Comparison of Permeable Pavement Types: Hydrology, Design, Installation, Maintenance and Cost

Prepared for
WisDOT Southeast Region

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Request for Report

WisDOT's regional storm water engineer for the Southeast Region is interested in developing a park-and-ride with porous pavement, possibly with the PaveDrain brand of permeable block. Research was needed to determine how well permeable pavements, including porous asphalt, pervious concrete and paver blocks, remove total suspended solids and other nutrients from runoff. Information was also requested on life-cycle costs, maintenance requirements, infiltration rates, installation and design (including aggregate base requirements).

Summary

Many research studies, manuals, fact sheets and other resources compare the hydrology, design, installation, maintenance and cost of permeable pavement types. We provide a selection of these resources, which generally provide similar conclusions, organized in five topic areas:

- General Comparisons of Permeable Pavement Types: Hydrology, Design, Installation, Maintenance and Cost
- Cost Comparisons of Permeable Pavements
- Porous Asphalt
- Pervious Concrete
- Paver Blocks and Permeable Interlocking Concrete

Hydrology

Our research shows that all permeable pavement types do similarly excellent jobs of preventing stormwater runoff and removing pollutants. To quote guidance from the Environmental Protection Agency included in this report:

> Porous asphalt, pervious concrete, and permeable pavers all have the same underlying stormwater storage and support structure. The only difference is the permeable surface treatment. The choice of permeable surface is relevant to user needs, cost, material availability, constructability, and maintenance, but it has minimal impact on the overall stormwater retention, detention, and treatment of the system.

Infiltration rates are generally hundreds of inches per hour. Even as pavements clog with time, infiltration rates remain above 1 inch per hour, sufficient for most stormwater events. (Regular maintenance will keep permeability even higher.) We found one study on PaveDrain specifically showing that there was no runoff for a one-hour event simulating 4.6 inches of rainfall over a sandy subgrade, and no runoff for a one-hour event simulating 5.1 inches of rainfall over a clayey subgrade. (Note: This study was commissioned by the manufacturer of PaveDrain.)

For all systems, pollutant removals are:

- Total suspended solids: 85 percent to 95 percent
- Total phosphorus: 65 percent to 85 percent
- Total nitrogen: 80 percent to 85 percent
- Nitrate (as N): 30 percent
- Metals: 98 percent

Design, Installation, Maintenance and Cost

Material costs (2005 figures) are 50 cents to $1 per square foot for porous asphalt, $2 to $7 per square foot for pervious concrete and $5 to $10 per square foot for concrete pavers. While these costs are higher (generally by 10 percent to 20 percent) than costs for nonpermeable materials, they are said to be offset by the elimination of the need for detention basins and other stormwater infrastructure. Each pavement type will have a similar base with costs depending on site requirements. (Excavation is $8 to $10 per cubic yard; aggregate is $30 to $35 per cubic yard with base depth dependent on soil type; and geotextile fabric is 70 cents to $1 per square foot.) Other costs vary with materials availability, site conditions, project size, stormwater management requirements and subgrade; for example, clay soils require more base material.

This report includes a number of manuals and specifications detailing the design and installation of permeable pavements, including base aggregate requirements. (For base layer specifications, see page 15 of *Permeable Pavement: Stormwater Design Specification No. 7* in the **Manuals, Specifications and Books** section of **General Comparisons of Permeable Pavement Types: Hydrology, Design, Installation, Maintenance and Cost**.)

Maintenance costs are $400 to $500 per year for vacuum sweeping a half-acre parking lot three to four times annually. One analysis suggests that the 25-year life-cycle cost of a 40,000-square-foot parking lot constructed with one brand of block paver (including installation, biannual vacuum sweeping and other maintenance) is $190,200 compared to $275,875 for impervious asphalt. (See *Permeable Paver Research Summary* in the **Cost** section of **Paver Blocks and Permeable Interlocking Concrete**.) Longevity is assumed to be 20 to 30 years for pervious concrete and block pavements, and 15 to 20 years for porous asphalt.

