OREGON STATE UNIVERSITY EXTENSION SERVICE

Decorative pervious concrete sidewalk in China.
Photo: David C. Mitchell, Bunyan Industries

LOW-IMPACT DEVELOPMENT FACT SHEET

POROUS PAVEMENT

Maria Cahill, Derek C. Godwin, and Jenna H. Tilt

Porous pavement, also known as permeable or pervious pavement, is a stormwater management system that allows water to move through void spaces within the pavement and eventually infiltrate into underlying soils. In most cases, porous pavement can substitute for conventional, impervious pavements—used by pedestrians and vehicles alike—without the need for any additional stormwater management feature such as a detention basin or rain garden. These systems reduce runoff volumes otherwise produced by impervious surfaces such as parking lots, roads, and sidewalks.

Three primary variations of porous pavement surfaces provide a range of aesthetic options:

- **Porous asphalt and pervious concrete** are similar to impervious asphalt and concrete, respectively, but the mixes use aggregate that is uniformly graded, meaning it has no fine small particles. This creates interconnected voids that, when properly designed and constructed, result in a porous surface. There is no loss of structural support when compared to impervious asphalt and concrete because fines in the impervious mix serve only to make it easier to compact. The larger pieces of crushed aggregate in both mixes

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Photo: Willamette Graystone

Permeable pavers add aesthetics and functionality to a development at Shelvins Commons in Bend, Oregon.

provide enough structural stability for even high-traffic applications such as large trucks on highways.

- **Permeable pavers** are paver units of stone, concrete, or another durable material set within and over a base rock. The gaps between the pavers provide voids for water to reach subsoils.
- **Flexible paving systems** are prefabricated grids made of plastic or other solid materials, filled in with clean sand, gravel, dirt, or vegetation. The grids provide a stable surface as well as a porous media, and they sometimes resemble a lawn.

When properly installed and maintained, these pavements can function for decades—with most outlasting their impervious counterparts in durability (PSAT 2005, Hicks and Lundy 1998). For instance, in areas with freeze-thaw cycles, the pores in pervious pavement give water a place to expand without breaking up the pavement. Porous pavement has been used effectively throughout the United States in arid climates such as Tucson, Arizona; wet climates such western Oregon, Washington, and Florida; and areas with significant seasonal temperature variations such as Ohio, Minnesota, and Colorado. This is good news considering the differences in environmental conditions across Oregon.

Site conditions

Porous pavement can be used almost anywhere impervious pavement is used (PBMP 2006). Using porous pavement can lower the overall cost of stormwater management by eliminating the need for stormwater facilities that could compete for space with wooded and open-space areas or additional developable land (Hicks and Lundy 1998). Porous pavements have been used all over Oregon in many different conditions—from commercial parking lots, sidewalks, and driveways to public and private roads and highways. Porous pavement functions well in upland areas where water has not yet pooled and soils tend to drain more efficiently (Hicks and Lundy 1998). Porous pavement can also be combined with impervious pavement, such as in the case of a driveway that uses strips of traditional pavement for tire tracks, with geogrids filling in center strips and edges (Barr 2001).

Porous pavements can handle truck weights such as H-20 loading; however, they are generally not recommended for high-traffic areas due to the higher risk of spills and levels of contaminants.

POROUS PAVEMENT APPLICATIONS FOR SURFACES THAT RECEIVE RAINFALL ONLY:

- **Where seasonal-high groundwater table,** bedrock, or other subsurface impermeable layer is lower than 18 inches from the bottom of the base rock
- **In low-infiltration rate soils** such as clay (i.e., as low as 0.1 inches/hour)
- **In limestone bedrock**
- **Under trees**

SETBACKS FOR SURFACES THAT RECEIVE BOTH RAINFALL AND RUNOFF:

- **5 feet** from property lines (although they are allowed to be situated on the right-of-way line);
- **10 feet** from building foundations;
- **20 feet** if a structure is located downslope;

- **100 feet** if located upslope of steep slopes;
- **30 feet** from surface waters (although buffer requirements may not allow excavation work or other disturbance this close to surface water);
- **500 feet** from water supply wells and drinking water springs (ODEQ 1998);
- **100 feet** from septic tanks or drain fields;
- **20 feet** from riparian buffers or growth protection easements; and
- **50 feet** from the top of slopes greater than 15 percent (Barr 2001, LCREP 2006, Field 2007, BES 2008, NCDWQ 2007).

