value)	°F · ft² · h/BTU (°C · m²/W) at 75°F	5.0	5.0	5.0	5.0	5.0
	°F · ft² · h/BTU (°C · m²/W) at 40°F	5.2	5.2	5.2	5.3	5.3
Water Vapor Permeance	Max perm (ng/Pa · s · m²)	4.0	3.1	3.1	3.1	2.5
Water Absorption by Total Immersion	Max volume % absorbed	1.1	1.1	1.1	1.1	1.1
Flexural Strength	psi	25.0	32.0	39.0	40.0	50.0
Density	lbs/ ft³ (min)	0.90	1.15	1.35	1.45	1.80
Flame Spread	Index	5				
Smoke Development	Index	25				

Please note:
R means resistance to heat flow. The higher the R-value, the greater the insulating power. Ask your representative for the fact sheet on R-values.
The technical and physical metrics provided in this table are reference values for insulation products made of Neopor Plus GPS.
The values and properties may vary depending on how they are processed and produced. The R-value properties are based on 1-1/16 in thickness.
Water absorption rates typical when tested according to C272.


Neopor®

Neopor®

Important Note:
While the descriptions, designs, data and information contained herein are presented in good faith and believed to be accurate, they are provided for guidance only. Because many factors may affect processing or application/use, BASF recommends that the reader make tests to determine the suitability of a product for a particular purpose prior to use. NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE MADE REGARDING PRODUCTS DESCRIBED OR DESIGNS, DATA OR INFORMATION SET FORTH, OR THAT THE PRODUCTS, DESCRIPTIONS, DESIGNS, DATA OR INFORMATION MAY BE USED WITHOUT INFRINGING THE INTELLECTUAL PROPERTY RIGHTS OF OTHERS. In no case shall the descriptions, information, data or designs provided be considered a part of BASF's terms and conditions of sale. Further, the descriptions, designs, data and information furnished by BASF hereunder are given gratis and BASF assumes no obligation or liability for the descriptions, designs, data or information given or results obtained, all such being given and accepted at the reader's risk.

BF-10308 05/17r4
Neopor® U.S.A.

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www.Neopor-insulation.com

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We create chemistry

Neopor®
Innovation in Insulation

Neopor® HPE-130 Product Data Sheet

Innovation in Insulation Enhanced with Graphite.

Why Builders Rely on Neopor® High Performance Insulation.

- Graphite-enhanced R-5 performance
- Meets 2009, 2012 and 2015 International Residential Code (IRC) for Continuous Insulation (CI), Below Grade, Attics and Crawl Spaces
- Moisture-resistant and Vapor-open
- GREENGUARD Gold Indoor Air Quality
- Attractive incentive program
- R-value Warranty

Product Description.

Neopor HPE-130 is an Innovation in insulation product with a maximum R-value enhanced with graphite.

Neopor HPE-130 is a premium grade insulation manufactured to provide builders and contractors all the features and benefits inherent in a high quality insulation.

Applications.

- Exterior above and below grade insulation

Technical Data.

Code Compliances.

Neopor HPE-130 is manufactured under an industry leading quality control program monitored by UL and further recognized in UL Evaluation Report UL ER5817-02.

Applicable Standards.

Neopor HPE-130 meets ASTM C578, Type VIII, "Standard Specification for Rigid Cellular Polystyrene Thermal Insulation". Applicable standards include:

- ASTM D1621 – Standard Test Method for Compressive Properties of Rigid Cellular Plastics
- ASTM C518 – Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
- ASTM C203 – Standard Test Methods for Breaking Load and Flexural Properties of Block-Type Thermal Insulation
- ASTM E96 – Standard Test Methods for Water Vapor Transmission of Materials
- ASTM C272 – Standard Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
- ASTM D2126 – Standard Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging

R-value.

Neopor HPE-130 has air in its closed cells and therefore has a stable R-value. Many other insulations use blowing agents that cause R-value loss and are harmful to the environment.

As temperatures drop, the R-value of Neopor HPE-130 increases significantly. Many other insulations lose R-value at low temperatures.

Innovation in Insulation.

Neopor® is an advanced rigid thermal insulation material available locally and world-wide that allows builders to achieve energy code while still meeting client budget expectations.

BASF
We create chemistry

Installation.
Neopor HPE-130 boards are easy to handle, cut using a utility knife or serrated blade, and install.

Moisture Resistance.
Neopor HPE-130 is manufactured to resist moisture absorption in wetting conditions and release absorbed moisture quickly during drying periods, which means Neopor HPE-130 maintains R-value. The drying potential of Neopor HPE-130 sets it apart from other insulation materials.

Product Protection.
Neopor HPE-130 can be damaged by prolonged direct sunlight exposure or by reflected sunlight. Neopor HPE-130 must be protected during storage, transportation, and at the project with a light colored opaque material.

Please refer to the Neopor HPE-130 Handling Instructions.

Flame Retardants
Although flame retardants present in Neopor HPE-130 provide an important margin of safety, all Neopor HPE-130 products must be considered combustible.

A protective barrier or thermal barrier is required as specified in the appropriate building code.

Temperature Exposure.
Neopor HPE-130 is able to withstand the rigors of temperature cycling, assuring long-term performance. The maximum recommended long-term exposure temperature for Neopor HPE-130 is 165°F (74°C).

Termites.
Neopor High Performance Insulation can be manufactured with Termiticide.

Physical Properties of Neopor HPE-130.

Compressive Strength[1,2] @ 10% deformation, min. ASTM D1621		psi	13
R-value[1],Thermal Resistance, ASTM C518	40ºF	ºF·ft²·h/Btu	5.2
	75ºF	ºF·ft²·h/Btu	5.0
Density, Nominal ASTM C303		lb/ft³	1.25
Flexural Strength[1], min. ASTM C203		psi	32
Water Vapor Permeance[1] of 1.0 in. thickness, max., perm ASTM E96			3.1
Water Absorption[1] by total immersion, max., volume % ASTM C272			1.1
Flame Spread Index ASTM E84			<25
Smoke Developed Index ASTM E84			<450
Maximum use temperature			165ºF (74ºC)
ASTM C578 Compliance, Type			VIII

[1] Please refer to ASTM C578 specification for complete information. R-values are based on 1-1/16" thickness.
[2] Compressive strength is measured at 10 percent in accordance with ASTM C578. A safety factor is required to prevent long-term creep for sustained loads. For static loads, a safety factor of 3:1 is recommended.

Product and Packaging Data.

Product	Product Dimensions Thickness (in) x Width (in) x Length (in)	Pieces per Bundle
R-3	11/16 x 48 x 96	16
R-5	1-1/16 x 48 x 96	11
R-10	2-1/8 x 48 x 96	5

Warranty.
Neopor HPE-130 is covered by a 50 year limited warranty ensuring thermal performance

Product Availability and Support.
Neopor HPE-130 is supported by a team of experts who work with you to answer your questions, offer solutions, and do everything they can to make sure your project goes smoothly and ends successfully.

Neopor HPE-130 is manufactured and sold by a network of locations throughout North America.

BASF Corporation
1609 Biddle Avenue
Wyandotte, MI 48192 USA
Web: neopor.basf.us
Phone: 1-800-543-1747
Email: neopor-us@basf.com

Neopor®
Innovation in Insulation

Neopor® HPE-130 Tech Data Sheet

Innovation in Insulation Enhanced with Graphite.

Product Description.

Neopor HPE-130 is an Innovation in insulation product with a maximum R-value enhanced with graphite.

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We create chemistry

Neopor® HPE-130 Physical Properties.

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Enhanced Multi-Family Compartmentalization

AEROSEAL®

August 2, 2018

Neal Walsh neal.walsh@aeroseal.com
Randy Williams randy.williams@aeroseal.com

Agenda

- Big Picture
- Compartmentalization sealing
- Technology, FAQ, sealant & cost
- Examples
- Who is Aeroseal?

	Aeroseal	AeroBarrier
Development	Original technology	Derivative technology
Purpose	Duct sealing	Building envelope & compartmentalization sealing

Commonality
Invented by Dr. Mark Modera
Seals from the inside
Seals holes that are difficult for humans to find
Verifiable & guaranteed

Aeroseal Duct Sealing Video

AeroBarrier Compartmentalization Sealing

- **Air sealing / acoustical sealing**
- Derivative of Aeroseal
- Sealing & real-time verification, with documented results
- Consistently tighter apartments
- Faster & cost effective

➔ **TURNKEY SOLUTION PROVIDED BY AEROSEAL**

Certified Results

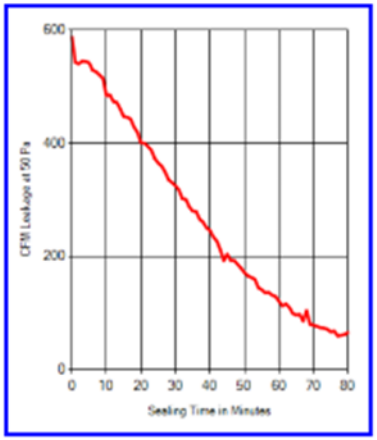
AEROBARRIER™

Breakthrough Envelope Sealing Technology By Aeroseal

Certificate of Completion

Envelope Sealing Performed For:

Beach Green North, floor 2 apt L
45-5 rockaway Beach Blvd
Far Rockaway, NY 11691



Overall Sealing Results

When we arrived,

YOUR HOME HAD:

587.5 CFM of Leakage, equivalent to a

73.2 Square Inch Hole or **6.7 Air Changes per Hour**

*(for your **653** square-foot structure enclosing an approximate volume of **5224** cubic feet).*

After we finished,

YOUR HOME HAS:

65.4 CFM of Leakage, equivalent to a

8.1 Square Inch Hole or **0.8 Air Changes per Hour**

This corresponds to a 88.9% Reduction in Envelope Leakage.

Note: Envelope leakage and air-change results are calculated at a standard pressure of 50 Pa.

Aeroseal Technician

Aeroseal Case ID **9917**

Date of Seal **10/19/2016**

System Description **Home Envelope**

Seal Description **Envelope Sealing**

Hardware **EnvelopeSeal**

AEROSEAL

Envelope Sealing Performed By:

Aeroseal LLC
7989 S Suburban Road
Centerville, OH 45458
Phone: 937.428.9300

Agenda

- Big Picture
- Compartmentalization sealing
- Technology, FAQ, sealant & cost
- Examples
- Who is Aeroseal?

Why "Compartment" in Apartment

Increases Energy Efficiency

- Air leakage in apartment buildings can contribute 20% of the annual space-heating energy load (CMCH)

Reduces

- Noise
- Odors
- Smoke
- Pests

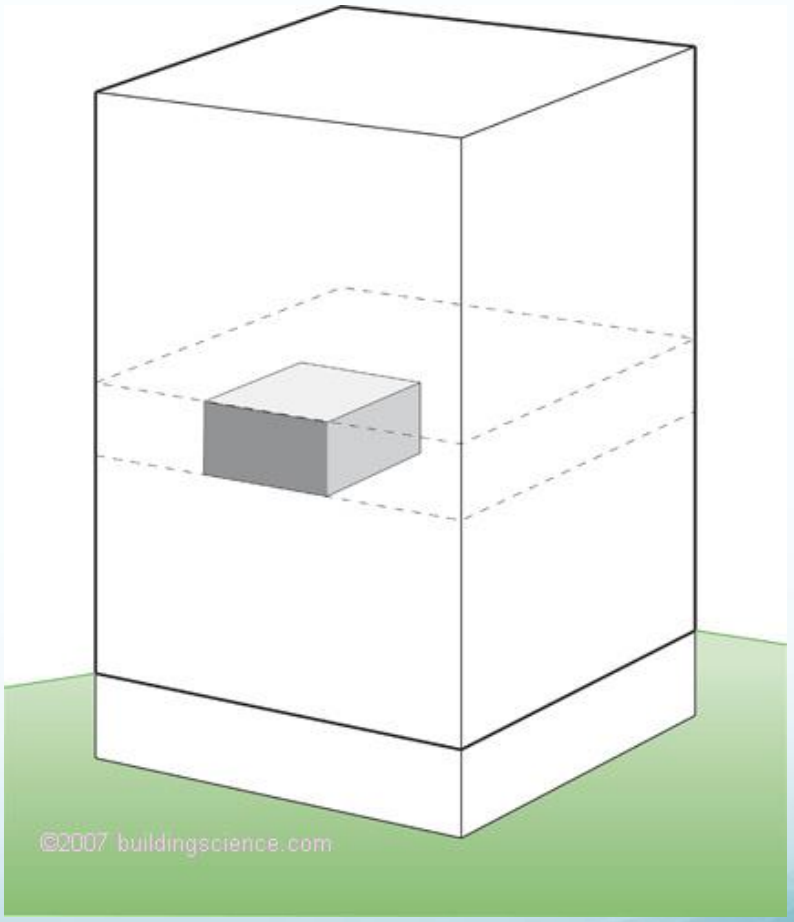
LEED m/f:

- 0.23 CFM* = requirement
- 0.15 CFM* = 3 points

Energystar m/f:

- 0.30 CFM* = requirement

Helps achieve Enterprise Green Communities certification



* at 50Pa, per sq ft of enclosed area

Compartmentalization Is Laborious

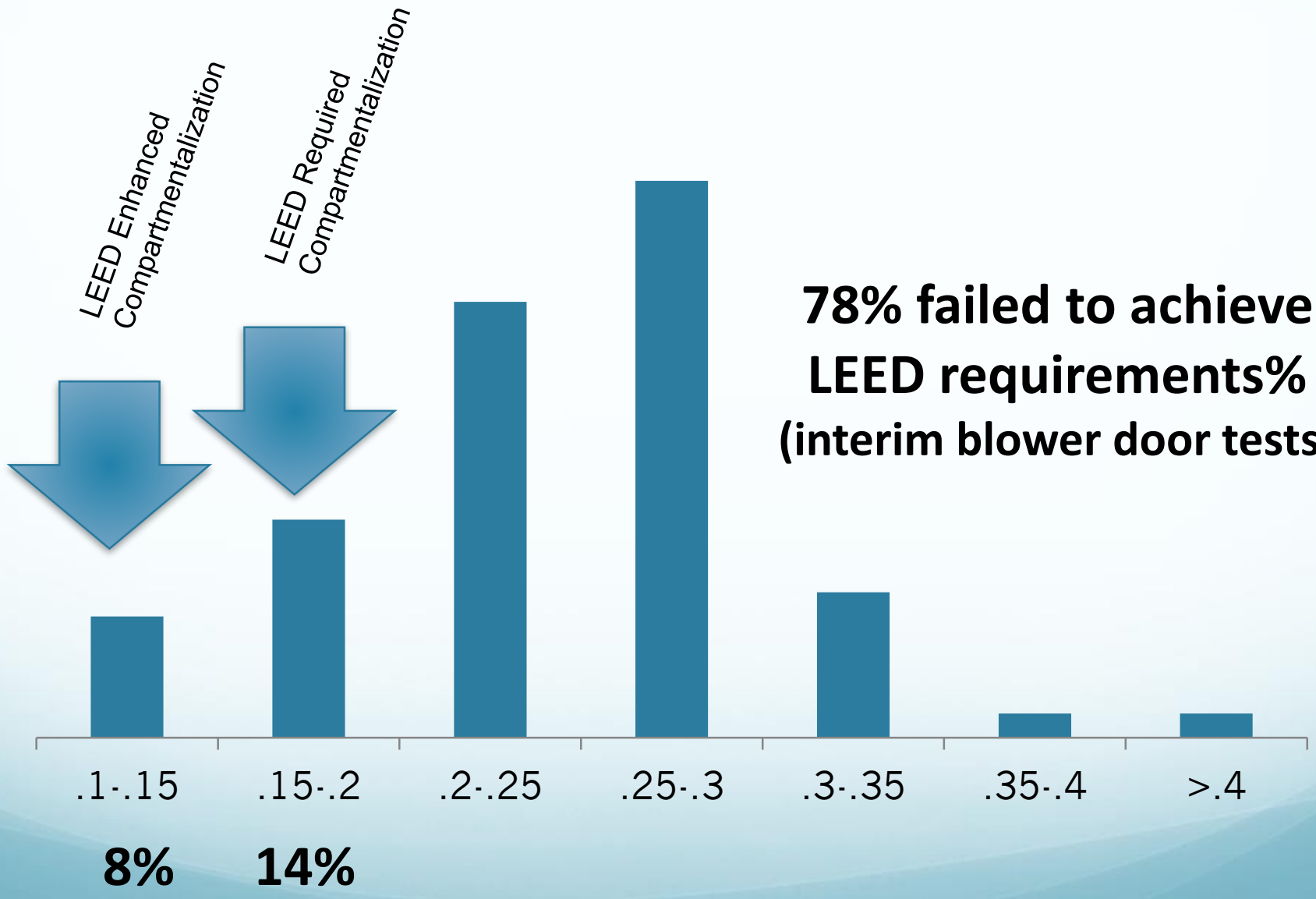
Time consuming & labor intensive, multi-trade & multi-step process

Costly to identify shortfalls . . .

