DEVELOPMENT OF AN ASCE STANDARD FOR PERMEABLE INTERLOCKING CONCRETE PAVEMENT

David K. Hein, P. Eng.

Vice-President, Applied Research Associates Inc., 5401 Eglinton Avenue West,
Suite 204, Toronto, ON, Canada, M9C 5K6, Tel: (416) 621-9555; email: dhein@ara.com

Paper prepared for presentation at the
Design, Construction and Maintenance of Permeable Pavements Session

Of the 2014 Conference of the
Transportation Association of Canada
Montréal, Québec

ABSTRACT

This paper describes the technical development of the emerging ASCE standard for permeable interlocking concrete pavement or PICP. The draft standard notes key design elements which include high strength, impermeable concrete units for the surface that meet American Society for Testing Materials or Canadian Standards Association standards. When installed, the joints between units are filled with permeable aggregate. The units are placed over an open-graded aggregate bedding course which rests on an open-graded aggregate base and subbase for water storage and structural support.

While common to all permeable pavements, the document provides a design flow chart for structural and hydrologic design and outlines three commonly used infiltration approaches determined by site and subgrade conditions, as well as designs for sloped subgrades. The draft standard addresses structural design for supporting traffic by modifying conventional flexible pavement design methodology from the American Association of State Highway and Transportation Officials.

The draft standard considers many design variables and how to address them. It resolves a key design consideration common to all permeable pavements; the dichotomy between not compacting the soil subgrade for infiltration and compacting for enhanced structural support especially in saturated conditions. Besides guide construction specifications, construction and maintenance guidelines are provided via checklists. A key tool for assessing surface infiltration and subsequent vacuum cleaning is adoption of an ASTM surface infiltration test for pervious concrete which has been successfully used for porous asphalt and PICP.

Keywords: Permeable pavement standards, permeable interlocking concrete pavement, permeable pavement structural/hydrologic design, permeable pavement construction and maintenance.

INTRODUCTION

The three primary permeable pavement types are pervious concrete (PC), porous asphalt (PA) and permeable interlocking concrete pavement (PICP). These are typically constructed over an open-graded (unstabilized) aggregate base and subbase layers. With years of experience and performance research, adoption of design guidelines, construction specifications and maintenance guidelines by stormwater agencies continues. Transportation agencies are slower in adoption of permeable pavements in part due to lack of experience. Such experience needs to be based on standards that codify accepted design, construction and maintenance practices. In addition, permeable pavements are generally restricted to parking lots, alleys and low-volume roads. Structural performance data for heavier load applications is needed for unstabilized and stabilized bases/subbase that enables wider use.

PC utilizes the American Concrete Institute for development and distribution of ACI 522 [1] which consists of guidance on material mix design and construction, as well a guide construction specification. In addition, PC has ASTM standards to characterize material properties. Similar ASTM standards exist for PA materials and there is an ASTM guideline under development for PA construction.

For PICP, the ASCE Transportation & Development Institute is creating a comprehensive (and eventual American National Standards Institute) standard for design, construction and maintenance. The highest design loads using unstabilized bases will be 1 million 80 kN equivalent single axle loads. Typical PICP parking lot, alley and street applications are shown in Figures 1 through 3.

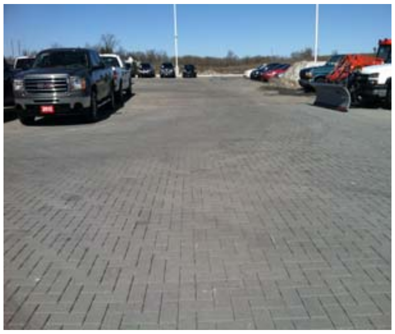

Figure 1. Automobile Dealership, Aberfoyle, Ontario.

Figure 2. Large Shopping Mall, Burnaby, British Columbia.

Figure 3. Winery Parking Area, Niagara-on-the-Lake, Ontario.

When completed, the standard will complement ASCE 58-10 *Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways* [2]. This standard covers base designs for conventional interlocking concrete pavement (ICP) up to 10 million ESALs using unstabilized, cement and asphalt-stabilized or asphalt bases. The paving units are typically jointed with sand and placed on sand bedding over an unstabilized dense-graded or stabilized base.