WHERE NOT TO USE POROUS PAVEMENT IN OREGON:

- **Where the seasonal groundwater table,** bedrock, or other subsurface impermeable layer is higher than 18 inches from the bottom of the base rock;
- **In areas** of new heavily compacted fill (fill less than five years old);
- **In contaminated soils;**
- **In expansive soils,** except when pockets can be removed;
- **On slopes exceeding** 10 percent, unless the bottom of the facility can be stepped down the hill with a series of berms;
- **In possible spill areas;**
- **Over septic tanks** or drain fields;
- **Where design cannot be executed** to prevent excessive sediment from being deposited on the surface from upslope areas;
- **Where sites receive** regular application of sand for maintaining traction in the winter; or
- **Where cars or trucks** may track a significant amount of dirt onto the surface, such as a construction site.

Removing pollutants

The primary stormwater function of porous pavement is reducing the volume of runoff. Secondary functions include flow attenuation (retaining water and then slowly infiltrating it), and nutrient reduction.

Two processes remove pollution:

- **Sediments settle out** in the aggregate.
- **Pollutants can be sequestered or broken down** by microbes in the aggregate and native soils below the system.

The Center for Watershed Protection estimates the total amount of phosphorus removed for level 1 and 2 designs at 59 to 81 percent, and nitrogen removal at 59 to 81 percent. Runoff reduction was estimated at 45 to 75 percent (CWP&CSN 2008), although studies in Oregon indicate that a reduction of runoff of 95 to 99 percent is possible. Runoff reduction itself contributes to pollutant removal, simply by reducing the volume of pollutants going downstream. Other studies have found that porous pavement effectively removes suspended solids, metals, oils, and grease (UDFCD 2008).

Cost

Although porous pavements are more expensive than impervious pavements, there are several potential offsets such as reduced piping, curbs, excavation, and fewer to no additional downstream stormwater facilities (Hicks and Lundy 1998, UDFCD 2008). Generally, the most expensive aspect of porous pavement installation is the underlying stone beds. Cost of the pavement itself varies by type and manufacturer (LIDMM 2008). Where detention basins would have been used in conventional large-lot subdivisions, the additional cost of porous pavements has been offset by the ability to sell an extra lot.

Regardless of what type of porous pavement is used, the cost of installing porous pavement may be offset by several factors:

- **Savings on infrastructure:** pipes, detention ponds, water quality facilities, catch basins, manholes, and excavation;
- **More land** made available for development;
- **The addition** of an attractive landscape amenity;
- **Lower stormwater fees** in some jurisdictions;
- **Lower permitting fees** and faster timelines in some cases; and
- **Increased durability** compared to impervious pavements.

