

# 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 must make provisions for water that infiltrates the paving and collects on the membrane to travel laterally to a drainage outlet.

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.

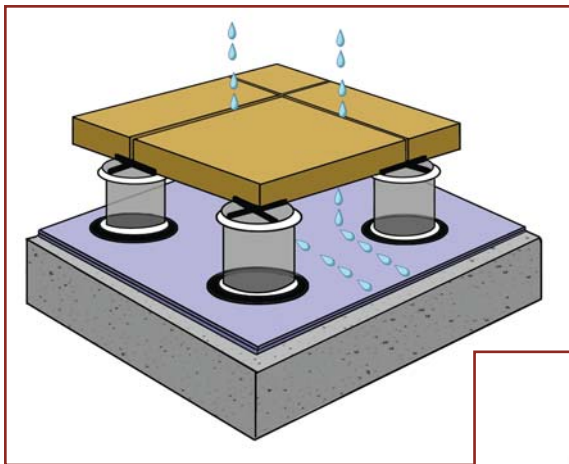
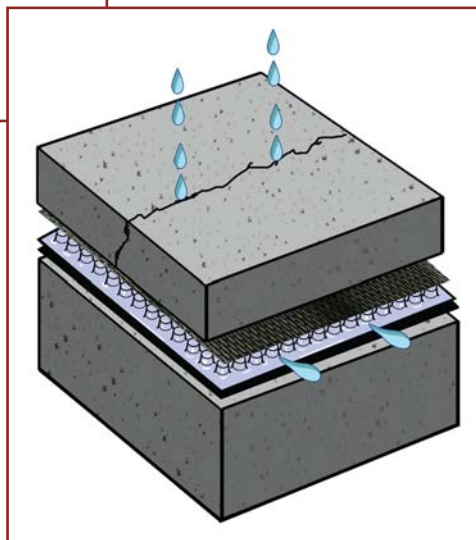


Figure 1A (above) and 1B (right) – Two examples of plaza paving systems with membrane-level drainage: unit pavers on pedestals, and concrete paving slab over drainage composite.



### 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.

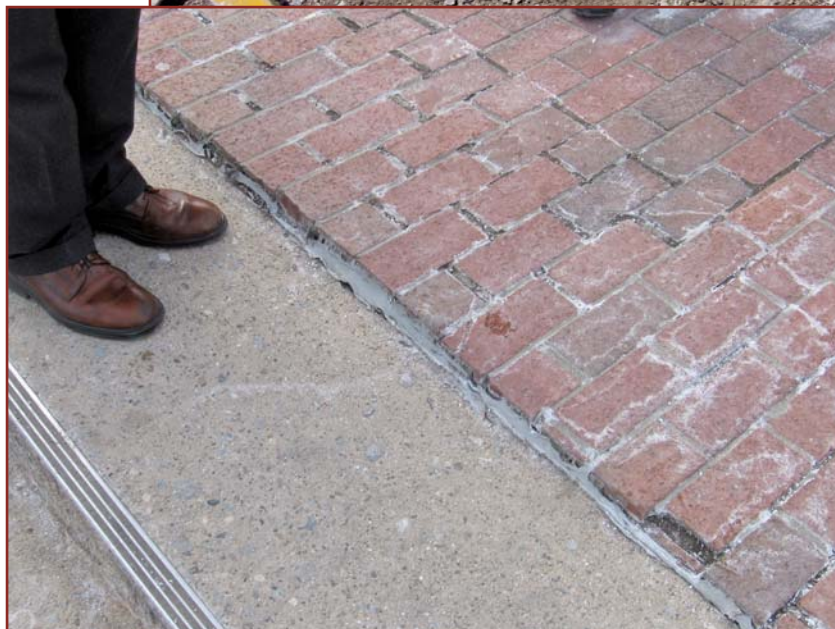


Photo 3 – Frost heaving of brick pavers.

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



Photo 5 – Leakage to interior spaces below a plaza.



