Thank you to all of our 2016 sponsors:
Development of a National ASCE Standard for Permeable Interlocking Concrete Pavement

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Vice-President, Transportation

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Director – Commercial Solutions
Oaks by Brampton Brick
Spring 2014: Permeable Pavements
Recommended Design Guidelines
ASCE EWRI Committee Report – online only

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

Establishes common terms for all permeable pavements
ASCE PICP Standard Guidelines

Content

Section 1 – General Scope
Section 2 – Preliminary Assessment
Section 3 – Design (structural & hydraulic design, additional considerations)
Section 4 – Construction
Section 5 – Maintenance

Goal: end of 2016 completion

Uses

Adoption by State, Provincial & Local agencies
Design professional & contractor guidance
Permeable Interlocking Concrete Pavement (PICP)

- **Pavers, bedding & jointing stones**
- **Base reservoir**
  - Stone – 100 mm. thick
- **Subbase stone - thickness**
  - Varies with water storage & traffic
Permeable Pavement Functions

- Permeable Surface
- Open Graded Base
- Open Graded Subbase
- Subgrade

Full infiltration

Partial infiltration

Outlet Pipe

- Impermeable Liner
- Subgrade

No infiltration
## Assessing Suitability (S 2.1)

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost efficiency (including life cycle costs)</td>
<td>Capital cost assessment needs to consider cost of pavement, drainage infrastructure, stormwater quality management, and land use. Overall long-term life-cycle costs can be very competitive if stormwater quality and quantity benefits are taken into account.</td>
</tr>
<tr>
<td>Environmental approval process</td>
<td>Verify permeable pavements are permitted, or if additional environmental approvals are required.</td>
</tr>
<tr>
<td>Stringent receiving water quality standards</td>
<td>The presence of protected watersheds, cold water streams, marshland, etc. may preclude the use of permeable pavement systems, or require more extensive water quality treatment.</td>
</tr>
<tr>
<td>Safety</td>
<td>Pavements are able to accommodate safety features such as traffic calming (rumble strips), and colored units for identification. Reduced ice formation and slip hazards.</td>
</tr>
<tr>
<td>Site grades</td>
<td>For grades of more than 5 percent, system will be less effective at promoting infiltration and have reduced water storage capabilities.</td>
</tr>
<tr>
<td>Depth of water table</td>
<td>Permeable pavements that include an infiltration component should not be used in areas where the water table is within 0.6 m (2ft) of the top of the soil subgrade.</td>
</tr>
<tr>
<td>Winter maintenance, winter sanding</td>
<td>Procedures for snow and ice removal are similar to those for conventional pavements. De-icing salt usage can be reduced, use of courser sand for traction control recommended. PICP are proven to perform even during below freezing conditions.</td>
</tr>
<tr>
<td>Risk of accidental chemical spill</td>
<td>PICP may assist in containment of accidental spills (requires the use of a geomembrane liner).</td>
</tr>
</tbody>
</table>
## Assessing Suitability (cont.)

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount and intensity of precipitation</td>
<td>Supplemental quantity control may be required in areas of frequent, high intensity storms.</td>
</tr>
<tr>
<td>Complexity of site conditions</td>
<td>The design and construction of permeable shoulders may be problematic in areas where retaining walls, utilities, septic systems, municipal or private wells are present.</td>
</tr>
<tr>
<td>Geotechnical Aspects</td>
<td>Presence of organics, fill soils, swelling clay soils, karst geology, or shallow bedrock may pose geotechnical risks that introduce added design complexity.</td>
</tr>
<tr>
<td>Mandates for water quality control</td>
<td>Permeable pavements may contribute substantially to water quality improvement.</td>
</tr>
<tr>
<td>Mandates for water quantity control</td>
<td>Permeable pavements provide stormwater management alternatives to more costly or complicated practices.</td>
</tr>
<tr>
<td>Maintenance protocols</td>
<td>Permeable pavement systems require mandatory non-traditional maintenance practices such as vacuum sweeping.</td>
</tr>
<tr>
<td>Structural design</td>
<td>Design of PICP for moderate to heavy axle loads or high traffic counts may require additional analysis and details.</td>
</tr>
<tr>
<td>Interest in innovation</td>
<td>Designs that include PICP can provide opportunity for innovation and sustainable benefits.</td>
</tr>
<tr>
<td>Owner experience and resources</td>
<td>Permeable pavements should be designed to address owners expectations for performance, aesthetics, inspections, maintenance, benefits, costs, etc.</td>
</tr>
</tbody>
</table>
Pedestrian areas, parking lots, low-speed residential roads

