POROUS ASPHALT PAVEMENTS

Porous asphalt is an environmentally friendly tool for stormwater management.

In the natural environment, rainfall sinks into soil, filters through it, and eventually finds its way to streams, ponds, lakes, and underground aquifers. The built environment, by way of contrast, seals the surface. Rainwater and snowmelt become runoff which may contribute to flooding. Contaminants are washed from surfaces directly into waterways without undergoing the filtration that nature intended.[1]

Stormwater management tools can mitigate the impact of the built environment on natural hydrology. Unfortunately, however, they also can lead to unsound solutions such as cutting down stands of trees in order to build detention ponds.

Porous asphalt pavements allow for land development plans that are more thoughtful, harmonious with natural processes, and sustainable. They conserve water, reduce runoff, promote infiltration which cleanses stormwater, replenish aquifers, and protect streams.

A typical porous pavement has an open-graded surface over an underlying stone recharge bed. The water drains through the porous asphalt and into the stone bed, then, slowly, infiltrates into the soil. Many contaminants are removed as the stormwater passes through the porous asphalt, stone recharge bed, and soils through filtration and microbial action.

OVERVIEW AND HISTORY

In 1977, researchers at the Franklin Institute in Philadelphia published a design guide for porous pavements.[2] This document has been widely referenced ever since, and provides a solid foundation for porous pavement designers.

Many porous pavements have been constructed since the late 1970s. Cahill Associates has been involved in the design and construction of more than 200 porous asphalt pavements since the 1980s and have reported no failures of pavements for which proper design and construction practices were followed. For maintenance, an important caveat is that fine material such as silt or sand must be prevented from clogging the surface.

WATER QUALITY

Porous pavements are highly effective in reducing pollution in stormwater runoff from pavements. Cahill reports that, although sampling on porous pavement systems has been limited, the available data indicate a high removal rate for total suspended solids (TSS), metals, and oil and grease.[3]

Table 1 shows the pollution removal efficiency for a porous parking lot constructed at the University of New Hampshire (UNH) in 2004.[4] The University reports that

> The water quality treatment performance of the porous asphalt lot generally has been excellent. It consistently exceeds EPA's recommended level of removal of total suspended solids, and meets regional ambient water quality criteria for petroleum hydrocarbons and zinc. Researchers observed limited phosphorus treatment and none for nitrogen, which is consistent with other non-vegetated infiltration systems.

They also observed that the system did not remove chloride, but since it drastically reduced the salt needed for winter maintenance, it may prove effective at reducing chloride pollution. They reported that winter maintenance requires "between zero and 25 percent of the salt routinely applied to impervious asphalt to achieve equivalent, or better, deicing and traction."

PAVEMENT STRUCTURE

From the bottom up, the standard porous asphalt pavement structure consists of:

- An uncompacted subgrade to maximize the infiltration rate of the soil.
- A geotextile fabric that allows water to pass through, but prevents migration of fine material from the subgrade into the stone recharge bed.
- A stone recharge bed consisting of clean single-size crushed large stone with about 40 percent voids. This serves as a structural layer and also temporarily stores stormwater as it infiltrates into the soil below.
- A stabilizing course or "choker course" consisting of a clean single-size crushed stone smaller than the stone in the recharge bed to stabilize the surface for paving equipment.
- An open-graded asphalt surface with interconnected voids that allow stormwater to flow through the pavement into the stone recharge bed.

DESIGN

The design of a porous pavement can be broken down into location, hydrology and structural design. This brochure will not address hydrologic design, as this should be performed by a licensed engineer proficient in hydrology and stormwater design.

The general guidelines for the porous asphalt pavement design are:

- Consider the location for porous pavements early in the site design process.
- Soil infiltration rates of 0.1 to 10 inches/hour work best.
- Minimum depth to bedrock or seasonal high water should be greater than two feet.
- The bottom of the infiltration bed should be flat to maximize the infiltration area.
- Limit the maximum slope of porous pavement surface to 5 percent. For parking areas on steeper slopes, terrace the parking areas with berms between parking areas.
- Look for opportunities to route runoff from nearby impervious areas to the infiltration bed to minimize stormwater structures. Pretreatment may be required.

