DEVELOPMENT OF A NATIONAL ASCE STANDARD FOR PERMEABLE INTERLOCKING CONCRETE PAVEMENT

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ABSTRACT.

This paper reviews technical development of the new American Society of Civil Engineers (ASCE) standard for permeable interlocking concrete pavement or PICP. The standard notes key design elements which include high strength, impermeable concrete units for the surface that meet American Society for Testing Materials (ASTM) or Canadian Standards Association (CSA) standards.

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. The draft considers many design variables and how to address them. It resolves a key design consideration common to all three 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.

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

1. 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. Since the early 2000s, the National Pollutant Discharge Elimination System (NPDES) incentivized use of permeable pavements as part of permit compliance required under this national legislation. With years of experience and research, adoption of design guidelines, construction specifications and maintenance guidelines by state and local stormwater agencies continues. State and local transportation agencies are slower in adoption in part due to lack of experience. Such experience needs to be based on national 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 (ACI) for development and distribution of ACI 522 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 (T&DI) has created a comprehensive 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, 2 and 3.

Figure 1. *Parking Lot at Elmhurst College, Illinois*

Figure 2. *Green Alley in Richmond, Virginia*

Figure 3. *PICP Street in Berkeley, California*

The standard complements ASCE 58-10 *Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways* [ASCE 2010]. 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 1988, Madrid 2003] indicates that ICP runoff coefficients typically range between 80 and 95 percent 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

2. Design Goals

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

- ♥ 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 state or local regulations. These include:

- ♥ PICP as a lower-cost alternative to conventional pavement and drainage system designs
- ♥ Stormwater utility fee credits or cost-sharing
- ♥ State or local building codes that address pavements such as the International Green Construction Code, ASHRAE Standard 189.1 or CALgreen

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 Institute for Sustainable Infrastructure's Envision™, Greenroads, GreenPa

Highway Administration INVEST or Infrastructure Voluntary Evaluation Sustainability Tool.

3. 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 intermittent and perennial 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 NPDES, 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 percent 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**.**

3.1 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 to infiltrate water 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 8 cm. 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 meeting the gradation requirements for ASTM No. 8, 89 or 9 material. 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 10 cm thick and made of crushed stone primarily 2.5 cm down to 1.3 cm. 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 7.5 cm down to 5 cm, 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.

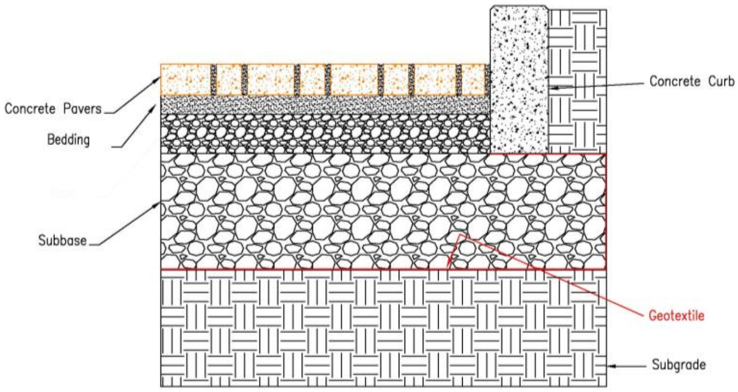

Figure 4. PICP with full infiltration design

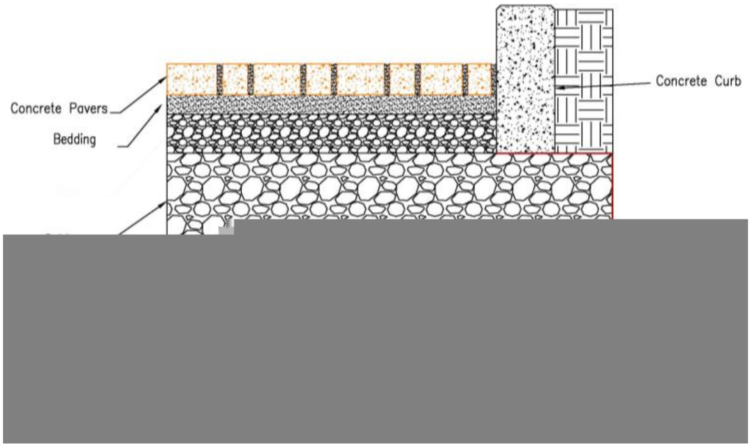

Figure 5. *PICP with a partial infiltration design using an underdrain*