A common error in some state and municipal stormwater guidance documents is in their characterization of ICP defined in ASCE 58-10 as permeable. The research literature Hade [3] and Madrid [4] indicates that ICP runoff coefficients typically range between 80% and 95% thereby characterizing the imperviousness similar to that of conventional asphalt and concrete pavements. In contrast, PICP takes in all rainfall and runoff from contributing impervious areas.

DESIGN GOALS

The emerging ASCE design standard for PICP meets the following site design goals.

- U.S. National Pollutant Discharge Elimination System (NPDES) permit compliance
- Runoff volume and pollutant control for new development and redevelopment
- Limits on impervious cover (i.e., roofs and pavements) and resulting runoff
- Runoff volume storage and/or infiltration to reduce overflows, especially combined sewer overflows.
- Total maximum daily load (TMDL) requirements for receiving waters.
- Managing quality and or quantity storm events, typically expressed as a percentile; e.g. 85th percentile storm depth, or the 95th percentile storm depth as is required for U.S. federal government facilities in Section 438 of Energy Independence and Security Act.

There are other reasons for using PICP besides conformance to local regulations. These include:

- PICP as a lower-cost alternative to conventional pavement and drainage system designs
- Stormwater utility fee credits or cost-sharing
- Project owner preference for voluntary conformance rating systems for buildings, sites, roads and transportation infrastructure. Building and site evaluation system examples include Leadership in Energy and Environmental Design (LEED®), the Sustainable Sites Initiative, and GreenGlobes. Road and transportation infrastructure evaluation system examples are the

Transportation Association of Canada Green Guide for Roads, Ontario Ministry of Transportation GreenPave, Institute for Sustainable Infrastructure's Envision™ , Greenroads, or the U.S. Federal Highway Administration INVEST or Infrastructure Voluntary Evaluation Sustainability Tool.

DESIGN ELEMENTS

Prior to addressing PICP design elements, the designer investigates site-specific items common to all permeable pavement design. Considerations for preliminary design include but are not limited to the following:

- Federal, state, provincial, or municipal stormwater drainage design criteria which may include design storm or storm depths, percentile or return period, intensity, and duration of storms to manage
- Underlying geology and soils maps, horizons, soil types, and estimated depth to the seasonal high ground water table, depth to bedrock or other confining layers
- Identify hydrologic soil groups (i.e., A, B, C, D) as defined in Chapter 7 of the *Engineering Handbook Part 630* published by the U.S. Department of Agriculture Natural Resource Conservation Service
- Soil classification (Unified or AASHTO) and mechanical properties such as strength, erodibility, permeability, etc.
- Site history of fill soil, contamination, previous disturbances, or compaction
- Natural drainage systems including streams, lakes, rivers, and wetlands
- Surrounding land use, potential sources of pollution etc.
- Existing underground utility lines, e.g., sanitary/storm sewers and structures, water supply, electric, natural gas, cable lines, etc.
- Current and future land uses draining onto the site via overland flow, natural drainage courses, and/or storm sewers
- Applicable brown field or other special requirements
- Identification and avoidance of stormwater hotspots

Design elements include the following:

- Traffic loads typically expressed in 80 kN equivalent single axle loads or ESALs
- Soil testing that establishes relationships among soil subgrade compaction, density, and permeability via infiltration tests
- Outflow via underdrains or pipes to handle water not infiltrated within a given time period (typically 48 to 72 hours)
- Slopes adjacent to the permeable pavement that may contribute runoff or sediments
- Sloped PICP subgrades over 3% that typically use berms or barriers to slow water flow and promote infiltration
- Maintenance-sensitive design features to minimize maintenance (such as slope of adjacent surfaces, supplemental surface drainage features, curbing type and locations, outflows)
- Pollutant loads and treatment designs including targeted pollutants, total maximum daily loads (TMDLs), and airborne sand and dust typical to semi-arid regions
- Geosynthetics such as geotextiles, geogrids and geomembranes
- Rainwater capture and reuse

- Treatment train design where up and down flow practices assist each in moderating water volumes, flows and pollutants**.**

System Components and Approaches

Since PICP is a fairly new technology, the ASCE standard defines its components and they are illustrated in Figures 4 through 6. Hydrologic design options provide for full, partial or no infiltration. Full infiltration is where all of the rainfall and runoff infiltrate the soil subgrade under the PICP; partial infiltration where some is infiltrated and the remainder exits visit perforated underdrains (often used in low infiltration soils). No infiltration stores water inside the base/subbase using an impermeable liner for eventual release of the stored water.

