Pervious Pavement

Pervious pavements reduce the amount of runoff by allowing water to pass through surfaces that would otherwise be impervious. Water can either infiltrate into the ground, if soil permeability rates allow, or be conveyed to other BMPs or a storm water system by an under-drain.

Design Criteria

- Pervious pavement is typically used in low traffic areas including overflow parking areas, emergency vehicle lanes, and pedestrian areas.
- In-situ soils should have field-verified minimum permeability rates greater than 0.3 in./hr. Contributing runoff from offsite should be limited to a 3:1 ratio of impervious area to pervious pavement area.
- The selected systems load bearing surface should be suited to maximum intended loads.
- Design storms should be infiltrated within 48 hours.

Grasspave® at Bradshaw Celebration of Life Center - Stillwater, MN

Benefits

- Good for highly impervious areas – particularly parking lots.
- Reduces need for other storm water BMPs by reducing runoff.
- Construction costs of some systems are less than traditional paving.
- Soil-enhanced turf systems resist compaction, increase infiltration, and provide soils for healthier vegetation.

Limitations

- Construction costs of some systems are more expensive than traditional paving
- Use depends on infiltration rates of underlying soils.
- Maintenance costs are higher than conventional paving.
- Not recommended for high traffic areas because of durability concerns.

Description

Pervious pavements can be subdivided into three general categories: 1) Porous Pavements – porous surfaces that infiltrate water across the entire surface (i.e. porous asphalt and porous concrete pavements); 2) Permeable Pavers – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e. block pavers, plastic grids, etc.); 3) Amended Soils - Fiber or artificial media added to soil to maintain soil structure and prevent compaction. There are many different types of modular porous pavers available from different manufacturers.

Pervious pavement systems reduce runoff from impervious surfaces by allowing stormwater to pass through the load bearing surface and infill that are selected based upon the intended application and required infiltration rate. Runoff is stored in the stone aggregate base course/ storage layer, if present, and allowed to infiltrate into the surrounding soil (functioning like an infiltration basin), or collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters (functioning like a surface sand filter).

Regular maintenance of pervious pavements is necessary to ensure long-term effectiveness. Annual or semi-annual sweeping or vacuuming of surface debris (litter, sediment, etc.) is STRONGLY RECOMMENDED for pavement or pavers. If clogging occurs, the filtration media below the surface may need to be replaced. Manufacturers should be consulted for specific maintenance requirements.

Currently, the MPCA will allow site designers to reduce the water quality volume sizing when using pervious pavement, up to a maximum of ½ acre of new impervious surface. The MPCA will not allow pervious pavements as a replacement for water quality treatment BMPs, such as infiltration or filtration practices.

Runoff Volume Minimization

MANAGEMENT SUITABILITY

High/ Med.	Water Quality (V_{wq})
Med.	Channel Protection (V_{cp})
Low	Overbank Flood Protection (V_{p10})
Low	Extreme Flood Protection (V_{p100})
High/ Med.	Recharge Volume (V_{re})

MECHANISMS

X*	Infiltration *with appropriate site conditions
X	Screening/ Filtration
X	Temperature Control
	Settling
	Evaporation
X*	Transpiration *if vegetation present
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

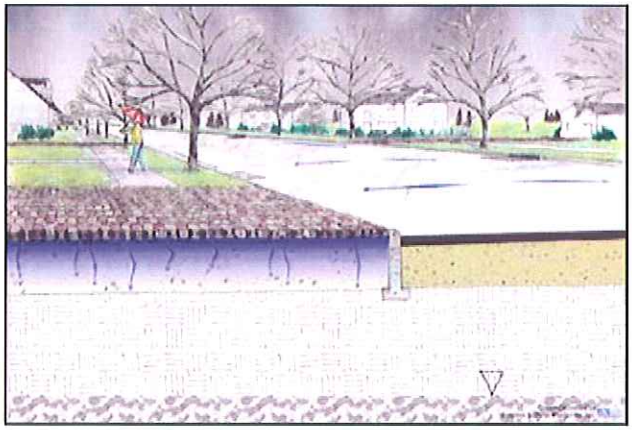
NA*	Total Suspended Solids *pretreatment for TSS is recommended if adjacent areas drain to pervious pavement
80%/ 80%	Nutrients - Total Phosphorus/ Total Nitrogen
90%	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Coliform, Streptococci, E. Coli
NA	Toxins - Hydrocarbons, Pesticides