General Comparisons of Permeable Pavement Types: Hydrology, Design, Installation, Maintenance and Cost

Below we highlight several websites, publications and presentations that include design, maintenance and cost information related to porous asphalt, pervious concrete and permeable paving blocks. A 2011 article summarizes several case studies that incorporate permeable pavement solutions.

EPA Guidance

Porous Asphalt Pavement, National Pollutant Discharge Elimination System, U.S. Environmental Protection Agency, September 2009.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=135&minmeasure=5
This Web page gives an overview of design criteria, maintenance, stormwater management and pollutant removal efficiencies, and costs for porous asphalt. The base/subbase depth is 18 to 36 inches, with greater width required when installed over less permeable clay soils. The base is typically 3 to 4 inches thick and consists of crushed stones typically 3/4 to 3/16 inch. Subbase stone sizes are larger than the base, typically 3/4 to 2½ inches. Porous asphalt has reduced strength compared to conventional asphalt and will not be appropriate for applications with high volumes and extreme loads. However, these pavements have less freeze-thaw stress than conventional pavements, and in northern climates the service life of a porous parking lot may be doubled to 30 years from the usual 15. Infiltration rates are very high initially—in the hundreds of inches per hour—but are reduced as pavement pores are gradually clogged. (Cold weather does not affect infiltration rates.) However, even when pavement surfaces become clogged,

infiltration rates usually will exceed 1 inch per hour, which is sufficient for most stormwater events. Regular vacuum sweeping will help maintain permeability. Sand should not be used in winter on these pavements, and salt and deicing chemicals must be used in moderation. This page also compares pervious concrete, porous asphalt and permeable pavers (blocks): "Porous asphalt, pervious concrete, and permeable pavers all have the same underlying stormwater storage and support structure. The only difference is the permeable surface treatment. The choice of permeable surface is relevant to user needs, cost, material availability, constructability, and maintenance, but it has minimal impact on the overall stormwater retention, detention, and treatment of the system." The page includes charts comparing volume retention and pollutant reduction for different case studies involving the three types of permeable pavement. Porous asphalt has been recorded to retain 25 percent to 100 percent of stormwater volume; permeable pavers, 34 percent to 100 percent; and pervious concrete, 99 percent to 100 percent. Pollutant removal rates are detailed in Table 3 and comparable for each system. The cost of the porous asphalt material ranges from 50 cents to $1 per square foot (2005 figures); other costs will vary with contractor rates, materials availability, site conditions, project size, stormwater management requirements and subgrade (such as clay soils, which require more base material).

Pervious Concrete Pavement, National Pollutant Discharge Elimination System, U.S. Environmental Protection Agency, September 2009.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=137&minmeasure=5
This Web page provides an overview of design criteria, maintenance, stormwater management and pollutant removal efficiencies, and costs for pervious concrete. Base and subbase requirements are the same as for porous asphalt (above). Like porous asphalt, pervious concrete has less strength than conventional materials. Unless properly designed, it is more susceptible to freeze-thaw damage than porous asphalt. Infiltration rates are hundreds of inches per hour initially but over time become as low as 5 inches per hour because of clogging. As with porous asphalt, vacuum sweeping helps maintain permeability. Sand should not be used for snow and ice conditions, but salt and deicing chemicals can be used in moderation. The cost of the pervious concrete material ranges from $2 to $7 per square foot (2005 figures); other costs will vary with contractor rates, materials availability, site conditions, project size, stormwater management requirements and subgrade (such as clay soils, which require more base material).

Permeable Interlocking Concrete Pavement, National Pollutant Discharge Elimination System, U.S. Environmental Protection Agency, September 2009.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=136&minmeasure=5
This Web page gives an overview of design criteria, maintenance, stormwater management and pollutant removal efficiencies, and costs for permeable paving blocks. Base and subbase requirements are similar to porous asphalt and pervious concrete. As with porous asphalt and pervious concrete, infiltration rates are in the hundreds of inches per hour immediately after construction and become lower over time with clogging. However, even clogged pavements have infiltration rates well above 1 inch per hour, and permeability can be maintained with vacuum sweeping. Sand is not used and deicing salts can be used in moderation. Stormwater volume retention and pollutant removal are similar to those of porous asphalt and pervious concrete. The cost of these systems ranges from $2 to $8 per square foot; other costs will vary with contractor rates, materials availability, site conditions, project size, stormwater management requirements and subgrade, such as clay soils, which require more base material.