Concrete Pavers – Paving units assembled in a pattern that creates joints or openings that receive and filled with permeable jointing material. These units comply with ASTM C936 (2012) or CSA A231.2 (2009). For vehicular traffic, pavers have an aspect ratio or length to thickness less than or equal to 3:1 and a minimum thickness of 80 mm. The designer may consider using paving patterns suitable to machine installation for accelerated construction. A 45- or 90-degree herringbone pattern should be used for vehicular pavements. Alternative laying patterns may be considered as long as they are functionally and structurally equivalent.

Permeable jointing material – Permeable crushed stone typically ASTM No. 8, 89 or 9. Selection of aggregate sizes depends on the joint widths created by the assembled concrete pavers.

Open-graded bedding course – This permeable layer of crushed stone is typically 50 mm thick and provides a level bed for the pavers. It consists of small-sized, open-graded aggregate, typically ASTM No. 8 stone or similar sized material.

Open-graded base reservoir – Aggregate layer 100 mm thick and made of crushed stone primarily 25 mm down to 13 mm. Besides storing water, this layer provides a gradational transition between the bedding and subbase layers. The stone size is typically ASTM No. 57 or similar sized material.

Open-graded subbase reservoir – The stone sizes are larger than the base, primarily 75 mm down to 50 mm, typically ASTM No. 2, 3 or 4 stone. Like the base layer, water is stored in the spaces among the stones. The subbase layer thickness depends on water storage requirements and traffic loads. A subbase layer may not be required in pedestrian or residential driveway applications. In such instances, the base layer thickness is increased to provide water storage and support.

Underdrain (as required) **–** In sites where PICP is installed over low-infiltration soils underdrains facilitate water removal from the base and subbase. The underdrains are perforated pipes that “daylight” to a swale or stream, or connect to an outlet structure. Pipe elevation, spacing, diameter and slope will impact outflow volumes and rates from connected PICP. Another design option to which underdrains connect is plastic or concrete vaults or plastic crates. These can store significant amounts of runoff.

Geosynthetic – A geogrid, impermeable liner, or geotextile.

Geotextile (design option per engineer) – A fabric (woven or non-woven) that separates the bedding/base/subbase from the subgrade and prevent migration of soil into them. Selection is based on AASHTO M-288 [5].

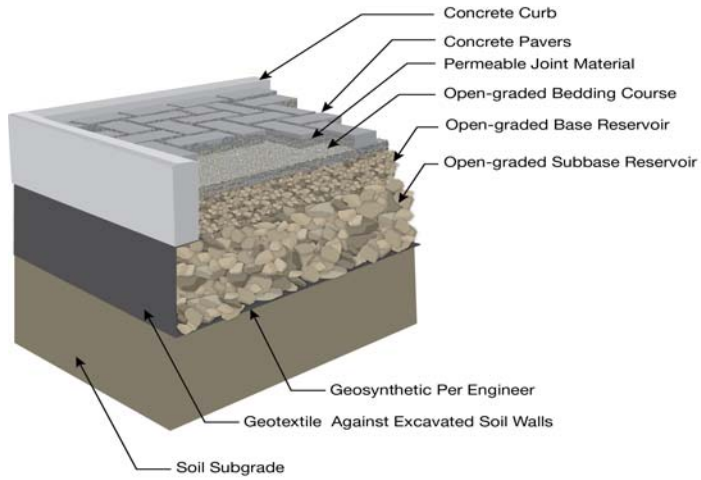

Figure 4. PICP with full infiltration design.

