Project Profiles

Permeable Interlocking Concrete Pavements

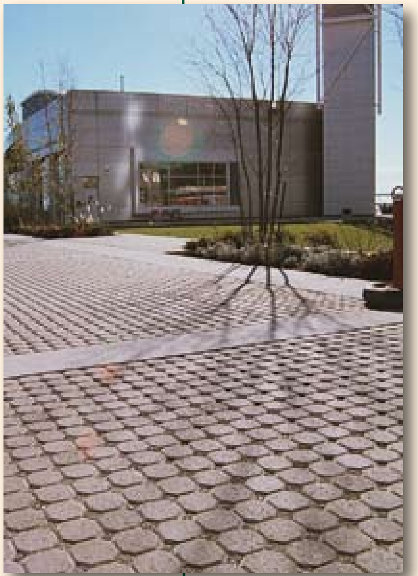
ICPI
INTERLOCKING CONCRETE PAVEMENT INSTITUTE ®

Introduction

As urbanization increases, so does the concentration of pavements, buildings and other impervious surfaces. These surfaces generate additional runoff and pollutants during rainstorms causing streambank erosion, as well as degenerating lakes and polluting sources of drinking water. Increased runoff also deprives groundwater from being recharged, decreasing the amount of available drinking water in many communities. Recreational opportunities from lakes, streams and rivers decline from the impacts of urban runoff. Commercial fishing productivity can decline in estuaries and bays thereby negatively impacting regional economies.

In response to environmental and economic impacts from stormwater runoff, U.S. federal law mandates that states control water pollution in runoff through the National Pollutant Discharge Elimination System (NPDES). Among many things, the law requires that states and localities implement best management practices (BMPs) to control non-point source pollution in runoff from development. BMP's can include storage, filtration and infiltration land development practices. Infiltration practices capture runoff and rely on infiltration through soils, vegetation, or aggregates for the reduction of pollutants. Detention ponds are a common BMP example used to hold, infiltrate, and release stormwater. Infiltration trenches are another that reduce stormwater runoff and pollution, and replenish groundwater. All of these BMPs provide some treatment and reduction of runoff pollutants.

Pavement that Detains and Infiltrates Runoff



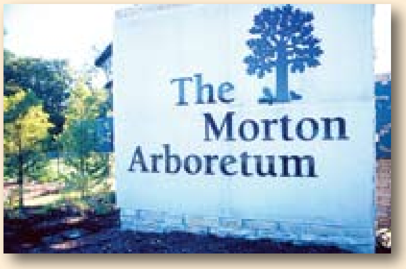
Like infiltration trenches, permeable interlocking concrete pavements (PICPs) are highly effective in providing infiltration, detention and treatment of storm water pollution. The base can be designed to filter, treat and slowly release water into a storm sewer or water course while providing a walking and driving surface. PICPs answer the call from municipal regulations to limit impervious cover and runoff into storm drains working at capacity, or when sites have limited space for detention ponds.

The U.S. Environmental Protection Agency and several state agencies consider PICPs an infiltration BMP. An increasing number of cities, counties and states are incorporating them into land development and runoff standards, low-impact development guidelines and design manuals on stormwater control. With proper design, material selection, construction and routine maintenance, PICP is a sustainable low-impact BMP used by landscape architects, architects, engineers, developers and public agency staff.

PICPs have been widely used across Europe, especially Germany since the early 1990s. The paving products shown in the following project profiles were supplied by members of the Interlocking Concrete Pavement Institute (ICPI). Several projects were also constructed by ICPI contractor members. The projects demonstrate runoff reduction and improved water quality in a range of climates, soils, hydrological and regulatory environments. ICPI appreciates the following contributions from member producing companies, designers, contractors and project owners.

Morton Arboretum Visitor's Center Parking Lot, Lisle, Illinois

When Morton Arboretum in suburban Chicago decided to build a new visitor's center, it also developed a new entrance, parking lot and bus passenger drop off area. The need for detention facilities to capture runoff from these areas was unacceptable to the arboretum. PICP was instead chosen to protect water quality, manage stormwater and provide a durable surface for vehicular traffic. The Arboretum wanted to implement as many best management practices as possible into their new parking lot design since runoff from the project is being monitored under the U.S. EPA Section 319 National Runoff Monitoring Program. The parking lot consists of 173,000 sf (16,000 m^2) mechanically installed PICP as well as 32,000 sf (2,970 m^2) of interlocking concrete pavement. Constructed in 2003 and 2004, the paving units used custom color blends selected by the Morton Arboretum staff.