Manuals, Specifications and Books

Permeable Pavement: Stormwater Design Specification No. 7, Version 1.7, Virginia Department of Conservation and Recreation, March 2010.
http://www.cwp.org/cbstp/Resources/d2s6a-dcr-bmp-permeable.pdf
This specification addresses pervious concrete, porous asphalt and interlocking concrete pavers. Table 7.2 (page 3 of the PDF) compares design, performance and cost, including thickness and gradation of pavement layers:

- Permeability: 10 feet per day for porous concrete, 6 feet for porous asphalt and 2 feet for interlocking pavers
- Construction cost: $2 to $6.50 per square foot for porous concrete, 50 cents to $1 for porous asphalt and $5 to $10 for interlocking pavers

- Longevity: 20 to 30 years for porous concrete, 15 to 20 years for porous asphalt and 20 to 30 years for interlocking pavers.

Pages 4-15 of the PDF provide detailed information about design, with Tables 7.5 and 7.6 (page 15) comparing base layer and pavement layer specifications for each. Pages 17 to 21 of the PDF provide step-by-step construction instructions for each type; and pages 22 to 24 address maintenance.

Related Resources:

> **Chapter 9.7, Standard for Pervious Paving Systems**, New Jersey Stormwater Best Management Practices Manual, New Jersey Department of Environmental Protection, February 2004.
> http://www.nj.gov/dep/stormwater/bmp_manual/NJ_SWBMP_9.7.pdf
>
> **Chapter 3.3.7, Porous Concrete, Georgia Stormwater Management Manua**l, Volume 2 (Technical Handbook), Atlanta Regional Commission, Georgia Department of Natural Resources–Environmental Protection Division, August 2001.
> http://www.georgiastormwater.com/vol2/3-3-7.pdf
>
> **Iowa Stormwater Management Manual**, Iowa State University, 2009.
> http://www.intrans.iastate.edu/pubs/stormwater/index.cfm
>
> **Chapter 4.2, Permeable Pavement Systems**, Green Infrastructure Supplemental Stormwater Document (draft), Stormwater Design and Specification Manual, Indianapolis Department of Public Works, 2009.
> http://www.indy.gov/eGov/City/DPW/SustainIndy/WaterLand/Documents/4.2%20Permeable%20Pavement%20Systems.pdf
>
> **Stormwater Management Manual for Western Washington**, Washington State Department of Ecology, 2005.
> http://www.ecy.wa.gov/programs/wq/stormwater/manual.html
>
> **Low Impact Development (LID) Guidance Manual for Kitsap County**, **Washington**, Washington State Department of Ecology, 2009.
> http://www.kitsapgov.com/dcd/dev_eng/sw_design_manual/Cookbook061009Print3.pdf

Section 6, Comprehensive Stormwater Management: Structural BMPs, Pennsylvania Stormwater Best Management Practices Manual, Pennsylvania Department of Environmental Protection, January 2005.
http://www.lowimpactdevelopment.org/raingarden_design/downloads/PASWManualStrucBMPsSec6.pdf
A discussion of porous pavement design, maintenance and costs, including for asphalt, concrete and paver blocks, begins on page 203 of the report. Porous asphalt is 10 percent to 20 percent more expensive than standard asphalt, and pervious concrete or blocks are more expensive than asphalt. However, these costs are offset by the elimination of the need for detention basins, which cost $2,000 to $2,500 per parking space. See pages 219-224 of the report for detailed specifications and installation guidance.