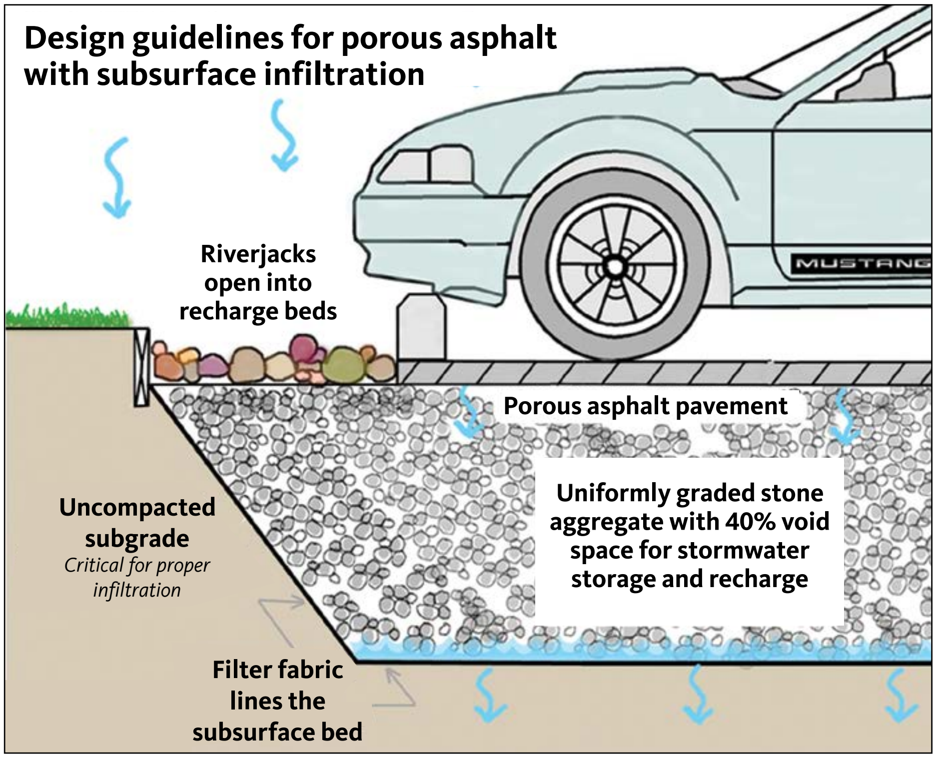
Design

Rainfall varies across time, in intensity and volume. To quantify these patterns, it's helpful to understand the concepts of a "design" storm and rainfall distribution.

A design storm is a theoretical storm the porous pavement is designed to manage. We know that different sizes of storms occur at a given frequency; thus, we usually see these described as 6-month, 1-year, 2-year, 5-year, 10-year, 25-year, or 100-year storms that occur over a 6-hour or 24-hour period. The size and duration of the design storm developers plan for is typically specified by local regulations.

A rainfall distribution is a statistical representation of the intensity and duration of rainfall that occurs on average for each storm. These distributions provide a way to model the intensity and duration of rainfall for a given design storm. Oregon has three different rainfall distributions, called Type IA, Type I, and Type II. Type IA is a lower intensity, longer duration storm typical of western Oregon, while Type II storms are higher intensity, shorter duration storms. Type I storms fall in between these two. Each jurisdiction develops its own requirements for the size of storm (design storm) and distribution type (1A, 1 and II) based on local goals for water quality and quantity.

Porous pavement sizing requirements, which consist of specifying an adequate depth of base rock to store the desired storm until it infiltrates, vary significantly, where standards exist. Most porous pavements infiltrate the required design storm by storing stormwater in the voids of uniformly sized base rock below the pavement surface. Infiltration of a larger storm, such as the 25-year, 24-hour design used to mitigate downstream flooding, can be achieved easily in soils with infiltration rates as low as 0.1 inches per hour. As a rule, however, infiltrating the two-year storm will reduce runoff volumes from the site enough to mitigate downstream flooding impacts of peak flows from the 25-year storm. Porous pavements should be able to pass a 100-year, 24-hour storm, which requires the construction of overflow or control structures to ensure that the pavement does not saturate and potentially destabilize. When considering porous pavement, as with all infiltration best practices, review with the project team the potential for groundwater contamination.



Graphic: Thomas Cahill

If the infiltration rate of the native subgrade soils and storage capacity in the base rock is properly balanced, porous pavements can be designed to infiltrate runoff from roofs or surrounding areas, in addition to the rainfall they receive. Additional storage in the system can be achieved by increasing the depth of the rock base—in other words, increasing the amount of uncompacted subgrade filled with uniformly sized rocks, or base rock, between the porous pavement and the filter fabric. Water can be conveyed directly into this base rock (sometimes referred to as an “infiltration bed” or “rock trench”) via infiltration through a rain garden or similar surface system.

Installing a perforated pipe in an infiltration facility is considered an underground injection control (UIC) in Oregon (see Permits, page 10).

All runoff, even from roofs, should be pretreated for sediment to protect the base rock from long-term clogging. Pretreatment facilities settle sediments and particulates before the runoff enters the base rock layer. Carefully design the grading plan to prevent untreated runoff and landscape areas from draining towards porous pavements because sediment and other debris are likely to clog the pavement voids (LIDMM 2008).

Since the placement of conventional fill requires so much compaction that the process can give soil a similar density (and similar runoff characteristics) to concrete, porous pavement should never be designed so that the bottom of the base rock sits on areas of new fill, unless it’s fill of the pavement or base rock itself (See Construction, page 7). The pavement section should ideally be situated in a cut in native, uncompacted soil. Use lightly compacted open-graded base rock to bridge the depth between the bottom of the pavement and uncompacted native soil; this step can add significant cost. In impervious pavements, compaction of the soil provides a portion of the structural stability, allowing designers to reduce the depth of the base rock. In porous pavements, instead of compacting the subgrade, consider increasing the thickness of pavement surface or the depth of the base rock. Porous pavement surface thicknesses are calculated relative to estimated traffic weight and frequency (UDFCD 2008). Consult a geotechnical engineer to find the appropriate pavement section (surface and rock course thicknesses as well as geotextile recommendations) for the site’s soils in a wet, uncompacted condition. This will vary by porous pavement type.