Morton Arboretum in suburban Chicago expanded its parking facilities with 173,000 sf (16,000 m^2) of PICPs without building detention ponds. The pavement absorbs rainfall from most rainstorms.

Indentations in the curbs allow runoff from heavy storms to overflow and seep into vegetated areas. Construction (lower right) shows the open-graded, crushed stone base drainage layers under compaction equipment.

Drains are provided to remove excess water from the heaviest, infrequent rainstorms.

Three layers of open graded base enabled filtering and drainage while providing a stable structure during construction.

Typical cross-section:
3 1/8 in. (80 mm) thick permeable interlocking concrete pavers
1 1/2 in. (40 mm) Illinois DOT CA-16 (Class A) (10 to 1 mm) crushed stone bedding
6 in. (150 mm) Illinois DOT CA-7 (25 to 5 mm) crushed stone base
12 in. (300 mm) Illinois DOT CA-1 (63 to 25 mm) crushed stone subbase

Subgrade:
Clay soil

Construction Manager:
Hanscomb, Faithful, & Gould
Chicago, IL

Engineer:
Christopher B. Burke
Engineering West
St. Charles, IL

Landscape Architect:
Conservation Design Forum
Elmhurst, IL

General Contractor:
V3 Construction Group
Woodridge, IL

Wal-Mart Parking Lot, Rehobeth Beach, Delaware

Rehobeth Beach is situated along the Atlantic coast just north of the mouth of the Chesapeake Bay. When the shopping center owner needed to expand parking behind a Wal-Mart in 2002, there wasn't sufficient space for the parking lot and a separate detention pond. PICPs combined the two functions. PICP enabled partial exfiltration from the base to the soil, with backup from perforated pipe and surface drains for saturated conditions from heavy rainstorms.

Like many of the projects shown in this brochure, PICP at this Wal-Mart was mechanically installed. Mechanical installation requires that the pavers be manufactured in their final laying pattern, stacked, and delivered to the job site for installation by specialized equipment. The equipment includes a clamp that grabs a stacked layer of pavers (about a square yard or square meter) and places each on the screeded bedding material. After placing a layer, the machine operator returns to the stack to grab and place the next. With each layer only taking about 20 seconds to place, paving production rates can be increased as much as five times compared to manual installation.

A 2003 study of surface infiltration by North Carolina State University of this parking lot and several other permeable interlocking concrete pavement sites indicated a surface infiltration rate of 1000 in./hour (25 m/hr) using a modified double ring infiltration test equipment (2). This is considered excellent for new permeable pavements.

Typical cross-section:
3 1/8 in. (80 mm) thick permeable interlocking concrete pavers
3 in. (75 mm) ASTM No. 8 crushed stone
6 in. (150 mm) ASTM No. 57 crushed stone
Geotextile

Subgrade:
Sandy soil

Designer:
Davis Bowen & Freidel Engineers
Milford, Delaware

General Contractor:
A.P. Croll & Son
Georgetown, Delaware

About 40,000 sf (3,716 m²) of PICP eliminated the need for building detention pond when a parking lot was expanded behind a Wal-Mart shopping center.

The bedding layer of No. 8 stone is screeded or smoothed to receive mechanically installed PICP.

