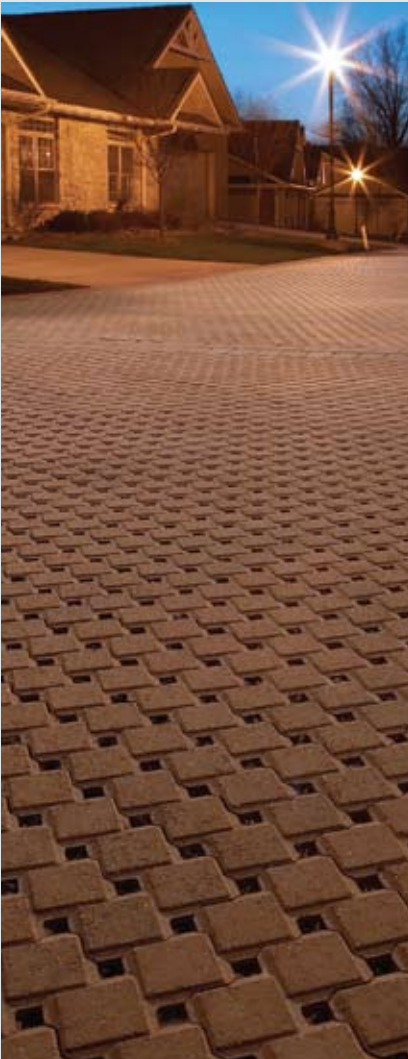
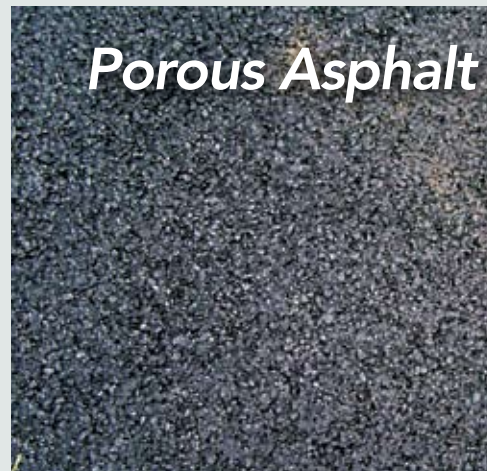


Permeable Interlocking Concrete Pavement

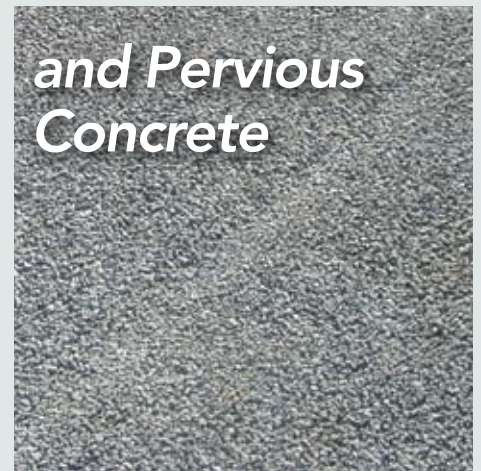


A Comparison Guide to

Porous Asphalt



*and Pervious
Concrete*



Permeable pavement is becoming a major tool for on-site stormwater management.

Background

The past century has seen a tremendous growth of pavements for vehicular traffic. These impervious surfaces created significant environmental and economic impacts such as stream bank erosion, flooding and polluted streams, lakes, rivers and estuaries. Fortunately, on-site stormwater management is a priority in site design, rather than only collecting it off-site in detention/retention ponds and storm sewers. Infiltration via permeable pavement is rising as a major tool for on-site stormwater management.

The National Pollutant Discharge Elimination System in the U.S. for permitting stormwater discharges recognizes the viability of using permeable pavement as a best management practice (BMP) for stormwater control. Permeable pavements are recognized as a BMP by the U.S. Environmental Protection Agency and many provincial, state and local stormwater management agencies. In addition, rating systems for “green” or sustainable building such as Leadership in Energy and Environmental Design (LEED®) and GreenGlobes offer credit to site designs that use permeable pavement. Moreover, permeable pavement has become a cornerstone of low impact development design and regulations.