BASE COURSE DESIGN

The base rock should be made up of uniformly graded (all the same size) and washed, crushed aggregate. Generally, any rock that is all the same size has a void ratio between 30 percent and 40 percent (UDFCD 2008). Typical specifications are AASHTO #3, #4, #8, #57, or #67. Assume that your base rock has 30 percent voids, or have it tested by a lab using the ASTM C29 Bulk Density Test, and use this void ratio to determine the depth of rock needed to store the volume of water from the regulatory storm event. Depths generally range from 6 to 12 inches for vehicular traffic applications and may go up to 36 inches when engineered to address local flooding issues.

CLOGGING DESIGN PRECAUTIONS

Clogging is often less of an issue than people think. The infiltration rate of porous asphalt and concrete may exceed 1,500 inches per hour, while long-term infiltration rates have been observed to fall to as low as 0.5 inches per hour (Hunt 2006). Considering that the void space is so high when it's first installed, a "mostly clogged" surface can still be effective. For example, the largest 2-year design storm in Oregon is 6.5 inches of rainfall in a 24-hour period. If that 6.5 inches just happened to concentrate over 6 of the 24 hours, a surface infiltration rate of 1 inch per hour would be all that is needed to pass the storm through the surface. Consult your local municipal codes and guidelines before installing porous pavement.

Take a few prudent steps to protect the surface. Design landscape slopes around porous pavements so that if they erode, the sediment will not reach the pavement surface. In addition, signage can prevent people from dumping landscaping materials on it. Porous pavements vary by manufacturer, so closely follow the instructions for design, construction, and installation, since clogs can easily occur during construction.

Sizing

Porous pavements that infiltrate only the rainfall they receive—and not concentrated runoff from other areas—can be surprisingly effective, even in slow-draining clay soils. In locations throughout Oregon, it is possible to infiltrate the entire 25-year, 24-hour design storm in clay soils with an infiltration rate of 0.1 inches per hour and a base-rock depth of less than 8 inches.

In Table 1, models show that porous pavements can effectively manage the rainfall in slowly draining soils from any storm distribution in Oregon. The peak flow in cubic feet per second is the modeled runoff that could be generated from an impervious area of 10,000 square feet. This theoretical runoff is then directed to the voids in the base rock. Since the infiltration area of the base rock is the same as the pavement, a very large area is available to infiltrate. In all cases, the likelihood of peak flow exceeding the base rock storage and leaving the site during a large, infrequent 25-year storm event is zero for Oregon cities.

For porous pavements that receive runoff from other areas, the minimum infiltration rate needed for the same area of pavement increases. Alternatively, the base rock could be expanded horizontally under landscape and imperious areas to increase the infiltration area and therefore increase the effective infiltration rate from the base rock as a whole.

Due to the continuous nature of Type IA storms in western Oregon, soils should drain a storm event in 30 hours or less to be ready for the next storm. Type I and Type II storm areas in central and eastern Oregon occur much less frequently, and up to 72 hours is often an acceptable emptying out period of the base rock.

Table 1: Modeling output showing the effectiveness of porous pavement to fully infiltrate large storms in slow-draining soils across Oregon

	25-year event depth (in)	Distribution	Peak flow (cfs)	Peak flow exceeding base rock storage (cfs)	Maximum ponding depth in base rock (in)
Salem	4	Type IA	0.22	0.00	4.1
Coos Bay	5.5	Type IA	0.30	0.00	7.6
Redmond	1.8	Type I	0.29	0.00	1.3
Wasco	2.3	Type I	0.38	0.00	1.9
La Grande	2.4	Type II	0.78	0.00	3.0
Pendleton	1.6	Type II	0.51	0.00	1.8

Modeled in HydroCAD v9.10 assuming a design infiltration rate = 0.10 inches/hour and a time of concentration of 5 minutes.

EXPANSIVE SOILS

Expansive soils, often found in the D soils group, have the greatest runoff potential due to their clayey and often saturated composition. When constructing in these conditions, remove pockets of expansive soils under the direction of a geotechnical engineer in the field and replace them with additional open graded base rock (USDA NRCS 2007).

