APPENDIX D – GREEN INFRASTRUCTURE

Porous Pavement

Overview

A porous paved surface is one that is designed to absorb stormwater and allow it to return to the ground, as opposed to a non-porous paved surface, which is designed to repel water and direct it toward a storm drain. Porous pavements can be achieved through a variety of different materials, including pervious concrete, porous asphalt, and permeable pavers. The function of the paved porous surface is to act as a hard, durable surface that can be walked or driven on, but that also permits stormwater to pass through it into subsurface layers of crushed stone. While a typical, non-porous pavement section also sits on a bed of crushed stone, this layer is normally compacted to be as dense as possible, providing the strongest possible foundation for the paved surface. With porous pavements, the crushed stone bed is not compacted to this degree. The rock layer is deeper than in standard construction (two to four feet), and it is designed with lots of gaps between the stones: up to 40 percent of the subsurface can be "void" space. Sometimes called a recharge bed, this layer of stones allows water to filter through and into the underlying water table.

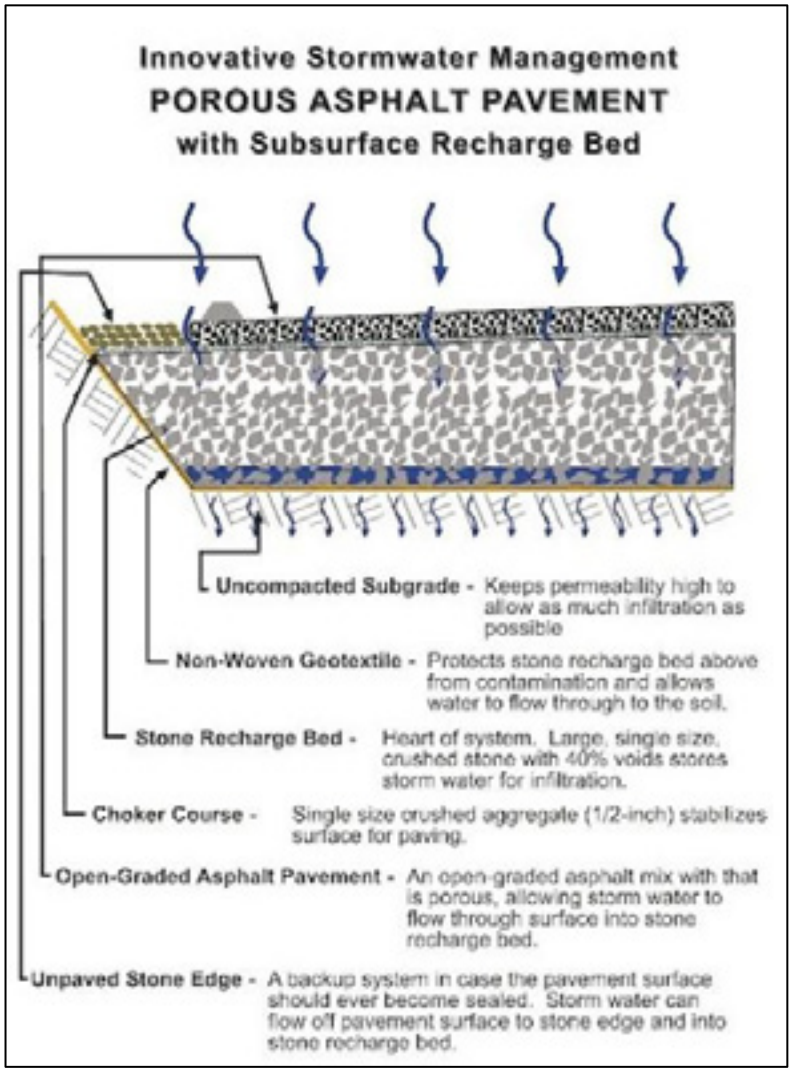

Figure D-7-3: Porous Asphalt Cross-Section
Source: National Asphalt Pavement Association

Porous asphalt and concrete are frequently compared to a Rice Krispies™ treat, because they consist of relatively coarse particles of aggregate (crushed rock) glued together with either asphalt or cement. Fine particles, such as sand, are either not used or are used in smaller proportions than in impervious surfaces. The texture of these pervious surfaces is rougher than impervious concrete or asphalt.