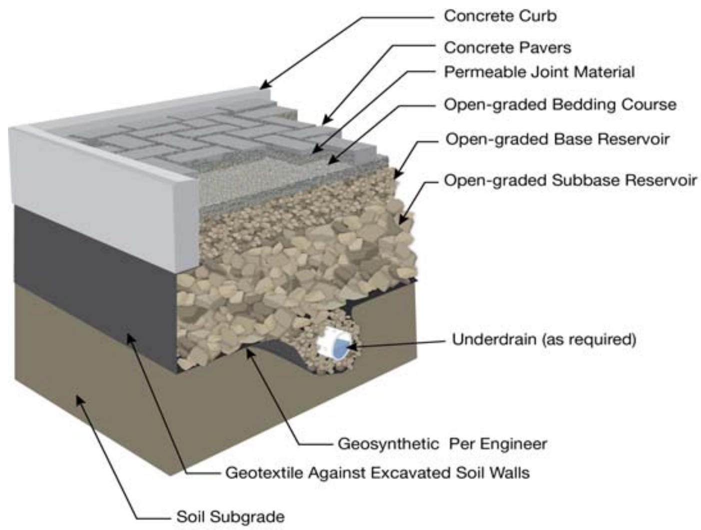

Figure 5. PICP with a partial infiltration design using an underdrain.

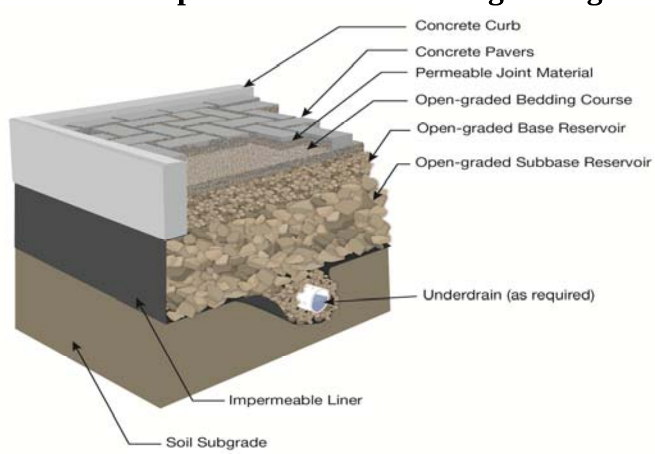

Figure 6. PICP with a no infiltration design using an impermeable liner.

Impermeable liner – A plastic or rubber geomembrane that completely prevents passage of water except through constructed penetrations via pipes.

Subgrade – The layer of soil immediately beneath the aggregate base or subbase.

STRUCTURAL AND HYDROLOGIC DESIGN METHODS

Structural and hydrologic design processes for determining the subbase thickness are illustrated in Figure 7. First, the designer conducts a structural analysis. Pedestrian use pavement design requires determining the subgrade soil characteristics and then surface and base/subbase thicknesses from established surface, base and subbase properties. In addition to the previous considerations, vehicular use pavement design requires determining traffic loads expressed as lifetime ESALs or Caltrans Traffic Index (TI). Since the aggregate bedding and base layers remain at consistent thicknesses for pedestrian and vehicular designs, the Engineer develops a pavement subbase thickness solution for the subbase layer.

The structural analysis procedure follows the requirements of the American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Design of Pavement Structures* [6]. This design procedure for flexible pavements has been adopted for the ASCE standard because the load distribution and failure modes of PICP are similar to those of other flexible pavement systems (i.e., the main failure mode is increasing roughness due to repetitive shear deformations.

The joint width range for purposes of the structural layer coefficients used in the design procedure should be 5 to 10 mm. Joints should be completely filled with ASTM No. 8 stone to the bottom of the paver chamfer. If no chamfers are present, the joints should be filled with aggregate to within 6 mm of the paver surface. ASTM No. 89 or 9 stone may be used to fill paver joints less than 10 mm wide.

For design purposes, the assumed AASHTO layer coefficient for the minimum 80 mm thick paver and 50 mm aggregate bedding layer is 0.3. This layer coefficient considers wider joints and larger aggregates in PICP paver joints compared to the 0.44 layer coefficient for sand-filled paver joints for interlocking concrete pavement as described in ASCE 58-10 *Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways* [2].

Manufacturers of pavers used in PICP may have additional information and test results that characterize the layer coefficient for their pavers, using specific jointing and bedding materials. They may also have additional information that characterizes benefits of specific paver shapes on structural and hydrologic design, installation and maintenance.

The layer coefficients of the open-graded base and subbase aggregates are assumed to be a portion of that for conventional dense-graded aggregate bases. Since there is a paucity of data characterizing the strength of these materials under traffic loads, the base structural layer coefficient is assumed at 0.09 and the subbase at 0.06. This conservative approach also accounts for base weakness from being completely saturated in high depth rain events. The design reliability is conservatively set at 80% confidence level. The resulting base and subbase thickness are illustrated in Table 1.