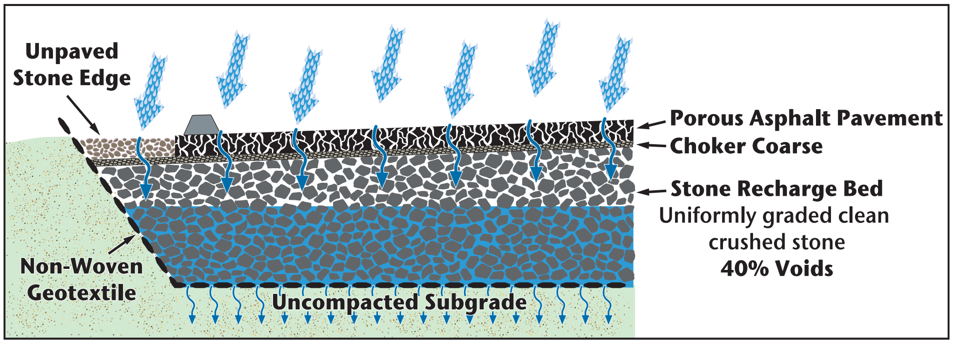
TABLE 1

Pollution removal efficiencies (University of New Hampshire)

Treatment System	**Total Suspended Solids** (% Removal)	**Total Phosphorus** (% Removal)	**Total Zinc** (% Removal)	**Total Petroleum Hydrocarbons in the Diesel Range** (% Removal)
Porous Pavement	99	38	96	99

FIGURE 1

Typical porous pavement cross section



- Spread out the infiltration. The maximum ratio of impervious to pervious area should be 5:1. For carbonate soils where there is a risk of sinkholes, the maximum ratio should be 3:1. Do not place porous pavements over known sinkhole areas.
- The design should provide for an alternate path for stormwater to enter the stone recharge bed in the event that the pavement surface becomes plugged or experiences extreme storm events.
- An overflow system should be included to prevent water in the stone bed from rising into the pavement surface during extreme storm events.
- The stone recharge bed should be able to drain within 12 and 72 hours.
- The bottom of the infiltration bed should be flat to maximize the infiltration area and reduce the amount of stone required.
- Porous pavements work best on flat or gently sloping areas. The slope of the surface should not exceed 5 percent. For parking on sloping areas, consider terracing the parking areas with berms separating the parking bay as shown in Figure 2.

Frost

In the past it has been recomended that the bottom of the recharge bed should exceed the depth of frost penetration in the region where the porous pavement is to be installed. More recently this has come into question, since a number of porous pavements have been installed in freezing climates with total depths much shallower than this. These include pathways at Swarthmore College, Pennsylvania, and a parking lot at Walden Pond Visitor Center, Massachusetts, both with a bed depth of 12 inches. None of these pavements have shown damage due to frost heave. The only research on frost depth has occurred at UNH, where the frost depth is 48 inches. While the porous pavement at the site extends to below the frost depth, their data from 2006 show frost penetration in the recharge bed of less than one foot. UNH conservatively recommends the depth of the bed be 65 percent of the frost depth in their design specifications.[4]

Routing Stormwater from Impervious Areas

Using the stone recharge bed for stormwater management for adjacent impervious areas such as roofs and roads can reduce project costs. This will reduce or eliminate the need for a detention basin and reduce stormwater structures and pipes. To achieve this, stormwater can be conveyed directly into the stone bed, where perforated pipes in the stone bed can distribute the water evenly. Use of a sediment control device is recommended (Figure 3).

