PICP Drivers

- *It costs less*
- NPDES MS4 permit compliance
- EPA permit for transportation agencies — new permit expected
- Mitigate CSOs in older urban areas - 770+ cities under court decrees to implement green infrastructure e.g., green alley & streets - TMDL compliance
- Impervious cover regs
- SW utility fee credits & incentives
- Infrastructure redevelopment
- Updates to state & local SW & LID manuals e.g., CA, WA, MN, WI, VA, MD, NC…PA
Efficient water use  Recharge aquifers for water supplies, reduce in/out of state imports, store/use urban irrigation water; support shade tree watering & longevity

Transportation/safety  Traffic calming, support way finding, mark on/off-street parking areas, increase neighborhood identity & support urban design contexts

Energy Efficiency  Use with horizontal ground source heat pumps for building cooling/heating; reduce lighting use to with reflective surfaces on sidewalks/parking lots/roadways to enhance high-efficiency lighting
**PICP Green Infrastructure**

**Recycling/reuse**  
Reinstate same pavers; specify paving materials with a minimum 10% recycled content e.g., flyash, silica fume, glass, etc. LEED v4: Attain material from sources within 100 mile radius of project site; compare product LCAs.

**Urban Heat Island**  
Reduce ambient summer temperatures on streets and sidewalks through reflective pavers on roadways, light colored units on sidewalks and use of trees for shading.

**Education**  
Municipal PICP projects & infiltration demos, project signs to highlight sustainable design; maintenance education for owners/clients.

**Economic Development**  
PICP street investment a driver for private sector reinvestment.
ICPI: PICP Guidance

100+ pages
60+ figures
Industry consensus
• Hydrologic Design
• Structural design
  Follows Permeable Design Pro software
• Guide specs
• Construction guidelines
  Promotes using contractors with ICPI PICP course certificate
  Certificate appearing in specs
• Maintenance guidelines
Permeable Design Pro Software for PICP

ICPI Interlocking Concrete Pavements Structural and Hydrological Design Inputs

Design Title: Example 2 US Customary

Site Information
- Pavement Length: 500 ft
- Pavement Width: 50 ft
- Pavement Area: 25,000 ft²
- Catchment Area: 25,000 ft² (Avg CN=73.2)

Layer Information
- Paving Layer
  - Structural Coefficient: 0.3
  - Structural Number: 1.5 in
  - Thickness: 5.1 in

- Base Material
  - Structural Coefficient: 0.05
  - Structural Number: 0.2 in
  - Thickness: 4.0 in
  - Permeability: 103.791 ft/day

- Subbase Material
  - Structural Coefficient: 0.05

Analysis
- Analysis period: All years
- Analysis Results: Graph, Details, Summary, Report

Graph

Precipitation (in)
Permeable Interlocking Concrete Pavement (PICP)

Pavers, bedding & jointing stones

Base reservoir - Stone - 4 in. thick

Subbase stone - thickness varies with water storage & traffic
Full Exfiltration PICP
Full exfiltration subbase construction (with & without geotextiles)
Full exfiltration: no subsurface drain pipes

Overflow drains to bioswale

Elmhurst College
Elmhurst, IL
Impermeable Liner

Woven geotextile protects liner
No exfiltration
Possible water harvesting
17 Volume/Pollutant Reduction Studies

1999 to present:

University of New Hampshire Stormwater Center - Roseen
NC State University – Hunt (5)
Toronto & Region Conservation Authority – Van Seters (2)
University of Calgary – Duin
University of Guelph – James
University of Washington – Brattebo
University of Auckland, New Zealand - Fassman
Stantec Michigan – Dierks
Coventry University, UK – Pratt /Coupe
University of New South Wales, Australia – Shackel
Florida Gulf Coast University – Kim
University of Connecticut – Clausen
Ongoing: US EPA Edison, NJ; NCSU Durham & Cleveland; Others
Reductions Compared to Impervious Pavements

**Volume:** 25 – 99% (clay – sand)

**TSS:** 60 – 80%

**Total Nitrogen:** 30 – 60%

**Total Phosphorous:** 23 – 50%

**Metals:** 12 – 70%

VA Stormwater Manual – Chapter 7 Permeable Pavements...runoff reduction calculator

- **Level 1:** 45% volume & 25% phosphorous reduction
- **Level 2:** 75% volume & 25% phosphorous reduction

Level 2 = treatment train design, other factors
Pedestrian areas, parking lots, low-speed residential roads