Figure 1. On-site infiltration practices such as permeable pavement are emerging as preferred stormwater management solutions to off-site controls that consume valuable land including detention (foreground) and retention (background) ponds shown here. Permeable pavement can reduce or eliminate these facilities.

While there are several ways to make vehicular and pedestrian pavement permeable, the three primary technologies are porous asphalt, pervious concrete and permeable interlocking concrete pavement (PICP). Figure 2 provides typical cross sections. This brochure offers stormwater agencies, design professionals, contractors and homeowners an overview of each and presents the advantages of PICP over the alternatives.

Making pavements permeable emerged from the environmental movement of the late twentieth century. PICP has been used in Germany and elsewhere in Europe since the early 1990s and in North America since 1995. Pervious concrete pavement was first used in Florida in the early 1970s and porous asphalt emerged at the same time. Each of the pavement systems has been used in a variety of soils and climates.

All permeable pavements have high initial surface infiltration rates and all can immediately infiltrate and store rainfall and runoff from the heaviest of rainstorms. In many cases, runoff is completely eliminated. Permeable pavements rely on the ability of open-graded aggregate in their surfaces and base to receive, store and infiltrate runoff back into the soil beneath. Pavements with smaller sized open-graded aggregate surfaces support wheel loads while larger aggregate provides a base reservoir that filters stormwater. Research has demonstrated the ability of permeable pavements to substantially reduce urban runoff and suspended solids, nutrients and metals in it.

PICP Advantages

Pervious concrete and porous asphalt rely on small-sized aggregates bound with asphalt or cement to create a porous matrix that supports vehicular traffic. In contrast, PICP relies on solid, high-strength precast concrete units to support traffic surrounded by small, highly pervious stone-filled joints to receive and infiltrate stormwater. The stone-filled joints also contribute to interlocking and spreading wheel loads. Figure 3 illustrates PICP construction. The table on pages 4 and 5 summarizes similarities and differences among these pavement surfaces.

Depending on the paving unit design and pattern, PICP joints can vary between $\frac{1}{8}$ and $\frac{1}{2}$ in. (3 and 13 mm). Small-sized aggregate in the joints that allow water to pass through it can be somewhat

deceptive. While PICP has less visible permeable surface area than porous asphalt or pervious concrete, PICP openings still provide high surface infiltration rates. These rates are well above practically all rainfall intensities, making their hydrological performance equal to or better than other permeable surfaces. The small aggregate in the joints and bedding also facilitates interlock and load transfer to neighboring pavers. Unlike standard interlocking concrete pavement, no sand is used in PICP joints or bedding since it has very low permeability.