Porous Pavements, Integrative Studies in Water Management and Land Development, Bruce K. Ferguson, Taylor & Francis Group, 2005.
Available for purchase at http://www.amazon.com/Porous-Pavements-Integrative-Studies-Management/dp/0849326702
Overview: http://www.rmc-foundation.org/images/PCRC%20Files/Applications%20&%20Case%20Studies/Porous%20Pavements%20-%20The%20Overview.pdf
This book provides extensive information on the design of pervious concrete, porous asphalt and pervious concrete blocks. See especially chapters on dimensions (Chapter 2, page 35); structure (Chapter 3, page 69); hydrology (Chapter 4, page 119); aggregate (Chapter 6, page 199); blocks (Chapter 9, page 323); concrete (Chapter 11, page 417); and asphalt (Chapter 12, page 457). The manual gives infiltration rates for various surfaces (page 124), including aggregates of various sizes (1,300 to 50,000 inches per hour); blocks (9.2 initially and 4.1 after six years); porous concrete (670 to 900); porous asphalt (initially 170 to 500+ but 15 to 39 after four years and 1.4 after four

years of winter sanding); dense concrete (less than 0.00002); and dense asphalt (0.00006 to 6). It likewise gives runoff coefficients (page 126) and other hydrology information (Chapter 4), and aggregate gradation information for walking/parking surfaces (page 216). Many chapters provide cases studies, and the chapter on blocks compares several vendors.

Brochures, Presentations, Fact Sheets and Websites

Pervious Concrete Applications and Stormwater Management, John Kevern, Louisiana Transportation Conference, January 2011.
http://www.ltrc.lsu.edu/ltc_11/pdf/Pervious%20Concrete%20Applications%20and%20Stormwater%20Management.pdf
This presentation compares pervious concrete and interlocking block pavers, and includes several pictures of construction, including excavation and placement. It also provides a chart of permeability in inches per hour as related to the number of maintenance passes, including sweeping and vacuum, wet sweeping, vacuum only, and wash and vacuum. It concludes with several case studies.

Pervious Pavement, LakeSuperiorStreams: Community Partnerships for Understanding Water Quality and Stormwater Impacts at the Head of the Great Lakes, 2011.
http://www.lakesuperiorstreams.org/stormwater/toolkit/paving.html
This Web page includes information for permeable paving systems, including cost comparisons:

- Porous asphalt is 10 percent to 15 percent higher than regular asphalt.
- Porous concrete is approximately 25 percent greater than regular concrete.
- Pavers can be as much as four times the expense of either regular concrete or asphalt.

For all systems, pollutant removals are:

- 82 percent to 95 percent of sediments
- 65 percent total phosphorous
- 80 percent to 85 percent total nitrogen
- High removal rates reported for zinc, lead and chemical oxygen demand

Maintenance contracts stipulating quarterly vacuuming and/or power washing are recommended. If equipment and resources are not available for maintenance, pervious pavement is not recommended.

Permeable Pavement Fact Sheet, University of New Hampshire Stormwater Center, 2008.
http://www.crwa.org/projects/bmpfactsheets/crwa_permeable_pavement.pdf
This fact sheet includes information for both porous asphalt and pervious concrete. Permeably paved areas are typically designed to infiltrate runoff from at least a two-year storm; therefore runoff will be reduced by 100 percent for most rainstorms. Permeably paved areas generally infiltrate 70 percent to 80 percent of annual rainfall.

Pollutant efficiencies:

- Total suspended solids: 85 percent to 95 percent
- Total phosphorus: 65 percent to 85 percent
- Total nitrogen: 80 percent to 85 percent
- Nitrate (as N): 30 percent
- Metals: 98 percent

Installation costs are estimated to be between $7 and $15 per square foot, and maintenance costs are $400 to $500 per year for vacuum sweeping of a half-acre parking lot. Repaving will be required every 15 to 25 years in cold climates.

Permeable Interlocking Concrete Pavement: A Comparison Guide to Porous Asphalt and Pervious Concrete, Interlocking Concrete Pavement Institute, February 2008.
Available for purchase at http://www.icpi.org/node/1234
Brochure and overview: http://www.icpi.org/sites/default/files/pdfs/PICP_Comparison_Brochure.pdf
This brochure advertises the advantages of permeable interlocking concrete pavement over porous asphalt and pervious concrete, including high resistance to freeze-thaw and deicing salt; deicing chemicals are not recommended on pervious concrete (but are on porous asphalt). While permeable interlocking concrete pavement is more expensive than porous asphalt and pervious concrete, this brochure claims reduced life-cycle costs. Other advantages include consistent quality, availability in a wide range of textures and colors as well as mechanical installation (which can be done in freezing temperatures).