In the case of porous pavers, the paved surface itself is not (necessarily) porous or pervious, but the gaps between the pavers is intended to be wide enough to allow stormwater to pass through. The sand or gravel mixture between the pavers is not glued together with polymeric fillers. While this improves water infiltration, it can also mean that the material between pavers is washed away or vacuumed up during maintenance.

Because of the lack of subgrade compaction, porous pavements are not normally used in mainline roads that carry heavy truck traffic. The depth of the subgrade can be adjusted to provide greater stability, but standard applications are for parking lots, sidewalks and the parking lanes of city streets.

Figure D-2: Grand Avenue Porous Pavement Sidewalk Test Segment

Source: OCWEP / Save the Rain

Benefits and Costs

There are numerous benefits associated with porous pavements, including reduced costs for off-site stormwater treatment, reduced need for salting during the winter months and increased traction. Combined with other technologies, such as structural soils or a suspended sidewalk, the use of porous pavement design can reduce or eliminate conflicts between tree roots and sidewalks.

STORMWATER TREATMENT

Porous pavements can significantly reduce stormwater treatment costs. As stated in the National Cooperative Highway Research Program's *Evaluation of Best Management Practices for Highway Runoff Control,* "Permeable pavements are a unique stormwater control technique because the infrastructure is the BMP." When implemented properly, porous pavements can reduce the need for other forms of on-site stormwater mitigation, such as retention ponds and drainage to off-site treatment plants. Many studies agree that, when combined with savings in stormwater management, the overall costs of porous pavement are similar to or lower than conventional paving materials.

ICE AND SNOW CONTROL

When snow melts on a pervious cement sidewalk, it is absorbed by the sidewalk itself and will not re-freeze on the sidewalk's surface. For this reason, standard ice control methods, such as the use of rock salt, is either not necessary or can be greatly reduced.

DURABILITY AND CLIMATE

In cold weather climates such as in Central New York, porous pavements show durability comparable to that of impervious asphalt and concrete. Because porous pavements are designed to allow water flow through, there is insufficient moisture in the paved material to result in pavement heaving or cracking as a result of freeze-thaw cycles. Also, at least one study has shown that porous pavements have a warmer subgrade and fewer freeze-thaw cycles than impervious pavement, possibly as a result of air trapped in the base material.[6] Figure D-3 shows a comparison between two parking lots on a winter day. One hour after plowing, there is less snow on the porous pavement lot (left) than on the dense graded asphalt lot (right). In the context of sidewalks, this may suggest that porous pavement sidewalks would

Figure D-3 - Porous asphalt (left) and dense mixed asphalt (right) parking lots shown one hour after plowing on a 25° F day in February, 2007. Source: University of New Hampshire Stormwater Center

Figure D-4 - Porous asphalt (left) and dense mixed asphalt (right) parking lots shown after a spring rain on snow event Source: University of New Hampshire Stormwater Center

[6] "Subgrade Temperature and Freezing Cycles in Pervious Pavements", *Cold Regions Engineering 2009, ASCE*. 2009.

PEDESTRIAN SAFETY

A study in the journal *Safety Science* concludes that there is "preliminary support for the use of pervious concrete as a slip-resistant walking surface in areas of high pedestrian traffic where slip and fall injury are likely during inclement weather."[7] The study took biomechanical readings of adults as they walked across both porous and non-porous concrete surfaces and determined that the porous surface was more slip-resistant in icy conditions. This suggests that an added advantage to the use of porous pavements in Central New York could be a reduction in pedestrian slip and fall accidents.