➔ ***How do we identify the leaks?***

➔ ***Who didn't seal the holes!?!?***

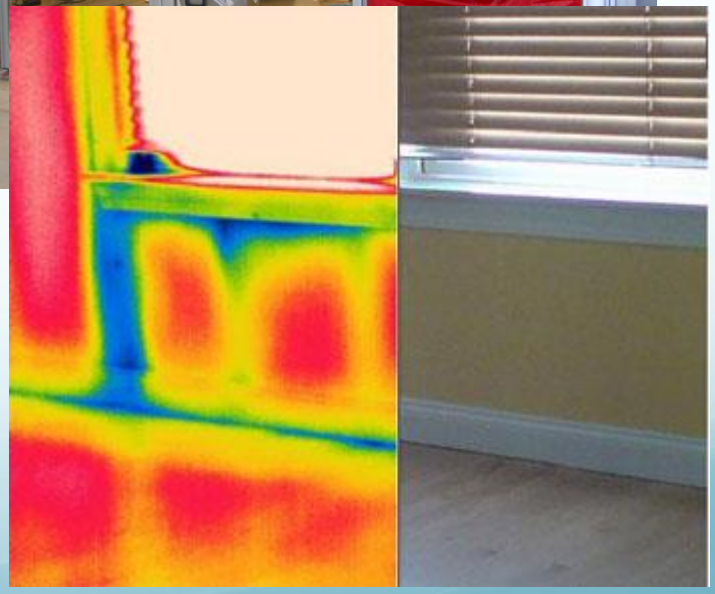
600+ NYC Apartments



78% failed to achieve LEED requirements%
(interim blower door tests)

Effective Air Barriers Are Costly

Audits For Air Tightness Ain't Cheap



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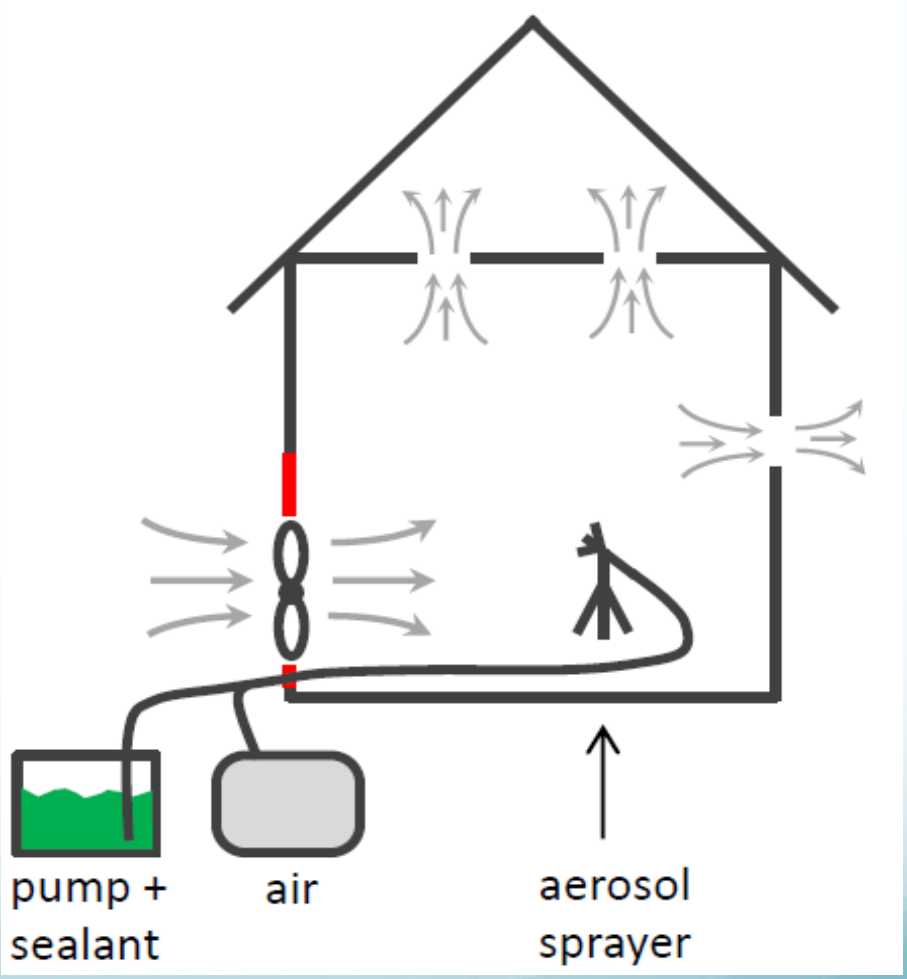
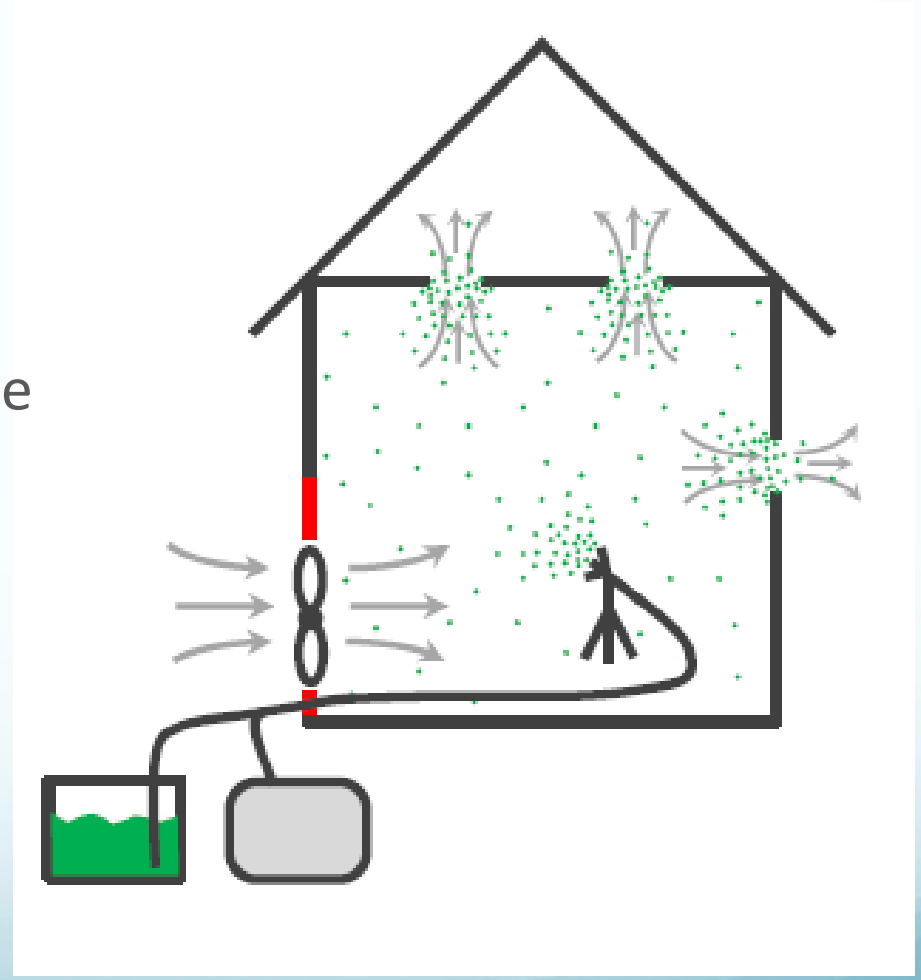
Step 1

- Cover all large openings (drains, HVAC vents)
- Set up equipment
- Pressurize apartment



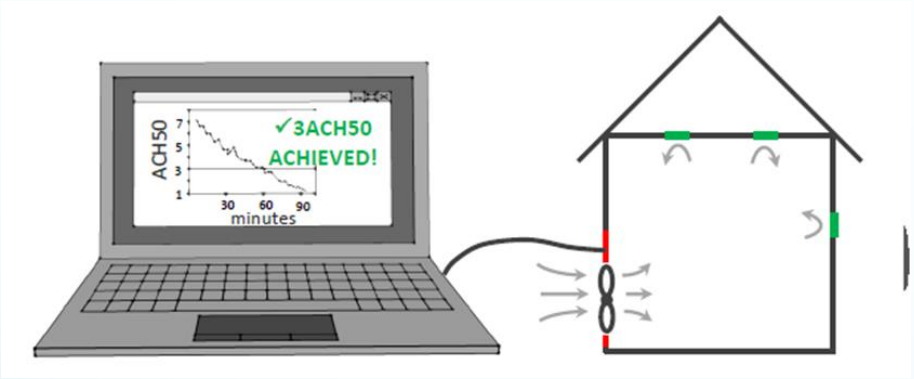
Step 2

- Aerosolize the sealant
- Air currents transport sealant
- Particles deposit along the leaks.



Step 3 – Certified Results

- Software regulates the process parameters, monitors, records and, verifies air-tightness target achieved.



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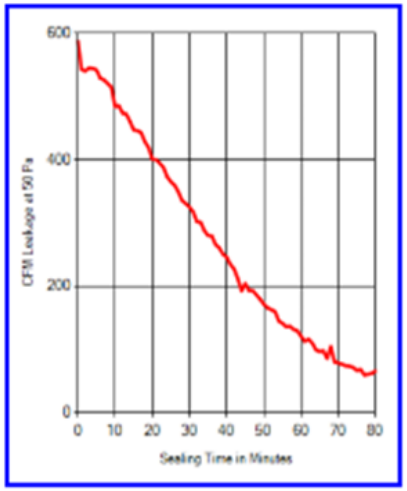

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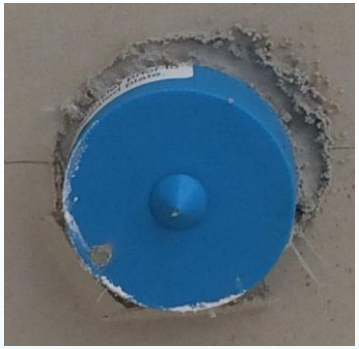
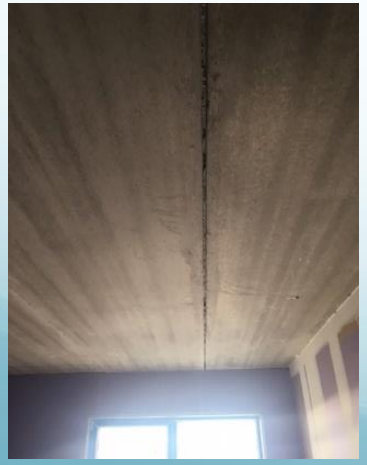
Results








AeroBarrier Video

Process FAQs

Turnkey solution provided by Aeroseal

Air tightness levels as low as 0.2 ACH @50Pa, per sq ft

Applied at temperatures of 40F or more with no special prep

Seal gaps up to1/2” and as small as 10 microns

Three hours, on average, to install per unit

Space can be occupied 10 minutes after sealing

Staging

- Typically after drywall and taping
- Can be applied before insulation or drywall
- Before installing fixtures and finishes
- Do not cover windows and unfinished floors

Sealant FAQs

- Vapor permeable elastomeric membrane
- Acrylic polymer
- Low VOC's
- Complies with ASTM E2357, E2178, and NFPA 285
- Commercially available as a caulk
- Looks like grey caulk and can be painted
- *GreenGuard Gold Certified* for use in schools & hospitals
- 10 year warranty

Chemical Name	CAS-No.	Weight %
Water	7732-18-5	> 60.0
Acrylic polymer	NJ TSRN# 51721300-5277P	15.0 - 40.0
White mineral oil	8042-47-5	1.0 - 5.0
Amorphous silica	7631-86-9	1.0 - 5.0
Titanium dioxide	13463-67-7	0.5 - 1.5

Cost Of Air Tightness

Air / Acoustical Sealing Labor & Materials Cost for 800 Sq Ft Apartment

- LEED Required: $700 - $900 per unit
- LEED Enhanced: $1400 - $1800 per unit
- Compliance Audits and Blower Door Testing: $150 - $250 per unit

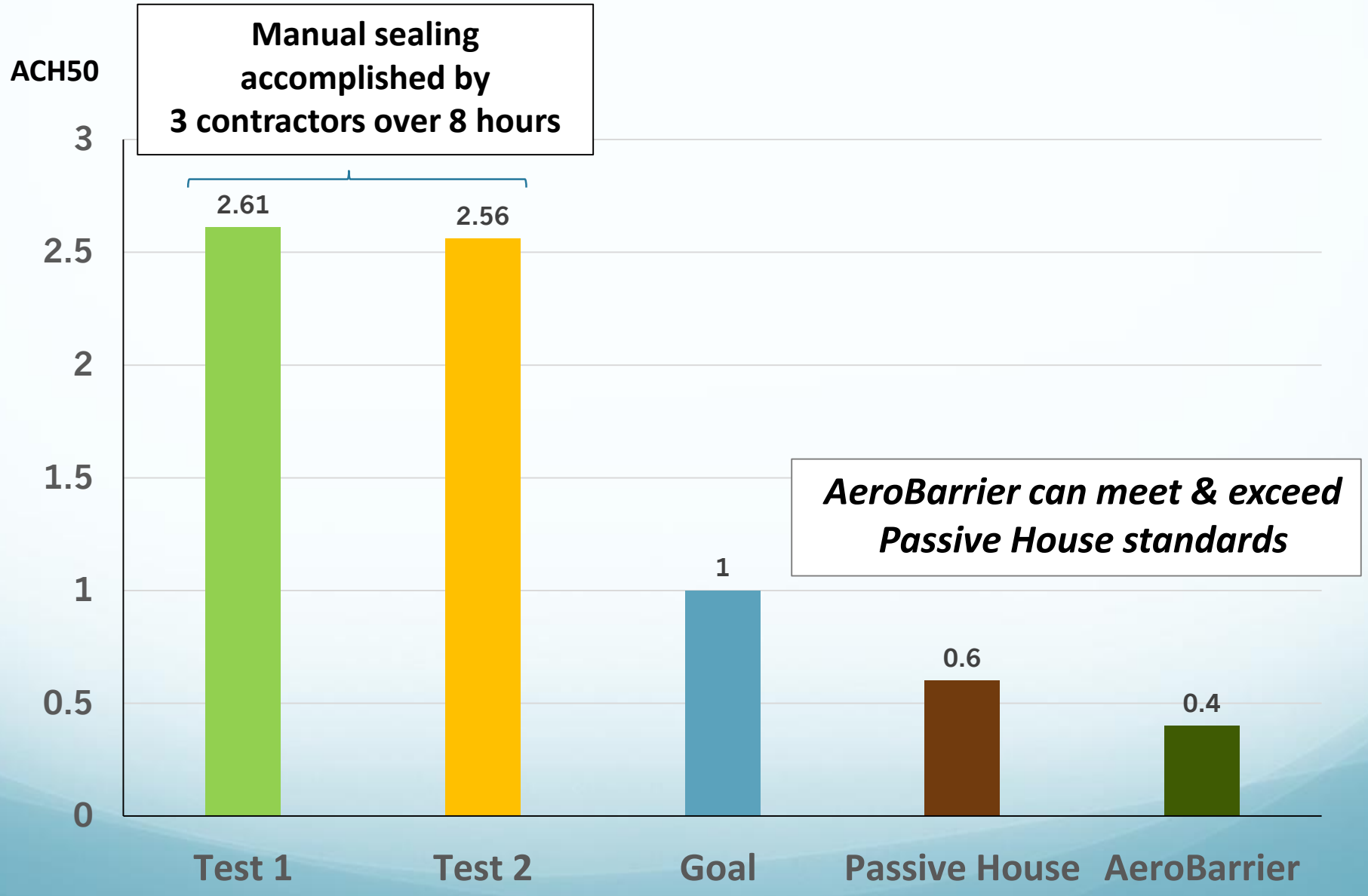
AeroBarrier Price - Guaranteed

- ~$1 per square foot ➔ $800

Savings

- Fewer blower door tests
- Fewer commissioning inspections
- Can be used to satisfy HERS rating requirements
- No costly call backs, sometimes ripping things out
- Eliminate contingency costs – guaranteed
- Avoid occupancy delays

Comparison to Old Methods



RFQ / Turnkey Solution

Provide Info

1. Location
2. # of units
3. Size
4. Stage
5. Prints
6. Goals

Budgetary quote

Drawing review and/or walkthrough

Project plan & proposal

Evaluation, contract & installation provided as a turnkey solution

Agenda

- Big Picture
- Compartmentalization sealing
- Technology, FAQ, sealant & cost
- Examples
- Who is Aeroseal?