30 m from wells

3 m from building foundations unless waterproofed

Infiltrating base: Min. 0.6 m to seasonal high water table

Max. contributing impervious area: PICP = 5:1

Surface slope: as much as 18%...w/ subgrade check dams

Subgrade slope: >3% - use berms
Permeable Pavement Design Flowchart

**Section 3.2**

**Structural Analysis**
- Pedestrian Use
  - Subgrade Properties: Mr, CBR, R-Value
    - Determine Surface & Base/Subbase Thickness
      - Increase Thickness
      - Structurally Adequate? (No)
      - Yes

- Vehicular Use
  - Traffic ESALs, Traffic Index
    - Surface & Base/Subbase Properties

**Section 3.3**

**Hydrologic Analysis**
- Design Storm
  - Infiltration Rate & Volume Into Subgrade
    - Determine Depth of Water & Base/Subbase Thickness
      - Revise Thickness or Adjust Outflow

- Contributing Area Runoff
  - Outflow Rate & Volume Through Underdrains
  - Yes
  - No

**Select Limiting (Thicker) Cross-Section for Design**
- Yes
  - Hydrologically Adequate? (Yes)
- No
  - Yes
Characterization of soil strength using AASHTO, ASTM, or State DOT lab tests

**Resilient Modulus or $M_r$ (PSI or MPa)**
- Measures stiffness (resistance to loads)
- Dynamic test (repeated loads) on a soil or base sample under simulated confining stresses (from field tests)

**California Bearing Ratio (CBR in percent)**
- Tests vertical bearing capacity compared to a high-quality compacted aggregate base

**Resistance or R-value (dimensionless number)**
- Tests vertical bearing and horizontal shear
- Used in California & a few other states

Strengths correlate to each other
Resilient Modulus, $M_r$
AASHTO T-307
CBR ASTM D1883
R-value ASTM D2844

AASHTO Soil Classification
AASHTO M-45

Unified Soil Classification
ASTM D2487
Equivalent Single Axle Loads or 18,000 lb ESALs Characterizes performance (rutting)

What is an ESAL?
ESALs per Truck

**LEF:** Load Equivalency Factor = \( \left( \frac{\text{axle load}}{80 \text{ kN}} \right)^4 \)

- **2 x 80 kN**
  \[ \text{LEF} = \left( \frac{80}{80} \right)^4 = 1 \times 2 \]
- **2 x 70 kN**
  \[ \text{LEF} = \left( \frac{70}{80} \right)^4 = 0.6 \times 2 \]
- **50 kN**
  \[ \text{LEF} = \left( \frac{50}{80} \right)^4 = 0.14 \]