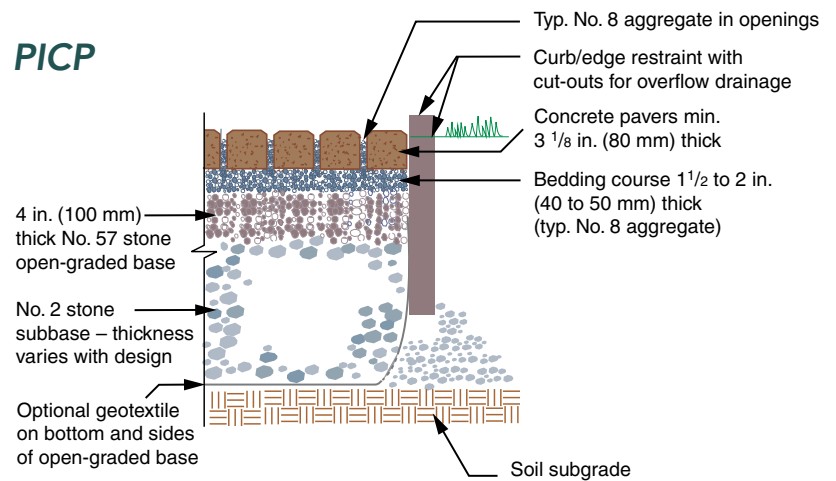
Materials and Construction

Porous asphalt and pervious concrete are supplied in a 'plastic' state and formed on the job site. This makes them subject to weather. PICP can be installed in freezing weather, however, porous asphalt and pervious concrete cannot. In above-freezing temperatures, plastic asphalt and concrete mixes must be regularly checked by the contractor for consistency and conformance to specifications. These materials impose time limits within which the contractor must work before asphalt cools and concrete cures and stiffens. These time and temperature-constrained materials rely on a high degree of site control in order to achieve a successful installation.

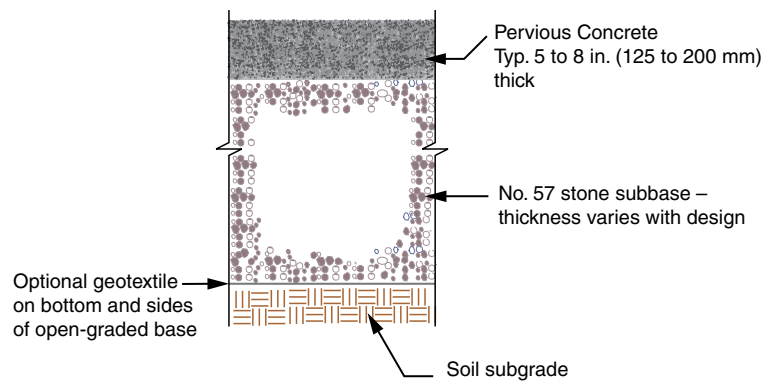
In contrast, PICP units are manufactured in a factory and delivered to the site. They are not subject to time and temperature limitations in installation. PICP paving units should comply with national product standards (ASTM C 936 or CSA A231.2). These product standards require manufacture of high compressive strength concrete averaging 8,000 psi (55 MPa). Pervious concrete has a typical compressive strength of about 2,500 to 4,000 psi (17 to 28 MPa). Unlike pervious concrete and porous asphalt, concrete pavers have freeze-thaw durability test methods and requirements within their product standards to help assure adequate field performance in winter conditions. Freeze-thaw durability and higher strength PICP offers a more durable surface under wheel loads, snow plow abrasion and deicing materials.

Because PICP is ready to install, there is no curing time making it ready for traffic when placed. PICP is typically mechanically installed with a machine that can place more than 5,000 sf (500 m²) per machine per day thereby accelerating construction

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Pervious Concrete



Porous Asphalt

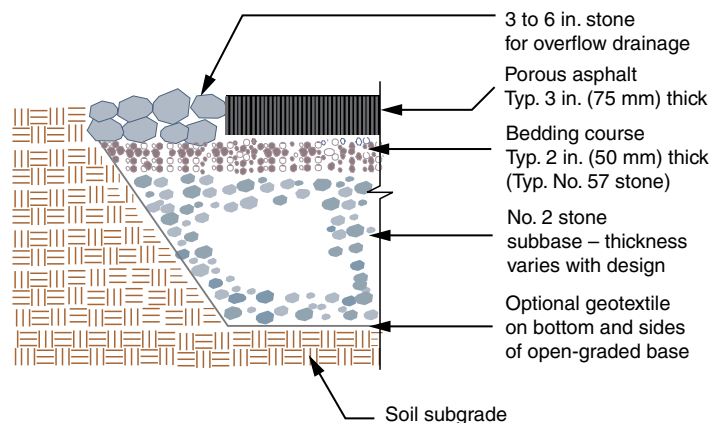





Figure 2. Typical PICP, pervious concrete and porous asphalt pavement sections. Surface and base thicknesses vary with traffic. Slower draining soils generally require thicker bases to store and infiltrate water. All can accommodate perforated drain pipes in the base for low infiltration soils.