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**

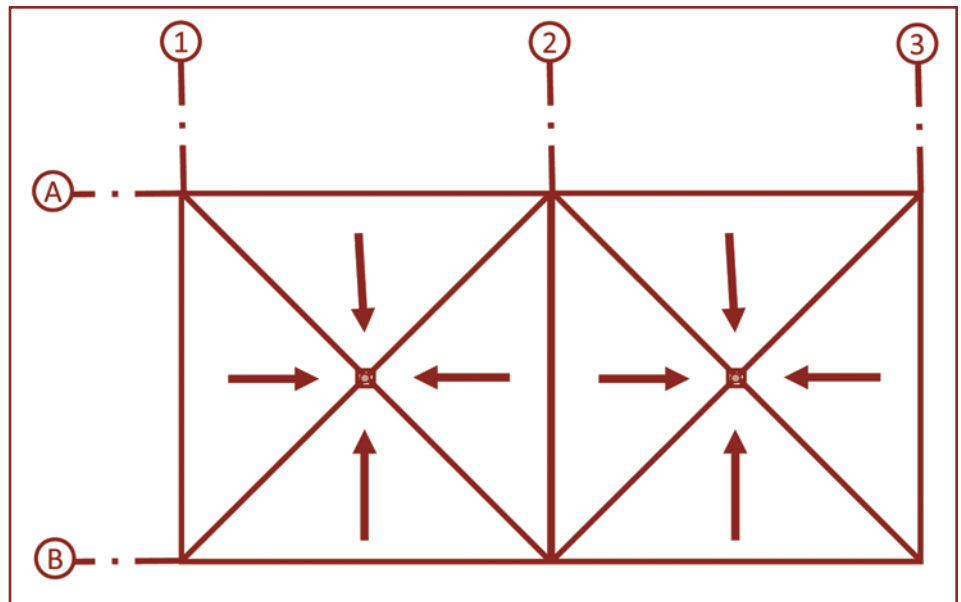
Provide positive slope-to-drain at the waterproofing membrane level. An inverted diamond pattern (four-way slope to an internal drain – *Figure 2*) is generally the most efficient layout. The slope on the waterproofing should be a minimum of one-quarter in per ft (approximately 2%). Lesser

- 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

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



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

simple, level survey of the structural deck can determine existing slopes and locate low points.

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

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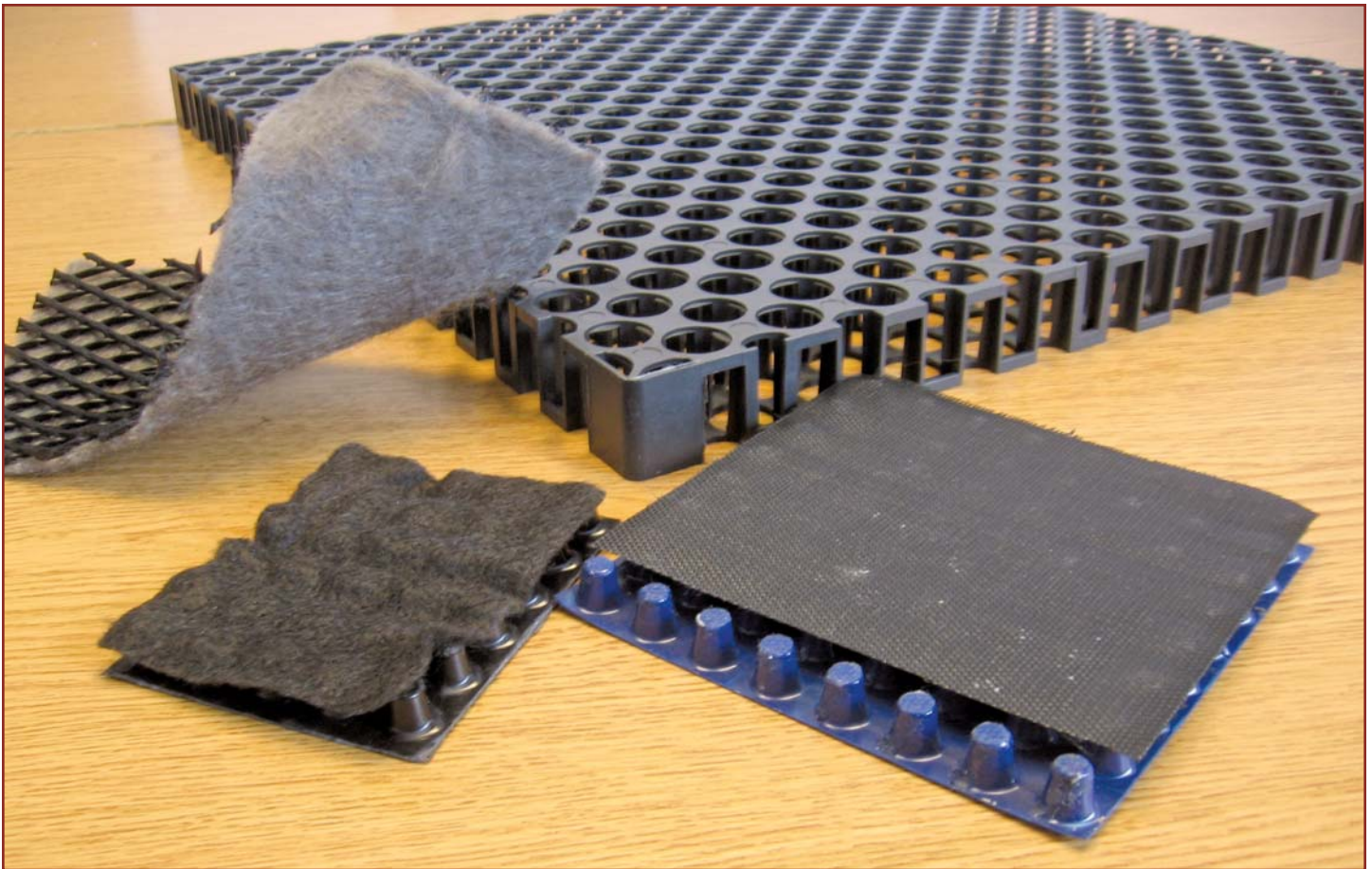