**One pass =** \[ 2 + 1.2 + 0.14 = 3.34 \text{ ESALs} \]

**How many ESALs does one pass of a car equal?**
**Assume 1 axle = 10 kN**

\[ 0.00015 \text{ ESALs} \]
## Traffic Loading and Design

<table>
<thead>
<tr>
<th>Pavement Class</th>
<th>Description</th>
<th>Design ESALs</th>
<th>Design TI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial</td>
<td>Through traffic with access to high-density, regional, commercial and office developments or downtown streets. General traffic mix.</td>
<td>9,000,000</td>
<td>11.5</td>
</tr>
<tr>
<td>Major Collector</td>
<td>Traffic with access to low-density, local, commercial and office development or high density, residential sub-divisions. General traffic mix.</td>
<td>3,000,000</td>
<td>10</td>
</tr>
<tr>
<td>Minor Collector</td>
<td>Through traffic with access to low-density, neighborhood, commercial development or low-density, residential sub-divisions. General traffic mix.</td>
<td>1,000,000</td>
<td>9</td>
</tr>
<tr>
<td>Bus Terminal</td>
<td>Public Transport Centralized facility for buses to pick up passengers from other modes of transport, or for parking of city or school buses.</td>
<td>500,000</td>
<td>8.5</td>
</tr>
<tr>
<td>Local Commercial</td>
<td>Commercial and limited through traffic with access to commercial premises and multi-family and single-family residential roads. Used by private automobiles, service vehicles and heavy delivery trucks.</td>
<td>330,000</td>
<td>8</td>
</tr>
<tr>
<td>Residential</td>
<td>No through traffic with access to multi-family and single-family residential properties. Used by private automobiles, service vehicles and light delivery trucks, including limited construction traffic.</td>
<td>110,000</td>
<td>7</td>
</tr>
<tr>
<td>Facility Parking</td>
<td>Open parking areas for private automobiles at large facilities with access for emergency vehicles and occasional use by service vehicles or heavy delivery trucks.</td>
<td>90,000</td>
<td>7</td>
</tr>
<tr>
<td>Commercial Parking</td>
<td>Restricted parking and drop-off areas associated with business premises, mostly used by private automobiles and occasional light delivery trucks. No construction traffic over finished surface.</td>
<td>30,000</td>
<td>6</td>
</tr>
<tr>
<td>Commercial Plaza</td>
<td>Predominantly pedestrian traffic, but with access for occasional heavy maintenance and emergency vehicles. No construction traffic over finished surface.</td>
<td>10,000</td>
<td>5</td>
</tr>
</tbody>
</table>
Design Tables for PICP
Accelerated Pavement Testing
UC Pavement Research Center
Sponsors: CA Paver Manufacturers, ICPI Foundation, CA Cement Assoc.

Need: Validated Base Thickness Charts
UC Davis Pavement Research Center Tasks

- Prepare accelerated load testing plan based on the results of the mechanistic analysis
- Test responses/failure of three PICP structures in dry and wet condition with a Heavy Vehicle Simulator (HVS)
- Analyze the results revise/update ICPI structural design tables as needed
Section 1

Section 2

Section 3

CURB
150 x 225 MM

80 MM THICK CONCRETE PAVERS W/ JOINTING STONE

50 MM BEDDING NO. 8 STONE

100 MM BASE NO. 57 STONE

NO. 2 STONE SUBBASE

450 MM

200 MM

300 MM

GEOTEXTILE ON ALL SIDES AND BOTTOM
PICP Test Track Construction
## Native Soil Subgrade Moisture

<table>
<thead>
<tr>
<th>Wheel Load (kN)</th>
<th>Load Repetitions</th>
<th>ESALs</th>
<th>Surface Rut Depths, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>450 mm Subbase</td>
</tr>
<tr>
<td>25</td>
<td>100,000</td>
<td>13,890</td>
<td>8.6</td>
</tr>
<tr>
<td>40</td>
<td>100,000</td>
<td>100,000</td>
<td>13.6</td>
</tr>
<tr>
<td>60</td>
<td>140,000</td>
<td>768,619</td>
<td>23.7</td>
</tr>
<tr>
<td>Total</td>
<td>340,000</td>
<td>882,509</td>
<td></td>
</tr>
</tbody>
</table>

## Saturated Subbase & Soil

<table>
<thead>
<tr>
<th>Wheel Load (kN)</th>
<th>Load Repetitions</th>
<th>ESALs</th>
<th>Surface Rut Depths, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>450 mm Subbase</td>
</tr>
<tr>
<td>25</td>
<td>100,000</td>
<td>13,890</td>
<td>13.7</td>
</tr>
<tr>
<td>40</td>
<td>100,000</td>
<td>100,000</td>
<td>25.2</td>
</tr>
<tr>
<td>60</td>
<td>140,000</td>
<td>768,619</td>
<td>47.2</td>
</tr>
<tr>
<td>80</td>
<td>40,000</td>
<td>735,167</td>
<td>58.0</td>
</tr>
<tr>
<td>Total</td>
<td>380,000</td>
<td>1,617,676</td>
<td></td>
</tr>
</tbody>
</table>