For large areas of expansive soils, consider an impermeable liner with an underdrain so rainfall does not expand the soils. This system won't reduce overall stormwater volume. Neither will it significantly improve water quality, because the runoff does not infiltrate back into the soil but is exported via the underdrain, carrying the dirt from the base rock. In other words, stormwater just runs through the porous pavement and is carried off to another location via a pipe, which shouldn't be considered low-impact development (LID). In expansive soils, it may be better to use a different approach, such as draining impervious pavements to an infiltration rain garden.

FREEZE-THAW CONDITIONS

Properly designed porous pavement installations have performed well in the Midwest and northeast U.S. where freeze-thaw cycles are severe (Adams, 2003 and Wei, 1986). The University of New Hampshire's cold weather guidelines are recognized in many regions as the foremost source of authority on the design of permeable pavement in cold climates (UNHSC 2009).

Routing

Porous pavements should be designed to infiltrate appropriate volumes out of the bottom of the facility; however, a storm larger than the design storm should not be allowed to flow up through the pavement because this could destabilize the pavement.

Underdrains—perforated pipes encased in gravel-filled trenches—can be used to convey water from large storm events down into the ground or to a stormwater conveyance system.

Injecting stormwater into the ground via perforated infrastructure triggers UIC requirements and increases the cost of porous pavement. When underdrains are used as an overflow for large storms, the pipe can be placed on the bottom of the facility for adequate cover but should be regulated by a catch basin with a weir or some other structure that will allow as much water as possible to back up behind the weir and infiltrate within the desired time. (See graphic, page 4.)

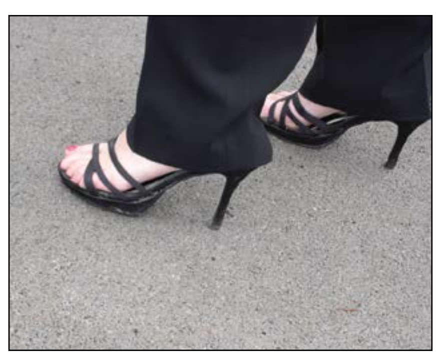
If the underdrain is set on the bottom of the facility with no controls to allow water to back up into the rock base, the system will not provide adequate water-quality treatment since that process is largely a result of infiltration into the soil below. In this case, stormwater

Photo: Gregg Smith, River Bend Materials

Crews install pervious pavement at Stayton Veterinary Clinic, Stayton, OR.

Photo: Maria Cahill

Porous asphalt pavement is shown next to impervious pavement.



Pervious concrete was once thought to have too rough a surface for high-heeled shoes.

Photo: Maria Cahill

would have to be directed to another LID facility such as a rain garden to ensure that water-quality and volume-reduction goals have been met.

Construction

Prior to construction, investigate the site for suitability for porous pavements. This includes infiltration testing to determine infiltration rates and the existence of impermeable soil strata, known as fragipan, or bedrock (Field 2007). Some jurisdictions, such as the City of Portland, require these tests to be performed by a registered professional engineer when installing porous pavement streets (PSMM 2008); however, infiltration testing is a relatively simple endeavor than can be understood and undertaken by the average designer (See the Infiltration Testing fact sheet).

POROUS ASPHALT

Porous asphalt, also known as porous asphaltic concrete, is a mixture of crushed aggregate (without the fines) and asphalt binder. Asphalt mixtures tend to experience surface scuffing or raveling on the pavement surface when containing less than 5.75 to 6 percent bituminous asphalt by weight. Enhance scuffing protection with an additional polymer-modified, Performance Graded Asphalt Binder. The surface of a successfully designed and installed porous asphalt typically will have 10 to 20 percent voids.

Installation of porous asphalt, as with other porous pavements, should follow the guidelines below for protecting the soil, installing the geotextile, and washing the base rock. Because asphalt is a flexible pavement, the base rock serves not only as storage for stormwater but also as an integral part of the structural support for the pavement surface.

When the base rock is lightly compacted, it may be difficult to roll asphalt on top of it. The base rock can sometimes roll, causing a wavy appearance to the asphalt surface. The choker course sits between the base course and pavement surface to lock in, or choke, the larger base rock aggregate below and stabilize the surface for rolling. You may need to experiment in the field, but depths generally range from 1 to 2 inches (PSAT 2005) and should be composed of a smaller, uniformly graded, clean and washed, crushed aggregate. Larger depths of choker course will not choke the pavement beneath it but will instead start to roll again like the base course. So, depending on the size of the base course aggregate, exceeding a depth of 2 inches probably will not be helpful.

