PERMEABLE INTERLOCKING CONCRETE PAVEMENT

A Comparison Guide To Porous Asphalt and Pervious Concrete

ICPI
Interlocking Concrete Pavement Institute®
Permeable pavement is becoming a major tool for on-site stormwater management.

Background

The past century saw 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 by 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 Sustainable Sites offer credit to site designs that use permeable pavement. Moreover, permeable pavement has become a component of stormwater impact development (LID) design and regulations. An LID goal is to maintain and enhance the predevelopment hydrologic regime of urban and developing watersheds.

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.

PICP has been used in Germany and elsewhere in Europe since the late 1980s and in North America since 1992. 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 climates and soils. 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. Porous asphalt and pervious concrete with smaller sized open-graded aggregate surfaces support wheel loads, while larger aggregate provides a structural base and reservoir that retains and filters stormwater.

Research has demonstrated the ability of all permeable pavements to substantially reduce urban runoff. Over the past 20 years, PICP has been researched extensively in North America and overseas. Studies point to significant runoff reductions, as well as lower suspended solids, nutrients, oils and metals. Reports are available upon request from the Interlocking Concrete Pavement Institute and many are publicly available online.

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 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.

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 1/8 and 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. Typically between 300 and 800 in. per hour (750 and 2000 cm/h), initial 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. In addition, the aggregate traps sediment and this must be removed regularly with vacuum equipment to maintain surface infiltration. 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 C936 or CSA A231.2). These product standards require manufacture of high compressive strength concrete averaging 4,000 psi (28 MPa). Pervious concrete has a typical compressive strength of about 2,500 to 6,000 psi (17 to 41 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.

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

Figure 2. Typical PICP, pervious concrete and porous asphalt pavement sections for vehicular traffic. 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.
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<tr>
<td><strong>Permeable Interlocking Concrete Pavement</strong></td>
<td>Manufactured 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</td>
<td>Competitive with pervious concrete; life-cycle costs may be lower than pervious concrete or porous asphalt in some markets</td>
<td>Compiles; narrower openings and/or regular interlocking pavers can be used if desired</td>
<td>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</td>
<td>Surface should be regularly 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</td>
<td>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</td>
<td>High initial surface infiltration; can receive 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</td>
<td>Medium to high, can achieve solar reflectance criteria of 0.33 for new surfaces and 0.28 for three-year-old surfaces with selected aggregate colors and cements</td>
<td>Manufactured concrete units can accommodate cement substitutes (e.g. flyash, slag, silica fume, etc.); pavers can be crushed and recycled</td>
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<tr>
<td><strong>Pervious Concrete Pavement</strong></td>
<td>Limited range of colors and surface textures are available</td>
<td>Cast-in-place construction may yield varying concrete quality; requires formwork; on-site control of water/cement content critical to lifetime performance; requires min. seven-day cure prior to traffic; 2,500 to 4,000 psi (17 to 28 MPa) concrete</td>
<td>Competitive with permeable interlocking concrete pavement</td>
<td>Deicing chemicals not recommended in the first year of use; saturation when frozen may damage concrete; snow melts and immediately drains, reducing ice hazards; plastic or rubber tipped snow plow blade recommended; sanding prohibited</td>
<td>Surface should be vacuumed and pressure washed to remove sediment and debris; difficult to open and restore deeply clogged surface</td>
<td>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</td>
<td>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</td>
<td>Medium to high, can achieve a solar reflectance &gt; 0.33 with selected aggregate color and cement</td>
<td>Generally not manufactured with recycled aggregate or cement substitutes; concrete can be crushed and recycled</td>
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<tr>
<td><strong>Porous Asphalt Pavement</strong></td>
<td>Black or shades of dark gray</td>
<td>Requires no formwork, maintaining mix temperature on site critical to lifetime performance; requires 24-hour cure prior to traffic</td>
<td>Less expensive than permeable interlocking and pervious concrete pavements</td>
<td>Compiles</td>
<td>Resist 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</td>
<td>Surface should be power washed or vacuum swept to remove sediment and debris; difficult to open and restore deeply clogged surface</td>
<td>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</td>
<td>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</td>
<td>Low, cannot achieve a minimum solar reflectance of 0.33</td>
<td>Generally not manufactured with recycled asphalt or recycled aggregate; pavement can be recycled</td>
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*These attributes can earn LEED® v4 points under Sustainable Sites and Materials & Resources credits. Such attributes may apply to other sustainable building/site evaluation systems. See ICPI Tech Spec 36—Achieving LEED® Credits with Segmental Concrete Pavement for additional information on PICP’s advantages in earning LEED® points.

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**Figure 3.** Left to right: After excavation, PICP construction begins with placing and compacting a clear, crushed stone 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, clear crushed stone. The rightmost photo illustrates small aggregate in the openings and joints that enable high surface infiltration. The pavers and aggregate are compacted to create an interlocking pavement.
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 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 off 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, concrete or pervious concrete. 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 some 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 freezing winters. This is not the case with PICP because the same units can be reused after an underground repair. Also, unlike pervious concrete and porous asphalt, PICP will not crack.

Other Sustainable Aspects

Bxes reduction of stormwater runoff and water pollution, PICP paving units can be made in light colors to increase surface reflection or albedo. This reduces temperatures and heat typical to impervious pavements. Light colored units can also reduce 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 use oil-based products for their binders.

Design for the Disabled

The Americans with Disabilities Act (ADA) design guidelines require that surfaces in pedestrian access routes 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 concrete. Because they are monolithic materials, their original structural capacity is likely reduced after repairing cut pavement.

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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.