Surface	Colors	Construction Aspects	Cost	ADA Compliance	Winter durability
Permeable Interlocking Concrete Pavement 	Wide range available; various shapes and textures fit with surrounding architecture and landscape	Precast units provide consistent quality concrete; requires no form work and can be mechanically installed; can be installed in freezing temperatures; immediately ready for traffic upon completion; 8,000 psi (55 MPa) concrete	Competitive with pervious concrete and porous asphalt; life-cycle costs may be lower than pervious concrete or porous asphalt in some markets	Complies; narrower openings and/or regular interlocking pavers can be used if desired	High freeze-thaw and deicing salt resistant concrete; water in base does not freeze and heave; complete saturation when frozen will not damage pavement; snow melts and immediately drains, reducing ice hazards; accepts normal snow plowing equipment; sanding prohibited; less deicing materials needed
Pervious Concrete Pavement 	Limited range of colors and surface textures are available	Cast in place construction may yield varying concrete quality; requires formwork; on-site control of water/cement content critical to lifetime performance; requires seven-day cure prior to traffic; 2,500 to 4,000 psi (17 to 18 MPa) concrete	Competitive with permeable interlocking concrete pavement	Complies	Deicing chemicals not recommended; saturation when frozen may damage concrete; snow melts and immediately drains, reducing ice hazards; plastic or rubber tipped snow plow blade recommended; sanding prohibited
Porous Asphalt Pavement 	Black or shades of dark gray	Requires no formwork, maintaining mix temperature on site critical to lifetime performance; requires 24-hour cure prior to traffic	Less expensive than permeable interlocking concrete and pervious concrete pavements	Complies	Resists freeze-thaw; liquid deicing materials recommended; saturation when frozen may damage asphalt; snow melts and immediately drains, reducing hazards; sanding prohibited; less deicing materials needed

*See ICPI Tech Spec 16—Achieving LEED® Credits with Segmental Concrete Pavement for additional information on PICP's advantages in earning LEED® points.



Surface Cleaning	Repairs	Water Quantity Reduction/Water & Air Quality Improvement*	Urban Heat Island Reduction*	Recycled Content & Reuse*
Surface should be vacuum swept to remove sediment and debris; aggregate in drainage openings trap most sediments at surface; aggregate can be removed and replenished if deeply clogged	Units and aggregate can be removed and reinstated if surface or base is damaged or to install in-service utility lines; no ugly patches; repair surface matches surrounding surface	High initial surface infiltration; can receive most design storms; runoff storage capacity dependent on base reservoir design and soil subgrade infiltration rate; reduces TSS, nutrients and metals; does not release oils or cement into runoff; surface can be coated with titanium dioxide to reduce smog	Medium to high, can achieve Solar Reflectance Index (SRI) > 29 with selected aggregate colors and cements	Precast concrete units can accommodate cement substitutes (e.g. flyash, slag, silica fume, etc.); pavers can be crushed and recycled
Surface should be vacuumed and pressure washed to remove sediment and debris; difficult to open and restore deeply clogged surface	Damaged or highly clogged areas can be cut out and replaced with pervious concrete; repaired area needs to cure with no traffic; will not match surrounding surface	High initial surface infiltration; can receive most design storms; reduces TSS, nutrients and metals; does not release oils into runoff; can initially release high pH flows; surface cannot be coated with titanium dioxide to reduce smog	Medium to high, can achieve SRI > 29 with selected aggregate color and cement	Generally not manufactured with recycled aggregate or cement substitutes; concrete can be crushed and recycled
Surface should be power washed or vacuum swept to remove sediment and debris; difficult to open and restore deeply clogged surface	Limited repair potential; patch with impervious (conventional) asphalt up to 10% of pervious area; pavement cuts weaken pavement; repaired area will not match surrounding surface	High initial surface infiltration; can receive most design storms; initially releases oils into runoff; reduces TSS, nutrients and metals; surface cannot be coated with titanium dioxide to reduce smog	Low; cannot achieve minimum SRI > 29	Generally not manufactured with recycled asphalt or recycled aggregate; pavement can be recycled



Figure 3. Left to right: After excavation, PICP construction begins with placing and compacting an open-graded subbase and base as shown in the first two photos. The next photo shows mechanical installation of the concrete pavers on a screeded bedding layer of small aggregate. The rightmost photo illustrates small aggregate in the openings and joints that enable high surface infiltration. The pavers and aggregate are compacted to create and interlocking pavement.