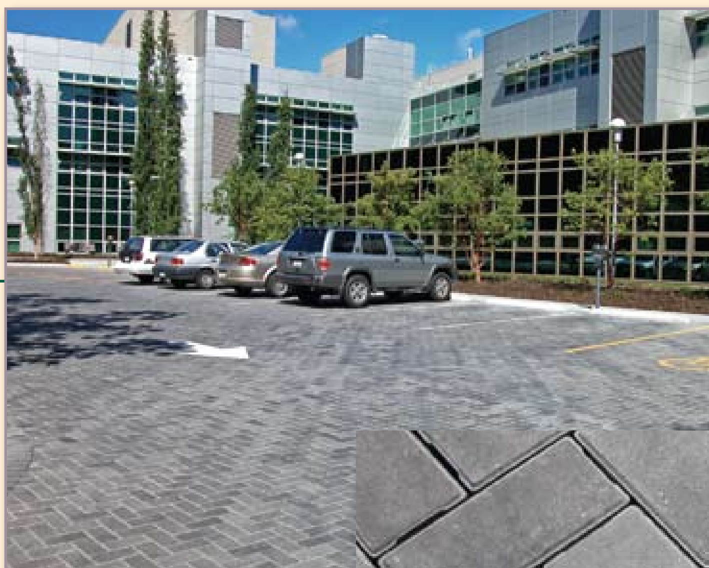
A clamp on specialized mechanical installation equipment grabs a layer of pavers for placement on the bedding. The pavers are compacted into the bedding layer, the openings and joints filled with the bedding material and compacted again to create interlock among the pavers. Since there is no curing, the pavers are immediately ready for traffic.

Engineering/Computer Science Building Entrance, Victoria University, British Columbia

Home to over 18,000 students and 4,000 staff, the university follows an integrated campus plan that incorporates sustainable practices in construction and operation of all new buildings and facilities. A natural fit was permeable interlocking concrete pavement at a new pedestrian drop off and short-term parking for the expanding Engineering/Computer Science building. Completed in March 2004, University officials asked the design engineer to create the 8,000 sf (743 m^2) parking that exceeded LEED® (Leadership in Energy and Environmental Design) criteria, specifically reducing the rate and quantity of runoff by 25% from a 2-year, 24 hour design storm. The open joints and notches in the paver surface enabled full infiltration of commonly occurring storms through a clean crushed jointing and bedding material.

The PICP pattern achieved a welcoming entrance with six parking spaces for disabled persons and six standard parking spaces. The pavement and subgrade slope gently to one end of the site where perforated pipe at the bottom of the subbase drains it within 24 hours. Existing catch basins handle overflows from extreme storm events.

According to Sarah Webb, the University's Sustainability Coordinator, "The paving stones have exceeded our expectations. Students, faculty and staff have commented on how aesthetically pleasing the drop off is. We have had no problems with wheelchair access, and the stones have continued to perform under our heaviest west coast rains." Maintenance has been minimal and deicers kept ice from the surface during the occasional winter freeze, nor have their been any problems from freeze-thaw cycles. Ms. Webb also noted that, "Paving stones, and other permeable products, will continued to be used on the campus as a part of our green building program and our commitment in our Integrated Stormwater Management Plan to reduce water runoff and improve water quality."



An 8,000 sf (743 m^2) entrance drop-off and parking lot creates a detention and infiltration for stormwater at the University of Victoria, British Columbia. The notched pavers and stone-filled joints infiltrate water from most commonly occurring storms.

The project specifications called for crushed, open-graded base and sub-base compaction with initial passes of a roller compactor in vibratory mode, then final passes in static mode.

Typical Cross-Section:
3 1/8 in. (80 mm) thick permeable interlocking concrete pavers
2 in. (50 mm) bedding layer (12.5 to 1.16 mm)
6 in. (150 mm) 19 mm clean crushed stone
10 in. (250 mm) 75 mm clean crushed stone

Subgrade:
Clay

Designer:
Bruce DeMaere, A.Sc.T.
Bullock Bauer Associates, Ltd.
Victoria, B.C.

General Contractor:
Excel Contracting
Victoria, B.C.

Runoff quantity and quality from driveways were monitored from water exiting slot drains.

Runoff and pollution monitoring has demonstrated the benefits of permeable interlocking concrete pavements in the U.S. EPA funded Jordan Cove Urban Watershed National Monitoring Project. Driveways and a municipal street were paved in this low-impact, environmentally sensitive residential development.

Draining into a Long Island Sound estuary, this watershed is subject to a 10-year runoff monitoring project from a traditional subdivision, a single-family home development built with conventional pavements and stormwater management system, and a low-impact development built with runoff and pollutant-reducing BMPs. These include grass swales, bioretention areas and PICP. The U.S. EPA Section 319 National Monitoring Program supported the monitoring project conducted by the University of Connecticut.