A choker course is not always needed. At the Pringle Creek residential development outside of Salem, Oregon, for instance, the base rock was sufficiently hard and had enough angular faces that it locked together

Photo: Maria Cahill

Poured-in-place, impervious-concrete permeable pavers at the Broadway Cab Company in Portland, Oregon.

on its own under light compaction. This is common in Oregon where volcanic bedrock tends to be hard. If you're not sure you need it, it won't hurt to include it—but it does cost more.

Placing porous asphalt is very similar to placing impervious asphalt. Take care not to overcompact the surface by using a small roller and limiting the passes. Schedule installment during a time of the year when temperatures will not drop below 55°F.

A specification for porous asphalt suitable for all of Oregon can be adapted from Appendix D of the template for LID Stormwater Manual for Western Oregon at the ODEQ website: http://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-LID.aspx

PERVIOUS CONCRETE

Concrete mixtures are combinations of aggregate and Portland Cement. For pervious concrete, use a low cement-to-water ratio when mixing and use the mixture within one hour of adding water (LIDMM 2008). Water should be added only once to the mixture. Additional water can cause the cement to weaken and fail (UDFCD 2008). Depending on environmental conditions, the concrete should be covered within 15 minutes. On some very hot, dry days, you may not be able to install pervious concrete at all because of the cover limitation. Pervious concrete has no minimum temperature at which it can be installed.

Installation of pervious concrete, as with other porous pavements, should follow the general guidelines below for protecting the soil, installing the geotextile, and washing the base rock. Because concrete is a rigid pavement, the base rock may be needed only to store stormwater. The choker course is unnecessary because porous concrete is not rolled like asphalt.

The installation of pervious concrete differs enough from impervious concrete that installation should be done by a certified contractor. There are several training programs in Oregon certified by the National Ready Mixed Concrete Association called the NRMCA Pervious Concrete Technician training. The use of a certified installer is strongly recommended.

PERMEABLE PAVERS

Pavers of many different materials can be purchased new from a manufacturer. They can also be made of salvaged material such as bricks, stones, or sawcut concrete sidewalk squares. Place Pavers atop a lightly compacted leveling course. Space between pavers should be between 8 and 20 percent of the paver size to allow for infiltration. The infill between the pavers is a coarse sand that conforms to a standard specification such as ASTM C-33. The area should be lightly compacted and refilled if infill drops below the surface of the pavers. Both the leveling and infill courses should be clean and washed on-site, with no fines or dirt.

In vehicular applications, the entire facility area should be contained by a 6-inch-thick perimeter of concrete (UDFCD 2008) or equivalent permanent structure.

Pavers are applicable in several settings where vehicle movement is slower than 45 miles per hour, such as airports, parking lots, aprons, and maintenance roads (UDFCD 2008). They are also an attractive option for plazas, parks, patios, parking areas, or low-speed streets (LIDMM 2008).

POROUS FLEXIBLE PAVING SYSTEMS

These concrete or plastic frameworks or matrices are filled with turf grass or gravel. The framework allows the site to retain structure and durability while the large spaces between the structures provide areas for infiltration. Prepare the subgrade and base rock to the general design guidelines for all pavements, then fill the voids with aggregate or growing medium to store runoff and provide infiltration to underlying soils (LIDMM 2008). A 2006 study found that turf was easier to establish in plastic units because the plastic does not absorb water and preserves moisture in the soil. Plastic also lasted longer (PBMP 2006).

Flexible paving systems are a good choice for fire access lanes, overflow parking, and infrequent parking use, especially when turf is a part of the design. They can also be used to supplement a narrowed standard pavement street to meet required widths for emergency vehicles (LIDMM 2008).

Photo: Thomas Cahill

Lay sheets of geotextile fabric sacross the intended area with an additional 4 feet beyond the bed to ensure that sediments do not enter the bed during construction. Sheets should overlap at least 18 inches.