FIGURE 2

Terraced porous parking

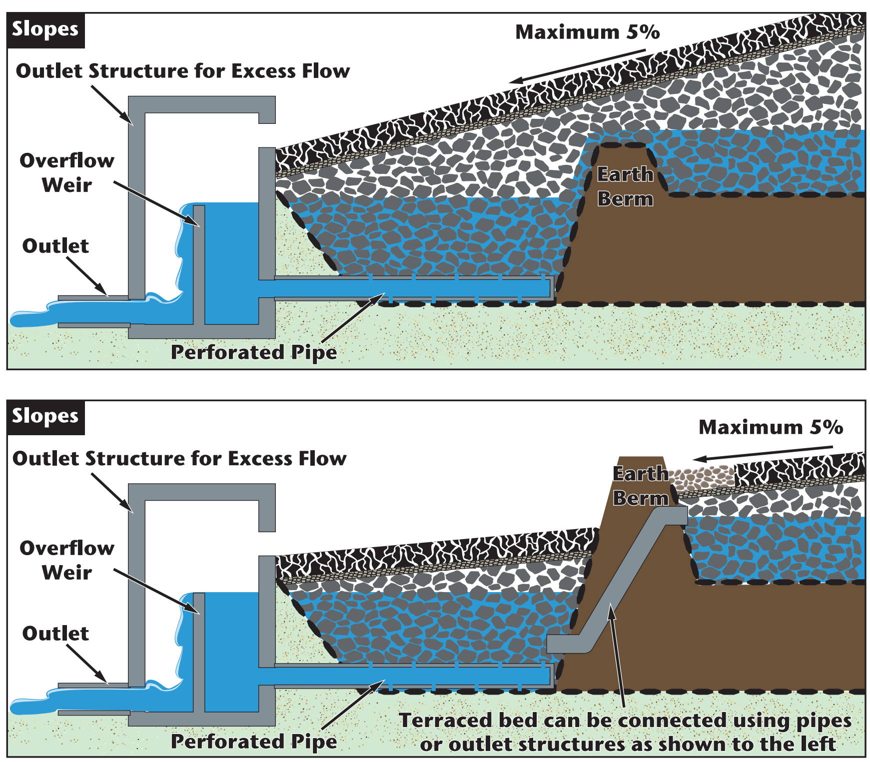
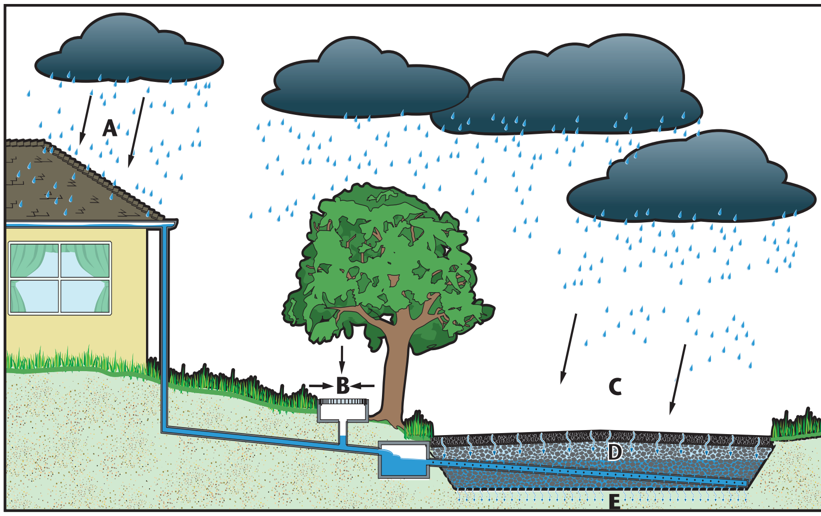


FIGURE 3

Roof leaders can be connected directly to the subsurface infiltration bed

(Based on Cahill Associates illustration)



A Precipitation is carried from roof by roof leaders to storage bed.

B Stormwater runoff from impervious areas and lawn areas is carried to storage bed.

C Precipitation that falls on porous parking enters storage bed directly.

D Stone bed stores water. Continuously perforated pipes distribute the stormwater from impervious surfaces evenly throughout the bed.

E Stormwater exfiltrates from storage bed into soil, recharging groundwater.

Provide Alternate Path for Stormwater to Enter Stone Recharge Bed

Often, the designer will provide an alternate means for stormwater to enter the stone recharge bed if the pavement surface should ever become plugged or sealed, or for extreme storm events. For pavements without curbs, this can be a two-foot-wide stone edge connected to the bed (Figure 4).

Overflow Structure

Porous pavements are not normally designed to store and infiltrate all stormwater from all storms. Therefore, it will be necessary to include overflow devices to prevent the water from rising into and over the porous asphalt surface (Figure 4).

Paths

In addition to parking lots and roads, porous pavements have also been used successfully for paths and trails. One complication in using porous pavements for paths is that they normally follow the natural contours of the land, so the bed bottoms might not necessarily be flat. They do reduce the amount of impervious surface. They also mimic the natural infiltration of the surrounding terrain and will therefore reduce runoff and improve water quality. Because the pavement/infiltration system follows the surrounding contours, it is necessary to provide drains at low points as shown in Figure 5.

