Memo

Christopher J. Webb PE
• Civil Engineering
• Sustainable Design
• International Development

Christopher Webb P.E. Inc. P.S.
PO Box 1721, Bellingham, WA 98227-1721 USA
Phone: (360) 752-0088 Fax: (360) 752-5767
chris@christopherjwebb.com

To: Scott Erickson
Quality Concrete

Date: Tuesday, July 19, 2005

Cc:

From: Christopher J. Webb, PE

Re: A discussion of the stormwater treatment capability of Pervious Cement Concrete (PCC) Pavement

Introduction. This memo is written to discuss the stormwater treatment capabilities of Pervious Cement Concrete (PCC) pavement. The use of PCC pavement can reduce or eliminate stormwater run-off from paved areas and provide groundwater recharge.

PCC Pavement is a portland cement based concrete mixture that has open-graded coarse aggregate with no fines. The absence of fines leaves enough void space to allow rapid infiltration of rainwater. According to the National ready Mix Concrete Association "Pervious Concrete is a special type of concrete with a high porosity used for concrete flatwork applications that allows water from precipitation and other sources to pass through it, thereby reducing the run-off from a site and recharging groundwater levels. The porosity is attained by a highly interconnected void content. Typically pervious concrete has little to no fine aggregate and has just enough cementitious paste to coat the course aggregate particles while preserving the interconnectivity of the voids. Pervious concrete is traditionally used in parking areas, areas with light traffic, pedestrian walkways, and greenhouses."

Water quality issues. The ability of PCC pavement to provide acceptable stormwater quality depends on 1. siting, 2. design and construction, and 3. maintenance. The proper siting of PCC pavement depends on both the existing site soils conditions and the layout of the proposed development. The criteria for acceptable soils are outlined below in the design criteria section. In terms of the layout of the PCC pavement on a site, it is important that the PCC pavement not be used on projects where a high impact use is anticipated (i.e. gas stations, mini-marts, commercial truck parking areas, areas with heavy industrial activity (as defined by US EPA regulations), or areas with high pesticide use. Further, it is important that the PCC pavement not be used in areas of a project where a heavy sediment load is anticipated, such as areas used to store landscaping materials, or adjacent to unpaved areas subject to vehicle travel to and from the PCC paved areas, etc. Proper design and construction is necessary to ensure subsoils and the pavement material itself has the proper void ratio and infiltration rates following construction. And finally maintenance of the PCC pavement will ensure its water quality performance over time. Typically this maintenance entails twice annual vacuum sweeping with a simple small vacuum sweeper vehicle such as the Tymco 210 (http://www.tymco.com/mod210.html.)

Stormwater treatment mechanisms. The stormwater filtration capability of the PCC pavement occurs in both the pavement matrix itself, the pavement base materials, and the upper horizon of the subbase soils. In contrast to typical stormwater filtration BMP's, the use of PCC pavement allows the stormwater pollutants to remain diffuse. The non-concentrated nature of the stormwater pollution with PCC pavement allows the latent treatment capability of much larger areas to be used than with traditional off-line treatment BMP's which receive concentrated flows from larger areas.

As stated in a 1999 USEPA fact sheet (EPA 832-F-99-023), "Porous pavement pollutant removal mechanisms include absorption, straining, and microbiological decomposition in the soil. An estimate of porous pavement pollutant removal efficiency is provided by two long-term monitoring studies conducted in Rockville, MD, and Prince William, VA. These studies indicate removal efficiencies of between 82 and 95 percent for sediment, 65 percent for total phosphorus, and between 80 and 85 percent of total nitrogen. The Rockville, MD, site also indicated high removal rates for zinc, lead, and chemical oxygen demand."

Research by Thelen and Howe suggest "aerobic bacteria within the soil consume and reduce organic matter…populations can thrive under Pervious pavement if the underlying soils get a chance to dry out every few days." (Scheuler, 1987) In a 1977 report, the US EPA found that "most of the sorption occurs within the first foot of soils, and is bound up for long periods of time." (Scheuler 1987). The Washington State Department of Ecology 2001 Stormwater Management Manual states: "Pervious concrete provides runoff treatment through filtration and allows for ground water recharge… mimics natural soils filtration throughout the pavement depth, underlying sub-base drainage filter, and native soils for improved groundwater quality."