Perch in Harlem

- Upper West Side, Manhattan
- First Passive House apartment
- After old sealing, further reduced leakage by 47%
- Exceeded PHIUS parameters

From The Field

"It was blowing people's minds – mostly because monitoring compartmentalization in a multi-family building under construction is typically a very difficult, time consuming task. The level of coordination and commitment you need to get from all contractors on the job is as critical as it is nearly impossible to achieve. With Aerobarrier, it's simply not a problem."

- Chris Benedict, R.A., Architect
CBRA

From The Field

"I don't know of any other way to get the level of tightness we were looking for. No amount of caulking could get this type of result. Most importantly, with Aerobarrier, you know you're going to get the results you want in the end. It's cost-effective and highly efficient at reducing energy costs and improving livability for our tenants. There's nothing that can compete with that."

- Justin Palmer, Founder and CEO, Synapse Development Group

More Projects

YOTEL Hotel
San Francisco CA

Beach Green North
Passive House
Rockaway NY

Agenda

- Big Picture
- Compartmentalization sealing
- Technology, FAQ, sealant & cost
- Examples
- Who is Aeroseal?

About Aeroseal LLC

Location	Dayton, Ohio
Owners	JMD Corporation, (owned by UTC/Carrier, 2001 to 2010)
Service Providers	400+ in USA (residential & commercial)
Employees	~50
Sealing work	Residential: 125,000+ homes sealed Commercial: 35 million sq ft;
Management	Seasoned HVAC experience
Invention	Lawrence Berkeley National Lab
Original Funding	Department of Energy

Milestones

Consumer Reports

2014

COMFORTECH 2013
The National HVACR, Hydronics and Plumbing Seminar and Product Showcase

2013 “Best of Show”

STATE OF CALIFORNIA ENERGY COMMISSION

Certified

nyserda
Energy. Innovation. Solutions.

Approved energy savings

2018	Aeroseal becomes an approved ECM with most ESCOs
2017	AeroBarrier introduced
2016	“Product of the Year” AHR Expo(ASHRAE)
2012	Introduced into commercial market
2010	JMD acquires Aeroseal from UTC/Carrier
1997	Aeroseal founded
1994	Patent awarded to Lawrence Berkeley National Laboratory

AHR EXPO
INNOVATION AWARDS
2016

ASHRAE

Recognized in 2005

U.S. DEPARTMENT OF ENERGY

2002 100 most beneficial technologies in 23 years

FEMP
Federal Energy Management Program

Certified

Thank You!

AEROSEAL®

Senergy®

Senershield-R

Vapor Permeable Air/Water-Resistive Barrier Membrane

Product Bulletin

BASF

We create chemistry

Senershield-R

DESCRIPTION

SENERSHIELD-R is a one-component, fluid-applied vapor permeable air/water-resistive barrier. This waterproof, resilient coating may be spray-, roller-, brush-, or trowel-applied directly to approved above grade wall substrates. It provides excellent secondary moisture protection behind most wall claddings including EIFS, stucco*, brick, siding and metal panels. SENERSHIELD-R is listed in ICC ESR-1878, ESR-1794 and ESR-2986.

*A slipsheet is required for stucco claddings.

USES

For use over the following exterior wall substrates:
Poured concrete/unit masonry, ASTM C1177 type sheathings, including DensGlass™ or DensElement exterior sheathing, eXP™ sheathing, GlasRoc® sheathing, Securock™ glass-mat sheathing, Weather Defense™ Platinum sheathing, GreenGlass® sheathing, PermaBase™ cement-board by National Gypsum and other cement-boards (ASTM C1325 Type A Exterior), Untreated Exposure I or exterior plywood sheathing (grade C-D or better), Untreated Exposure I OSB, gypsum sheathing (ASTM C79/ASTM C1396).

Do not use SENERSHIELD-R for below-grade applications or on surfaces subject to water immersion.

COLOR

Gray

COVERAGE*

Substrate	Embed Sheathing Fabric
ASTM C1177 Type Sheathing	**4" Sheathing Fabric**
41 m² (450 ft²) per pail	192 m (630 ft) per pail
Cement Board	**6" Sheathing Fabric**
46 m² (500 ft²) per pail	128 m (420 ft) per pail
Plywood*	**9" Sheathing Fabric**
24 m² (265 ft²) per pail	85 m (280 ft) per pail
Oriented Strand Board (OSB)*	
24 m² (265 ft²) per pail	
Concrete Masonry Units (CMU)*	
Standard Weight 24 m² (265 ft²) per pail	
Medium Weight 17 m² (180 ft²) per pail	
Light Weight 12 m² (125 ft²) per pail	
Poured Concrete	
46 m² (500 ft²) per pail	

Note: Coverage for C1177 sheathing, cement board, poured concrete is at 10 mils WFT; for plywood OSB and CMU are at 20 mils WFT.

PACKAGING

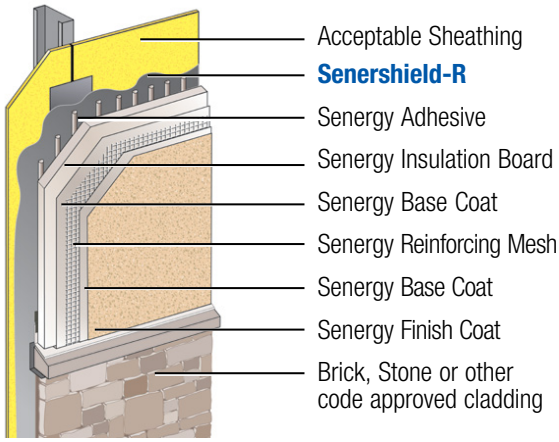
27.2 kg per 19-liter pail (60 lbs per 5-gallon pail)

4" SHEATHING FABRIC: 101.5 mm x 54.8 m (4" x 180 ft) roll
6" SHEATHING FABRIC: 152.4 mm x 54.8 m (6" x 180 ft) roll
9" SHEATHING FABRIC: 228.5 mm x 54.8 m (9" x 180 ft) roll

* Roll or spray / backroll for optimum coverage rate. Other application methods may provide less coverage. Actual results may vary depending on surface porosity, roughness, moisture uptakes, or other factors.

Features	Benefits
Can be used with most code-compliant claddings	One continuous air/water-resisitve barrier for buildings with multiple claddings
ICC ESR-2986 Evaluation Report	Confirms compliance with IBC, IRC, and IECC requirements.
ABAA evaluated	Approved for projects requiring ABAA specifications and quality assurance
<1% of allowable air leakage per ASTM E2357 Air Leakage of Building Assemblies test	Easily meets air tightness requirements defined by ASHRAE 189.1, ASHRAE 90.1 and ABAA
Meets ASTM D1970 nail sealability requirements with and without Sheathing Fabric	Self sealing performance
One component, low-VOC formulation	Easy to apply, meets VOC requirements in all 50 states
Nonflammable as applied	Workplace safety
Mineral oil and plasticizer free	Will not dry out or crack due to loss of oil / plasticizer over time
Water based	Cleans up with water; solvents and citrus based cleaners not required
Tough, abrasion resistant	Rugged membrane resists damage after installation
Low temperature performance with LT ADDITIVE	Extends minimum application temperature to 4˚ C (25˚ F)
180 day outdoor exposure rating	Flexible construction scheduling

SENERSHIELD-R complies with the air barrier requirements of the Massachusetts State Energy Code.



Multi-Clad Wall Assembly using Senershield-R

TEST RESULTS

TEST	RESULT
Air Leakage of Air Barrier Assemblies ASTM E 2357	0.0066 l/s·m² (0.00132 cfm/ft²) @ 75 Pa (1.57 psf) positive / post conditioning 0.0014 l/s·m² (0.0003 cfm/ft²) @ 75 Pa (1.57 psf) negative / post conditioning
Air Permeance of Building Materials ASTM E 2178	0.0002 l/s·m² @ 75 Pa (0.0000 cfm/ft² @ 1.57 psf)
Rate of Air Leakage ASTM E 283	0.0185 l/s·m² @ 75 Pa (0.0037 cfm/ft² @ 1.57 psf)
Water Vapor Transmission ASTM E 96 Method B	18 Perms (grains/Hr. in Hg. ft²) @ 10 mils wet film thickness 14 Perms (grains/Hr. in Hg. ft²) @ 20 mils wet film thickness
Pull-Off Strength of Coatings ASTM D 4541	Pass - Min. 110 kPa (15.9 psi) or substrate failure (Tested over exterior gypsum sheathing, ASTM C1177 glass-mat sheathing, cement board, OSB, plywood; pvc and galvanized flashing)
Nail Sealability (without Sheathing Fabric) ASTM D 1970	Pass - No water penetration at galvanized roofing nail penetration under 127 mm (5") head of water after 3 days at 4° C (40° F)
Surface Burning ASTM E 84	Class A flame spread <25 Class A smoke developed index <450
Radiant Heat Multi-Story Tests NFPA 268, NFPA 285	Pass using many wall designs; including Senergy EIFS cladding with 12" EPS insulation Engineering analyses available on request
Water-Resistive Barriers under EIFS ASTM E 2570	Pass (Meets all criteria in the standard)
Compound Stability (Elevated Temperature) ASTM D5147 Section 15	No flowing, dripping, or drop formation up to 177° C (350° F)
Fire Resistance ASTM E119/UL 263	Will not add or detract from the rating of a fire resistive wall assembly
Drainage Efficiency ASTM E 2273	99%

ICC-ES AC 212 Acceptance Criteria for Water-Resistive Coatings used as Water-Resistive Barriers over Exterior Sheathing	
Sequential Testing - Structural, Racking, Restrained Environmental Conditioning and Water Penetration	
1. **Structural:** ASTM E 1233 Procedure A	No cracking at joints or interface of flashing
2. **Racking:** ASTM E 72	No cracking at joints or interface of flashing
3. **Restrained Environmental Conditioning:** ICC-ES AC 212	No cracking at joints or interface of flashing
4. **Water Penetration :** ASTM E 331	No water penetration after 90 min @ 299 Pa (6.24 psf) Tested over OSB and gypsum sheathing
Sequential Testing - Weathering	
1. **UV Light Exposure:** ICC-ES AC 212	No cracking or bond failure to substrate
2. **Accelerated Aging:** ICC-ES AC 212	No cracking or bond failure to substrate
3. **Hydrostatic Pressure Test:** AATCC 127-1985	No water penetration under 55cm (21.7") head of water for 5 hours

TEST RESULTS

ICC-ES AC 212 (Continued from the previous page)	
Freeze-Thaw ASTM E 2485 (Method B)	No sign of deleterious effects after 10 cycles (Tested over exterior gypsum sheathing, ASTM C1177 glass-mat sheathing, cement board, OSB, plywood)
Water Resistance ASTM D 2247	No sign of deleterious effects after 14 day exposure (Tested over exterior gypsum sheathing, ASTM C1177 glass-mat sheathing, cement board, OSB, plywood)
Tensile Bond ASTM C 297	>103 kPa (15 psi) Tested over exterior gypsum sheathing, ASTM C1177 glass-mat sheathing, cement board, OSB, plywood, CMU; pvc and galvanized flashing
Tensile Bond (before & after freeze-thaw) ASTM C 297	>103 kPa (15 psi) avg; no failure of the lamina after 10 cycles freeze-thaw (Tested over various substrates)

ICC-ES AC 148 Acceptance Criteria for Flexible Flashing Materials	
Sequential Testing - Weathering	
1. UV Light Exposure: ICC-ES AC 148	No cracking or bond failure to substrate
2. Acclerated Aging: ICC-ES AC 148	No cracking or bond failure to substrate
3. Hydrostatic Pressure Test: AATCC 127-1985	No water penetration under 55cm (21.7") head of water for 5 hours
Peel Adhesion ASTM D 3330 Method F	Tested over ASTM C1177 glass-mat sheathing, OSB, plywood, pvc and uncoated aluminum
After UV Exposure	Pass
After Accelerated Aging	Pass
After Elevated Temperature Exposure	Pass
After Water Immersion	Pass
Nail Sealability after Thermal Cycling ASTM D 1970 (Modified), AAMA 711	Pass
Tensile Strength after UV Exposure ASTM D 5034, AAMA 711	All samples meet the minimum requirement of 3.5 N/mm (20 lbs/in)
Cold Temperature Pliability ASTM D 1970, AAMA 711	No cracking after bending around a 25 mm (1") mandrel after 2 hour exposure to -18° C (0° F)
Resistance to Peeling AAMA 711	No signs of distress or failure after 24 hours of exposure at room temperature, 50° C (122° F), 65° C (149° F), 80° C (176° F)

CCMC Tech Guide 07240	
Joint Disruption Resistance	No cracking, delamination or other deleterious effects at L/180 deflection
Joint Relaxation Resistance	Pass Max water transmission rate 2×10^{-7} kg/m^2 · s (4.1×10^{-8} lbs/ ft^2 · s) after extension and environmental cycling
Adhesive/Cohesive Bond	Pass Min 0.3 MPa (43.5 psi) in dry state, 0.1 MPa (14.5 psi) after 48 hour water immersion
Nail Popping Resistance	No cracking or delamination around nail head following 1 mm (0.04") protrusion
Water Absorption	Pass Maximum 0.004 kg/m^2 · s (0.0008 lbs/ ft^2 · s)
Accelerated Weather Resistance	No visible effects (cracking, flaking, other deleterious effects) after 334 total hours

MIXING

1. Use directly from original packaging or prepare in a container that is clean and free of foreign substances. Do not use a container which has contained or been cleaned with a petroleum-based product.
2. Mix SENERSHIELD-R with a clean, rust-free paddle and drill until thoroughly blended. Dilution of SENERSHIELD-R is not recommended.
3. Additives, other than LT ADDITIVE, are not permitted.
4. Close container when not in use.
5. Clean tools and equipment with water immediately after use. Dried material can only be removed mechanically.

APPLICATION

Job Conditions

To apply to SENERSHIELD-R at ambient temperatures below 4°C (40°F) but greater than -4°C (25°F), thoroughly blend 1 full quart of LT ADDITIVE with one full 5-gallon pail of SENERSHIELD-R. When using LT ADDITIVE, extended drying time can be expected. Do not apply SENERSHIELD-R to frozen or frost-laden substrates.

Do not apply SENERSHIELD-R in ambient temperatures below 4°C (40°F) or onto substrates below 4°C (40°F) unless LT ADDITIVE is used.