Case Studies

Runoff Remedy, Bob Drake, *Civil Engineering News*, August 2011.
http://www.cenews.com/magazine-article-cenews.com-8-2011-runoff_remedy-8423.html
This article summarizes recent projects incorporating permeable pavement solutions, including the:

- **Thorndike Park** parking lot in Arlington, Mass., using BodPave85, which unlike some paving systems does not require vacuuming or sediment removal:
  - "The project called for a cost-effective porous paving solution that required very little maintenance, was highly porous to absorb runoff from adjacent asphalt pavement, would provide a unique aesthetic, and be durable to withstand the wear associated with regular vehicular traffic and the Massachusetts climate."
  - "The highly porous reinforced gravel profile also provides storage capacity during rainfall events; the 4-inch clean gravel profile will accommodate an additional 0.75 inch to 1 inch of rainfall over its relative area, reducing the depth of engineered sub-base storage needed to accommodate the designed storm event."
  - "After its first year of use, the project is 100 percent functional, shows no signs of wear, and has required no maintenance."
- **The Preserve and Clam Farm** in Charleston, S.C., which used the Gravelpave2 permeable paving system for the entrance road, driveways and on-site parking. The system has held up well under traffic, but requires regular maintenance and annual brooming.
- **Porous pavement demonstration** in Timonium, Md., which used 4 inches of porous asphalt over a 3/8-inch aggregate base, 48-inch stone reservoir and clay subgrade.

Cost Comparisons of Permeable Pavements

Below we highlight a 2005 report that provides high-volume retailers with strategies for integrating low-impact development stormwater management techniques and a 2003 handbook that examines installation and maintenance costs.

Low Impact Development for Big Box Retailers, The Low Impact Development Center, November 2005.
http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf
Installation and maintenance cost estimates for permeable pavements can be found on page 62. Costs for installation are (2005 dollars):

- Excavation: $8 to $10 per cubic yard
- Porous asphalt: 50 cents to $1 per square foot
- Porous concrete: $2 to $6.50 per square foot
- Concrete paving blocks: $5 to $10 per square foot
- Aggregate: $30 to $35 per cubic yard
- Geotextile fabric: 70 cents to $1 per square foot

Maintenance costs are estimated at $500 per year for vacuuming sediment three to four times annually.

Pervious Pavements, California Stormwater BMP Handbook, California Stormwater Quality Association, January 2003.
http://www.cabmphandbooks.com/Documents/Development/SD-20.pdf
According to this handbook, permeable pavements are 25 percent cheaper when lack of drainage costs are taken into account. See page 5 for recommended maintenance regimes and page 7 for a detailed breakdown of installation and maintenance costs.

Porous Asphalt

Below we highlight several publications and a 2010 presentation that provide guidelines for porous asphalt pavement design and maintenance.

General

Porous Asphalt Pavements in Minnesota, Jill Thomas, *Hot Mix Asphalt Technology*, November/December 2010.
http://www.asphaltisbest.com/PDFs/Porous%20Pavement%20Article%20HMAT%20Nov-Dec%202010.pdf
This article discusses the use of porous asphalt for several permeable pavements in Minnesota, including use of porous asphalt for the Ramsey-Washington Metro Watershed District Building. Water depth monitoring shows that there has never been discharge into the storm sewer; the greatest water depth was 3 inches after a 5-inch rainfall. The project cost $60,000; maintenance involves two vacuum sweepings a year. After two years, there are signs of clogging, but this has not affected infiltration rates, and there has never been runoff from the parking lot.