Built in 2001, the Glen Brook Green

Rather than being paved, the center of the cul-de-sac in Glen Brook Green subdivision provides a bioswale to absorb runoff and overflow from the permeable pavement.

Table 1. Average infiltration rates during 2002 to 2003 into pavements in the Glen Brook Green subdivision.

Test and Year	Asphalt	Permeable Pavement in./hr (cm/hr)	Crushed Stone in./hr (cm/hr)
Single Ring Infiltrometer test 2002	0	7.7 (19.6)	7.3 (18.5)
Single Ring Infiltrometer test 2002	0	6 (15.3)	5 (12.7)
Flowing infiltration test 2003	0	8.1 (20.7)	2.4 (6)

Table 2. Average weekly concentration of pollutants in stormwater during 2002 to 2003 from pavements in the Glen Brook Green subdivision. Within each variable, means followed by the same letter are not significantly different at σ=0.05.

Variable	Asphalt		Permeable Pavement		Crushed Stone	
Runoff depth, mm	1.8	a	0.5	b	0.04	c
Total suspended solids, mg/l	47.8	a	15.8	b	33.7	a
Nitrate nitrogen, mg/l	0.6	a	0.2	b	0.3	ab
Ammonia nitrogen, mg/l	0.18	a	0.05	b	0.11	a
Total Kjeldahl nitrogen, mg/l	8.0	a	0.7	b	1.6	ab
Total Phosphorous, mg/l	0.244	a	0.162	b	0.155	b
Copper, ug/l	18	a	6	b	16	a
Lead, ug/l	6	a	2	b	3	b
Zinc, ug/l	87	a	25	b	57	ab

subdivision within the watershed features over 15,000 sf (1,400 m^2) of PICP in a street and residential driveways that recharge the local aquifer, slow runoff velocities, oxidizes and filters some pollutants, filters suspended solids and cools water before it enters the estuary. Maintenance includes periodic sweeping and vacuuming with the same equipment used on other streets. An annual inspection ensures no ponding and aggregate is replaced in the pavement openings as needed.

The 2003 annual report of the multi-year monitoring project demonstrates the effectiveness of PICP in reducing runoff and pollutants (1). Runoff quantity and quality from asphalt, PICP (with a dense-graded base) and crushed stone driveways entering single family homes were studied for 12 months in 2002 and 2003. A plan of the neighborhood and driveway types is shown below.

Besides higher infiltration rates than asphalt, PICP demonstrated lower concentrations of pollutants in runoff and similar concentrations to that from driveways with crushed stone. Table 1 shows the average infiltration rates from the surfaces in 2002 and 2003. Table 2 shows the average weekly concentration of pollutants in stormwater runoff for various pollutants. Concentrations are statistically significantly lower for all pollutants from PICP compared to asphalt. Pollutant levels in PICP are similar to that from the driveways with crushed stone.

Typical cross-section:
3 1/8 in. (80 mm) thick permeable pavers
8 to 10 in. (200 to 250 mm) dense-graded base
Geotextile