SITE FACTORS

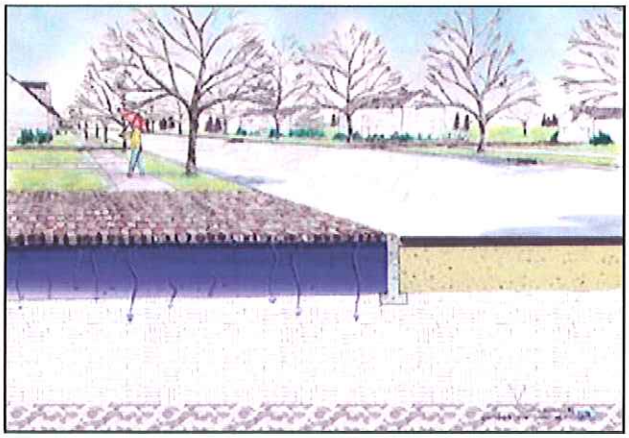
NA	Drainage Area
2% Max.	Max. Slope
3 ft	Min. Depth to Bedrock
3 ft	Min. Depth to Water Table
A,B	SCS Soil Type *can be used in C&D soil types with modifications (e.g. underdrains)
Good	Freeze/ Thaw Suitability *with adequate sub-grade
Yes	Potential Hotspot Runoff *requires impermeable liner if identified in hotspot area

Note: Pollution removal percentages apply to volume of runoff treated, and not to volume of runoff bypassed

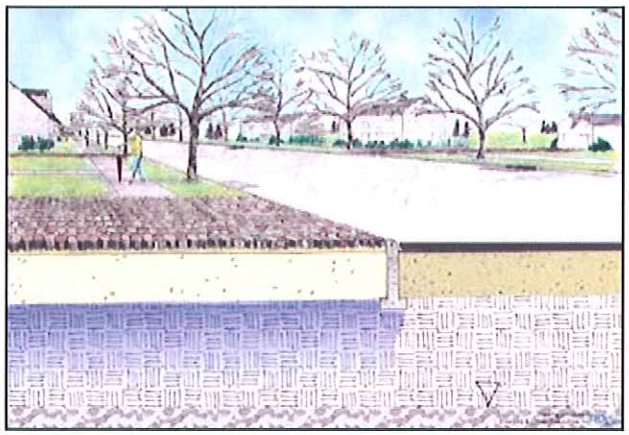
STORM SEQUENCE



Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Courtesy of Rice Creek Watershed District

Following Storm Event - Remaining storage draw-down

Best Management Practices Fact Sheet

Porous Concrete

PURPOSE: Porous concrete used in place of conventional concrete decreases the total amount of runoff leaving a site, promotes infiltration of runoff into the ground, reduces the amount of pollutants carried to a storm drain or waterway, and aids with reducing peak runoff velocity and volume.

Developing land for residential, commercial and industrial use carries the detrimental effect of vastly increasing the amount of impervious surface area as land is paved to create roads and parking lots. During a storm, runoff flows over impervious pavement, picking up pollutants such as dirt, grease and oil, and transports these contaminants to streams and storm sewer systems.

In response to this issue, designers developed porous paving systems that allow runoff to pass through the pavement into a stone reservoir, before infiltrating the soil below to recharge the groundwater supply. With proper installation and maintenance, porous paving allows for infiltration of up to 80% of annual runoff volume. Additionally, studies indicate that porous concrete systems can remove up to 65% of undissolved nutrients from runoff and up to 95% of sediment in runoff.