Porous Asphalt for Stormwater Management, Robert Roseen, University of New Hampshire Stormwater Center, March 2010.
http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/presentations/Porous%20Asphalt%20for%20Stormwater%20Management%20From%20the%20Rooftop%20to%20the%20Bay.pdf
This presentation includes information about the hydrology, pollutant removal, design and costs of permeable pavements. Costs are generally 10 percent to 20 percent more ($2.80 per square foot for porous asphalt, $4 to $5 for pervious concrete) but are offset by eliminating stormwater infrastructure installation.

Porous Asphalt Pavements for Stormwater Management: Design, Construction and Maintenance Guide, Information Series 131, National Asphalt Pavement Association, November 2008.
Available for purchase at http://store.asphaltpavement.org/index.php?productID=179
Topics covered include water quality, structural design, soil investigation, hydrologic design, materials, construction, cost and maintenance. A fact sheet based on this book (available at http://www.paiky.org/downloads/PorousBrochureWeb%5B1%5D.pdf) includes a table of pollution removal efficiencies and construction and maintenance guidelines.

Maryland Pervious Asphalt Design Guidelines, Maryland Department of Land and Natural Resources, December 1992.
http://www.smscland.org/pdf/MarylandPerviousAsphalt.pdf
This document includes guidelines for pervious asphalt pavement design; generally the surface course is 2 to 4 inches thick and is placed over a 1- to 2-inch-thick filter course of 0.5-inch crushed stone aggregate and 1.5- to 3-inch reservoir course. (See page 6 for a schematic of road layers.) Maintenance includes regular inspections for surface ponding (an indication of clogging) and vacuum sweeping followed by jet hosing four times per year.

Maintenance

Winter Maintenance Guidelines for Porous Asphalt, University of New Hampshire Stormwater Center, January 2011.
http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/UNHSC%20porous%20winter%20maintenance%20fact%20sheet_1_11.pdf
This fact sheet includes guidance about maintenance before, during and after winter events.

Pervious Concrete

Below we highlight three publications that address design and maintenance considerations for pervious concrete pavement. A 2010 study evaluates the mechanical and hydraulic properties of several pervious concrete pavement mix designs.

General

Stormwater Management with Pervious Concrete Pavement, American Concrete Pavement Association, 2006.
http://www.smscland.org/pdf/StormwaterManagement.pdf
This brief gives an overview of the use of pervious concrete for stormwater management. It includes design and maintenance considerations, and suggests that pervious concrete reduces runoff by 70 percent to 80 percent and pollutants by 80 percent.

Maintenance

Pervious Concrete Pavement Maintenance Guidelines, National Ready Mixed Concrete Association, 2007.
http://www.chaneyenterprises.com/files/productdocs/Pervious-Concrete-Maintenance-Guidelines.pdf
This document includes guidelines on cleaning, pavement section replacement and cold weather maintenance of pervious concrete.

Porous Pavement Operation and Maintenance Protocol, San Diego County Facilities, 2007.
http://www.sdcounty.ca.gov/reusable_components/images/dgs/Documents/Grants_Prop40_AppendIII_.pdf
This document includes detailed maintenance instructions for porous pavements.

Hydrology

An Investigation into Porous Concrete Pavements for Northern Communities, Report No. 2010-6, Vermont Agency of Transportation, July 2010.
http://www.aot.state.vt.us/matres/Documents/ACROBAT.pdf/R&DDox/McCain-Dewoolkar-PorousConcrete-FinalReport-06-23-10.pdf
Among the properties examined by this study is hydraulic conductivity, which was 225 to 1,729 inches per hour for various pervious concrete mixes. This project also finds that a Burlington, Vt., facility built using pervious concrete has a surface infiltration capacity of 3,500 to 10,600 inches per hour. (A representative 10-year/24-hour design storm for Vermont is about 4 inches per hour.) The study notes that porous pavements have been shown to be effective in pollutant removal, capable of eliminating up to 95 percent of the total suspended solids, 65 percent of the total phosphorous, 85 percent of the total nitrogen and 99 percent of the metals from stormwater runoff.

Paver Blocks and Permeable Interlocking Concrete

Below we highlight several studies that examine structural design as well as cost, performance and infiltration rates of permeable pavement systems.