Subgrade:
Sandy gravel

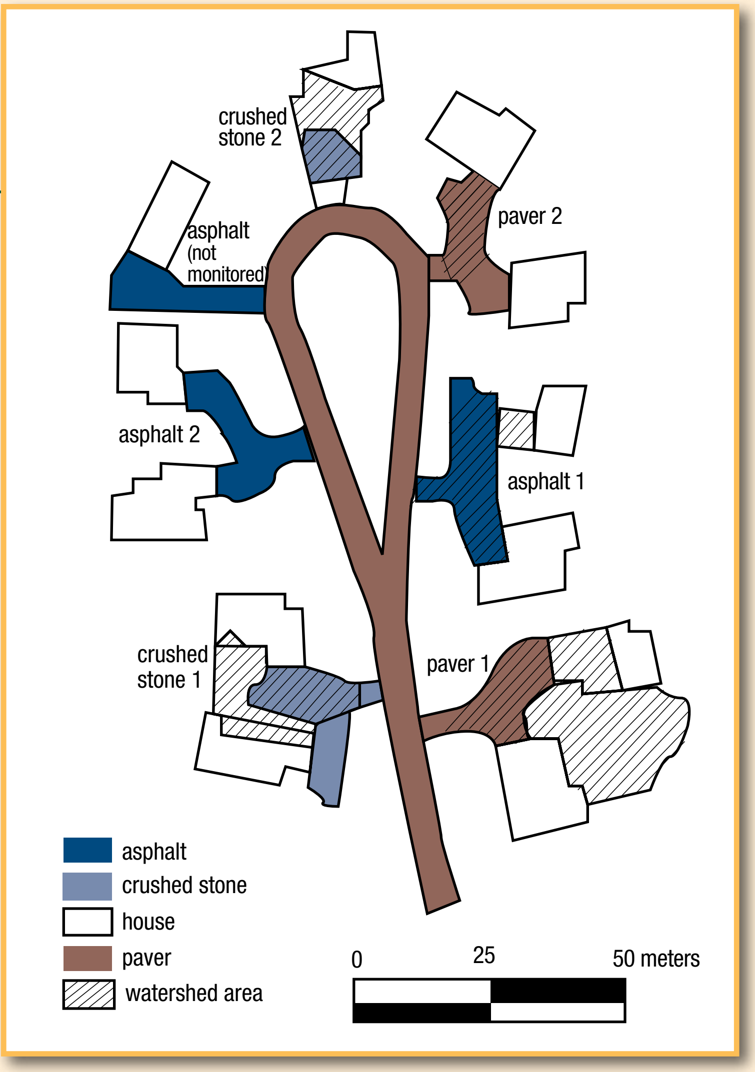
Developer:
Lombardi Inside/Out L.L.C.
Waterford, CT

Project Manager:
Aqua Solutions
East Hartford, CT

Engineering:
D.W. Gerrick Engineering
Waterford, CT

Landscape Architect:
John Alexopoulus
University of Connecticut

Water Quality Monitoring:
Dr. John Clausen
University of Connecticut



Runoff from various types of pavements are being monitored in the Glen Brook Green Subdivision in Waterford, Connecticut.

Robson Center, Gainesville, Georgia

Formerly known as the Southern Heritage Building, the Robson Center's 8,200 sf (760 m^2) parking lot represents one of the first pavements of its type in Gainesville, a city of 25,000 on the shores of Lake Lanier in northeast Georgia. "The Robson Center pavement was installed (in 2003) in order to meet a new municipal limitation on impervious cover, while getting full economic development from the site's acreage," according to Bruce Ferguson, FASLA, Professor and Director, School of Environmental Design, University of Georgia and author of the book, *Porous Pavements* (2). The pavement surface located in the development's entry lanes used brick color to match the building.

"The base course or 'base reservoir' is made with open-graded No. 57 crushed granite rock, which has void space of 30%+ and very high permeability," said Ferguson. "The bedding layer and joint fill is similar but smaller No. 89 aggregate, which also has high porosity and permeability. The combination gives the pavement high permeability and water storage capacity."

Since the soil was largely clay fill that had to be compacted, very little infiltration into the soil is expected, explained Ferguson. "Instead, a perforated pipe at the bottom of the base reservoir drains to the city's storm sewer system. A previously installed stormwater detention basin had been designed for impervious surfaces throughout the development. This pavement's permeability and in-pavement storage are expected to make the project's stormwater performance exceed the design expectations. In the unlikely event the pavement should generate surface runoff due to an extremely intense storm or clogging occur somewhere in the system, the runoff will drain to grate inlets at the side of the pavement, then into the conventional storm sewer system."

Typical Cross-section:
3 1/8 in. (80 mm) thick permeable pavers
3 in. (75 mm) ASTM No. 89 bedding layer
8 in. (200 mm) ASTM No. 57 crushed stone base
Geotextile

Subgrade:
Clay soil

Designer:
Bruce Ferguson, FASLA, Athens, Georgia

General Contractor:
U.S. General Construction, Alpharetta, Georgia

Runoff from the impervious asphalt surfaces is infiltrated into the PICP. The runoff is detained, filtered and infiltrated into to the soil subgrade. Excess water is drained to storm sewers through perforated drain pipes in the base.