CONSTRUCTION GUIDELINES FOR ALL POROUS PAVEMENT TYPES

As in all stormwater management facilities, take care to construct porous pavement properly. Since the native subgrade soil is necessary to infiltrate stormwater, porous pavement areas should be off-limits to construction traffic and stockpiling activities. Use orange protection or chain-link fence and clear signage to restrict traffic. Because porous pavement surfaces are susceptible to clogging, there are several staging and construction phasing considerations. Never stockpile landscape, soil, or other materials on porous pavements. Porous pavement construction is ideally completed at the very end of a large project or development. A few planned unit developments in Oregon, including Pringle Creek outside of Salem, have had challenges with building the pervious road network first and then requiring builders to protect the pavement with geotextile; use steel plates where alternate access paths cannot be developed ahead of time.

Use track equipment or excavate from the sides of the infiltration area to protect soils during excavation. If the soils are exposed to rain, fine particles could be picked up and moved around, clogging the native subgrade soils. On a dry day, rake the surface to a depth of 3 inches to loosen soil before proceeding.

Once the native subgrade has been exposed, install geotextile to preserve the voids in the overlying base rock (LIDMM 2008). The geotextile functions as a separator whenever storage of rainfall is needed; however, if soils infiltrate quickly, a geotextile may not be necessary because the rock is not necessary.

Where geotextile fabrics are required, they should be high quality and resistant to punctures from sharp edges and rocks (UDFCD 2008). Sheets should overlap at least 18 inches and be laid across the intended area with an additional 4 feet beyond the bed to ensure that sediment and runoff do not enter the bed during construction (LIDMM 2008). The extra geotextile fabric can be cut at the very end of construction.

Next, install the base rock, if needed. (Depending on the structural capacity and drainage characteristics of your native soils, base rock may not be needed for pervious concrete installations.) Base rock should be washed on site, even if delivered "clean" from the quarry due to the high risk of dust or fine particles clogging the geotextile and creating an unintentional impervious surface (Hicks and Lundy 1998). One successful method is to hose the rock off in the delivery truck when it arrives. Another method might be to dump the rock and wash off the pile. Include this process in the erosion and sediment control plan for the construction site to remove sediment before it enters a stormwater conveyance system. Scoop the rock from the surface and closely monitor for fines. As you work your way down the pile, fines from above might only have been washed off halfway through.

Place base rock in 6-inch lifts by dumping rock at the beginning of the porous pavement area and backing over it to dump and spread the next 6-inch lift. Do not compact the rock with vibratory compaction. Light compaction can be achieved simply by driving back over the 6-inch lift.

Maintenance

On private land, consider a maintenance agreement between landowners and the jurisdiction overseeing road maintenance. Ideally, grades on site were all designed and constructed to flow away from porous pavements. For those landscape areas that may flow toward the pavement, avoid bare soil that may be transported to clog the surface. Inspect the pavement twice a year and remove trash and litter regularly, which may carry dirt that can also clog pavements. Notify all landscape contractors of their responsibility to help maintain the pavement by requiring them to identify an alternative place to dump landscape materials. Control structures, such as catch basins and manholes, should be cleaned out twice a year.

Settling subgrade may expose pervious pavements to potholes; proper construction measures can help you avoid potholes. If potholes do occur, patch damaged areas less than 50 square feet with pervious mix or suitable standard pavement (SMCOG 2008).

Exercise caution when using fertilizers, pesticides, herbicides, or fungicides on or near LID facilities. These are all potential pollutants. Instead, practice integrated pest management on the entire site, and on the stormwater facility at a minimum.

SNOW AND ICE REMOVAL

Porous pavements allow air to pass freely through the pavement voids. In cold weather, a convective process occurs when the ground is warmer than the outside air and melts snow and ice faster on porous pavements than on impervious pavements. Snowplowing won't hurt porous pavements; however, snowplows could catch the edges of permeable pavers (Barr 2001). Simply raise the plow height slightly. Cinders and sand clog porous pavement and should not be used. Also, plowed snow from impervious areas should not be stored on porous pavements, since it may contain cinders and sand. Consider using an environmentally sound, salt-free, liquid de-icer instead. According to the National Ready Mixed Concrete Association, deicers should not be applied to pervious concrete in the first year after installation. Their use is acceptable on other pavements.

ASPHALT AND CONCRETE MAINTENANCE

Porous asphalt should be vacuumed twice a year with standard street-cleaner equipment. If the pavement is in a public right-of-way where agencies sweep the streets with a vacuum truck, then porous pavements may not need additional maintenance.