Regulatory Issues. The use of pervious concrete pavement is discussed in Volume V of the 2001 and 2005 editions of the Washington State Department of Ecology Stormwater Manual for Western Washington. The manual states "Permeable/porous pavements can be used in place of traditional concrete or asphalt pavements in many low traffic applications". Prior to the 2005 edition, the manual contained best management practice information for the use of PCC pavement (BMP T5.40 Porous Concrete and Porous Asphalt). A copy of this BMP from the 2001 edition of the manual is provided for reference at the end of this memo. This BMP was removed from the 2005 manual due to the publication of the "Low Impact Development: Technical Guidance Manual for Puget Sound" by the Puget Sound Action Team (PSAT). Readers are referred now to the PSAT manual for guidance on the design and installation of all LID approaches such as PCC pavement (see additional information section below).

Design criteria for water quality. In addition to design for the hydraulic and structural performance of the pavement, the following water quality criteria for the subbase soils are recommended in the BMP.

1. a long-term infiltration rate of 0.25 – 2.4 inches per hour
2. a cation exchange capacity of 5 milliequivalents CEC/100 grams dry soil (based on organic content and related to the subsoil's ability to adsorb pollutants
3. a minimum depth to groundwater, bedrock, or other confining layer of 36" (min.)

Summary and Conclusions. The use of PCC pavement is a promising technology to enhance groundwater recharge and reduce the negative environmental problems associated with run-off from pavement. With prudent siting, design and construction, and maintenance PCC pavement can provide a high degree of stormwater quality and flow control.

Additional information:

Concrete in Practice #38 National Ready Mix Concrete Association	http://www.nrmca.org/aboutconcrete/cips/38p.pdf
USEPA Storm Water Technology Fact Sheet: Porous Pavement (EPA 832-F-99-023)	http://www.epa.gov/owmitnet/mtb/porouspa.pdf
"Low Impact Development: Technical Guidance Manual for Puget Sound" by the Puget Sound Action Team (PSAT) pp. 142	http://www.psat.wa.gov/Publications/LID_tech_manual05/LID_manual2005.pdf
Florida Concrete Products Association (see publications)	www.fcpa.org
Portland Cement Association (see publications)	www.cement.org

5.3.4 Permeable/Porous Pavements

The BMPs described in this section relate to the use of porous and permeable concrete and asphalt.

BMP T5.40 Porous Concrete and Porous Asphalt

Purpose and Definition

Porous concrete, also known as "no fines concrete," is a special type of concrete that allows stormwater to pass through it, thereby reducing the runoff from a site. In addition, porous concrete provides runoff treatment through filtration and allows for ground water recharge.

Porous concrete or "No Fines Concrete Paving" is a structural, open textured pervious concrete paving surface consisting of standard Portland cement, fly ash, locally available open graded coarse aggregate, admixtures, fibers, and potable water. When properly handled and installed, porous concrete has a high percentage of void space (approximately 17% - 22%) which allows rapid percolation of stormwater through the pavement. Figure 5.6 illustrates a porous concrete paving section.

Porous asphaltic paving material consists of an open graded coarse aggregate cemented together by asphalt cement into a coherent mass, with sufficient interconnected voids to provide a high rate of permeability to water. Figure 5.7 illustrates a porous asphalt paving section.

Applications and Limitations

At the time of publication of this manual, use of Porous Asphalt and Porous Concrete do not qualify for flow control credits. The Permeable pavement buttons in the Western Washington Hydrology Model (WWHM) should not be used for these applications.

Porous concrete and asphalt pavements are a replacement for conventional asphalt pavement or other hard paving surfaces provided that the grades, subsoil drainage characteristics and ground water table conditions are suitable for its use:

- Not recommended on slopes greater than 5 percent and best with slopes as flat as possible
- The minimum infiltration rate in the subsoils should be 0.25 inches per hour. Infiltration rates less than 2.4 inches per hour and a cation exchange capacity of 5 milliequivalents CEC/100 grams dry soil or greater) will provide water quality treatment in the subsoils.

- Minimum depth to bedrock and seasonally high water table should be 3 feet.

Possible areas for use of this paving material include:

- Commercial, public, and municipal parking lots, including perimeter and overflow parking areas;
- Parking aprons, taxiways, and runway shoulders at airports;
- Vehicle access areas, including roadway shoulders, medians, fire lanes, on-street parking areas, emergency stopping lanes, and vehicle cross-overs on divided highways;
- Low-speed residential roads;
- Residential driveways, patios, sidewalks, and sport courts;
- Sidewalks, bicycle trails, golf cart paths, community trail/pedestrian path systems, or any pedestrian accessible paved area,
- Areas where additional drainage capabilities are desired with improved structural capacity such as soccer fields, open space areas, or drainage fields; and
- Fill or underlayment for precast, modular paver, or grid systems.