Walls shall be capped to prevent moisture and precipitation from entering wall during construction.

Limit the weather exposure of SENERSHIELD-R to a maximum of 180 days. Verify surfaces are free of dirt, contaminants, or other deleterious conditions before application of cladding. Report and correct any such conditions prior to cladding application. Dry/cure times of adhesively applied EPS insulation board installed over SENERSHIELD-R may be prolonged, particularly in cool and/or damp weather. Non-cementitious adhesives are not recommended for EPS insulation board attachment to SENERSHIELD-R. Proper application is the responsibility of the user.

Surface Preparation

Substrate shall be dry, clean, sound and free of release agents, paint or other residue or coatings. Verify substrate is flat, free of fins or planar irregularities greater than 6.4 mm in 3 m (1/4" in 10'). Unsatisfactory conditions shall be reported to the general contractor and corrected before application of SENERSHIELD-R.

Equipment

Use a 20 mm (3/4") nap roller or paint brush. If spraying, refer to *Spray Application* technical bulletin for spray application equipment and application instructions.

Note: If using roller application, it is necessary to pre-wet the synthetic roller pad with water and spin out the excess water. The pre-wetting only needs to be done once at the start of application.

Procedure

1. Substrate shall be of a type acceptable by BASF and shall be installed per substrate manufacturer's instructions and local code requirements.
2. Rough openings and sheathing joints can be treated with MAXFLASH Liquid Flashing Membrane or SHEATHING FABRIC saturated with SENERSHIELD-R. See following sections for addiitional steps.

USING MAXFLASH

Flashing Rough Openings:

A. Apply a bead of MAXFLASH in each corner of the rough opening and tool MAXFLASH into corners, ensuring that corners are fully sealed. Where wood bucks are used, tool MAXFLASH into gaps between bucks and between the buck and building structure.

B. Apply additional MAXFLASH in a zigzag pattern onto head, sill, jambs and exterior substrate. Spread MAXFLASH evenly across the rough opening to form a uniform, continuous, void- and pinhole-free membrane with a 12-30 mil thickness. Spread MAXFLASH before it skins, typically within 2-3 minutes of application.

C. Extend MAXFLASH membrane minimum 4-inches onto the exterior wall, maintaining 12-30 mil thickness.

D. Allow MAXFLASH to skin before applying BASF fluid-applied air/water-resistive barrier to sheathing. Lap air/water-resistive barrier a minimum of 2-inches onto MAXFLASH, creating a continuous, monolithic air/water-resistive barrier.

E. Allow MAXFLASH to cure before installing windows.

Sheathing Joints:

MAXFLASH can be used to fill sheathing joints up to ½" wide.

A. Apply a thick bead of MAXFLASH to sheathing joints.

B. Spread MAXFLASH evenly 1-inch beyond the joint on either side. Apply 20-30 mils of MAXFLASH across the sheathing joint.

C. Spot fastener heads with MAXFLASH or BASF fluid-applied air/water-resistive barrier.

D. Allow MAXFLASH to skin before applying subsequent coat of air/water-resistive barrier.

See the MAXFLASH product bulletin for coverages and additional product highlights.

- OR -

USING SHEATHING FABRIC

Flashing Rough Openings:

Wrap openings with SHEATHING FABRIC. Apply a generous amount of mixed SENERSHIELD-R to all surfaces and immediately embedding SHEATHING FABRIC, completely saturating the SHEATHING FABRIC. If necessary, apply a second coat of SENERSHIELD-R to ensure a complete, void-free membrane.

Sheathing Joints:

A. Spot all fasteners and precoat sheathing joints, terminations, inside and outside corners with mixed SENERSHIELD-R using a 101 mm (4") wide by 20 mm (3/4") nap roller,brush or spray.

B. 1. Immediately place and center SHEATHING FABRIC over wet SENERSHIELD-R at all sheathing joints, terminations, inside and outside corners, as well as knot holes and check cracks that may exist in plywood or OSB. Ensure SHEATHING FABRIC extends evenly on both sides of the sheathing joint. Completely saturate SHEATHING FABRIC with SENERSHIELD-R.

2. Lap SHEATHING FABRIC 63.5 mm (2 1/2") minimum at intersections.

3. If using roller, brush, or trowel application, allow to dry tothe touch before applying SENERSHIELD-R to entire wall surface. If spraying, "wet on wet" application is acceptable.

3. a. Apply SENERSHIELD-R to concrete, DensGlass™ or DensElement exterior sheathing, eXP™ sheathing, GlasRoc® sheathing, Securock™ glass-mat sheathing, Weather Defense™ Platinum sheathing, GreenGlass® sheathing, PermaBase™ cement-board by National Gypsum and other cement-boards (ASTM C1325 Type A Exterior) and gypsum sheathing (ASTM C79/ASTM C1396) with a 20 mm (3/4") nap roller, stainless steel trowel, brush or spray gun to a consistent, minimum 10 wet mil thickness that is free of voids and pin holes. A fully loaded roller pad is required to obtain a consistent, minimum 10 wet mil thickness. Backrolling may be needed to produce a pinhole-free film.

Note: Refer to Spray Application technical bulletin for spray application equipment and application instructions.

b. Apply SENERSHIELD-R to plywood, OSB or CMU substrate(s) with a 20 mm (3/4") nap roller or spray to a consistent, minimum 10 wet mil thickness. Prior to application of the second coat, visually inspect to assure sheathing surface is blister free and coating is free of voids and pinholes. Repair if needed and then apply a second coat after the initial coating is sufficiently dry. **Note: A minimum of two (2) 10 mil wet coats of SENERSHIELD-R is required over OSB, plywood and CMU. SENERSHIELD-R may be sprayed to a 20-mil thickness over OSB and plywood in one wet application. Backrolling may be needed to produce a pinhole-free film.**

Drying Time

Allow to dry completely, typically 2 to 10 hours, before proceeding with EIFS or other cladding installation. Protect from rain and from temperatures less than 4°C (40°F) for 24 hours.

For Best Performance

Prior to application of EPS insulation boards for EIFS or alternative claddings, visually inspect the SENERSHIELD-R for voids, pinholes, surface deficiencies, etc. Repair deficiencies and areas that are not intact. Apply additional SENERSHIELD-R as necessary such that SENERSHIELD-R is free of voids, pinholes, etc. All sheathing joints, terminations, inside and outside corners must be reinforced with 4", 6" or 9" SHEATHING FABRIC or WS FLASH 4 or 9 or treated with MAXFLASH. Reference *Air/Vapor/Water-Resistive Barrier Guidelines* technical bulletin for proper treatment of rough openings and sheathing joints.

LIMITATIONS

Shipping & Storage

Protect BASF materials during transportation and installation to avoid physical damage. Store BASF materials in a cool, dry place protected from freezing. Store at no less than 4°C (40°F). Protect from extreme heat and direct sunlight.

Stacking

Do not stack pallets.

Shelf Life

Approximately 2 years, properly stored in original containers.

TECHNICAL SUPPORT

Consult the BASF Wall Systems Technical Services Department for specific recommendations concerning all other applications. Consult the Senergy website, www.senergy.basf.com, for additional information about products and systems and for updated literature.

HEALTH AND SAFETY

Follow good safety and industrial hygiene practices during handling and installing products and systems. Take necessary precautions and wear the appropriate personal protective equipment as needed. Read Safety Data Sheet (SDS) and related literature on this product before specification and/or installation.

Solids

74% solids

VOC Content

11 g/l, or 0.09 lbs/gal less water and exempt solvents per ASTM D2369 (based in part on EPA method 24).

For medical emergencies only call CHEMTREC at (800) 424-9300.

Warranty

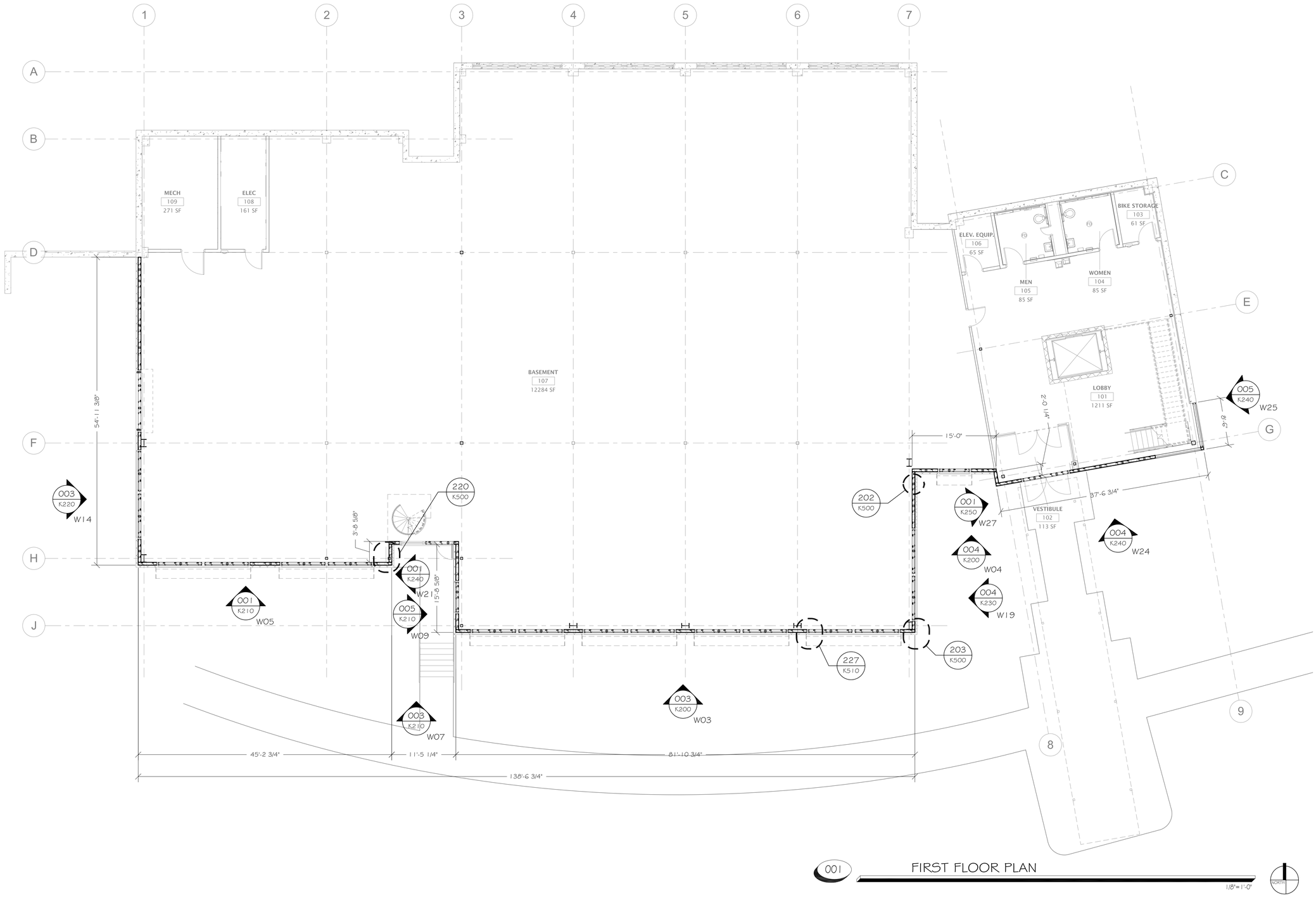
BASF warrants this product to be free from manufacturing defects and to meet the technical properties on the current Product Bulletin, if used as directed within shelf life. Satisfactory results depend not only on quality products but also upon many factors beyond our control. BASF MAKES NO OTHER WARRANTY OR GUARANTEE, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO ITS PRODUCTS. The sole and exclusive remedy of Purchaser for any claim concerning this product, including but not limited to, claims alleging breach of warranty, negligence, strict liability or otherwise, is shipment to purchaser of product equal to the amount of product that fails to meet this warranty or refund of the original purchase price of product that fails to meet this warranty, at the sole option of BASF. In the absence of an extended warranty issued by BASF, any claims concerning this product must be received in writing within one (1) year from the date of shipment and any claims not presented within that period are waived by Purchaser. BASF WILL NOT BE RESPONSIBLE FOR ANY SPECIAL, INCIDENTAL, CONSEQUENTIAL (INCLUDING LOST PROFITS) OR PUNITIVE DAMAGES OF ANY KIND.

Purchaser must determine the suitability of the products for the intended use and assumes all risks and liabilities in connection therewith. This information and all further technical advice are based on BASF's present knowledge and experience. However, BASF assumes no liability for providing such information and advice including the extent to which such information and advice may relate to existing third party intellectual property rights, especially patent rights, nor shall any legal relationship be created by or arise from the provision of such information and advice. BASF reserves the right to make any changes according to technological progress or further developments. The Purchaser of the Product(s) must test the product(s) for suitability for the intended application and purpose before proceeding with a full application of the product(s). Performance of the product described herein should be verified by testing and carried out by qualified experts.

air barrier
abaa
association of
america

For the most current version of this literature, please visit our website at **www.senergy.basf.com**.

BASF Corporation - Wall Systems | 3550 St Johns Bluff Rd South Jacksonville, Florida 32224 Phone: 800.221.9255 Fax: 904.996.6300



001 FIRST FLOOR PLAN

1/8"=1'-0"

NORTH

GENERAL NOTES

No.	Revision/Issue	Date

PROJECT NUMBER:

DRAWN BY	
DATE	
SCALE	1/8"=1'-0"

SHEET NUMBER

K100

001 SECOND FLOOR PLAN

1/8"= 1'-0"

NORTH

GENERAL NOTES

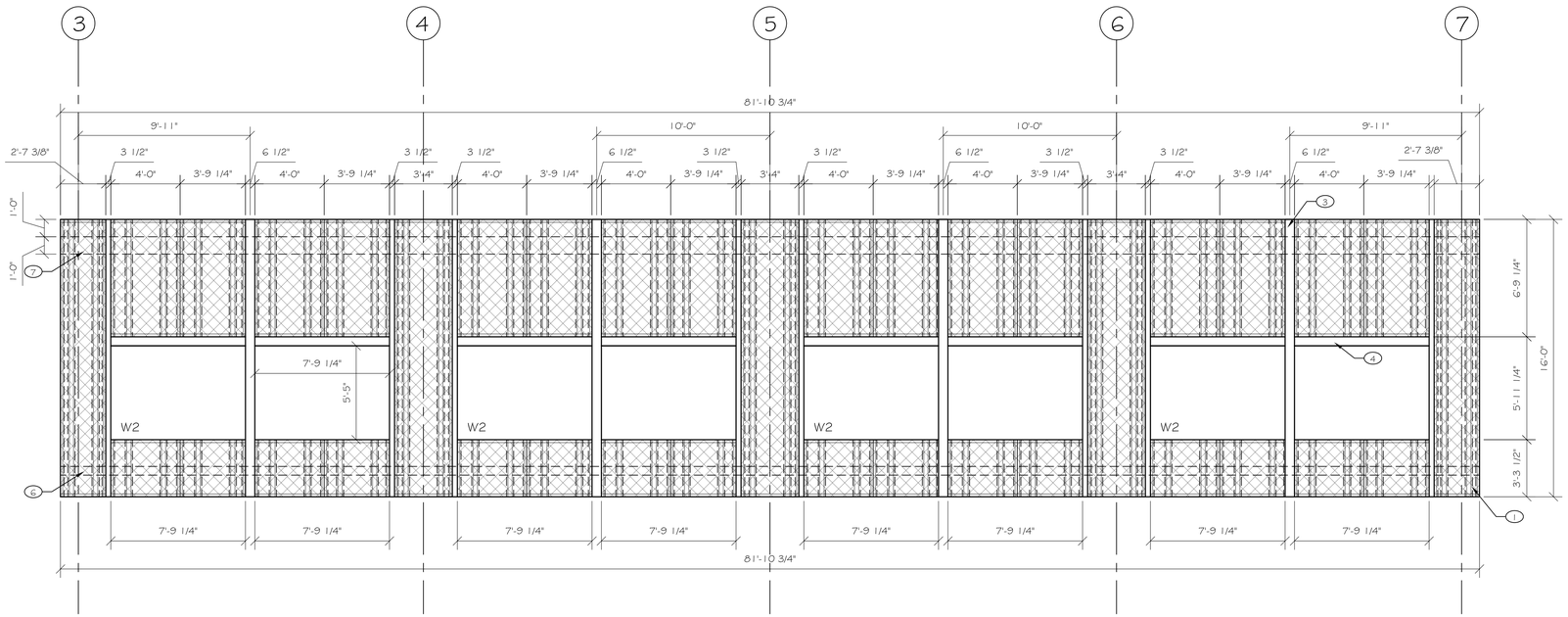
No.	Revision/Issue	Date

PROJECT NUMBER:

DRAWN BY	
DATE	
SCALE	1/8"= 1'-0"

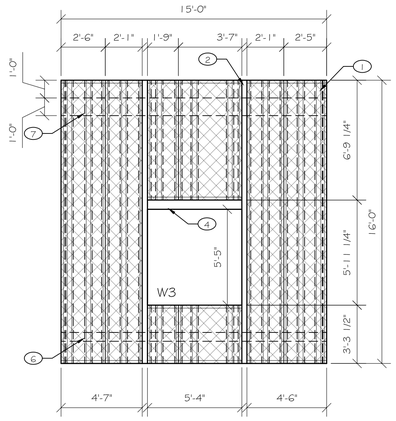
SHEET NUMBER

K110



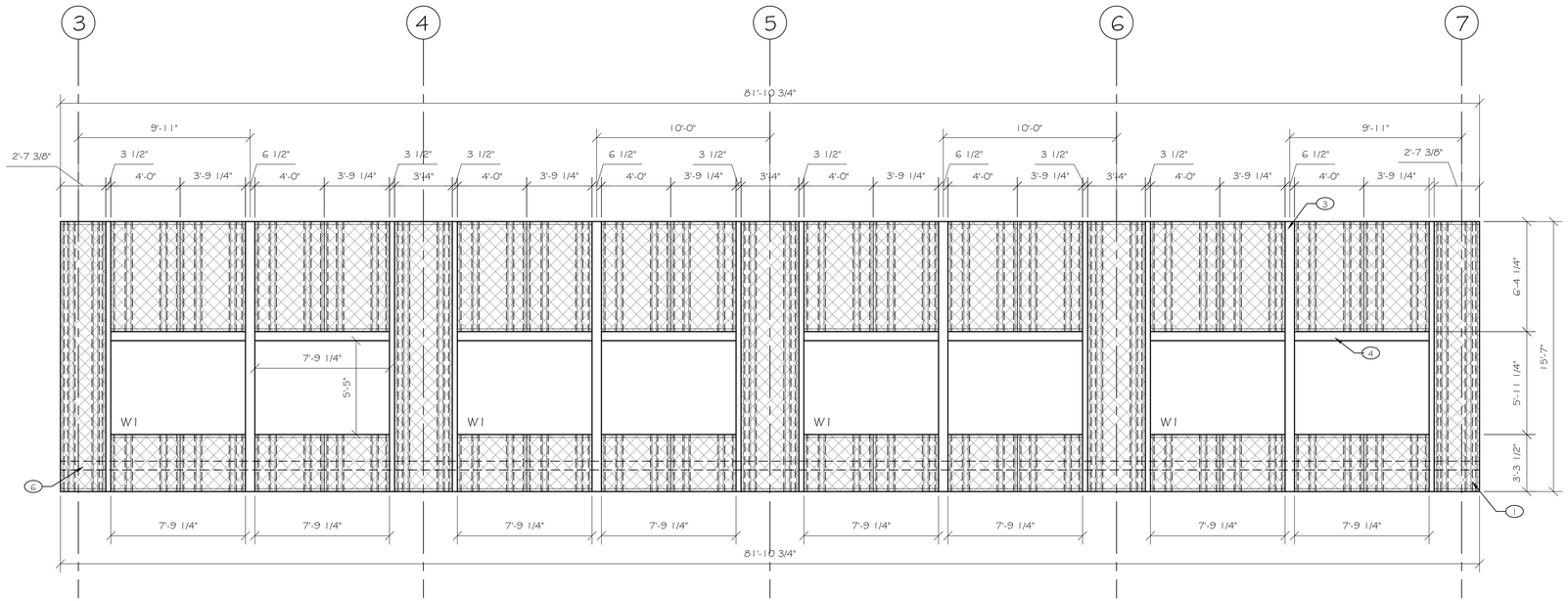
001 ELEVATIONS - WO1

1/4"=1'-0"



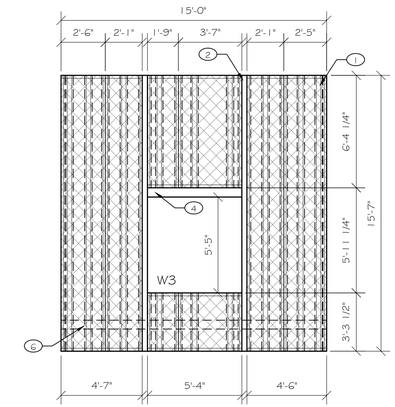
002 ELEVATIONS - WO2

1/4"=1'-0"



003 ELEVATIONS - WO3

1/4"=1'-0"



004 ELEVATIONS - WO4

1/4"=1'-0"

GENERAL NOTES

1. WALL
2. 6" METAL STUD FRAMING BY OTHERS
3. 6" METAL STUD FRAMING WITH ALUMINUM PLATE FOR SUNSHADE BY OTHERS
4. 6" BOX HEADER BY OTHERS
5. 3- 6" METAL STUDS BY OTHERS
6. 6" UTILITY CHASE- REFER TO DETAIL 226/K510
7. WALL ATTACHMENT CHASE - REFER TO DETAIL 223/K510

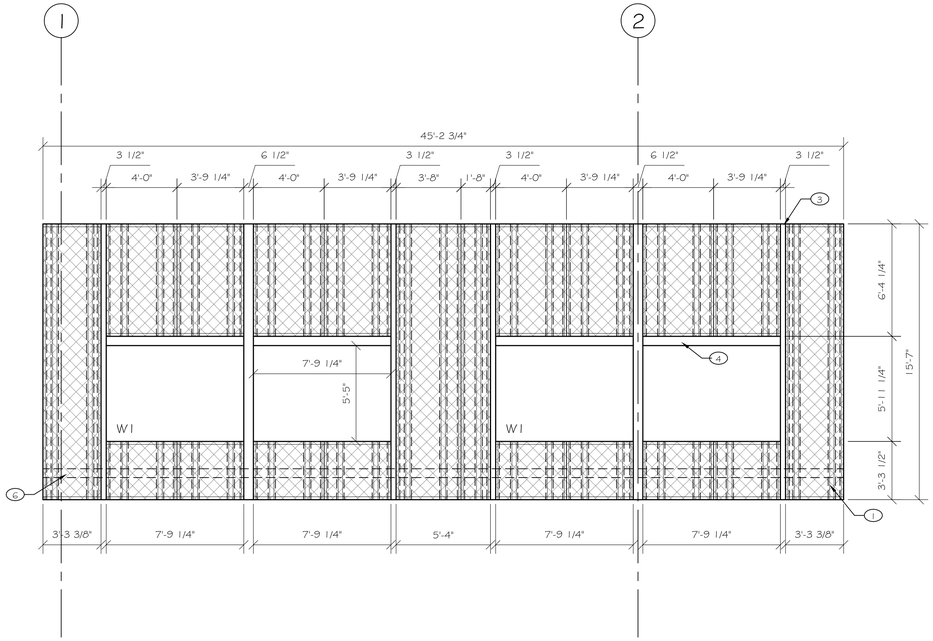
No.	Revision/Issue	Date

PROJECT NUMBER:

DRAWN BY	
DATE	
SCALE	1/4"=1'-0"

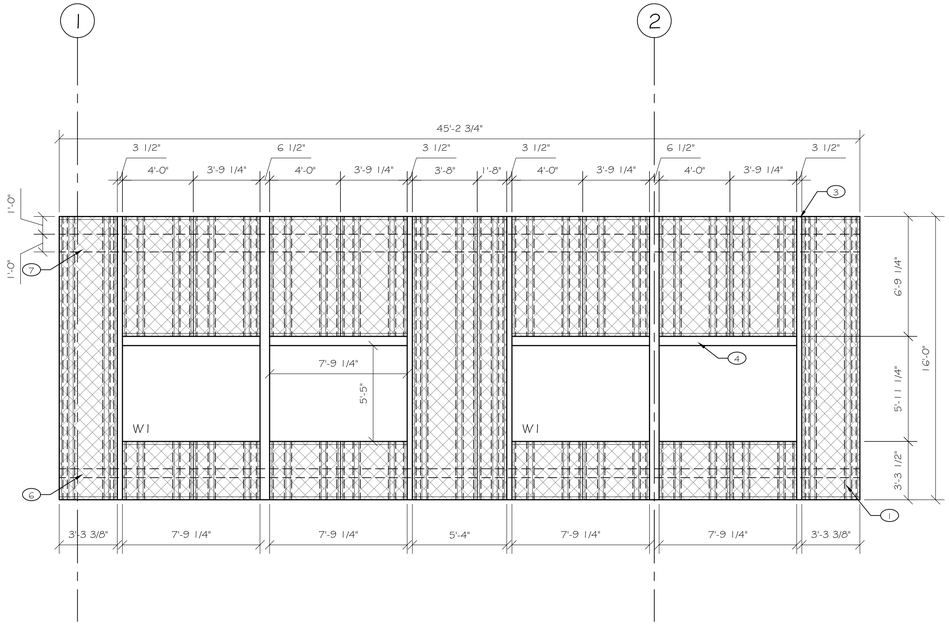
SHEET NUMBER

K200



001 ELEVATIONS - W05

1/4"= 1'-0"



002 ELEVATIONS - W06

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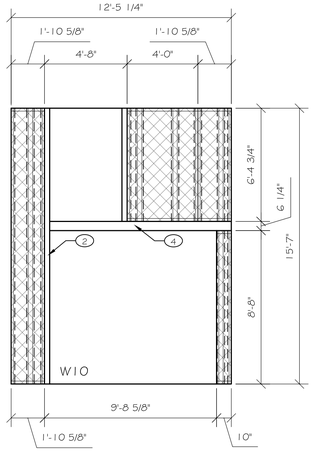

003 ELEVATIONS - W07

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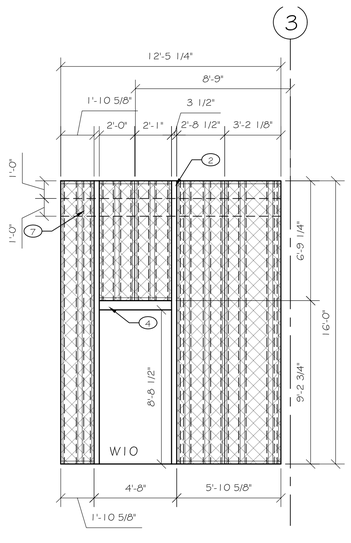
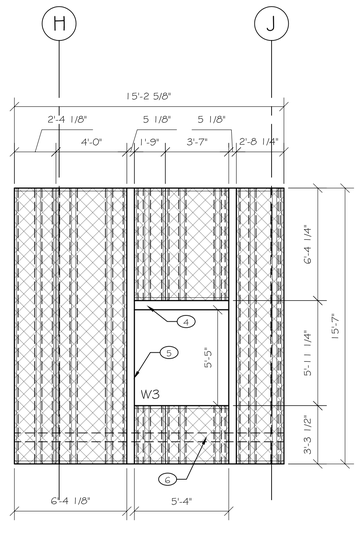


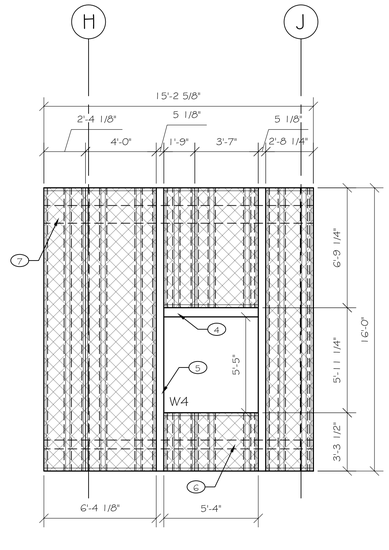
004 ELEVATIONS - W08

1/4"= 1'-0"



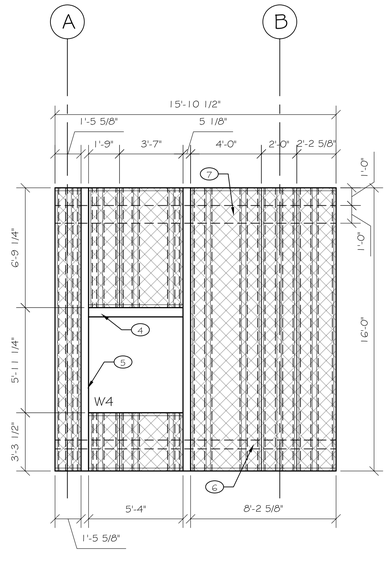
005 ELEVATIONS - W09

1/4"= 1'-0"



006 ELEVATIONS - W10

1/4"= 1'-0"



007 ELEVATIONS - W11

1/4"= 1'-0"

GENERAL NOTES

1. WALL
2. 6" METAL STUD FRAMING BY OTHERS
3. 6" METAL STUD FRAMING WITH ALUMINUM PLATE FOR SUNSHADE BY OTHERS
4. 6" BOX HEADER BY OTHERS
5. 3- 6" METAL STUDS BY OTHERS
6. 6" UTILITY CHASE- REFER TO DETAIL 226/K510
7. WALL ATTACHMENT CHASE - REFER TO DETAIL 223/K510

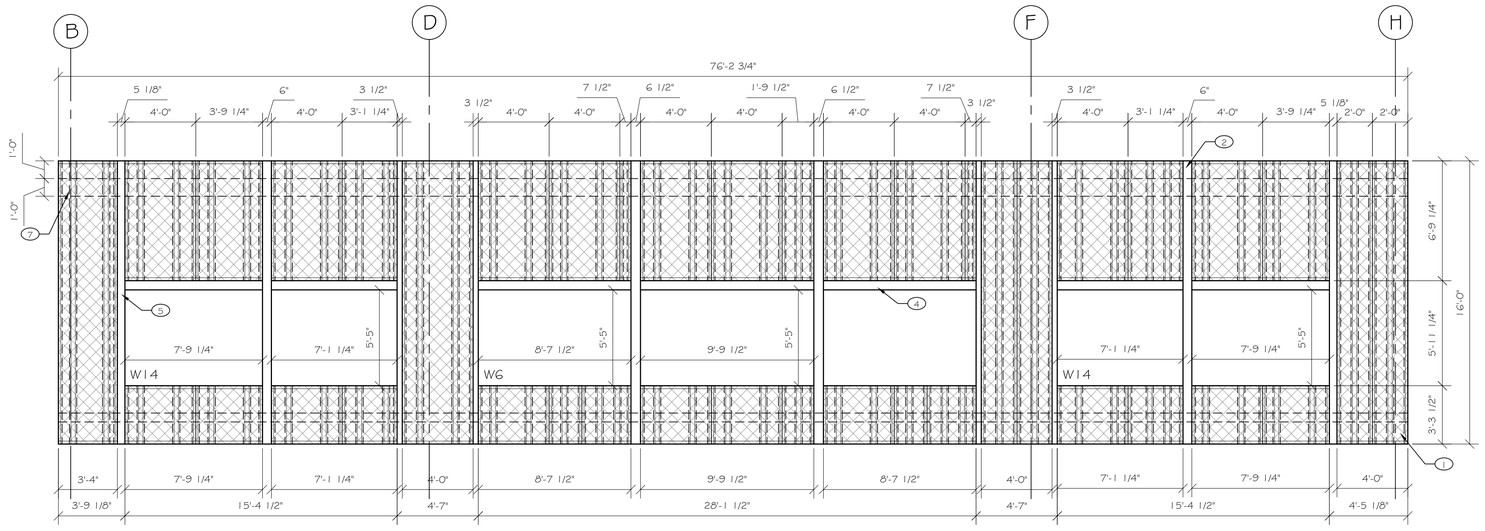
No.	Revision/Issue	Date

PROJECT NUMBER:

DRAWN BY	
DATE	
SCALE	1/4"= 1'-0"

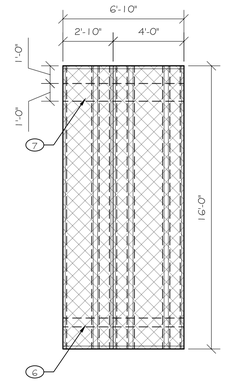
SHEET NUMBER

K210



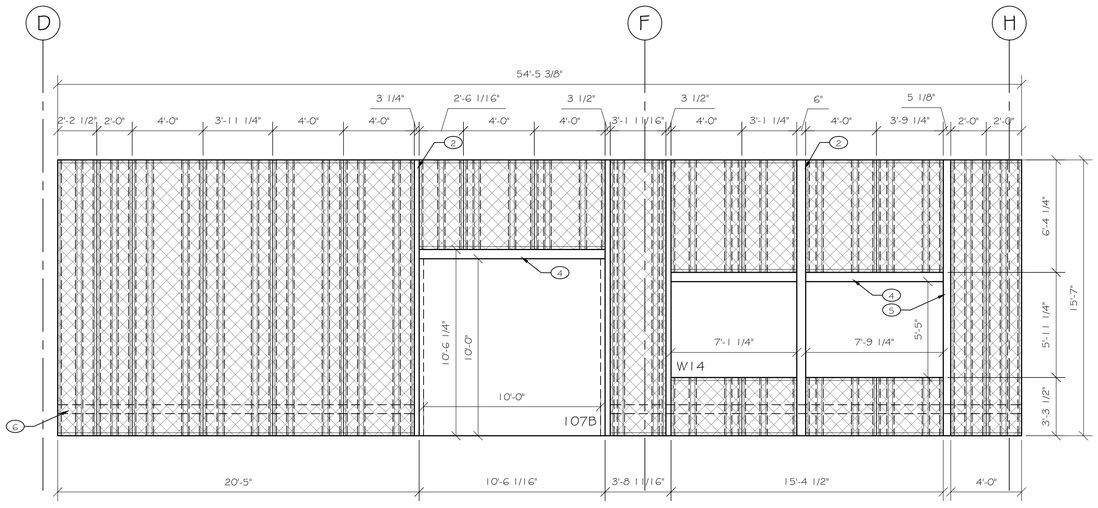
001 ELEVATIONS - W12

1/4"=1'-0"



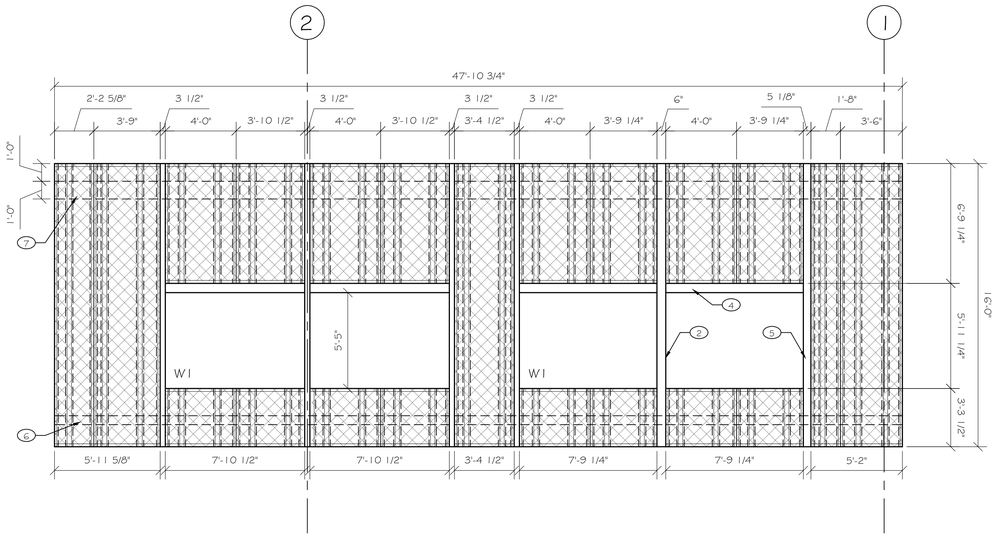
002 ELEVATIONS - W13

1/4"=1'-0"



003 ELEVATIONS - W14

1/4"=1'-0"



004 ELEVATIONS - W15

1/4"=1'-0"

GENERAL NOTES

1. WALL
2. 6" METAL STUD FRAMING BY OTHERS
3. 6" METAL STUD FRAMING WITH ALUMINUM PLATE FOR SUNSHADE BY OTHERS
4. 6" BOX HEADER BY OTHERS
5. 3- 6" METAL STUDS BY OTHERS
6. 6" UTILITY CHASE- REFER TO DETAIL 226/K510
7. WALL ATTACHMENT CHASE - REFER TO DETAIL 223/K510

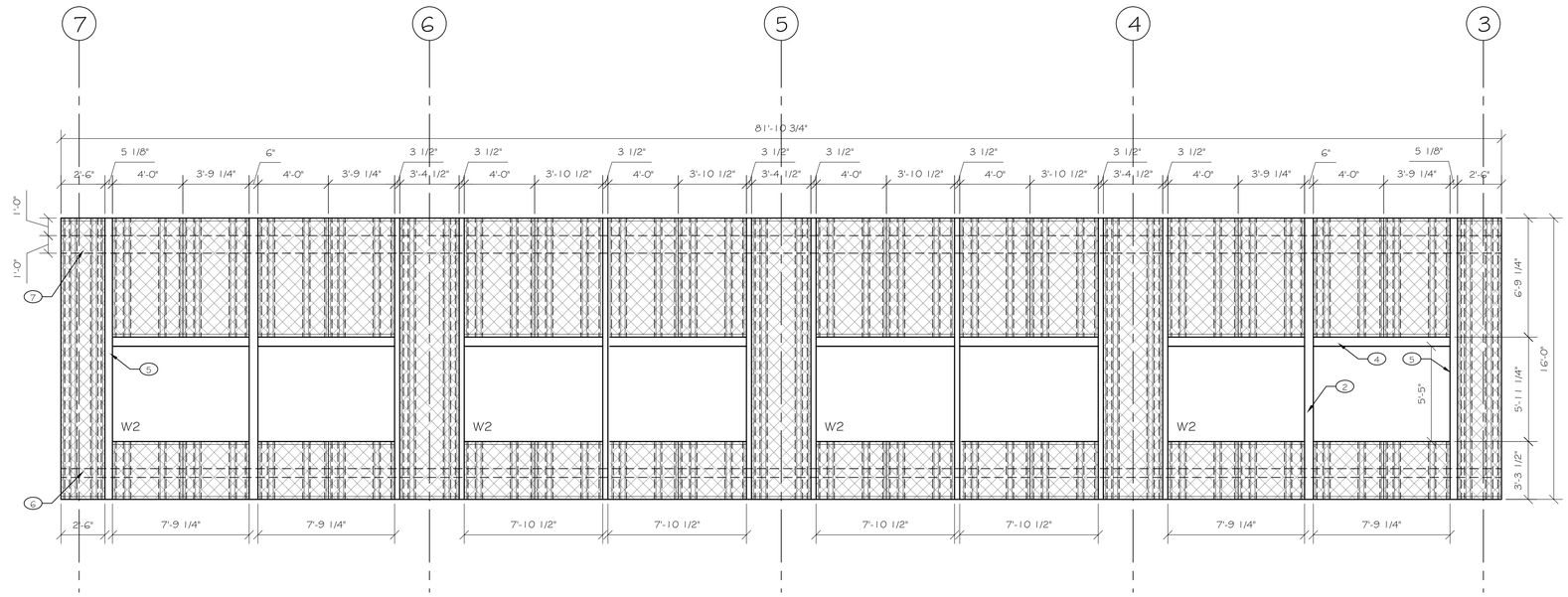
No.	Revision/Issue	Date

PROJECT NUMBER:

DRAWN BY	
DATE	
SCALE	1/4"= 1'-0"

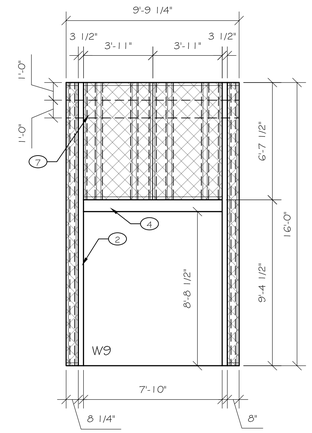
SHEET NUMBER

K220



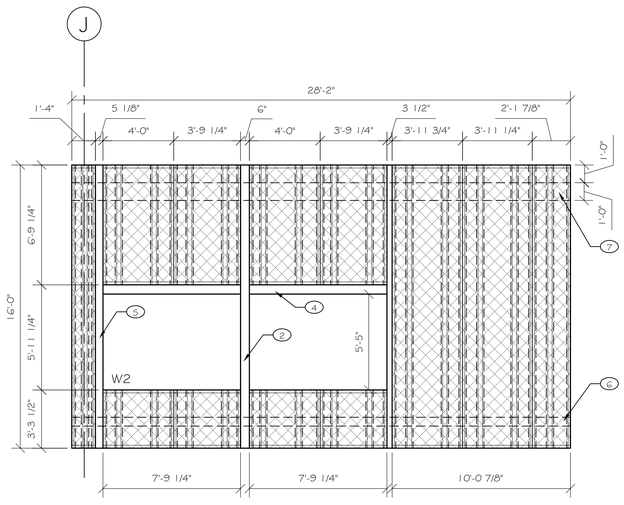
001 ELEVATIONS - W16

1/4"=1'-0"



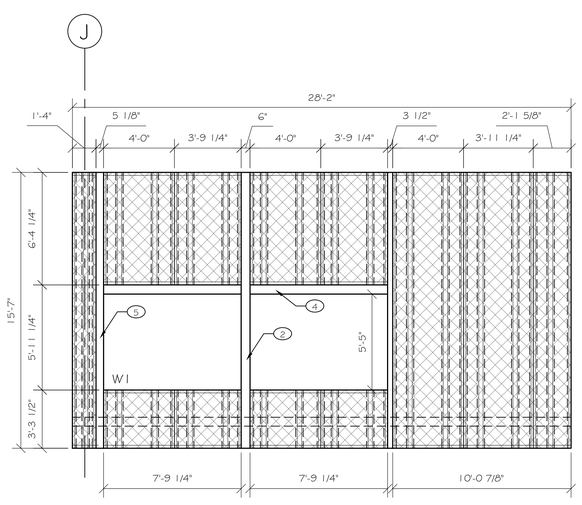
002 ELEVATIONS - W17

1/4"=1'-0"



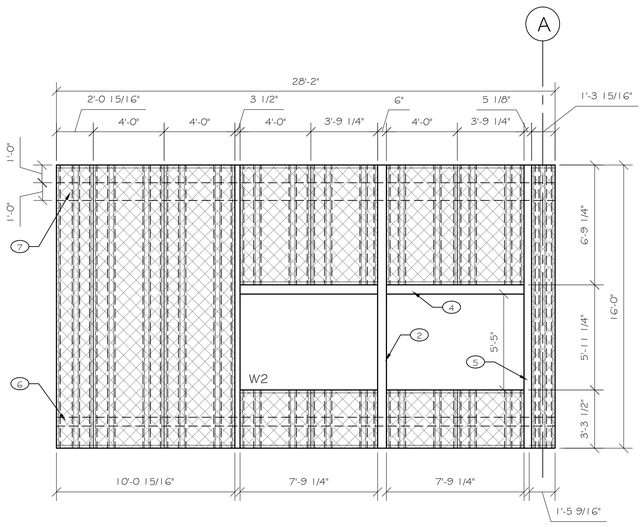
003 ELEVATIONS - W18

1/4"=1'-0"



004 ELEVATIONS - W19

1/4"=1'-0"



005 ELEVATIONS - W20

1/4"=1'-0"

GENERAL NOTES

1. WALL
2. 6" METAL STUD FRAMING BY OTHERS
3. 6" METAL STUD FRAMING WITH ALUMINUM PLATE FOR SUNSHADE BY OTHERS
4. 6" BOX HEADER BY OTHERS
5. 3- 6" METAL STUDS BY OTHERS
6. 6" UTILITY CHASE- REFER TO DETAIL 226/K510
7. WALL ATTACHMENT CHASE - REFER TO DETAIL 223/K510

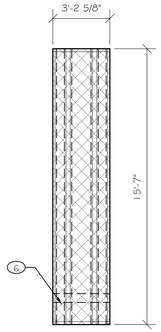
No.	Revision/Issue	Date

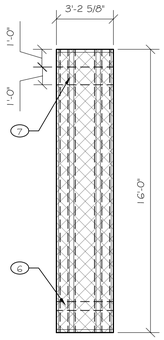
PROJECT NUMBER:

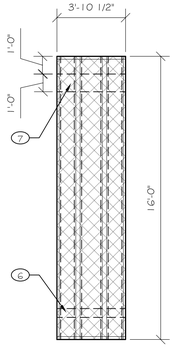
DRAWN BY	
DATE	
SCALE	1/4"=1'-0"

SHEET NUMBER

K230







001 ELEVATIONS - W21

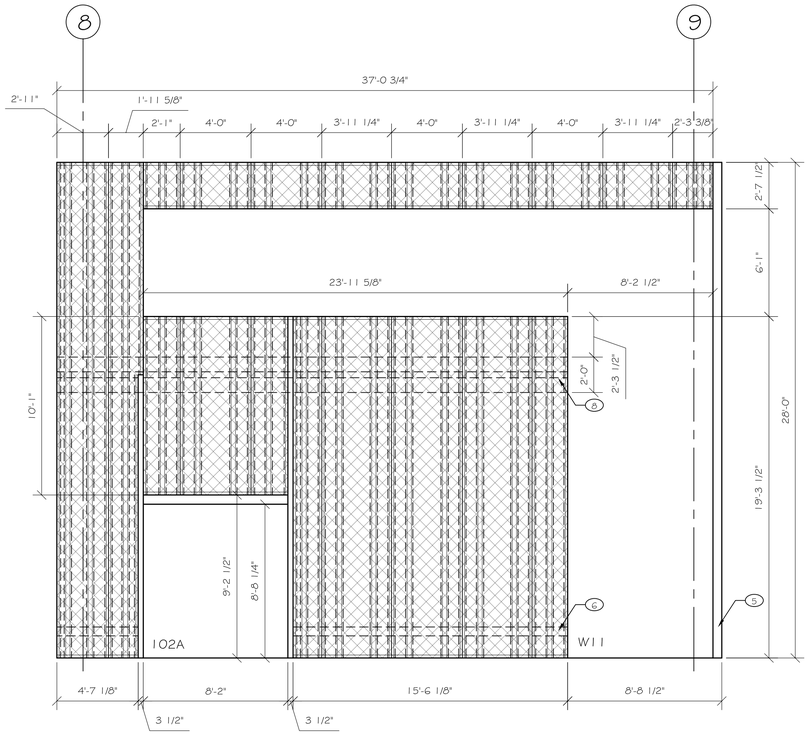
1/4"=1'-0"

002 ELEVATIONS - W22

1/4"=1'-0"