MATERIALS

Geotextile (Filter Fabric)

Non-woven geotextiles are typically used to prevent fines in the subgrade from migrating into the stone recharge bed.

Stone Recharge Bed and Choker Course

Aggregate for the stone recharge bed needs to be clean, crushed stone. In many cases AASHTO No. 3 stone is specified; however, other aggregate gradations such as AASHTO No. 1, No. 2, and smaller have also been used successfully.

Porous Asphalt

Porous asphalt pavements are fast and easy to construct. With the proper information, most asphalt

FIGURE 4

Example of stone edge for alternate path to bed and overflow device

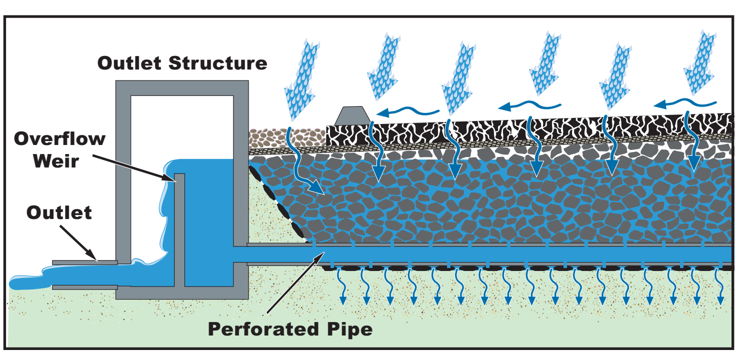
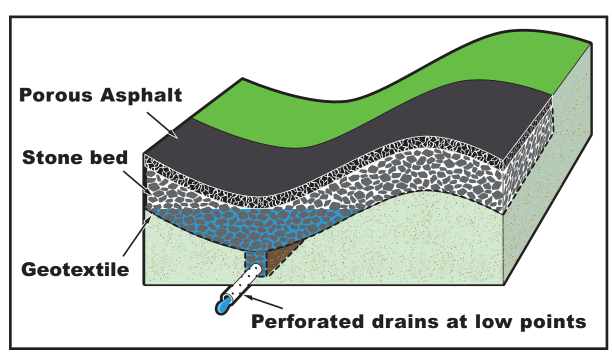


FIGURE 5

Porous asphalt path



plants can easily prepare the mix and general paving contractors can install it. While modified asphalts are often used, these are not always necessary or practical.

There are a number of guides and specifications available for porous asphalt mixes. These include NAPA publication IS-115, *Design, Construction, and Maintenance of Open-Graded Asphalt Friction Course*. The following key properties should be included as part of the specification:

- Air voids: 16 percent minimum – This assures permeability of the mix.
- Asphalt content: A good guideline is to require 5.75 percent minimum by weight of total mix. Adequate binder content is important for the durability of the mix.
- Draindown test: 0.3 percent maximum – This test is important to make sure that the asphalt binder does not drain down during storage, transportation and placement.
- Moisture susceptibility – Because porous asphalt surfaces do not hold water, they have very low risk of moisture-related damage.

CONSTRUCTION GUIDELINES

The following are some general guidelines for construction of porous pavements:

- The site area for the porous pavement should be protected from excessive heavy equipment running on the subgrade, compacting soil, and reducing permeability.
- Excavate the subgrade soil using equipment with tracks or oversized tires. Avoid narrow rubber tires as they compact the soil and reduce its infiltration capabilities.
- As soon as the bed has been excavated to the final grade, the filter fabric should be placed.
- Install drainage pipes if required.
- Place aggregate for the stone recharge bed, taking care not to damage the filter fabric. Aggregate should be dumped at the edge of the bed and placed in layers of 8 to12 inches using track equipment. Compact each lift with a single pass of a light roller or vibratory compactor.
- The use of a choker course over the top of the stone recharge bed is optional. The purpose of this course is to stabilize the surface for the paving equipment. The purpose is not to cover the large stone in the recharge bed but to fill some of the surface voids and lock up the aggregate. Therefore some of the large stones will be visible after the choker course has been placed and compacted.
- The porous asphalt layer is placed in 2- to 4-inch-thick lifts using track pavers, following state or national guidelines for open-graded asphalt mixes.
- After final rolling, traffic should be restricted for the first 24 hours.
- It is critical to protect the porous pavement during and after construction from sediment-laden water and construction debris that may clog it.