Figure 4. Many PICP projects are mechanically installed thereby decreasing construction time and labor costs because many pavers are placed at the same time.



Figure 5. PICP color and texture compliments the architecture of a Hilton Garden Inn in Calabasas, California while communicating the sustainable nature of the site.



Figure 6. Like all permeable pavements, PICP can extend tree life by sending air and water to the roots. An additional sustainable aspect is paving units can be made with cement substitutes and recycled concrete.



Figure 7. PICP combined with solid interlocking concrete pavers accommodates accessible parking and pedestrian areas.

time. Figure 4 shows this paving method where pavers are manufactured and delivered to the job site in the final laying pattern. Unlike PICP, traffic must be kept from porous asphalt for 24 hours after installation and seven days for pervious concrete so that it can cure. Pervious concrete must also be completely covered during this time to maintain moisture essential for curing.

PICP presents a much friendlier, human-scale appearance that cannot be achieved with porous

asphalt or pervious concrete (see Figure 5). It comes in a variety of colors and textures to fit any architecture and building character. Because they are monolithic materials, porous asphalt and pervious concrete provide a narrow range of colors and textures. In most cases, they appear similar to conventional concrete and asphalt but with a coarser texture. In contrast, PICP makes a visually strong statement about where stormwater is going and the sustainable nature of the site in which it is placed.



Figure 8. PICP surface openings promote faster snow melting thereby reducing hazardous ice in winter.

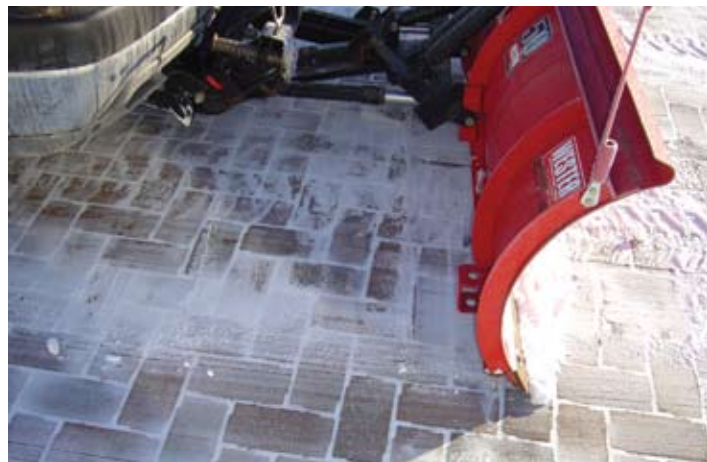


Figure 9. PICP is snow plowed like any other pavement.

Other Sustainable Aspects

Besides reduction of stormwater runoff and water pollution, PICP paving units can be made in light colors to increase surface reflection or albedo, thereby reducing temperatures and heat typical to impervious pavements. Light colored units can reduce also the need for nighttime lighting, thereby conserving electricity.

All permeable pavements promote cooling through evaporation and facilitate tree growth by allowing water and oxygen better access to adjacent tree roots (see Figure 6). However, PICP sustainability goes further. PICP units can be made with cement substitutes. This helps reduce the carbon footprint and subsequent global warming. Unlike porous asphalt, concrete materials do not rely on fossil fuel resources for their binders.