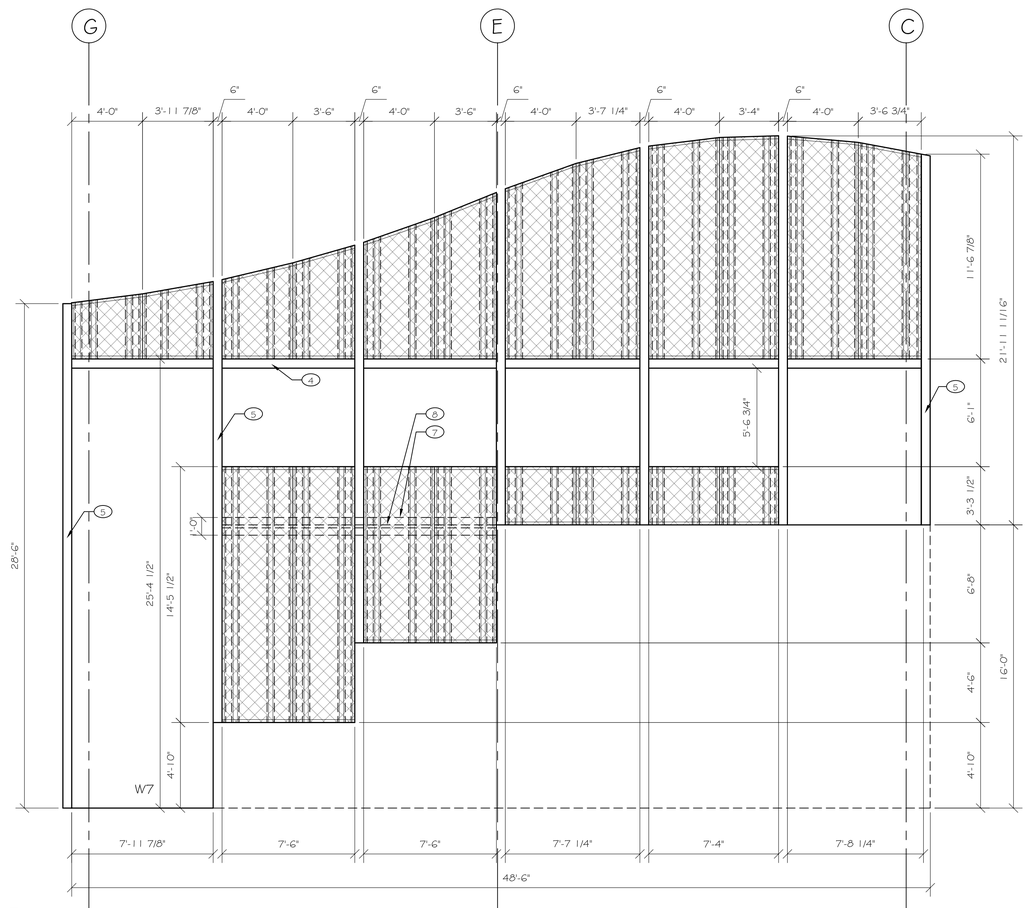
003 ELEVATIONS - W23

1/4"=1'-0"



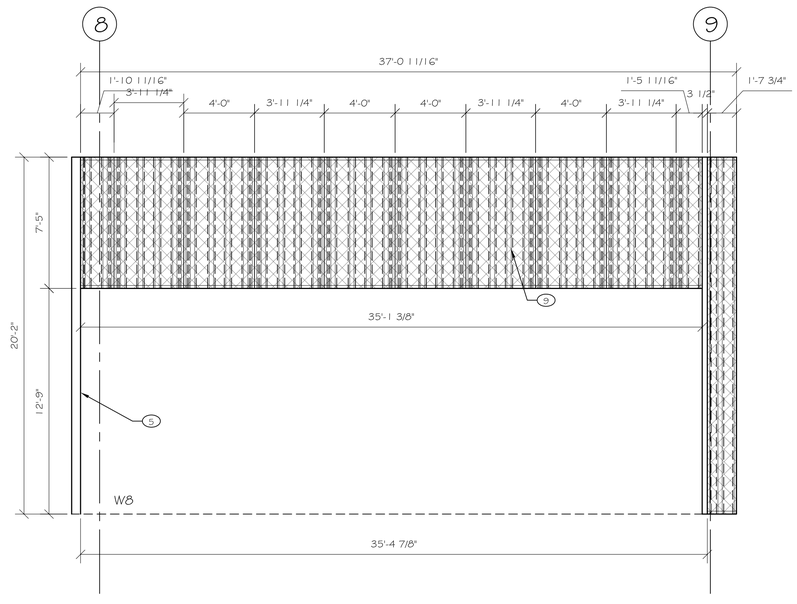
004 ELEVATIONS - W24

1/4"=1'-0"



005 ELEVATIONS - W25

1/4"=1'-0"



006 ELEVATIONS - W26

1/4"=1'-0"

GENERAL NOTES

1. WALL
2. 6" METAL STUD FRAMING BY OTHERS
3. 6" METAL STUD FRAMING WITH ALUMINUM PLATE FOR SUNSHADE BY OTHERS
4. 6" BOX HEADER BY OTHERS
5. 3- 6" METAL STUDS BY OTHERS
6. 6" UTILITY CHASE- REFER TO DETAIL 226/K510
7. WALL ATTACHMENT CHASE - REFER TO DETAIL 223/K510
8. WIND GIRT- BY OTHERS
9. 14 GA. METAL STUDS AT 12" O.C.

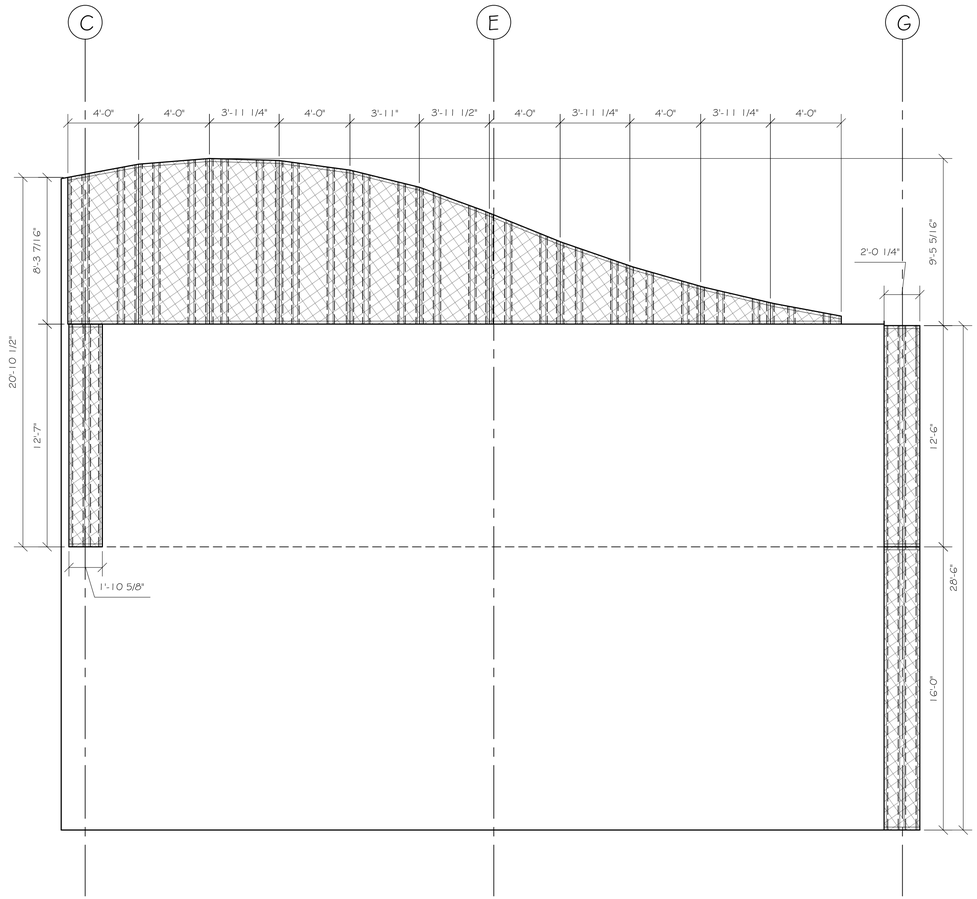
No.	Revision/Issue	Date

PROJECT NUMBER:

DRAWN BY	
DATE	
SCALE	1/4"=1'-0"

SHEET NUMBER

K240



001 ELEVATIONS - W27

1/4"=1'-0"

GENERAL NOTES

1. WALL
2. 6" METAL STUD FRAMING BY OTHERS
3. 6" METAL STUD FRAMING WITH ALUMINUM PLATE FOR SUNSHADE BY OTHERS
4. 6" BOX HEADER BY OTHERS
5. 3- 6" METAL STUDS BY OTHERS

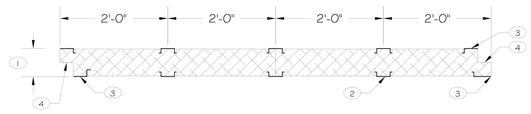
No.	Revision/Issue	Date

PROJECT NUMBER:

DRAWN BY	
DATE	
SCALE	1/4"=1'-0"

SHEET NUMBER

K250

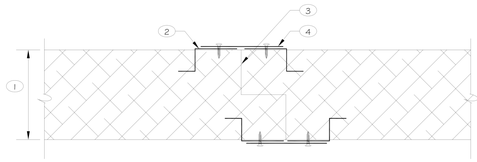


1 WALL THICKNESS PER PLAN
2 STUD
3 HALF HAT STUD
4 SHIPLAP JOINT WITH APPROVED EXPANSIVE ADHESIVE

NOTES:
ADHESIVE SHALL BE ISO GRIP ST 3000
ICBO/ICC# AC05

101 WALL SECTION

NO SCALE

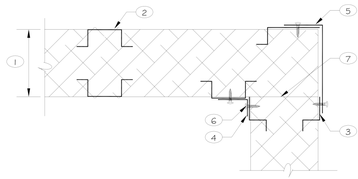


1 WALL THICKNESS PER PLAN
2 HALF HAT STUD
3 SHIPLAP JOINT WITH APPROVED EXPANSIVE ADHESIVE
4 SIMPSON TIE (LTP4) OR EQUIVALENT

NOTES:
ADHESIVE SHALL BE ISO GRIP ST 3000
ICBO/ICC# AC05

102 WALL SECTION @ SHIPLAP

NO SCALE



1 WALL THICKNESS PER PLAN
2 HAT STUD
3 HALF HAT STUD
4 1-1/2" x 1-1/2" INSIDE CORNER ANGLE
5 OUTSIDE CORNER ANGLE
6 #8 X 1/2" SD SCREWS 12" O.C., TYP.
7 APPROVED EXPANSIVE ADHESIVE AT SECTION JOINT

NOTES:
ADHESIVE SHALL BE ISO GRIP ST 3000
ICBO/ICC# AC05

103 WALL SECTION @ CORNER

NO SCALE

1 WALL THICKNESS PER PLAN
2 HAT STUD
3 HALF HAT STUD
4 1-1/2" x 1-1/2" INSIDE CORNER ANGLE
5 2" WIDE STRAPS @ 16" O.C. INTO STUDS U.N.O.
6 #8 X 1/2" SD SCREWS 12" O.C., U.N.O.

104 WALL SECTION TO WALL SECTION CONNECTION

NO SCALE

1 WALL PER PLAN
2 HAT STUD
3 ANGLE HEADER EA. SIDE, REFER TO STRUCTURAL DRAWINGS
4 2x TOP PLATE ATTACHMENT, REFER TO STRUCTURAL DRAWINGS
5 ANGLE AT ROUGH OPENING, FASTEN TO NEAREST STUD
6 #8 X 1/2" SD SCREWS - SIZE AND SPACING AS SPECIFIED PER PLANS
7 3" JAMB STUD

105 WALL SECTION HEADER SPANS TO 4'-0"

NO SCALE

1 WALL PER PLAN
2 HAT STUD
3 ANGLE HEADER EA. SIDE, REFER TO STRUCTURAL DRAWINGS
4 2x TOP PLATE ATTACHMENT, REFER TO STRUCTURAL DRAWINGS
5 ANGLE AT ROUGH OPENING, FASTEN TO NEAREST STUD
6 #8 X 1/2" SD SCREWS - SIZE AND SPACING AS SPECIFIED PER PLANS
7 5" JAMB STUD

106 WALL SECTION HEADER SPAN 4'-0" TO 8'-0"

NO SCALE

1 ANCHOR BOLT/EMBED, REFER TO STRUCTURAL DRAWINGS.
2 NOTCH OUT WALL SECTION @ ALL ANCHOR BOLT/EMBED LOCATIONS.
3 WALL SECTION
4 CONCRETE SLAB, REFER TO STRUCTURAL DRAWINGS.
5 BOTTOM ANGLE

107 WALL SECTION EDGE OF SLAB

NO SCALE

1 2" WIDE STRAPS AT 16" O.C. W/ (2) #8 X 1/2" SCREWS EACH END TO STUD
2 BOTTOM TRACK
3 WOOD/METAL STUD FRAMED WALL.
4 WALL SECTION

108 WOOD/METAL STUD FRAMED WALL

NO SCALE

1 WALL SECTION
2 HAT STUD
3 BUILDING PAPER AS REQUIRED
4 SELF-FURRING METAL LATH
5 EXTERIOR STUCCO SYSTEM AS SPECIFIED
6 STUCCO WEEP SCREED, REFER TO ARCHITECTURAL DRAWINGS FOR DETAILS

109 EXTERIOR STUCCO/EIFS FINISH

NO SCALE

GENERAL NOTES

No.	Revision/Issue	Date

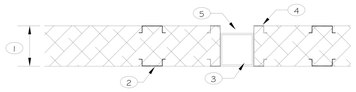
PROJECT NUMBER:

INSERT PROJECT NAME HERE

DRAWN BY	
DATE	
SCALE	AS SHOWN

SHEET NUMBER

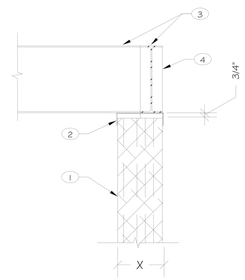
K510



1 WALL THICKNESS PER PLAN
2 HAT STUD
3 COLUMN, REFER TO STRUCTURAL DRAWINGS
4 U-CHANNEL POST-WALL ATTACHMENT W/ #10 X 3/4" 12" O.C. U.N.O.
5 FURR AS REQUIRED

110 WALL SECTION AT COLUMN

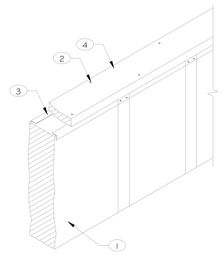
NO SCALE



1 WALL PER PLAN
2 SLIP TRACK, REFER TO STRUCTURAL DRAWINGS
3 STRUCTURAL BEAM. REFER TO STRUCTURAL DRAWINGS
4 TUBE STEEL COLUMN BEYOND. REFER TO STRUCTURAL DRAWINGS

111 WALL SECTION W/BEAM CONNECTION

NO SCALE



1 WALL SECTION
2 #10 x 3" SD SCREWS @ 6" O.C. STAGGERED, U.N.O.
3 2" x 2" TOP ANGLE EA. SIDE
4 WOOD TOP PLATE

112 WALL W/WOOD TOP PLATE

NO SCALE

1 WALL SECTION PER PLAN
2 JAMB STUD
3 U-CHANNEL TRACK CAP OVER TRIMMERS, COPED OVER : STUD AS SHOWN
4 2x TOP PLATE ATTACHMENT, REFER TO STRUCTURAL DRAWINGS
5 2- #10 X 3/4" SCREWS TO STUDS, U.N.O.
6 1/2" DIA. x 4" LONG LAG SCREW, U.N.O.
7 STRUCTURAL BEAM. REFER TO STRUCTURAL DRAWINGS
8 3"x3"x3"X16 GA. ANGLE, U.N.O.
9 2- #10 X 3/4" SCREWS, U.N.O.
10 JAMB STUD TRIMMERS

113 WALL AT WOOD BEAM CONNECTION

NO SCALE

1 HAT STUD
2 SHIPLAP JOINT WITH APPROVED EXPANSIVE ADHESIVE
3 "Z" STUD, REFER TO STRUCTURAL DRAWINGS FOR SIZE & SPACING

NOTES:
ADHESIVE SHALL BE ISO GRIP ST 3000
ICBO/ICC# AC05

114 WALL SECTION (ALT)

NO SCALE

1 WALL SECTION
2 HAT STUD
3 HALF HAT STUD
4 BOTTOM TRACK PER PLAN.
5 GUSSET, REFER TO STRUCTURAL DRAWINGS FOR SIZE & SCREW ATTACHMENT.
6 6" WIDE METAL X-BRACING STRAPS, REFER TO STRUCTURAL DRAWINGS FOR SIZE & SCREW ATTACHMENT.