## Drained Subbase & Soil

<table>
<thead>
<tr>
<th>Wheel Load (kN)</th>
<th>Load Repetitions</th>
<th>ESALs</th>
<th>Surface Rut Depths, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>450 mm Subbase</td>
</tr>
<tr>
<td>25</td>
<td>100,000</td>
<td>13,890</td>
<td>9.5</td>
</tr>
<tr>
<td>40</td>
<td>25,000</td>
<td>25,000</td>
<td>11.0</td>
</tr>
<tr>
<td>Total</td>
<td>140,000</td>
<td>38,890</td>
<td></td>
</tr>
<tr>
<td>Number of Days in a Year When the Subbase has Standing Water (Wet Days)</td>
<td>0</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td>---</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td><strong>Resilient Modulus of Subgrade (MPa)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Wet</td>
<td>24</td>
<td>36</td>
<td>48</td>
</tr>
<tr>
<td><strong>Cohesion (kPa),</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>10, 15, 20, 25,</td>
<td>10, 15, 20, 25,</td>
<td>10, 15, 20, 25,</td>
</tr>
<tr>
<td>Wet</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td><strong>Internal Friction Angle of Subgrade (°)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>6, 9, 12, 15,</td>
<td>6, 9, 12, 15,</td>
<td>6, 9, 12, 15,</td>
</tr>
<tr>
<td>Wet</td>
<td>12</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td><strong>Lifetime ESALs (Traffic Index)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Subbase Thickness in mm ASTM #2 for 25 mm Allowable Rut Depth (All designs have 80 mm Paver, 50 mm ASTM #8 Bedding Layer, &amp; 100 mm ASTM #57 Base Layer)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50,000 (6.3)</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>100,000 (6.8)</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>200,000 (7.4)</td>
<td>230</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>300,000 (7.8)</td>
<td><strong>150</strong></td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>400,000 (8.1)</td>
<td>330</td>
<td>220</td>
<td>150</td>
</tr>
<tr>
<td>500,000 (8.3)</td>
<td>360</td>
<td>250</td>
<td>160</td>
</tr>
<tr>
<td>600,000 (8.5)</td>
<td>385</td>
<td>275</td>
<td>185</td>
</tr>
<tr>
<td>700,000 (8.6)</td>
<td>410</td>
<td>295</td>
<td>205</td>
</tr>
<tr>
<td>800,000 (8.8)</td>
<td>425</td>
<td>310</td>
<td>220</td>
</tr>
<tr>
<td>900,000 (8.9)</td>
<td>440</td>
<td>325</td>
<td>235</td>
</tr>
<tr>
<td>1,000,000 (9.0)</td>
<td>455</td>
<td>340</td>
<td>250</td>
</tr>
<tr>
<td>Number of Days in a Year When the Subbase has Standing Water (Wet Days)</td>
<td>50</td>
<td>90</td>
<td>120</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>----</td>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td>Resilient Modulus of Subgrade (MPa) Dry</td>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Wet</td>
<td>24</td>
<td>36</td>
<td>48</td>
</tr>
<tr>
<td>Cohesion (kPa), Dry</td>
<td>10, 15, 20, 25</td>
<td>10, 15, 20, 25</td>
<td>10, 15, 20, 25</td>
</tr>
<tr>
<td>Internal Friction Angle of Subgrade (°) Dry</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Wet</td>
<td>6, 9, 12, 15</td>
<td>6, 9, 12, 15</td>
<td>6, 9, 12, 15</td>
</tr>
<tr>
<td>Lifetime ESALs (Traffic Index)</td>
<td>Minimum Subbase Thickness in mm ASTM #2 for 25 mm Allowable Rut Depth (All designs have 80 mm Paver, 50 mm ASTM #8 Bedding Layer, &amp; 100 mm ASTM #57 Base Layer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50,000 (6.3)</td>
<td>175</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>100,000 (6.8)</td>
<td>285</td>
<td>180</td>
<td>150</td>
</tr>
<tr>
<td>200,000 (7.4)</td>
<td>395</td>
<td>285</td>
<td>185</td>
</tr>
<tr>
<td>300,000 (7.8)</td>
<td>455</td>
<td>340</td>
<td>240</td>
</tr>
<tr>
<td>400,000 (8.1)</td>
<td>500</td>
<td>380</td>
<td>280</td>
</tr>
<tr>
<td>500,000 (8.3)</td>
<td>530</td>
<td>410</td>
<td>305</td>
</tr>
<tr>
<td>600,000 (8.5)</td>
<td>555</td>
<td>435</td>
<td>330</td>
</tr>
<tr>
<td>700,000 (8.6)</td>
<td>580</td>
<td>455</td>
<td>350</td>
</tr>
<tr>
<td>800,000 (8.8)</td>
<td>600</td>
<td>470</td>
<td>365</td>
</tr>
<tr>
<td>900,000 (8.9)</td>
<td>615</td>
<td>485</td>
<td>380</td>
</tr>
<tr>
<td>1,000,000 (9.0)</td>
<td>630</td>
<td>500</td>
<td>390</td>
</tr>
</tbody>
</table>
Final Comment – Structural Design