- 100 ft from wells
- 10 ft from building foundations unless waterproofed
- Infiltrating base: Min. 2 ft to seasonal high water table
- Lined base: Min. 1 ft to seasonal high water table
- Max. contributing impervious area: PICP = 5:1
- Surface slope: as much as 18%
- Subrade slope: >3% - use berms
Permeable Pavement Design

Structural Analysis

Pedestrian Use
- Subgrade Characteristics: $M_r$, CBR, R-Value
- Determine Surface & Base/Subbase Thickness
  - Structurally Adequate?
    - No
    - Yes: Select the Limiting (Thicker) Cross-Section for Design

Vehicular Use
- Traffic Load: ESALs, Traffic Index
- Surface & Base/Subbase Properties
  - Determine Depth of Water & Base/Subbase thickness
    - Infiltration Rate & Volume Through Subgrade
      - Outflow Rate & Volume Through Underdrains
        - Hydrologically Adequate?
          - Yes
          - No: Revise Thickness or Adjust Outflow

Hydrological Analysis

Design Storm(s)
- Contributing Area Runoff
  - Time Steps
    - Vehicular Use
      - Design Storm(s)
    - Pedestrian Use
      - Design Storm(s)

Revise Thickness
Critical Hydrologic Design Factor: Subgrade Infiltration

- Double ring infiltrometer test
- Use avg. infiltration rate
- Apply safety factor for clogging & construction compaction

Portable soil infiltration device

Multiple test holes

Test pit
Critical Structural Design Factors:

- Uncompacted or compacted soils...
- Strength characterization of saturated soils via...
  - California Bearing Ratio (96 hr soaked)
  - Resilient Modulus $M_r$
  - R-value
- Paver surface & bedding aggregate strengths
- Base/subbase aggregate strengths
Critical Construction Factors

- Minimizing compaction
- Maintaining clean aggregates & pavement surface
Mechanical PICP Installation
## Autumn Trails, Moline, IL 2006

<table>
<thead>
<tr>
<th></th>
<th>PICP</th>
<th>Concrete</th>
<th>Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per sf</td>
<td>~ 39,000 sf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No storm sewers</td>
<td>$10.95</td>
<td>$15.00</td>
<td>$11.50</td>
</tr>
<tr>
<td>With storm sewers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PICP & economic development...
Marine Market Way
Burnaby, BC
350,000 sf
Chicago
Green Alleys

Dubuque, IA
Los Angeles
Critical Maintenance Factors

• **Regenerative air vacuum sweeper**
  – Routine cleaning
  – Removes loose sediment, leaves, etc.
  – More common
  – ~$1000/acre

• **True vacuum sweeper**
  – 2X more powerful
  – Restores highly clogged surfaces
  – Narrower suction
Winter Maintenance

• Snow melts faster – lower risk of ice
• Surface does not heave when frozen
• Use normal plows - dirty snow piles clog surface
• Deicing salts okay
• Sand will clog system – use jointing material for traction
Must vacuum winter sand/sediment accumulation

Managing dirty snow

No.
Coming Soon: Permeable Pavements
Recommended Design Guidelines

ASCE Committee Report – online only

• Fact sheets
• Checklists
• Design information
• Maintenance
• Standards, guide specs & modeling methods
• Research needs

ASCE/ANSI PICP design, construction & maintenance standard under development
Design Tools

ICPI’s technical and educational resources provide design professionals with the latest design insights and technical developments on interlocking concrete pavement and permeable interlocking concrete pavement. As an ICPI member, you will receive timely updates on new publications, trends and industry news through subscription to the Interlocking Concrete Pavement Magazine and ICPI Design Professional Update. Visit our comprehensive Membership area and learn how ICPI can improve your business.

Be Inspired
Browse our Idea Gallery for design solutions that meet your project’s needs.

INDUSTRY PROFESSIONALS SAY

“From day one, the Board wanted a permeable lot, a view heightened by the long-term drought in the southeast which drastically lowered lake levels and threatened drinking water supplies. They declared it a top priority.”

LEED®
United States | Canada
Developed by the U.S. Green Building Council (USGBC) in 1998, LEED® is a voluntary system of design for buildings and sites that provides a rating system which encourages the use of technologies that reduce energy and conserve non-renewable resources.

Sustainable Design
Permeable Interlocking Concrete Pavements (PICPs) meet LEED® credit requirements under Sustainable Sites. These requirements limit runoff and water pollution by managing stormwater. The pavements can reduce runoff-generating impervious cover and decrease the rate and quantity of runoff. Learn more about