Second, the designer also conducts hydrologic analysis to develop a subbase thickness to store water. Inputs include the:

- Design storm or storms (typically provided by the local municipality)
- Any runoff that becomes inflow from adjacent pavements or roofs
  The soil subgrade infiltration rate and water volume into the subgrade
  outflow from underdrains if required.

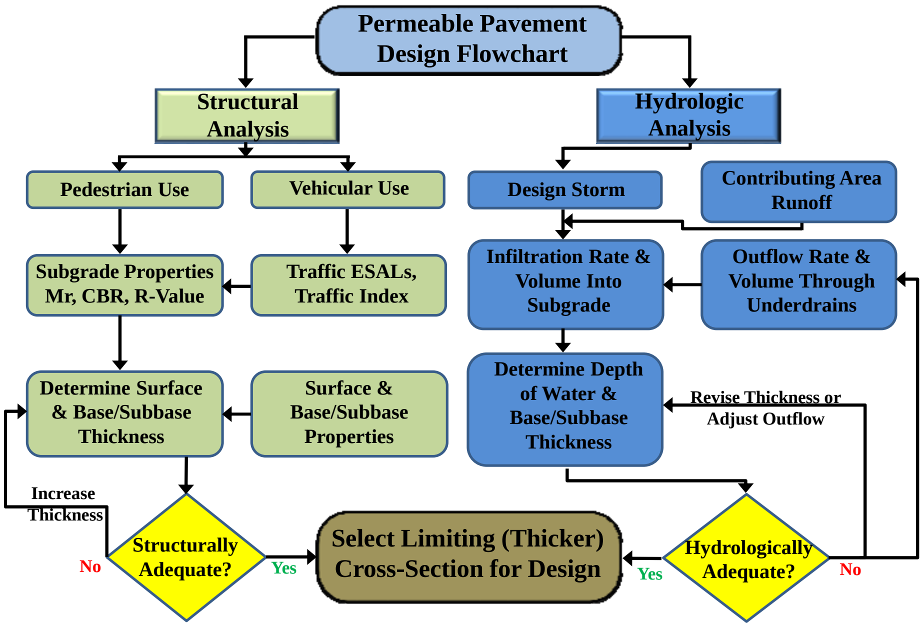

Figure 7. Permeable pavement design flow chart [7].

The Engineer calculates the base and subbase thicknesses required to store and infiltrate water, and drain any excess water via underdrains as needed. This analysis involves manual or computer calculated movement of water into the subgrade and outflow over the analysis time, usually 48 to 72 hours (or as specified by the stormwater regulatory agency). This analysis time is divided into time steps or increments to characterize the volume and rate water entering and leaving the pavement structure. The resulting subbase thickness is derived from finding the maximum water storage volume required for the rain event(s) plus any surface inflow while accounting for subgrade infiltration and subbase outflow over the analysis time. The base can also be used for water storage. From the structural and hydrologic analyses, the Engineer selects the thicker pavement subbase section for the project.

Resolving Compaction Versus Infiltration

The characterization of the subgrade is not only for structural design purposes. It is also important if one of the goals of the PICP design is to infiltrate water into the subgrade. The dichotomy of soil subgrade compaction for structural support and the need for uncompacted soils for infiltration can be resolved by establishing the relationship between soil permeability and in-situ soil density achieved during construction. This is important to establish a relationship between subgrade infiltration capability and the structural capacity necessary to support the design traffic. For example, a CBR determined at a soil compaction level of 95 percent of the standard Proctor maximum dry density will have lower infiltration capacity and higher structural capacity than a CBR determined at a soil compaction level of 90 percent. Therefore, the design must can use a lower compaction level or none at all and thicken the subbase to adjust for the reduced support from the soil subgrade. Further, in the event that the field density is less than the design density, it may be necessary to decrease the design CBR, which decreases the structural capacity especially when the soil is saturated, requiring a thicker subbase. While not considered in the standard, stabilized bases are also a design option including PA and PC.

Table 1. Base and subbase thickness design chart.