- Traffic Type and Composition - Permeable pavements can be used in heavy vehicular applications, but a qualified pavement engineer should be consulted for these specific applications.

- Limitations – speed limit should be less than 65kph (40 mph)
Hydraulic Design (S3.3)

Determine Hydraulic Goals

- Volume control (maintain pre-development conditions)
- Water quality (catch first flush)
- Thermal quality
- Peak flow control
- Downstream erosion control
- Infiltration/recharge targets
- Ecosystem/habitat maintenance
Water Balance

- $d_p = \text{DEPTH OF OPEN GRADED BASE AND SUBBASE}$
- $P = \text{DESIGN STORM RAINFALL CONTRIBUTING AREA, m (ft)}$
- $R = \text{RUN-ON DEPTH FROM THE CONTRIBUTING AREA, m (ft)}$
- $A_c = \text{ADJACENT CONTRIBUTING AREA}$
- $A_p = \text{SURFACE AREA OF PERMEABLE PAVEMENT}$
- $n = \text{POROSITY OF OPEN GRADED BASE AND SUBBASE}$
- $V_w = \text{VOLUME OF WATER THAT CAN BE STORED IN THE BASE/SUBBASE}$
- $Q_u = \text{UNDERDRAIN DISCHARGE}$
- $V = \text{VOLUME OF THE BASE AND SUBBASE}$
- $A_I = \text{SUBGRADE INFILTRATION AREA}$
- $I = \text{DESIGN INFILTRATION RATE OF SUBGRADE}$
Input - Precipitation Data

Rainfall Intensity Curves for City of Toronto

Equation of curve

$I = A (T)^C$

$I =$ Rainfall Intensity (mm/h)

$T =$ Time of concentration (hours) - Use 10 minutes inlet time

Return Period

<table>
<thead>
<tr>
<th>Parameters</th>
<th>2YR</th>
<th>5YR</th>
<th>10YR</th>
<th>25YR</th>
<th>50YR</th>
<th>100YR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient (A)</td>
<td>21.8</td>
<td>32.0</td>
<td>38.7</td>
<td>45.2</td>
<td>53.5</td>
<td>59.7</td>
</tr>
<tr>
<td>Exponent (C)</td>
<td>-0.78</td>
<td>-0.79</td>
<td>-0.80</td>
<td>-0.80</td>
<td>-0.80</td>
<td>-0.80</td>
</tr>
</tbody>
</table>

Percentile Storm Data

Intensity Duration Frequency Curves

Figure 1b - Total Average Annual Occurrences vs Daily Precipitation (based on 1991 Toronto Rainfall Data from 16 Rain Gauge Stations)
Output – Subgrade Infiltration

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

Multiple test holes
## Output – Subgrade Infiltration

### WHAT IS ENOUGH?

<table>
<thead>
<tr>
<th>Texture Class</th>
<th>Minimum Filtration Rate (f) inch per hour</th>
<th>Hydrologic Soil Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>8.27</td>
<td>5,251 mm/d A</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>2.41</td>
<td>1,469 mm/d A</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>1.02</td>
<td>621 mm/d B</td>
</tr>
<tr>
<td>Loam</td>
<td>0.52</td>
<td>317 mm/d B</td>
</tr>
<tr>
<td>Silt Loam</td>
<td>0.27</td>
<td>165 mm/d C</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>0.17</td>
<td>104 mm/d C</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>0.09</td>
<td>55 mm/d D</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>0.06</td>
<td>37 mm/d D</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>0.05</td>
<td>31 mm/d D</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0.04</td>
<td>24 mm/d D</td>
</tr>
<tr>
<td>Clay</td>
<td>0.02</td>
<td>12 mm/d D</td>
</tr>
</tbody>
</table>

