



# Permeable Interlocking Concrete Pavement

An Online Continuing Education Course for Engineers

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# Permeable Interlocking Concrete Pavement

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## INTRODUCTION

An undesirable consequence of urban development is the replacement of natural landscape with anthropogenic surfaces, most notably in the form of impervious pavements: roads, parking lots, driveways, walkways, and other "hardscapes." This transformation of natural, undisturbed terrain into man-made pavement drastically alters the hydrologic characteristics of a watershed. Surface water cannot infiltrate these impervious surfaces, which increases runoff into gutters, storm sewers, and other engineered collection systems. Runoff eventually discharges into common waterways: streams, lakes, estuaries, wetlands, aquifers, or even the ocean. Urban runoff degrades water quantity and quality. With regard to quantity, high runoff can exceed the infrastructure's capacity to store and convey it, causing erosion and overflows, particularly combined sewer overflows. With regard to quality, runoff transports not only debris, but also dissolved and suspended contaminants, and can even change the temperature of the receiving waterway. All these effects denigrate water quality and adversely impact flora & fauna that are sensitive to changes in their aquatic ecosystems.

Fortunately, low impact development (LID) can mitigate the hydrologic effects of the built environment. LID refers to techniques that use or mimic natural processes that result in the infiltration, evapotranspiration, or collection of storm water to protect water quality and associated aquatic habitat.

One such LID practice is permeable interlocking concrete pavement (PICP; Figure 1). PICP owes its permeability to the voids between individual aggregates used in the subbase, base, bedding, and joint filler (Figure 2). For any site, PICP must successfully perform in two primary facets:

- **hydrologic** to maximize storage & infiltration; and minimize runoff
- **structural** to handle vehicle loads at the surface



*Figure 1. PICP used for parking and driveway. Courtesy: FHWA*



*Figure 2. PICP photographic cross-section. Courtesy: ICPI*

The reader should note that the author repeatedly references the “Guide Spec” throughout the course, specifically referring to the U.S. PICP Guide Specification that is publicly available on the Interlocking Concrete Pavement Institute (ICPI) website. For simplicity, the author uses US units of measurement given that the target audience is licensed engineers in the USA. Finally, although PICP is perfectly suitable for pedestrian surfaces, this course shall focus more on vehicular loads.

## PICP BASICS

Figure 3 shows a representative cross-section of PICP, which shall be explained from bottom to top.

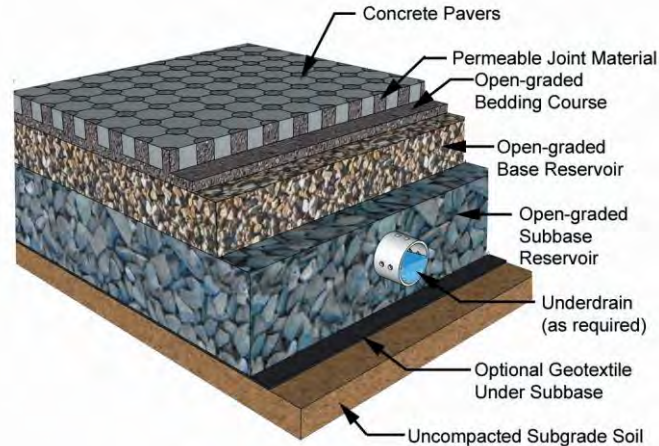


Figure 3. General PICP cross-section. Courtesy: ICPI

### Subgrade

Just as in conventional pavement, the subgrade in PICP is critical because it must have structural capacity to support the layers above it. Furthermore, its elevation and slope will, in turn, affect the elevation and slope of the overlying layers.

Specifically, for PICP, an important hydrologic property of the subgrade is its infiltration rate. Infiltration rate of the subgrade determines whether additional appurtenances like underdrains and liners are necessary to promote drainage on site. This will be addressed later in Design.

Compaction of the subgrade presents a dilemma to the designer. Although compaction may yield higher strength, it will reduce the subgrade's permeability and its hydrologic performance. Hence, the designer must consider the tradeoff in structural vs. hydrologic merits with compacting the subgrade.