The design for application of porous concrete consists of at least three layers: a two to four-inch layer of porous concrete, a one to two-inch filter layer of half-inch crushed aggregate, a 12-inch minimum reservoir layer of one to three-inch aggregate, and an optional layer of filter fabric. Porous concrete consists of a mix including Portland cement, uniform open-graded coarse aggregate, and water. The void space of porous concrete ranges between 15% and 22%, compared to a three to five percent void space in conventional concrete. The concrete itself provides for some pretreatment of runoff. The crushed aggregate filter layer aids with removing some pollutants. Runoff is stored in the reservoir bed, a highly permeable layer of open-graded clean-washed aggregate with at least 40% void space. The filtered runoff then percolates through the uncompacted soil base into the groundwater supply.

Porous concrete is placed using forms, then leveled with a screed. No finishing is required, and jointing is optional. *Take care not to overwork the surface.*

Porous concrete is applicable to many light-duty uses, including overflow parking areas, residential street parking lanes, parking pads in parking lots, sidewalks, golf cart and bike paths, and emergency access lanes. With proper maintenance, including regular vacuuming of the surface to prevent clogging by sediment, porous concrete can have a minimum service life of 20 years.

VARIATIONS: Installing a berm at the edge of porous paving keeps off-site runoff and sediment from entering the porous paved surface area, which prevents clogging. A subsurface drain may be incorporated into the design of the stone reservoir to collect water and route it to a detention or infiltration basin.

NOTE: Porous paving materials are not effective at removing dissolved nutrients from water; therefore, they should be located at least 100 feet from drinking water sources. Pre-treatment of runoff is necessary where oil, grease or other groundwater contaminants are expected.

Benefits and Uses

- Reduces total amount of impervious cover
- Reduces peak velocity and volume of stormwater runoff delivered to storm sewer system
- Alleviates flooding and erosion downstream
- Applicable to all types of sites (residential/commercial/industrial)
- Recharges groundwater supply
- Filters contaminants from runoff prior to its discharge to the storm sewer system
- Allows for land use in areas that otherwise would not meet stormwater retention guidelines
- Requires less need for curbing and storm sewers

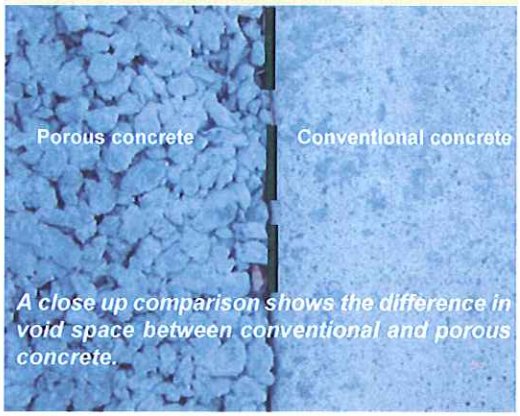
Additional Resources

PA Department of Environmental Protection
- www.dep.state.pa.us
- Pennsylvania Stormwater Best Management Practices Manual

US Environmental Protection Agency
www.epa.gov

Cahill Associates
www.thcahill.com - click on "Technologies" for project examples and general information

Villanova Urban Stormwater Partnership
www3.villanova.edu/VUSP/bmp.html



A close up comparison shows the difference in void space between conventional and porous concrete.