TREE ROOT CONFLICTS

Porous pavement systems include modifying both the walking surface and a considerable amount of subgrade material, which presents an opportunity to give tree roots room to grow without causing cracks and buckling in the sidewalk itself. "Suspended sidewalks" are built on supports that prevent the sidewalk from compacting the soil below. The area below the sidewalk can be filled with well-aerated, high-quality soil.[8]

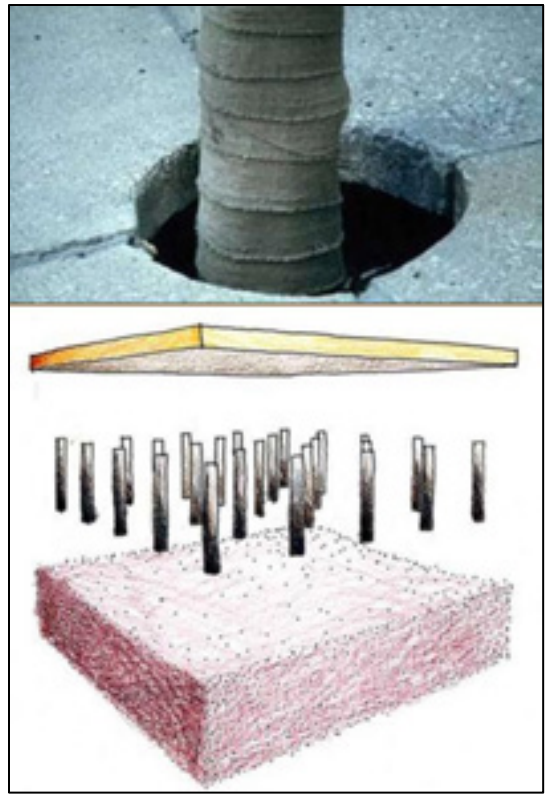

Figure D-5: A "suspended" sidewalk is built on vertical stabilizers that provide the sidewalk with structural support while giving tree roots room to grow

Source: Urban design for a wind resistant urban forest

CONSTRUCTION COSTS

Estimates of the difference in cost between porous pavement and non-porous pavement vary widely. In theory, there should be very little difference between the costs of the paving materials themselves, because they are produced using the same methods and materials as impervious pavements. However, the limited demand for these products means that they must be manufactured separately and generally in smaller quantities, making it difficult to achieve the economies of scale found in the production of impervious asphalt and concrete. Similarly, the techniques used to install these materials properly can be difficult for contractors to adjust to, because the materials and construction specifications are relatively new and may be unfamiliar to individual contractors.

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[7] "Slip-related characterization of gait kinetics: Investigation of pervious concrete as a slip-resistant walking surface", *Safety Science*, January 12, 2013.

[8] *Urban design for a wind resistant urban forest*, University of Florida, Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service, School of Forest Resources and Conservation and the Environmental Horticulture Department, Urban Forest Hurricane Recovery Program series. September 2007.

The question of cost difference is also confounded by the fact that, as noted earlier, porous pavements are a Best Management Practice for stormwater reduction. The stormwater captured in a porous pavement system is stormwater that does not need to be captured and managed elsewhere in a project. Properly planned, sited and constructed, a porous pavement system can mean the elimination of other infrastructure, such as pipes to a sewer system, retention ponds, and swales.

A 2007 article in the journal *Landscape and Urban Planning* identified porous pavement sidewalks and parking lots as the most cost-effective low impact development (LID) system for managing stormwater.[9] This article, focusing on options within a heavily urbanized area, compared porous pavements to green roofs, rainwater harvesting techniques and underground storage tanks.

Comparing only the cost of installing a square foot of porous pavement sidewalk, which is also a stormwater BMP, to the cost of installing a square foot of traditional concrete, which increases impervious surface and adds to total runoff, is misleading. An analysis conducted by the City of Olympia in 2005 took into consideration the total long-term maintenance costs of adding a stormwater retention pond to offset the addition of impervious surface when traditional concrete is used in sidewalks. This analysis indicated that "the cost per yard for traditional concrete sidewalk is $101.16 per square yard and the cost for pervious concrete sidewalk is $54.16 per square yard."[10] This analysis shows higher costs for the installation of a square yard of porous pavement compared to a square yard of traditional concrete: porous pavement is about 50 percent more expensive to install. However, the cost savings for a large project in an urbanized area with few alternatives for stormwater management more than offset these costs.

CONSTRUCTION ISSUES

Porous concrete is hard to batch and hard to place. A successful project needs good quality control at the batch plant, cement truck drivers who are familiar with the materials and experienced workers to do the application.[11] Locally, because the Save the Rain initiative has funded so many permeable pavement projects, it has meant that several local contractors have gained experience with these materials and processes.