### Open-graded Subbase

The subbase is immediately above the subgrade and is typically comprised of aggregate conforming to ASTM gradation No. 2, consisting of stones mostly 2 to 3 inches in sieve size. If No. 2 aggregate is unavailable, the Guide Spec allows ASTM No. 3 or No. 4. Minimum porosity is 0.32. Subbase thickness is determined based on hydrologic and structural design, with the thicker output being selected.

### **Open-graded Base**

The base layer is comprised of aggregate conforming to ASTM gradation No. 57, consisting of stones mostly 1/2 to 1 inch in sieve size. The Guide Spec sets the base thickness at 4 inches and minimum porosity at 0.32.

### **Open-graded Bedding**

Bedding is comprised of aggregate typically conforming to ASTM gradation No. 8, consisting of stones mostly between 3/8 inch and Number 4 sieve size. The Guide Specification sets the bedding thickness at 2 inches.

### **Interlocking Pavers and Joint Filler**

The concrete pavers themselves are not permeable; rather, permeability is achieved by spacing them a set distance apart from each other and filling the space with permeable, small-sized aggregate -- typically ASTM gradation No. 8. Depending on the joint widths, the total joint area that can receive rainfall and contributing runoff from adjacent areas is typically between 5% and 15%.

Notice above that all the aggregate layers -- subbase, base, and bedding -- are all OPEN-graded. That is, the gradation limits the range of aggregate size in order to ensure sufficient porosity among aggregate pieces. Such gradation is critical to creating porosity for infiltration and storage of surface water.

## **BENEFITS**

### **Storm water Management**

Usage of PICP in lieu of conventional pavement at a site can significantly reduce storm water runoff volume and peak flow, ensuring better compliance with National Pollutant Discharge Elimination System (NPDES) permitting and prevention of combined sewer overflows. Designs that leverage subgrade infiltration can also facilitate groundwater recharge. PICP not only addresses the runoff *quantity*, but also *quality*. The aggregate layers filter suspended and dissolved contaminants, enabling discharges into receiving waterways to stay below Total Maximum Daily Loads (TMDLs). Petroleum contaminants from vehicles can adsorb onto the aggregate and then degrade via long-term microbial digestion (i.e. natural attenuation). The permeability of PICP also means that storm water will not puddle on the surface, which is a nuisance for pedestrians. Liability from slipping on ice is reduced because when snow melts it often infiltrates rather than refreezing should temperatures drop.

### **Constructability**

- PICP is comprised of inert, solid materials: pavers and aggregate. Their properties require no time-sensitive mixing, storage, delivery, or placement.
- Pavers are precast concrete and therefore require no curing.
- PICP can be installed in freezing temperatures if subgrade and aggregates remain unfrozen.
- PICP can be installed in light rain.

### **Site Utilization**

PICP may provide sufficient storage and infiltration of storm water to reduce or eliminate the need for detention/retention ponds, culverts, sewers, and other drainage infrastructure. As part of a larger project, these reductions in project scope can substantially reduce development footprint; which in turn preserves existing vegetation, lowers construction costs, and simplifies permitting.

### **Heat Island Reduction**

Conventional asphalt cement concrete is dark and absorbs solar radiation, especially in the summer; the pavement then heats up and radiates heat to the surroundings. This is an urban phenomenon called heat island effect. To mitigate this effect, PICP pavers are available with light color enabling a high solar reflectance index (SRI) surface, to reduce absorption of solar radiation.

### **Sustainability Certification**

Reduction in both storm water runoff and heat island effect may earn points toward certification for projects that are registered with industry-recognized rating systems, such as the U.S. Green Building Council (USGBC) Leadership in Energy & Environmental Design (LEED). Additional points are possible for using locally available aggregate.

## **LIMITATIONS**

Despite the aforementioned benefits, there are applications and site conditions in which conventional pavement would be more suitable than PICP:

- Vehicular surfaces where the posted speed limit is above 35 mph
- Vehicular surfaces that experience more than 1,000,000 lifetime equivalent single axle loads (ESALs), i.e. repetitive bus or heavy truck passes