Produced by:
Dauphin County Conservation District
1451 Peters Mountain Road Dauphin, PA 17018
www.dauphincd.org p: (717) 921.8100

Proceed with Caution

Though permeable paving materials have been in existence since the 1970's, their implementation has been slow, due predominantly to unfamiliarity with correct procedure, leading to faulty installation, and a subsequently high rate of failure. However, with proper installation and maintenance, these systems can be very effective and long-lasting. Key design factors to ensure optimum pollutant removal and longevity include:

- Placement in areas with highly permeable soils; if underlying soil is damp, microbiological decomposition of pollutants may be impeded
- Existence of organic material in soil
- Vacuum sweeping on a quarterly schedule
- Use in low-density parking areas
- Restrictions on use by heavy vehicles
- Limited use of de-icing chemicals
- Inspection and enforcement of specifications during construction
- Pretreatment of runoff to paved area
- Implementation of a sediment control plan
- Extending the depth of reservoir level to below the frost line to prevent subgrade from frost heave

1. *(above)* Site is excavated.

3. *(above)* Concrete is poured and spread.

5. *(above)* Work edges and surface to a clean finish.

6. *(right)* Cover area for curing process.

Porous Concrete Installation

2. *(above)* Stone base layer is poured, spread and graded.

4. *(above)* Concrete is leveled with a screed.