Design for the Disabled

The Americans with Disabilities Act (ADA) design guidelines require that surfaces in pedestrian access routes be firm, stable and slip resistant. In addition, surface openings in these areas should not exceed $\frac{1}{2}$ in. (13 mm) to promote comfortable travel for disabled persons using wheeled mobility devices such as wheelchairs. When designed and constructed properly, all permeable pavements can meet these requirements. PICP units can be colored (or painted) to indicate pedestrian access routes as well as parking stalls and lanes for vehicles. Traditional concrete pavers can be combined with

PICP to help mark pedestrian access routes for disabled persons as well as vehicular travel lanes as a means to increase safety for pedestrians and drivers. In addition, some unit designs provide an exceptionally smooth surface for environments with shopping carts and strollers.

Maintenance

All permeable pavements infiltrate melted snow, thereby reducing snow plowing and the risk of hazardous ice patches (Figure 8). Deicing salts should be used sparingly on all permeable pavements and salts typically don't remain on the pavement surface. Should deicing materials accumulate on the surface, PICP can better resist deterioration because it consists of high-quality concrete. PICP is plowed like any other pavement (Figure 9). No special plows or blades are required. Should it receive damage, individual paver units can be easily removed and reinstated. Surface repair is much more difficult on pervious concrete or porous asphalt. Because they are monolithic materials, their original structural capacity is likely reduced after repairing cut pavement.

All permeable pavements require regular inspection and periodic removal of accumulated sediment from the surface. For PICP, this is achieved with a vacuum-sweeper. Vacuuming and sweeping is recommended at least once or twice a year. There are many PICP projects in service for years with no vacuuming, and have maintained adequate stormwater surface infiltration. Should there be an accidental spill of dirt, PICP units and stone

jointing materials can be removed by a strong vacuum if needed, then cleaned and replaced. This isn't possible with porous asphalt and pervious concrete.

A significant advantage of PICP is its modular nature. Units can be removed and reinstated if there is a need for base or underground utility repairs, or installation of new pipes or lines. There are no unattractive patches since the same removed pavers are reinstated. This also conserves materials. Small areas of porous asphalt and pervious concrete can be removed and replaced, but there will be an unattractive patch. Moreover, it can be difficult to obtain small quantities of pervious asphalt and porous concrete for patch and repair work, especially during cold winters. This is not the case with PICP because the same units can be re-used after an underground repair. Also, unlike pervious concrete and porous asphalt, PICP will not crack.

Cost and Longevity

Porous asphalt is typically the least expensive, with pervious concrete and PICP having similar prices. Local materials, pavement area and contractor experience influence job pricing. Experi-

enced PICP contractors that follow the Interlocking Concrete Pavement Institute's construction guidelines should be sought for proposals.

Permeable pavement systems can last more 20 years while providing an initial high level of surface infiltration even as the surface takes in moderate amounts of sediment. While cleaning frequency depends on the extent of use and deposited dirt, regular surface cleaning of all permeable pavements helps restore and maintain higher infiltration rates. Lifetime infiltration rates on maintained PICP surfaces can typically average 4 to 9 in. (10 to 23 cm) per hour thereby infiltrating the most intense rainstorms. Among the pavements, PICP, however, provides the best looking, easiest to maintain pavement choice with high in-service durability in a range of climates.

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Interlocking Concrete Pavement Institute

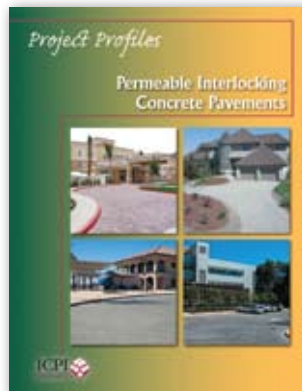
1444 I Street, NW, Suite 700
Washington, DC 20005-6542
Tel: 202-712-9036
Fax: 202-408-0285

E-mail: icpi@icpi.org
icpi.org

Canada

561 Brant Street
P.O. Box 85040
Burlington, Ontario L7R 4K2

ICPI offers these publications at icpi.org:



The *Project Profiles—Permeable Interlocking Concrete Pavements* brochure summarizes eight PICP projects across North America.



The 60-page *Permeable Interlocking Concrete Pavements* provides detailed information on design, specifications, construction and maintenance.