Use/ Parameter	Soaked CBR (%)	3	4	5	6	7	8	9	10
	R-Value	7.5	9	11	12.5	14	15.5	17	18
	Resilient Modulus (MPa)	36	43	49	55	61	67	72	77
Pedestrian Only	Base	150	150	150	150	150	150	150	150
	Subbase	0	0	0	0	0	0	0	0
Occasional Service/Emergency	Base	100	100	100	100	100	100	100	100
	Subbase	150	150	150	150	150	150	150	150
ESALs/TI									
50,000 (6.3)	Base	100	100	100	100	100	100	100	100
	Subbase	175	150	150	150	150	150	150	150
100,000 (6.8)	Base	100	100	100	100	100	100	100	100
	Subbase	275	200	150	150	150	150	150	150
200,000 (7.4)	Base	100	100	100	100	100	100	100	100
	Subbase	425	325	275	225	175	150	150	150
300,000 (7.8)	Base	100	100	100	100	100	100	100	100
	Subbase	500	400	350	300	250	225	200	175
400,000 (8.1)	Base	100	100	100	100	100	100	100	100
	Subbase	550	475	400	350	300	275	250	225
500,000 (8.3)	Base	100	100	100	100	100	100	100	100
	Subbase	600	525	450	400	350	300	275	250
600,000 (8.5)	Base	100	100	100	100	100	100	100	100
	Subbase	650	550	475	425	375	350	300	275
700,000 (8.6)	Base	100	100	100	100	100	100	100	100
	Subbase	700	600	525	450	425	375	350	300
800,000 (8.8)	Base	100	100	100	100	100	100	100	100
	Subbase	725	625	550	500	450	400	375	325
900,000 (8.9)	Base	100	100	100	100	100	100	100	100
	Subbase	750	650	575	525	475	425	400	350
1,000,000 (9)	Base	100	100	100	100	100	100	100	100
	Subbase	775	675	600	525	475	425	400	375

Note: (1) Thickness values given are based on the assumptions outlined.
(2) All thickness values in millimetres.
(3) Additional subbase thicknesses may be required in some areas for frost protection.
(4) Base = ASTM No. 57 Stone, Subbase = ASTM No. 2 Stone

CONSTRUCTION GUIDELINES

PICP construction for vehicular applications follows the steps listed below. The following lists the general construction steps:

- Attend the pre-construction meeting
- Plan site access and keep PICP materials free from sediment
- Excavate soil or an existing pavement
- Avoid soil compaction unless required in the plans and specifications

- Install geotextiles, impermeable liners and drain pipes if required in the plans and specifications
- Place and compact the aggregate subbase
- Install curbs or other edge restraints
- Place and compact the aggregate base
- Place and screed the bedding layer
- Install pavers manually or with mechanical installation equipment
- Fill the paver joints and sweep the surface clean
- Compact the pavers
- Fill joints with jointing stone as needed and sweep the surface clean
- Return within 6 months to inspect pavement and refill joints with aggregate

Commercial and municipal projects specifications often require a pre-construction meeting. The pre-construction meeting is held to discuss methods of accomplishing all phases of the construction operation, contingency planning, and standards of workmanship. The general contractor typically provides the meeting facility, meeting date and time. Representatives from the following entities should be present:

- Contractor superintendent
- PICP subcontractor foreman
- Concrete paving unit manufacturer's representative
- Testing laboratory(ies) representative(s)
- Engineer or representative

The following items is discussed and determined:

- Test panel (mock-up) location and dimensions
- Methods for keeping all materials free from sediment during storage, placement, and on completed areas
- Methods for checking slopes, surface tolerances, and elevations
- Concrete paving unit delivery method(s), timing, storage location(s) on the site, staging, paving start point(s) and direction(s)
- Anticipated daily paving production and actual record
- Diagrams of paving laying/layer pattern and joining layers as indicated on the drawings
- Monitoring/verifying paver dimensional tolerances in the manufacturing facility and on-site if the concrete paving units are mechanically installed
- Testing intervals for sieve analyses of aggregates and for the concrete paving units
- Method(s) for tagging and numbering concrete unit paving packages delivered to the site.
- Testing laboratory location, test methods, report delivery, contents and timing
- Engineer inspection intervals and procedures for correcting work that does not conform to the project specifications.