Even with low infiltration clay soil, permeable pavements manage runoff from typical rainstorms that fall on the parking lot at the Southern Heritage Building.

Hilton Garden Inn, Calabasas, California

The Hilton Garden Inn designers chose PICP to satisfy the City of Calabasas stormwater management requirements. These mandated at least 30% pervious cover to control the quantity and quality of runoff from the site, specifically by containing the "first flush" or the initial 1/4 in. (6 mm) of rain water within a 24-hour period. The site meets this requirement with PICP that filters runoff into an open-graded base, temporarily detaining water before passing it to the storm drain system.

A color blend of cream/brown, cream/charcoal and solid brown was selected for the 12,000 sf (1,110 m^2) project completed in June 2002. This maintains some reflectivity without blinding pedestrians on sunny days. The pavers were placed in a random color pattern to yield mottled tones throughout the pavement surface. The pavement covers the hotel driveway, entry area and parking lot.

The position of the pavers changed over the design stages of the project. Instead of laying the pavers at the lower side, away from the building, they were installed on the uphill side next to the hotel. Placement of pavers next to the hotel entry provided a visually pleasing appearance, but reduced the total amount of water infiltrated by the pavement's surface. Other measures were implemented to treat runoff which included a grassy swale to filter runoff next to the asphalt pavement and a filter in the catch basin.

PICPs at this hotel in Southern California capture and treat the first flush from the parking lot. The curbs are recessed to allow overflows to run into an adjacent grass swale.

PICPs accommodate markings for parking spaces and an access route for disabled persons.

Design:
Hewitt-Zollars Engineering
Irvine, California

General Contractor:
RD Olson
Irvine, California

Typical Cross-section:
3 1/8 in. (80 mm) thick permeable pavers
2 in. (50 mm) 1/4 by No. 10 (6 to 1 mm) crushed stone bedding layer
10 in. (250 mm) 3/4 to 1/2 in. (20 to 13 mm) crushed stone base
Geotextile

Subgrade:
Clay

Harbourfront Fire Station, Toronto, Ontario

Adjacent to the Toronto SkyDome and the CN Tower in Toronto, this fire station uses PICP to reduce runoff pollutants entering nearby Lake Ontario.

Located on a Lake Ontario, the Harbourfront Fire Station features 11,000 sf (1,022 m^2) of PICP in its entrance and parking lot. Built in the winter of 1998, the City of Toronto required a pavement that would reduce runoff pollution to Lake Ontario through infiltration while providing a parking lot in a highly urbanized area.

Built with a dense-graded base, the project exemplifies the ability of PICPs to withstand heavy loads from fire trucks in a winter environment with deep penetration of frost in pavements. The pavement is plowed and salted in the winter, but not sanded to prevent clogging of the aggregate in the openings and reduced infiltration. The lack of raised curbs enables snow plows to push snow directly off the pavement.

Typical cross-section:
3 1/8 in. (80 mm) thick permeable concrete pavers
2 in. (50 mm) bedding material
6 in. (150 mm) MTO Granular A aggregate base
12 in. (300 mm) MTO Granular B aggregate base

Architect:
Paul Jurecka Architect
Toronto, Ontario

Engineer:
Lloyd & Nodwell
Toronto, Ontario

General Contractor:
Dixon General Contractors
Missisauga, Ontario

PICP withstands salt and snow plowing, a regular part of Toronto winters.

Historic Tree Preservation at Alden Lane Nursery Livermore, California

Typical cross-section:
3 1/8 in. (80 mm) permeable pavers
1 in. (25 mm) 1/4 in. by No. 10 (6 to 1 mm) crushed stone bedding layer
6 in. (150 mm) 3/4 to 1/2 in. (25 to 20 mm) crushed stone base
Geotextile

Subgrade:
Clay soil

This upscale nursery in the San Francisco Bay area used 12,000 sf (1,115 m^2) of environmentally friendly, mechanically installed PICP to allow air and water to nourish the roots of a very large, 300 year-old oak tree. It is so old it has been designated as a heritage tree which protects it from being removed. The tree lives in clay soil and PICP was built to ensure that additional air and water reach its roots. The nursery's owner decided on permeable pavers as a solution to preserve the historic tree and provide an environmentally sensitive entrance to the store. Local runoff regulations were not a significant motivating factor. The owner simply wanted to give the tree an opportunity to survive and grow.