Some cities have found that vacuum trucks were ineffective in removing sediments, and sometimes cities do not have the resources to invest in a vacuum truck. Seattle, WA, and Beaverton, OR, have found pressure washing porous asphalt and concrete an effective alternative to vacuum trucks. Pressure washing should be done at an angle to the pavement and not directly into it. Leaf blowers are also an option during the dry season when material can be blown out of the pavement area. The cleaning interval, which might range from every six months to three years, should be based upon level of exposure to sediments, which is related to the average daily traffic counts. More traffic means more sediment.

Never apply a seal coat to porous asphalt.

PAVER MAINTENANCE

Weeds periodically creep into the spaces between permeable pavers. Pull them by hand, use a torch, or employ some other integrated pest management approach.

Unclogging a clogged paver installation is relatively easy. Simply vacuum up the rock in between the pavers and then replace it with the same kind of rock. For sustainability and financial reasons, you may also consider vacuuming the rock, washing it off, and replacing it. Take erosion control measures if you decide to wash it.

FLEXIBLE PAVING SYSTEM MAINTENANCE

For flexible paving systems with grass, maintenance is similar to that of turf. The requirement for irrigation may be a deterrent for drier regions in Oregon. On flexible paving systems that include gravel, simply sweep or rake dislodged gravel back into place. Some manufacturers recommend or allow the use of fertilizers, pesticides, herbicides, or fungicides, but integrated pest management techniques remain the better option for porous pavements and all other LID facilities.

Inspect paving systems for bare soil, exposed rings, ruts, poorly growing grass, and thatch. In the case of spills, ruts, or disturbance associated with access to underground utilities, flexible paving systems can be cut with a sod cutter, set aside, and put back in place after the subgrade has been reconstructed. Avoid aerating these areas since this machinery will damage the pavement. It's okay to use a truck-mounted snowplow with skids on the corners to keep the blade 1 inch above the surface.

Thatch can be addressed by adjusting the mowing height. For best results, combine these recommendations with those specific to the manufacturer's requirements.

Photo: Maria Cahill

Concrete grass pavers were used in the Willamette Park overflow parking area in Portland, OR, to grow grass and preserve site permeability in this low-traffic area.

Permits

Before starting a project that involves porous pavement, consult your local planning and building department. Ask specifically about the applicable permits, plumbing codes, and piping requirements for your site and porous pavement. In many cases, if building a porous pavement on a nonresidential site, a commercial building permit is required, and a clearing, grading, and erosion control permit may be required if ground disturbance is large enough. Use local site maps or as-built drawings, if available, to discuss site-specific constraints.

The Oregon Department of Environmental Quality (ODEQ) regulates stormwater facilities designed for the subsurface placement of fluids. The Class V UIC program protects groundwater from injection of pollutants directly underground and may require a more formal permitting process, depending on the potential for pollution.

According to the U.S. Environmental Protection Agency, a Class V UIC well is:

- **Any bored,** drilled or driven shaft; or
- **A dug hole** whose depth is greater than its largest surface dimension; or
- **An improved sinkhole;** or
- **A subsurface fluid distribution system** (an assemblage of perforated pipes or drain tiles used to distribute fluids below the surface of the ground)."

Consider these guidelines in the design phase to avoid triggering state UIC requirements:

- **When sizing porous pavement,** avoid designing a facility that is deeper than the widest surface dimension.
- **Understand that porous pavements** designed with underdrains may be considered a UIC. Underdrains composed of perforated pipe that convey runoff from other impervious areas into the ground trigger state UIC requirements. (See *Soakage Trenches,* EM 9204)
- **Routing runoff** from large events exceeding the storage capacity of the base rock to a stormwater conveyance system using perforated pipe may also trigger UIC requirements.

Additional guidance is available from the ODEQ at: www.oregon.gov/deq/wq/wqpermits/Pages/UIC.aspx. If you have questions about whether your design is a UIC, contact the ODEQ UIC Program in the Water Quality Division.

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Photo: Thomas Cahilll

Impervious concrete installed next to pervious concrete on North Gay Street in Portland, Oregon.

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ADDITIONAL RESOURCES

Pervious concrete technician certification: http://www.nrmca.org/certifications/pervious/

US Environmental Protection Agency guide to reducing stormwater costs: https://www.epa.gov/green-infrastructure/stormwater-costs

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