General

Permeable Interlocking Concrete Pavements Manual: Design, Specification, Construction and Maintenance, David R. Smith, 4th edition, Interlocking Concrete Pavement Institute, 2010.
Available for purchase: http://www.icpi.org/node/2962
From the abstract: This updated edition draws from a wealth of current permeable pavement research on stormwater management, structural design, and performance. The manual is a key resource for design professionals, plus stormwater and transportation government agency staff who support low impact development and green streets/infrastructure using permeable pavement. Since its first publication in 2000, the book remains the industry consensus on [permeable interlocking concrete pavements] and a valuable resource for this rapidly growing pavement system."

Cost

Permeable Paver Research Summary, Lake County Forest Preserves, February 2003.
http://atfiles.org/files/pdf/PermPavers.PDF
This document compares life-cycle costs for Uni-Lock permeable concrete pavers and asphalt (page 3). For a 40,000-square-foot parking lot over 25 years, the cost for installation, biannual vacuum sweeping and other maintenance for pavers is $190,200; for an asphalt parking lot of the same size over 25 years, the cost is $275,875 for installation, crack sealing, seal coat, striping, patching and surface replacement. The document includes numerous case studies.

Hydrology

PaveDrain Permeable Articulating Concrete Block/Mat Under Simulated Rainfall, American Excelsior Company, June 2011.
http://www.pavedrain.com/pdf/PaveDrain-Infiltration-Report.pdf
This study quantified PaveDrain's infiltration capabilities for two test plots with different underlying materials, showing that there was no runoff for a one-hour event simulating 4.6 inches of rainfall over a sandy subgrade, and no runoff for a one-hour event simulating 5.1 inches of rainfall over a clayey subgrade. (Note that this study was commissioned by the manufacturer of PaveDrain.)

Study on the Surface Infiltration Rate of Permeable Pavements, Eban Z. Bean, William F. Hunt, David A. Bidelspach, Jonathan T. Smith, Biological and Agricultural Engineering Department, North Carolina State University, May 2004.
http://www.bae.ncsu.edu/info/permeable-pavement/icpi.pdf
This study tested the surface infiltration rate of 25 permeable pavement sites in North Carolina, Maryland and Delaware using variations of the double ring infiltrometer test. Researchers found high infiltration rates for all sites, with a mean of 2.1 inches per hour for concrete grid pavers. Maintenance generally improved infiltration to a mean of 3.5 inches per hour. Permeable interlocking concrete pavements had a mean of 1.7 inches per hour if near loose fine particles and 900 inches per hour if not.

Long-Term Stormwater Quantity and Quality Performance of Permeable Pavement Systems, Benjamin Brattebo, Derek Booth, Center for Water and Watershed Studies, University of Washington, July 2003.
http://water.washington.edu/research/Reports/permeableparking.pdf
This study examined the long-term effectiveness of permeable pavement as an alternative to traditional impervious asphalt pavement in a parking area. Four commercially available permeable pavement systems were evaluated against a regular asphalt pavement over six years of daily parking usage for structural durability, ability to infiltrate precipitation and impacts on infiltrate water quality:

- Grasspave^2, a flexible plastic grid system with virtually no impervious area, filled with sand and planted with grass
- Gravelpave^2, an equivalent plastic grid, filled with gravel
- Turfstone, a concrete block lattice with about 60 percent impervious coverage, filled with soil and planted with grass
- UNI Eco-Stone, small concrete blocks with about 90 percent impervious coverage, with spaces between blocks filled with gravel

All four permeable pavement systems showed no major signs of wear. Virtually all rainwater infiltrated through the permeable pavements, with almost no surface runoff. (During the period of measurement, rainfall at the site totaled 570 mm.) The infiltrated water had significantly lower levels of copper and zinc than the direct surface runoff from the asphalt area. Motor oil was detected in 89 percent of samples from the asphalt runoff but not in any water sample infiltrated through the permeable pavement. Neither lead nor diesel fuel were detected in any sample. Infiltrate measured five years earlier displayed significantly higher concentrations of zinc and significantly lower concentrations of copper and lead.