Roots feeding a 300 year-old oak tree receive additional air and water from permeable paving units at a landscape nursery in Livermore, California.

The sidewalk adjacent to the nursery entrance uses permeable paving units to return water to nearby vegetation.

PICP FAQs

Should a dense-graded or open-graded aggregate base be used under PICPs?

An open-graded base is most commonly used because it has water storage capacity (void space between the aggregates) of typically 30% to 40%. The stone sizes in open-graded bases can be as large as 3 in. (75 mm) and as small as ¼ in. (6 mm). There is typically a thinner layer of small stone sizes (6 mm to 1 mm) used for bedding directly under the concrete pavers. The bedding and base bedding material maximizes storage, filtering, and treatment of pollutants in stormwater runoff entering the pavement surface. Open-graded bases are preferred because of the storage and treatment benefits.

Dense-graded bases are occasionally used under PICPs as in the Glen Brook Cove subdivision and the Harbourfront Fire Station. They may be used in areas of concentrated wheel loads from truck traffic. While there is additional structural support, most of the runoff from common rainstorms is stored in the bedding material and within the openings in the pavement surface. Maximum stormwater storage and infiltration benefits, however, come from PICP with an open-graded base.

What intensity and duration of storms can be managed?

That depends on amount of water that drains onto the PICP, the depth (and storage capacity) the base, the infiltration rate of the soil under an open-graded base, and the presence of drain pipes within an open-graded base. PICPs are intended to manage water quantities and pollutants from smaller, more frequent storms such as those with a return period of 10 years or less. These storms tend to be shorter in duration and often have the highest concentrations of pollutants. PICPs are not intended to control flooding from larger, infrequent rainstorms.

Are PICPs eligible for LEED® credits?

Yes, they can under the U.S. and Canadian Green Building Councils (USGBC and CaGBC) guidelines. PICPs typically can meet the requirements for Conservation of Material and Resources, Recycled Content under the USGBC LEED for new construction where at least 20% of the building products should be manufactured within a radius of 500 miles (800 km) of the project. Most paving units are locally manufactured and delivered to projects within 500 miles (800 km). To find the closest manufacturer or distributor, visit www.icpi.org and conduct a search for producers in the 'Find A Member' section.

PICPs can meet the LEED® credit requirements under Sustainable Sites. These requirements limit site disruption and water pollution by managing stormwater. The pavements can reduce runoff-generating impervious cover and decrease the rate and quantity of runoff. PICPs meet these credits through the filtering action of the base that reduces total suspended solids and phosphorous in runoff, as well as other pollutants.

PICPs can also meet the sustainable sites requirement to reduce urban heat islands (thermal gradient difference between developed and undeveloped areas) and minimize impact on microclimate, as well as human and wildlife habitat. This is accomplished through increased albedo (a measure of the solar energy reflected from a surface) or use of a pavement system with less than 50% imperviousness. PICPs have substantially higher reflectivity than conventional asphalt pavement and can meet the requirement for less than 50% imperviousness. For additional information on U.S. or Canadian LEED® credits see www.usgbc.org or www.cagbc.org

How well does the pavement perform in freeze and thaw conditions?

PICPs have been in service for years in freezing climates and have performed adequately as evidenced by the projects profiled in this publication. Many more projects throughout Canada and the northern U.S., in the United Kingdom and Germany speak to the durability of these pavement systems in cold climates, as well as their ability to accept snowplows and salts without paver damage. In order to ensure high durability in freezing climates, the paving units should conform to the requirements of ASTM C 936 in the U.S. or CSA A231.2 in Canada. Both of these product standards include tests for freeze-thaw durability.

When the sun and temperature are right, ice and snow on PICP can melt and immediately soak into the openings in the pavement surface. Water does not collect on the surface and re-freeze. This reduces slipping hazards. Obviously, sand shouldn't be used for foot or tire traction on PICPs. Deicing salts can be used. After plowing, melting of any remaining snow can occur if the temperature moves above freezing. This will help eliminate ice from forming and reduce salt contamination in groundwater.