Photo 6 – Various examples of geosynthetic drainage cores.

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 mem-

brane. 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 fil-

ter 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.

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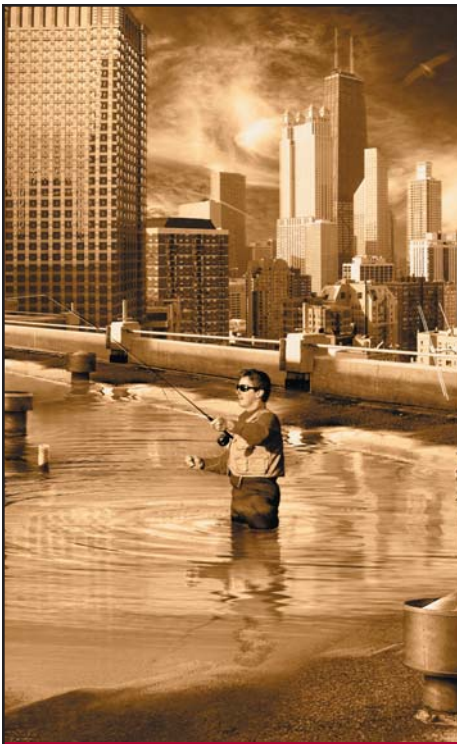
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- Trench drains are generally not effective for bi-level drainage applications such as waterproofing below paving; most do not have membrane-clamping hardware or subsurface weep slots. Those that have these features generally have only small, clog-prone 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.

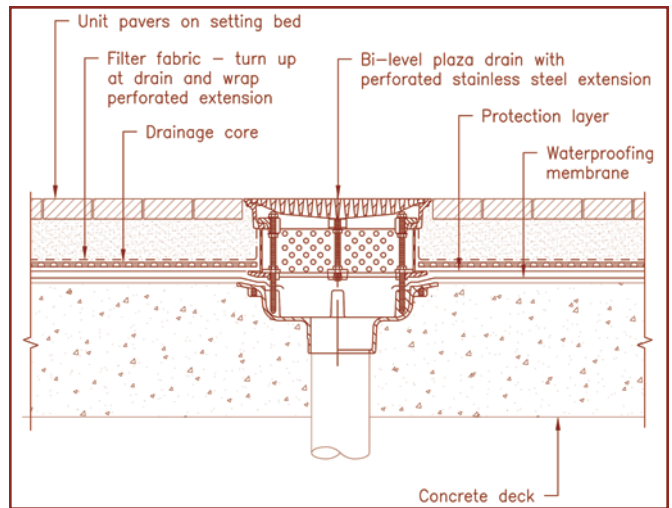



Figure 3

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. 

**Summary**

Many problems with paving systems installed over waterproofing membranes can be avoided with a basic understanding

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