*Source: Virginia Stormwater Management Program Manual*
Selecting the PICP System Type

Inputs: Precipitation/Run-on

Subgrade Infiltration Feasible/Permitted?
- Yes
  - Input Exceeds Infiltration Capacity?
    - Yes: Partial Infiltration Design
    - No: Full Infiltration Design
  - No: No Infiltration Design

No Infiltration Design
No-infiltration Design

\[ V_W = P(A_P) + R(A_C) - Q_U T_S \]

Pipe flow can be calculated using the orifice equation
Full-infiltration Design

\[ V_w = P(A_p) + R(A_c) - I(T_S)A_I \]

If \( V_w > 0 \), then make sure the subgrade is not saturated for too long \( (T_D) \) using:

\[ T_D \geq \frac{V_w}{A_I \times I} \]
Partial-infiltration Design

\[ V_W = P(A_P) + R(A_C) - I(T_S)A_I - Q_U T_S Z \]

Infiltration Storage volume dictates pipe location (elevation).

Underdrain elevation factor (Z) used to adjust for duration of pipe flow.
Additional Design Considerations (S3.5)

- Outlet structures provide for future modifications to the storage depth, and provide a convenient monitoring location.
Additional Design Considerations

- Sites with subgrade slopes over 3% often require buffers, weirs, check dams, etc. to control water flow.
Additional Design Considerations
Additional Design Considerations

- Roof water can be discharged onto, or into, the pavement.
Additional Design Considerations
Additional Design Considerations

- Impermeable liners can be used adjacent to buildings.

![Diagram of waterproofing and permeable paving system]

- PERMEABLE PAVERS
  - TYP. NO. 8, 89, OR 9 AGGREGATE IN OPENINGS
  - BEDDING COURSE 50 MM (2 IN.) THICK (TYP. NO. 8 AGGREGATE)
  - 100 MM (4 IN.) THICK NO. 57 STONE OPEN-GRADED BASE

- SURFACE WATER FLOWS THRU BETWEEN PAVERS
  - SLOPE 1% AWAY FROM BUILDING FOR 3 M (10 FT.)

- EXISTING BUILDING WALL
  - CUT IMPERMEABLE LINER FLUSH WITH TOP OF PAVERS
  - OPTIONAL DIMPLED MEMBRANE
  - 30 MIL PVC LINER + W 8 OZ. NONWOVEN PROTECTIVE GOTEKTEX
  - EXPANSION MATERIAL
  - EXISTING BUILDING FOOTING
  - DISTANCE TO SUIT LOCAL GROUND CONDITIONS

- MIN. 150 MM (6 IN.) THICK NO. 2 STONE SUBBASE
- OPTIONAL GEOTEXTILE ON SUBGRADE PER DESIGN
- PERMEABLE SUBGRADE
- EXTEND IMPERMEABLE LINER TO BOTTOM OF BUILDING FOUNDATION
Additional Design Considerations

- Separation is required between permeable and traditional base materials.
Additional Design Considerations

- Use anti-seep collars along utility trenches that bisect the PICP pavement area to prevent lateral migration of water.
Pre-Construction Meeting (S4.2)

- PICP construction sequence
- Erosion & sediment control plan
- Subgrade protection
- Material storage
- Paver stitching
- Inspection criteria
- Contractor certification
Erosion and Sediment Control (S4.3)
Minimizing compaction

DO NOT scarify
Construction Inspection Checklist

Place geomembranes and geotextiles as specified
Construction Inspection Checklist

Underdrain placement
Construction Inspection Checklist

Aggregate placement, compaction and testing
Maintenance Guidelines (S5)

• **Contaminant Loading** – Minimize/remove potential contaminants such as winter sand, biomass (tree leaves and needles, grass clippings, etc.) and sediment
Maintenance Guidelines

- **Infiltration Testing** – Test surface infiltration rate using ASTM C1781
Routine and Remedial Maintenance

- 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—lower risk of ice
- 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
Status of ASCE Standard Guideline

• Final Standard Development Meeting to be held in Houston in June 2016
• Full Standard will undergo editing before going to public comment for 45 days in the summer of 2016
• Intent to publish the standard by the end of 2016
Projections for Euro 2016?