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[9] *"Rapid assessment of the cost-effectiveness of low impact development for CSO control"*, Landscape and Urban Planning, Volume 82, Issue 3, September 24, 2007.

[10] "Traditional versus Pervious Concrete Sidewalks Construction and Maintenance Cost", memo from City of Olympia Project Engineer II Melissa McFadden to City of Olympia Stormwater Engineering Supervisor Andy Haub. February 11, 2005.

[11] "*Porous Concrete Sidewalks - How to Build Sidewalks and not Stormwater Ponds*"

"Generally the more engaged the batch plant is in the pervious concrete project, the more likely the product will be successful. A pre-batch meeting with all parties, as well as feedback about the quality of the material batched, is helpful."[12]

Conflicts with Ordinances

It is not unusual for local ordinances to specify the type of material to be used in sidewalk construction (see Table 3.3). For example, in the Village of Jordan, regulations specify that sidewalks should be built out of concrete with 3,000 pounds minimum strength and a "1-2-4" mix, which specifies the proportions of cement, fine aggregates and coarse aggregates in the concrete.

To date, in Onondaga County, porous pavement sidewalk installations have occurred largely through variances and other special permissions. As these materials and processes become more widely accepted as a means of both accommodating pedestrians and managing stormwater, local ordinances must adapt and include new types of materials. Until then, planned porous pavement installations should be discussed with local public works officials.

Maintenance

Over time, dirt, dust and debris can reduce porous pavements' porosity, reducing its effectiveness in absorbing stormwater. Even when clogged, however, studies have shown that "surface infiltration rates usually well exceed 1 inch per hour, which is sufficient in most circumstances for the surface to effectively manage intense stormwater events."[13]

The Onondaga County Department of Water Environment Protection (OCWEP) recommends using a power vacuum twice a year to remove sediment build-up in porous pavements, maximizing stormwater absorption. OCWEP has developed an extensive set of procedures for maintaining green infrastructure.

An analysis conducted for OCWEP put the cost of renting a small (23 to 30 inch effective vacuuming width) power-driven vacuum sweeper at $2,000 a month. This analysis also estimates the cost of buying a smaller walk-behind unit, appropriate for use on sidewalks, at between $9,000 and $10,000.

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[12] Ibid.

[13] USEPA Stormwater Menu of BMPs, online resource. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=135

Location Considerations

Porous pavements work best when stormwater that falls on the porous surface has time to infiltrate into the recharge bed, and in places where sediment loading from adjacent land uses is minimal. In other words, flat areas surrounded by lots of impervious surfaces are optimal locations for something like a porous pavement parking lot. In areas where there is a lot of dirt and dust, these sediments can clog the pavement's pores, reducing infiltration and requiring increased maintenance. Additionally, less costly BMPs, such as swales, may be appropriate in areas where there is sufficient right-of-way to accommodate them into the street's cross-section.

More Information

- *Porous Concrete Sidewalks - How to Build Sidewalks and not Stormwater Ponds,* ITE District 6 Annual Meeting
  Documents experiences in Olympia, Washington, with porous pavement sidewalks and provides some helpful guidance on planning, constructing and maintaining porous pavements.
  http://olympiawa.gov/~/media/Files/PublicWorks/Water-Resources/ITE%20Pervious%20Concrete%20Sidewalk%20Paper.ashx

- *Stormwater Menu of Best Management Practices*, National Pollutant Discharge Elimination System, USEPA
  Includes a section summarizing porous pavement specifications, benefits and costs with a short bibliography.
  http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=135

- *Urban design for a wind resistant urban forest*, University of Florida
  Street tree selection to minimize conflicts between tree roots and sidewalks.
  http://hort.ufl.edu/woody/documents/EP309.pdf

- *Stormwater Management Handbook*, US Environmental Protection Agency
  Chapter 5 of this handbook presents examples of streetscape improvements that minimize stormwater runoff, including porous pavement sidewalks and street trees.
  http://www.epa.gov/dced/pdf/northern_kentucky_ch5-6.pdf