FIGURE 6

The photos show a parking lot at University of New Hampshire one hour after plowing, with a close-up of the porous asphalt portion of the lot at bottom. A 75 percent reduction in salt application was possible: that is, with only 25 percent of the salt, the snow and ice cover on the porous asphalt was the same as on conventional dense-mix asphalt.

Post-Construction Practices

Where applicable, remove temporary stormwater drainage diversions after vegetation is established.

Although snow and ice tend to melt more quickly on porous pavement, it may still be necessary to apply de-icing compounds such as salt or liquid de-icer. **Do not use sand or ash on the surface since clogging may occur**. As previously mentioned, the University of New Hampshire has shown that significantly less deicer may be applied than with conventional pavements. (Figure 6).

Signs are often posted at porous pavement sites to alert maintenance personnel to keep silt and debris from entering the site. They should also warn not to seal the pavement or use sand or other abrasives for snow or ice conditions. In addition, these signs can include some educational information regarding the advantages of porous pavement.

MAINTENANCE

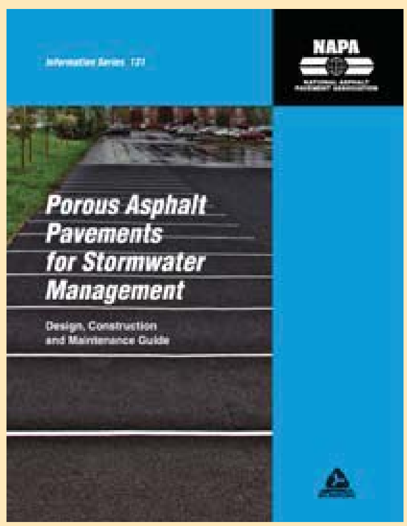
To prevent clogging of porous pavements it is recommended that they be vacuum swept twice per year. As previously discussed, it is also very important that sanding not be used for winter maintenance.

SUMMARY

Porous asphalt pavements provide excellent parking lots and roads. They tend not to exhibit cracking and pothole formation problems. The surface wears well. Porous asphalt has been proven to last for decades, even in extreme climates, and even in areas with many freeze-thaw cycles.[5] Using the underlying stone bed to manage stormwater for adjacent impervious areas such as roofs provides even more benefits.

Porous pavement is a sound choice on economics alone. A porous asphalt pavement surface costs approximately the same as conventional asphalt. Because porous pavement is designed to “fit into” the topography of a site, there is generally less earthwork. The underlying stone bed is usually more expensive than a conventional compacted sub-base, but this cost difference is offset by eliminating the detention basin and other components of stormwater management systems. On projects where unit costs have been compared, the porous pavement has been the less expensive option. Porous pavements are therefore attractive on both environmental and economic grounds.[1]

1. Cahill, Thomas H., et al., “Porous Asphalt: The Right Choice for Porous Pavements,” *Hot Mix Asphalt Technology*, National Asphalt Pavement Association, Lanham, MD, September/October 2003.
2. Thelen, E. a. (1978). *Porous Pavement*, The Franklin Institute Research Laboratories.
3. Cahill, T. H., Adams, M., & Marm, C. (2005, March). *Stormwater Management with Porous Pavements*. Government Engineering, p. 6.
4. University of New Hampshire Stormwater Center. (2007). *University of New Hampshire Stormwater Center 2007 Annual Report*. Durham, NH.
5. MacDonald, Chuck, “Porous Pavements Working in Northern Climates,” *Hot Mix Asphalt Technology*, National Asphalt Pavement Association, Lanham, MD, July/August 2006.



Additional Resources

The definitive guide for porous pavements is NAPA’s *Porous Asphalt Pavements for Stormwater Management: Design, Construction, and Maintenance Guide* (IS-131).

For porous asphalt mixes, consult NAPA’s *Design, Construction, and Maintenance of Open-Graded Asphalt Friction Courses* (IS-115).

For photos and videos visit www.porouspavement.net.

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