Sediment Control

Due care shall be applied to prevent and divert sediment from entering the aggregates and pavement surface during construction. Sediment must be kept completely away from aggregates stored on site as well as the PICP. Figure 8 shows a permeable pavement completely clogged after a storm during construction.

Figure 8. Clogged pavement due to lack of adequate protection during construction.

In some cases, it may be necessary to construct PICP before other soil-disturbing construction is completed. The standard provides planning options for sediment control for inclusion in the project specifications: These are as follows:

(1) Construct the aggregate subbase and base and protect the surface of the base aggregate with geotextile and an additional 50 mm thick layer of the same base aggregate over the geotextile. When construction traffic has ceased and adjacent soils are vegetated or stabilized with erosion control mats, remove geotextile and soiled aggregate (or the asphalt) and install the remainder of the PICP system per the project specifications.

(2) Install the PICP first and allow construction traffic to use the finished PICP surface. When construction traffic has ceased and adjacent soils are stabilized with vegetation or erosion control mats, clean the PICP surface and joints with a vacuum machine.

(3) Protect finished PICP system by covering the surface with a woven geotextile and a minimum 50 mm thick ASTM No. 8 open-graded aggregate layer. This aggregate layer and geotextile are removed upon project completion and when adjacent soils are stabilized with vegetation or erosion control mats. The PICP surface is swept clean.

(4) Establish temporary road or roads for site access that do not allow construction vehicle traffic to ride over and contaminate the PICP base materials and/or surface with mud and sediment. Other trades on the jobsite need to be informed on using temporary road(s) and staying off the PICP. The temporary road is removed upon completion of construction and opening of the PICP surface to traffic.

Other practices are noted such as keeping muddy construction equipment away from the PICP, installing silt fences, staged excavation, truck tire washing stations, and temporary drainage swales that divert runoff away from the area.

Construction Checklist

The standard provides a construction list for agency, owner and contractor use:

Pre-construction meeting
- Walk through site with builder/contractor/subcontractor to review erosion and sediment control plan/stormwater pollution prevention plan or SWPPP)
- Determine when PICP is built in project construction sequence; before or after building construction, and measures for PICP protection and surface cleaning
- Aggregate material locations identified (hard surface or on geotextile)

Sediment management
- Access routes for delivery and construction vehicles identified
- Vehicle tire/track washing station (if specified in Erosion & Sediment plan/SWPPP location/ maintenance

Excavation
- Utilities located and marked by local service
- Excavated area marked with paint and/or stakes
- Excavation size and location conforms to plan

Sediment management
- Excavation hole as sediment trap: cleaned immediately before subbase stone placement and runoff sources with sediment diverted away from the PICP, or
- All runoff diverted away from excavated area
- Temporary soil stockpiles should be protected from run-on, run-off from adjacent areas and from erosion by wind
- Ensure linear sediment barriers (if used) are properly installed, free of accumulated litter, and built up sediment less than 1/3 the height of the barrier
- No runoff enters PICP until soils stabilized in area draining to PICP

Foundation walls
- At least 3 m from foundation walls with no waterproofing or drainage

Water supply
- At least 30 m from municipal water supply wells

Soil subgrade
- Rocks and roots removed, voids refilled with permeable soil
- Soil compacted to specifications (if required) and field tested with density measurements per specifications
- No groundwater seepage or standing water, if so, dewatering or dewatering permit may be required

Geotextile (if specified)
- Meets specifications
- Placement and down slope overlap (minimum 0.6 m) conform to specifications and drawings

- Sides of excavation covered with geotextile prior to placing aggregate base/subbase
- No tears or holes
- No wrinkles, pulled taught and staked

Impermeable Liner (if specified)
- Meets specifications
- Placement, field welding, and seals at pipe penetrations done per specifications

Drain pipes/observations wells
- Size, perforations, locations, slope, and outfalls meet specifications and drawings
- Verify elevation of overflow pipes

Subbase, base, bedding and jointing aggregates
- Sieve analysis from quarry conforms to specifications
- Spread (not dumped) with a front-end loader to avoid aggregate segregation
- Storage on hard surface or geotextile to keep sediment-free
- Thickness, placement, compaction and surface tolerances meet specifications and drawings

Edge restraints
- Elevation, placement, and materials meet specifications and drawings