This BMP functions as an infiltration and retention area that can accommodate pedestrians, light and heavy load parking areas, is applicable in most impervious applications in both residential and commercial applications. This combination of functions offers the following benefits:

- Allows site precipitation to reach the root systems for plants and vegetation;
- Mimics natural soils filtration throughout the pavement depth, underlying subbase drainage filter and native soils for improved groundwater quality;
- Reduction of surface water runoff temperatures;
- Increased recharge of groundwater;
- Allows for natural infiltration characteristics of native are soils;
- Elimination of typical random cracking patterns commonly found in improperly jointed concrete;
- Year round construction ability; and
- Use of locally available aggregates.

Handling and placement practices for porous concrete are different from conventional concrete placement. Placement should be completed by contractors with experience in placing porous concrete. In the absence of experience in placement, contractors should be required to view instructional porous concrete construction videos.

If perimeter, narrow, or integral porous concrete strips are to be used in conjunction with “hard” pavements, drainage curtains should be provided to prevent water migration under adjacent paved areas. Consideration should also be given to areas immediately adjacent to porous concrete edges to minimize spill over of soils or other easily dislodged fine particles.

Pervious pavements should not be used in high vehicle traffic areas. Further, Some building codes may not allow for the installation of porous pavement.

Design Criteria

- Drainage time for the design storm: minimum is 12 hours, maximum is 72 hours, recommended is 24 hours.
- Run-on to the pavement from off-site areas is not allowed.
- On-site soils should be tested for porosity, permeability, and cation exchange capacity. These properties should be considered when designing the subbase layer.
- Subgrade soils should be uniformly compacted and prepared in accordance with other pavement design considerations.
- The gradation required to obtain a porous concrete pavement is of the “open” graded or coarse type. Generally 5/8” or 3/8”inch minus crushed materials are preferred. Readily available aggregates should be considered as not all gradations are locally available. Recycled aggregates are encouraged for open graded subbase materials.
- Local guidelines relating to specifying and constructing and suggested design procedures for use of pervious concrete is available through the Washington Aggregates & Concrete Association, 399 114th Ave. NE, Bellevue, WA 98004 (or through the website at www.washingtonconcrete.org). These suggested guidelines will assist material suppliers, contractors, specifying agencies and design professionals in the proper procedures used to place porous concrete.

Operation and Maintenance

- Routine maintenance involves removal of debris that is too coarse to be washed through the pavement system. Vacuuming pavement is required to remove particulates that are fine enough to be carried into the pavement but too large to pass through, thus clogging the void space. Porous pavements require no more repair maintenance than conventional pavements, so maintenance problems can generally be reduced to better "housekeeping" practices on the part of area residents and more efficient street cleaning procedures in municipalities.

- Pervious pavements may have a tendency to clog if improperly maintained. Maintenance procedures include standard vacuum trucks, street sweepers, leaf blowers, and other practices to remove or prevent leaves, needles, or other foliage from collecting in parking areas and streets. Should clogging occur, it is usually limited to spot areas. Remedies include localized vacuuming and power washing and, in severe cases, the clogged area may be removed and replaced.
- Clogging can be prevented by waiting until all other phases of construction are complete; covering and protecting until all landscaping, topsoil import, or hydroseeding are complete; avoiding areas where any pervious pavement would not be successful; and by regular inspection and preventive maintenance practices.
- If spills occur, they should be immediately vacuumed up followed by a pressure wash or other appropriate rinse procedure. This treatment will restore permeability to almost prespill levels (95 percent).

Resource Material

Virginia State Water Control Board, Best Management Practices Handbook: Urban, Planning Bulletin 321, Richmond, Virginia, 1979.

Thelen, E. and L.F. Howe, Porous Pavement, The Franklin Institute Press, Philadelphia. PA, 1978.

Thelen, E. et al., Investigation of Porous Pavements for Urban Runoff Control, prepared by the Franklin Institute Research Laboratories for the U.S. Environmental Protection Agency, NTIS PB-227-5, Springfield, VA, 1972.