NOTES:
1. DIAGONAL STRAP
2. 6"X30"X18 GA. STRAP WITH (28) #10 SREWS EA. FACE OF SPLICE (56 TOTAL), U.N.O.
3. STRAP SPLICE

115 SHEAR WALL X-BRACING

NO SCALE

GENERAL NOTES

No.	Revision/Issue	Date

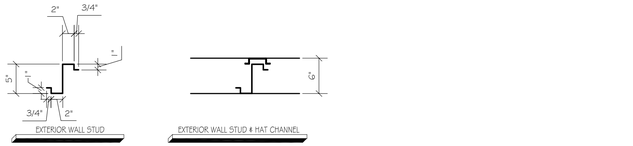
PROJECT NUMBER:

INSERT PROJECT NAME HERE

DRAWN BY	
DATE	
SCALE	AS SHOWN

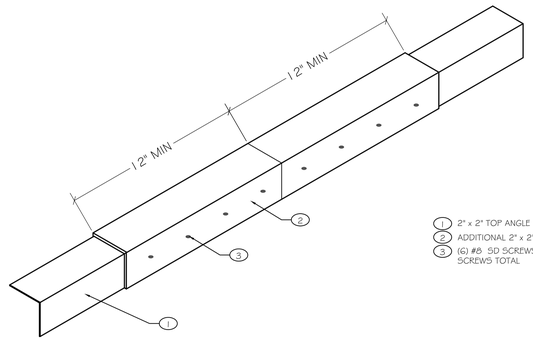
SHEET NUMBER

K511



002 MISCELLANEOUS PROFILES

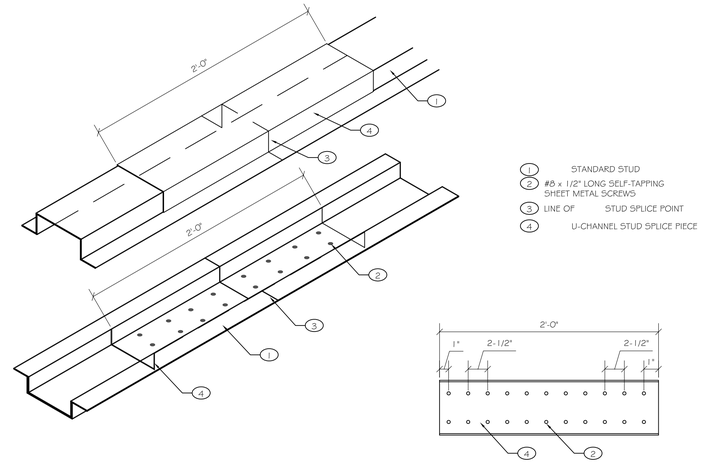
NO SCALE



1. 2" x 2" TOP ANGLE
2. ADDITIONAL 2" x 2" ANGLE @ SPLICE
3. (6) #8 SD SCREWS EA. SIDE, (12) #8 SD SCREWS TOTAL

004 WALL SECTION TOP ANGLE SPLICE

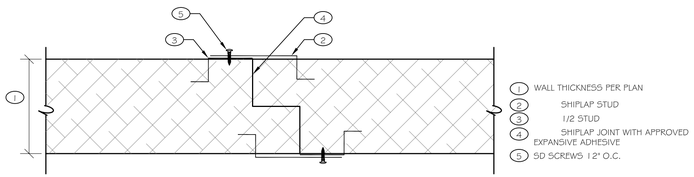
NO SCALE



1. STANDARD STUD
2. #8 x 1/2" LONG SELF-TAPPING SHEET METAL SCREWS
3. LINE OF STUD SPLICE POINT
4. U-CHANNEL STUD SPLICE PIECE

005 STUD SPLICE CONNECTION

NO SCALE

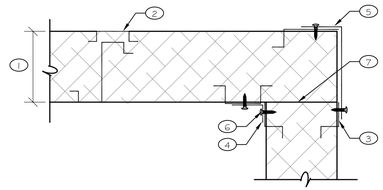


1. WALL THICKNESS PER PLAN
2. SHIPLAP STUD
3. 1/2 STUD
4. SHIPLAP JOINT WITH APPROVED EXPANSIVE ADHESIVE
5. 5D SCREWS 12" O.C.

NOTES:
ADHESIVE SHALL BE ISO GRIP ST 3000
ICBO/ICC# AC05

202 WALL SECTION @ SHIPLAP

NO SCALE

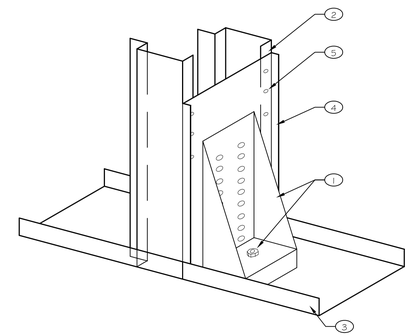


1. WALL THICKNESS PER PLAN
2. STUD
3. 1/2 STUD
4. 1-1/2" x 1-1/2" INSIDE CORNER ANGLE
5. OUTSIDE CORNER ANGLE
6. 5D SCREWS 12" O.C., TYP.
7. APPROVED EXPANSIVE ADHESIVE AT SECTION JOINT

NOTES:
ADHESIVE SHALL BE ISO GRIP ST 3000
ICBO/ICC# AC05

203 WALL SECTION @ CORNER

NO SCALE



1. SIMPSON OR EQUIVELANT HOLDOWN WITH ANCHOR BOLT, REFER TO STRUCTURAL DRAWINGS
2. STUD
3. U-CHANNEL BOTTOM TRACK
4. 24" LONG U-CHANNEL STUD. WIDTH TO MATCH WALL SECTION
5. 5D SCREWS, SIZE AND SPACING PER STRUCTURAL DRAWINGS.

104 HOLDOWN WALL SECTION

NO SCALE

GENERAL NOTES

No.	Revision/Issue	Date

PROJECT NUMBER:

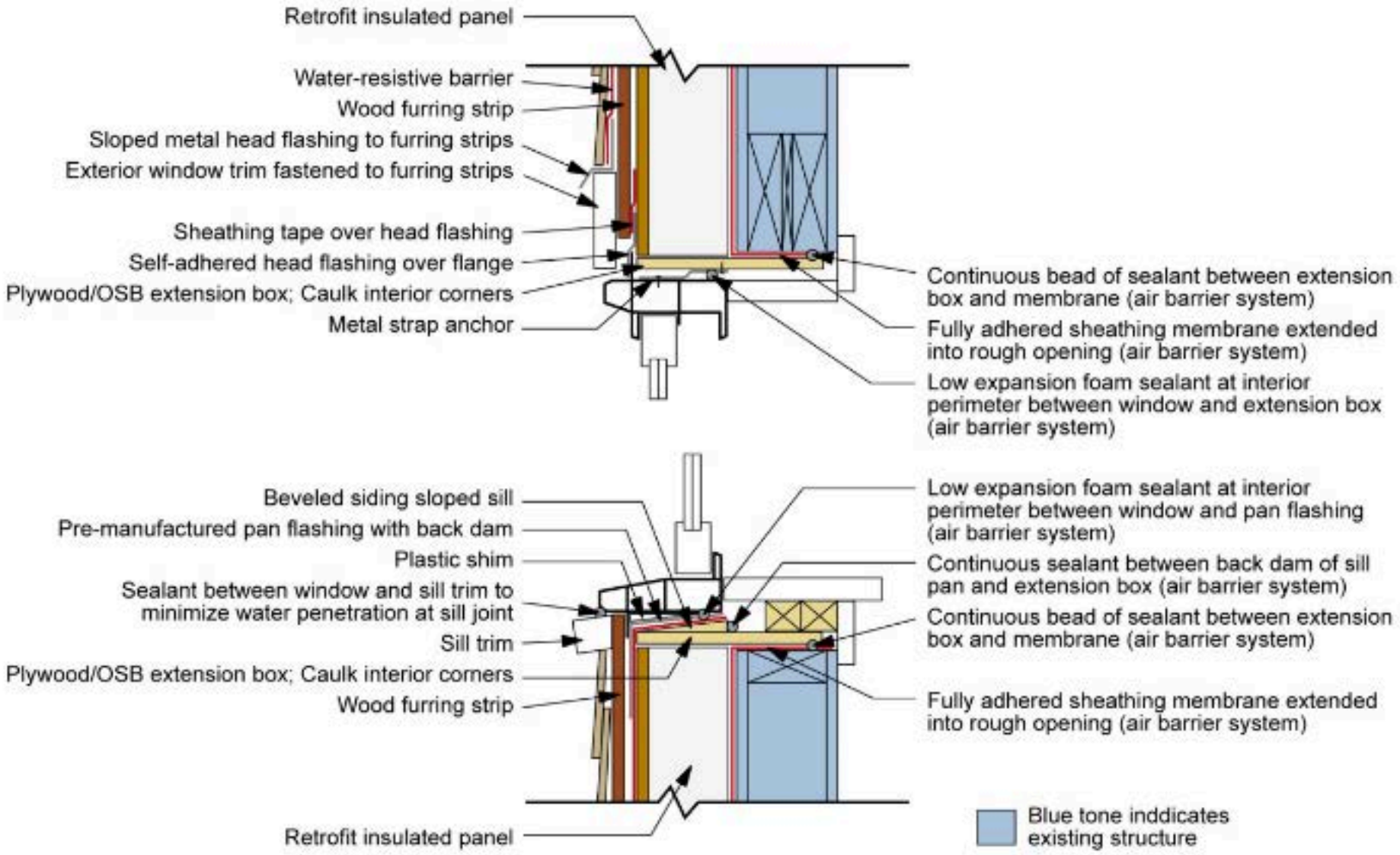
DRAWN BY

DATE

SCALE AS SHOWN

SHEET NUMBER

K500


Retrofit insulated panel
Water-resistive barrier
Wood furring strip
Sloped metal head flashing to furring strips
Exterior window trim fastened to furring strips
Sheathing tape over head flashing
Self-adhered head flashing over flange
Plywood/OSB extension box; Caulk interior corners
Metal strap anchor
Continuous bead of sealant between extension box and membrane (air barrier system)
Fully adhered sheathing membrane extended into rough opening (air barrier system)
Low expansion foam sealant at interior perimeter between window and extension box (air barrier system)
Beveled siding sloped sill
Pre-manufactured pan flashing with back dam
Plastic shim
Sealant between window and sill trim to minimize water penetration at sill joint
Sill trim
Plywood/OSB extension box; Caulk interior corners
Wood furring strip
Low expansion foam sealant at interior perimeter between window and pan flashing (air barrier system)
Continuous sealant between back dam of sill pan and extension box (air barrier system)
Continuous bead of sealant between extension box and membrane (air barrier system)
Fully adhered sheathing membrane extended into rough opening (air barrier system)
Retrofit insulated panel
Blue tone inddicates existing structure

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Drainage Planes and Air Spaces

Research Report - 0999
1999
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Abstract:

Every exterior cladding system needs an air space and drainage plane for performance and durability. This article presents the right materials and spaces for most exterior claddings—brick, stucco, and wood, metal and vinyl lap siding.

Drainage Planes and Air Spaces

All wood frame wall assemblies require a drainage plane coupled with a drainage space - where it rains. "Where it rains" is defined as locations in North America that receive more than 20 inches of rain annually. Traditionally, drainage planes consisted of tar paper installed shingle fashion behind exterior claddings coupled with a flashing at the base of each wall to direct rainwater that penetrated the cladding systems to the exterior. It was important that some form of air space or drainage space was also provided between the cladding system and the drainage plane to allow drainage.

With wood siding, the drainage space is typically intermittent and depends largely on the profile of the siding. Ideally, wood siding should be installed over furring creating a drained (and vented) air space between the drainage plane and wood siding. With vinyl and aluminum siding, the drainage space is more pronounced and furring is not necessary.

With stucco claddings, the drainage space was traditionally provided by using two layers of asphalt impregnated felt paper. The water absorbed by the felt papers from the base coat of stucco caused the papers to swell and expand. When the assembly dried, the papers would shrink, wrinkle and de-bond providing a tortuous, but reasonably effective, drainage space. This drainage space was typically around 1/8-inch wide.

With brick veneers, the width of the drainage space has been based more on tradition rather than physics. A 1-inch airspace is more-or-less the width of a mason's fingers. It is important that this 1-inch airspace is coupled with a functional drainage plane.

The Masonry Institute recommendation of a 2-inch airspace behind a brick veneer is based more on politics rather than physics. The masonry industry likes to see brick veneers installed over masonry block back-up walls. The masonry industry does not like steel stud back-up walls covered with gypsum board and a drainage plane. The reason is obvious - the masonry industry would like to sell you blocks, not steel studs.

However, the masonry industry is faced with a problem. In order to be cost competitive, the masonry back-up wall needs to be constructed at the same time as the brick veneer. This precludes the possibility of installing a drainage plane on the exterior surface of the masonry back-up wall. If a drainage plane is not present, an airspace greater than 1-inch is necessary to control rain entry - and this airspace must be free from mortar droppings. Of course, the corollary of this is as follows: if a drainage plane is present, and airspace or drainage space of 3/8-inch thickness will work just fine, even if it is filled with mortar droppings. Think of a traditional stucco wall - isn't it really a wall with a drainage plane that has a tortuous drainage space filled with mortar droppings?

Physics shows that free drainage occurs whenever an airspace is greater than 3/8-inch. The surface tension of water will not allow water to span a gap

greater than 3/8-inch. On the suction side, capillary suction will not occur with gaps greater than 1/8-inch.

When constructing stone veneers, a 3/8-inch airspace coupled with a drainage plane is common. This is often done with Enka-drain (thick plastic brillo pad covered with a filter cloth) installed over a #30 felt. With water managed EIFS, grooved foam with grooves 3/8-inch wide are common as well as plastic mesh spacers providing an airspace of 3/8-inch or more. The grooves or spacers are installed over a drainage plane. The problem with the standard EIFS have been due to the lack of a drainage plane and an associated drainage space.

With brick veneer, a minimum 3/8-inch airspace coupled with a drainage plane is required to control rainwater. Both are necessary. The drainage plane must also be vapor semi-permeable or impermeable to prevent the entry of solar driven water vapor. When brick gets wet and then is exposed to the sun, the moisture is pushed inwards.

Moisture moves from warm to cold (due to a thermal gradient) as well as from more to less (due to a concentration gradient). A vapor permeable housewrap such as Tyvek, Typar or #15 felt is not recommended behind a brick veneer for this reason. A more robust felt paper such as a #30 felt or a semi-permeable extruded foam such as the Dow blueboard or the Owens-Corning pinkboard is desirable.

When using foam sheathings, a drainage plane and drainage spaces are both still required. The foam sheathing can be installed in such a manner as to act as a drainage plane on its own or a drainage plane can be installed under the foam sheathing to provide this function. It is not recommended that building papers be installed over foam sheathing - they should be always installed under foam sheathing. It is not possible to staple building papers into foam and have the building paper be able to resist any wind load.

Foam sheathing can act as an effective drainage plane if vertical joints are shiplapped or tongue-and-grooved and if horizontal joints are flashed. An additional building paper is unnecessary in such a case.

About the Author

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