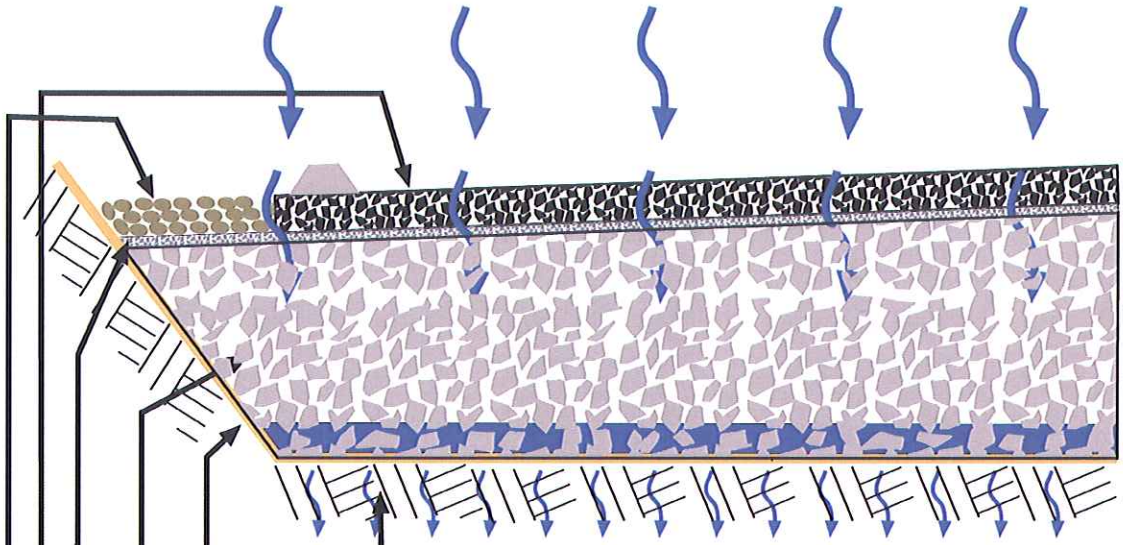
General Design Considerations

- Test soil at least four feet below base of stone reservoir for permeabilityof at least 0.5 inch per hour
- Porous surface permeability should be at least eight inches per hour
- Suitable for drainage area of less than 15 acres
- Existing soil base must be level to prevent ponding under the system
- Avoid compaction of soil base; if new fill is required, the addition of stone is recommended over adding compacted soil
- Install at least four feet above seasonal high groundwater table to prevent contamination
- Design should include overflow drainage to remove excess stormwater
- Perforated pipe placed in the stone bed will distribute runoff evently throughout bed and may provide additional storage volume, depending on size of pipe
- Stone bedding layer should drain within 72 hours of a rain event
- Slope of pavement surface should be no greater than 5%, 2% grade is recommended
- Aggregate for reservoir bed should be approximately 1 to 3 inches in diameter
- Reservoir aggregate must be clean-washed and contain at least 40% void space
- Reservoir layer should be at least twelve inches deep
- Air temperature during concrete pour must be at least 50°F
- Porous concrete sets up quickly
- Take care not to overwork porous concrete surface
- Design of system should consider expected type and frequency of usage
- Control of sediment is critical - remove surface sediment with a vacuum or by sweeping; avoid power-washing, as it will clog the system
- Design must provide for a backup method for water to enter stone reservoir (e.g. stone-edged drain near wheel stop if curbing is not in place)
- Concrete should be covered with polyethylene film for at least one week to aid with curing
- Not suitable for "stormwater hot spots", such as truck stops, gas stations, etc. due to high level of contaminants present
- Use snow plows with caution during snow removal
- Prohibit use of sand, ash, salt or de-icers
- Installation in areas of high traffic or heavy vehicles not recommended
- Not recommended in areas where wind erosion supplies significant amounts of windblown sediment
- Post signs to prevent vehicles with muddy tires from entering area
- Potholes and cracks may be patched with traditional patching mix, unless more than 10% of porous surface area needs to be repaired

Innovative Stormwater Management

POROUS ASPHALT PAVEMENT

with Subsurface Recharge Bed



Uncompacted Subgrade - Keeps permeability high to allow as much infiltration as possible

Non-Woven Geotextile - Protects stone recharge bed above from contamination and allows water to flow through to the soil.

Stone Recharge Bed - Heart of system. Large, single size, crushed stone with 40% voids stores storm water for infiltration.

Choker Course - Single size crushed aggregate (1/2-inch) stabilizes surface for paving.

Open-Graded Asphalt Pavement - An open-graded asphalt mix with that is porous, allowing storm water to flow through surface into stone recharge bed.

Unpaved Stone Edge - A backup system in case the pavement surface should ever become sealed. Storm water can flow off pavement surface to stone edge and into stone recharge bed.

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION
www.hotmix.org
www.PorousPavement.net
www.PaveGreen.com

Grasspave² Installation—Mats can be rolled out in minutes!

600 m² (6,000 sf) per two-person hour! For steps shown below—100 m² (1,080 sf) per two-person hour!

Place and compact sand and gravel base course.

Apply Hydrogrow mixture.

Roll out Grasspave².

Fill rings with clean sharp concrete sand.

Hydroseed or lay sod.

Roll sod with heavy roller.

Ready for use after two mowing cycles.

Use a regular lawn mower for maintenance.
Do not aerate!

The Grasspave² porous pavement system is comprised of a sandy gravel base course, Hydrogrow polymer-fertilizer mixture, the Grasspave² ring and grid structure, sharp concrete sand, and grass seed or sod.

Permeable or Pervious Pavers Cost Comparison

COST COMPARISON FOR PERMEABLE PAVERS... **from www.paversearch.com**

Introduction

It is true that Permeable Paver systems may incur a higher cost in the initial stages of installation, but you will find that in the long term, the overall costs will even out when you compare it to the more conventional methods of paving. Unlike like other types of Pavers, Permeable Pavers will reduce the costs entailed in obtaining piping for underground drainage purposes and other storm water systems.

Overall you will find that permeable or pervious pavers can actually save you money on things such as; investments in reservoirs, maintenance and repair of storm water drainage systems, and storm sewer extensions.

Commercial Savings

When you consider some of the larger, commercial types of Permeable Pavers installations, such as parking lots for shopping malls, contractors can save quite a lot of money. They can use the permeable pavers as the storm water management system, rather than having to have both the paved surface and a storm water drain. They save time on the actual installation process and save money on the materials and components they need to make sure that the surface is well drained. Then in turn, the client will save money as well!

Therefore, you can save on land costs and construction costs, while gaining the benefits of flood prevention and recharging the ground water. It is indeed a win-win situation!

COST COMPARISON

It is difficult to obtain accurate site costs and life-cycle costs for Permeable Pavements, for so many factors need to be taken into consideration. But there is a general cost comparison for the common types of Pervious Pavers.