Smith, R.W., J.M. Rice and S.R. Spelman, Design of Open Graded Asphalt Friction Courses, Federal Highway Administration, U.S. Department of Transportation, FHWA-RD-74-2, 1974.

United States Environmental Protection Agency, Storm Water Technology Fact Sheet, Porous Pavement, EPA 832-F-99-023, September 1999.

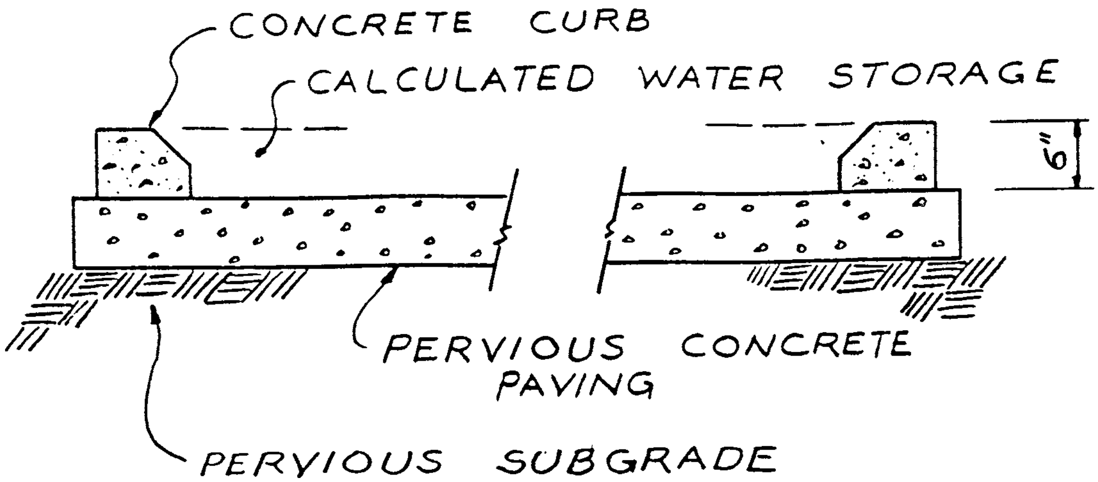

Figure 5.6 Porous Concrete Pavement Typical Section

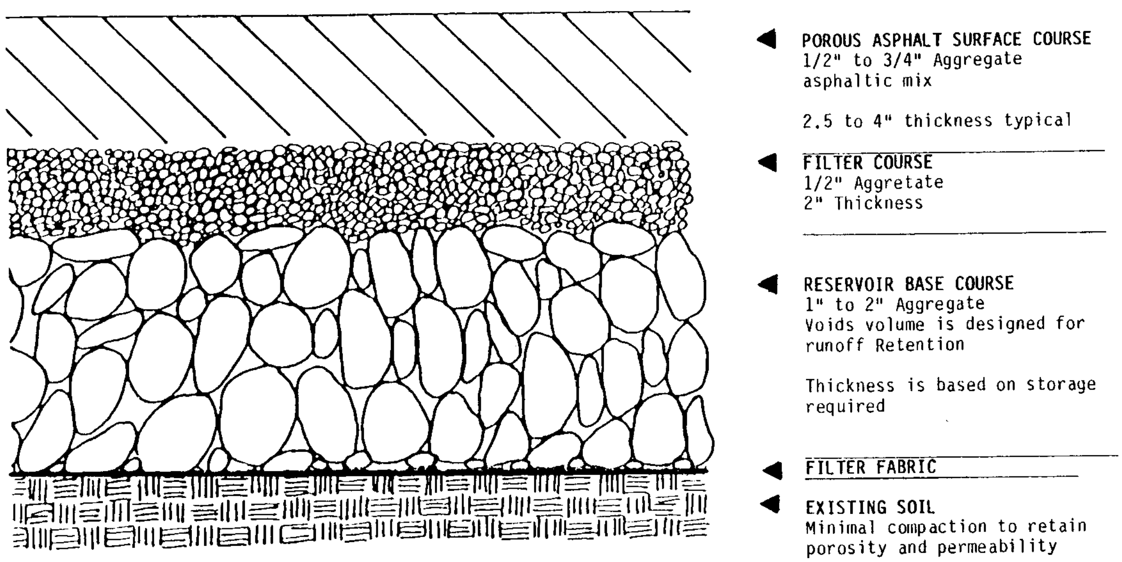

Figure 5.7 Porous Asphalt Pavement Typical Section