Permeable interlocking concrete pavers
- Meet ASTM/CSA standards (as applicable) per manufacturer's test results
- Elevations, slope, laying pattern, joint widths, and placement/compaction meet drawings and specifications
- No cut paver subject to tire traffic is less than 1/3 of a whole paver
- All pavers within 2 m of the laying face fully compacted at the completion of each day
- Surface tolerance of compacted pavers deviate no more than ±10 mm under a 3 m long straightedge

Final inspection
- Surface swept clean
- Elevations and slope(s) conform to drawings
- Transitions to impervious paved areas separated with edge restraints
- Surface elevation of pavers 3 to 10 mm above adjacent drainage inlets, concrete collars or channels (for non-accessible paths of travel); to 6 mm (for accessibility required paths of travel)
- Lippage: no greater than 3 mm difference in height between adjacent pavers
- Bond lines for paver courses: ±15 mm over a 15 m string line
- Stabilization of soil in area draining into permeable pavement (minimum 6 m) wide vegetative strips recommended)
- Drainage swales or storm sewer inlets for emergency overflow. If storm sewer inlets are used, confirm overflow drainage to them.
- Runoff from non-vegetated soil diverted from PICP surface
- Test surface for infiltration rate per specifications using ASTM C1701; minimum 2.5 m/hr recommended

MAINTENANCE GUIDELINES

The standard provides a maintenance checklist for project owners and facility managers. Like all permeable pavements, regular surface cleaning is key to maintaining surface infiltration rates throughout the pavement life.

- 1 to 2 times annually (typically spring/fall): vacuum surface, adjust vacuuming schedule per sediment loading and/or any sand deposits from winter
- Winter: Remove snow with standard plow/snow blowing equipment; monitor ice on surface for reduced salt use than typically used on impervious pavements
- As needed, indicated by water ponding on surface immediately after a storm (paver joints or openings severely loaded with sediment): test surface infiltration rate using ASTM C1701. Vacuum to remove surface sediment and soiled aggregate (typically 13-25 mm deep), refill joints with clean aggregate, sweep surface clean and test infiltration rate again per C1701 to minimum 50% increase or minimum 250 mm/hr.

Annual Inspection checklist

- Replenish aggregate in joints if more than 13 mm from chamfer bottoms on paver surfaces
- Inspect vegetation around PICP perimeter for cover & soil stability, repair/replant as needed
- Inspect and repair all paver surface deformations exceeding 13 mm
- Repair pavers offset by more than 6 mm above/below adjacent units or curbs, inlets etc.
- Replace cracked paver units impairing surface structural integrity
- Check drains outfalls for free flow of water and outflow from observation well after a major storm

REFERENCES

[1] American Concrete Institute (ACI), "ACI 522 Committee on Pervious Concrete", American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI, U.S.A.

[2] ASCE, "Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways", ASCE/T&DI/ICPI Standard 58-10, American Society of Civil Engineers, Reston, Virginia., www.asce.org/Product.aspx?id=2147489021, 2010.

[3] Hade, J. D. and Smith, D.R., "Permeability of Concrete Block Pavements", in *Proceedings* of the Second International Conference on Concrete Block Paving, Rome, Italy. Pave Italia, www.sept.org/techpapers/618.pdf, 1988.

[4] Madrid, G.G., Giraldo, E.A. and González, G.A., "Water Infiltration Through Concrete Block Pavements up to 26 Years Old", in *Proceedings* of the International Conference on Concrete Block Paving, Sun City, South Africa, Concrete Manufacturers Association of South Africa, www.sept.org/techpapers/1042.pdf, 2003.

[5] AASHTO, "Geotextile Specification for Highway Applications," AASHTO Designation M-288, in Standard Specifications for Transportation Material and Methods of Sampling and Testing, Part IB: Specifications, 31st Edition, American Association for State Highway and Transportation Officials, Washington, DC, 2010, https://bookstore.transportation.org/category_item.aspx?id=MA.

[6] AASHTO, “Guide for Design of Pavement Structures”, American Association of State Highway and Transportation Officials, Washington, DC, https://bookstore.transportation.org/category_item.aspx?id=DS, 1993.

[7] Smith, D.R., “Permeable Interlocking Concrete Pavements”, Interlocking Concrete Pavement Institute, Herndon, VA, 2008.