Asphalt: Asphalt tends to cost between 50c and $1 per square foot of installed pavement. This sounds quite cheap, but it does not include the costs of any storm water management systems or drainage piping.

Grass/Gravel Pavers: Grass and gravel pavers can range in the price bracket starting at around $1.50 and up to about $5.75, per square foot of installed pavement.

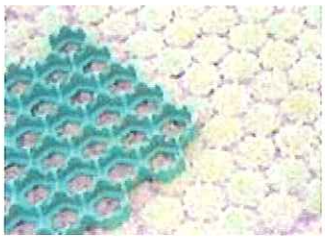
Porous Concrete: Porous concrete can cost anything from $2.00 up to about $6.50, per square foot of installed pavement.

Interlocking Concrete Paver Blocks: Interlocking concrete pavers range in price from $5.00 to about $10.00 per square foot of installed pavement.

A more accurate cost comparison can be defined if one takes into consideration the added costs of storm water management systems. When you add these costs to the Asphalt pavement, it will end up costing between $9.50 and $11.50 per square foot of installed pavement. So when you estimate the cost of a type of paver, you must calculate the water management costs also, because a Permeable Paver will provide these requirements automatically.

Permeable or Pervious Pavers FAQ's

FREQUENTLY ASKED QUESTIONS ABOUT PERMEABLE PAVERS...



Q. What are Permeable Pavers? **A.** Permeable pavers allow water to filtrate through the surface and down into the ground beneath. Unlike other paving materials where the water hits the surface then naturally flows to the lowest point possible, which is normally a drain, which would mean that this water is transported to our waterways. Therefore, water is absorbed into the earth rather than flooding and contaminating our waterways.

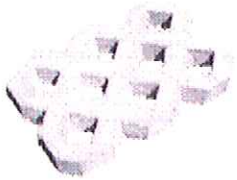
Q. Where can Permeable or Pervious Pavers be used?
A. Permeable pavers are used for many commercial and residential applications. They are commonly used for driveways, emergency access lanes, fire lanes, soil and land stabilization, public parks, parking lots and for landscaping purposes.

Q. What Materials are Permeable Pavers made of? A. Permeable pavers are made from many different materials. The one that is right for you will depend on the site where they will be installed and what the site will be used for. Here are some of the materials commonly used:

- There are Grass Pavers, which are made from plastic grids, and have vegetation planted in the holes or voids.
- All kinds of Mulches can be used to create a permeable surface, such as; sod, gravel and bark.
- Porous Concrete is also another type of material used to create a permeable surface, for it has pores or small holes, which is formes in the special mixture of concrete.
- Interlocking Concrete Pavers are a popular choice in permeable paving. They are made to look like concrete grids and are also filled in with some sort of pervious material, such as sand, gravel, mulch or vegetation.

Q. Are they more Expensive than Traditional Pavers? A. You could say that they are a little more expensive to purchase in the initial stages, than the more traditional types of pavers, however, in the long run they can actually end up saving you money. The reason is that when installing Permeable pavers you don't have to spend money on drainage pipes and retention systems, because it's all automatic. The paved surface will automatically drain most of the water that hits it. Therefore, you will save some money in the installation stage.

Q. Are Permeable Pavers strong enough to handle heavy loads and large vehicles? A. What happens is that permeable pavers resist heavy loads and forces by forming an interlock between them. The interlocking method of permeable pavers like the Grass and Concrete pavers allows the forces to be dispersed and transferred to the whole surface. It is recommended that you consider what the pavement will be used for and make sure that you do the correct research to ensure that your installation is suitable and will last.



Q. Do Permeable Pavers require a lot of maintenance? **A.** In order to get the best performance and drainage capacity from your pavers it is necessary to maintain them. The general requirements are that you sweep them on a regular basis, vacuum them about four times a year, and re-fill in the voids when necessary.