Since the pavement base temporarily stores rainfall, will the base heave and damage the pavement surface when frozen?

Water in the base typically should drain within 24 hours. It's unlikely that ice will form in the base within this time period should temperatures drop below freezing. If the water does freeze before draining, there should be adequate space for the ice to expand within the open-graded base as it freezes, thereby minimizing the risk of heaving. Should soil heaving occur, the pavement surface is flexible and should not be damaged from minor upward movement or from resettlement during a thaw.

Does the surface conform to ADA requirements?

Yes. ADA Design Guidelines require that surfaces be firm, stable and slip resistant. PICP designs can provide a firm and stable surface for visually impaired persons and those using wheeled mobility devices. If the openings in the surface are not desirable, solid units can be used in areas subject to disabled persons. Such areas might include designated spaces in parking lots.

ADA requires that the static coefficient of friction for flat surfaces along accessible routes be 0.6 and 0.8 for ramps. ADA advisory material recommends various test methods to assess surface slip resistance. PICPs can meet slip ADA resistance requirements using test methods recommended in ADA advisory literature. For additional information on these see *ICPI Tech Spec 13 – Slip and Skid Resistance of Interlocking Concrete Pavements*. This and other technical bulletins are available at www.icpi.org and www.access-board.gov.

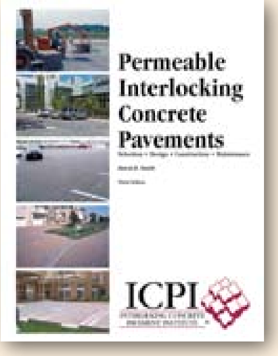
Is there any benefit to using PICPs on low-infiltration soils such as some types of clays?
Yes. If soil infiltration is slow (generally under 0.5 in./hour or 1.3 x 10^{-2} m/sec), perforated plastic pipe drains at the bottom of the base can remove excess water while still allowing some of the water to infiltrate into the soil. The drainage rate for the water contained in the base is typically no greater than 24 hours. Over practically impervious soils or high bedrock, an impervious pond liner can be used to detain, filter and release the water through drain pipes. Regardless of the rate of soil infiltration, the filtering action of the open-graded base can reduce water pollutants.

All permeable pavements require periodic surface cleaning. How is a PICP surface cleaned and how often?
The openings in the surface of PICPs will require periodic removal of detritus and sediment trapped by the small sized crushed stone. Dirt is typically removed by a vacuum-sweeping street cleaning machine. Cleaning is done when the pavement surface and detritus are dry and can be loosened by sweeping and vacuuming. The frequency of cleaning will vary with the use of the pavement and deposition of sediment, leaves, etc. from adjacent areas. Cleaning should be done at least once a year, and the surface monitored during the early life of the pavement so that a regular cleaning schedule can be established.

A North Carolina State University study has shown that the initial surface infiltration rate of PICPs can be as high as 2000 in./hour (5080 cm/hour) (3). Other research has shown that near initial surface infiltration rates can be restored through cleaning and replacement of the initial 3/4 to 1 in. (20 to 25 mm) depth of small stones in the openings of PICPs (4). For highly clogged pavement openings, the stones can be removed with vacuuming and replaced with clean material. This is a distinct maintenance advantage over monolithic pervious concrete and porous asphalt pavements.

What about high heel shoes?
Solid pavers can be introduced into PICP paving patterns in pedestrian areas to accommodate a variety of shoes including high heels.

Permeable Pavement Resources



The Interlocking Concrete Pavement Institute (ICPI) offers a manual, *Permeable Interlocking Concrete Pavements*, that covers selection, design, specification, construction, and maintenance. It synthesizes literature on infiltration trenches, porous asphalt pavement, research on and practical experience with permeable interlocking concrete pavements. ICPI's manual is essential for design professionals and municipal authorities that regulate storm water runoff. It can be purchased at www.icpi.org.

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3. Bean, E. Z., Hunt, W. F., Bidelspach, D. E., and Smith, J. E., *Study on the Surface Infiltration Rate of Permeable Pavements,* Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, North Carolina, May 2004.
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