Porous Asphalt Pavement

An Online Continuing Education Course for Engineers

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Porous Asphalt Pavement

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INTRODUCTION

An undesirable consequence of urban development is the replacement of natural landscape with anthropogenic surfaces, most notably in the form of impervious pavements: roads, parking lots, driveways, walkways, and other "hardscapes." This transformation of natural, undisturbed terrain into man-made pavement drastically alters the hydrologic characteristics of a watershed. Surface water cannot infiltrate these impervious surfaces, which increases runoff into gutters, storm sewers, and other engineered collection systems. Runoff eventually discharges into common waterways: streams, lakes, estuaries, wetlands, aquifers, or even the ocean. Urban runoff degrades water quantity and quality. Regarding quantity, high runoff can exceed the infrastructure's capacity to store and convey it, causing erosion and overflows, particularly combined sewer overflows. Regarding quality, runoff transports not only debris, but also dissolved and suspended contaminants, and can even change the temperature of the receiving waterway. All these effects denigrate water quality and adversely impact flora & fauna that are sensitive to changes in their aquatic ecosystems.

Fortunately, low impact development (LID) can mitigate the hydrologic effects of the built environment. LID refers to techniques that use or mimic natural processes that result in the infiltration, evapotranspiration, or collection of stormwater to protect water quality and associated aquatic habitat. One such LID practice is **porous asphalt pavements (PAP) with stone reservoirs.** PAP owes its permeability to both the asphalt layer at the surface as well the aggregate gradation underneath. Porous asphalt pavements use open-graded mixes placed atop a stone reservoir. Rainwater flows down through the open-graded mix layers into the stone reservoir where it can then infiltrate into the subgrade.

Not only does PAP provide a strong pavement surface for parking, walkways, trails, and roads; but PAP can also be designed to manage and treat stormwater runoff. With proper design, construction, and maintenance; PAP can provide a cost-effective solution for stormwater management and can reduce net environmental impact for a project.

PAP Basics

Unlike conventional pavements, porous asphalt pavements are typically built over an uncompacted subgrade to maximize infiltration through the soil (Figure 1). Above the uncompacted subgrade is a geotextile (i.e. filter fabric), which prevents the migration of fines from the subgrade into the stone reservoir while still allowing for water to pass through. The next layer is a stone reservoir (a.k.a. recharge bed) consisting of uniformly graded, clean crushed stone with 40% voids serving as a structural layer and to temporarily store water as it infiltrates into the soil below. Then, to stabilize the surface for paving, an optional thin layer (≈ 1 inch) of clean, smaller, single-size crushed stones is often placed on top; this is called the stabilizing course or choker course. The last layer consists of one or more layers of open-graded asphalt mixes with interconnected voids, allowing water to flow through the pavement into the stone reservoir. These open-graded asphalt layers consist of asphalt binder, stone aggregates, and other additives. By excluding fines, the open-graded mixture allows for more air voids; typically, 16% to 22%.

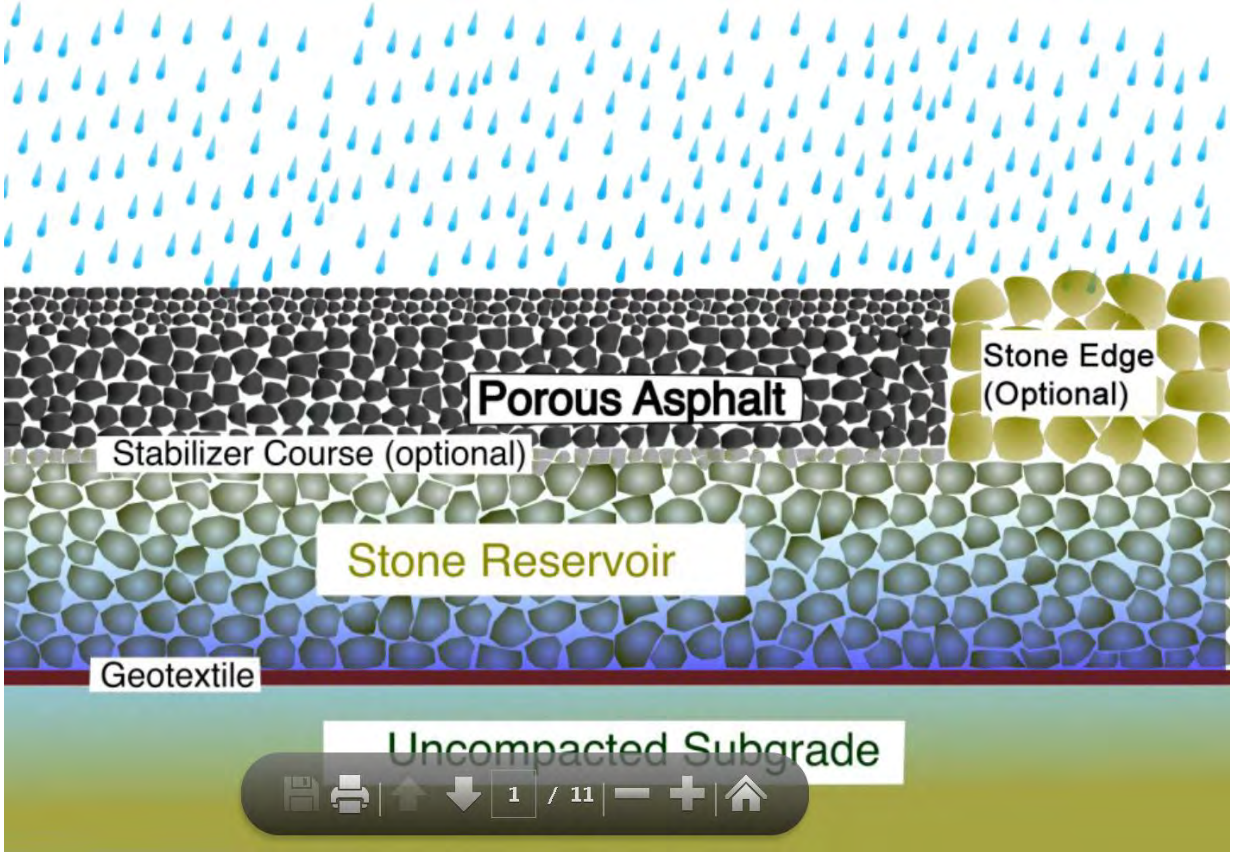

Figure 1. Typical PAP cross-section; courtesy FHWA.

Benefits

1. Stormwater Management

By far, the pivotal reason to use PAP in lieu of conventional pavement is to improve stormwater management – both in terms of *quantity* and *quality*.

Regarding water quantity, PAP can significantly reduce stormwater runoff volume and peak flow, ensuring better compliance with National Pollutant Discharge Elimination System (NPDES) permitting and prevention of combined sewer overflows. Designs that leverage subgrade infiltration can also facilitate groundwater recharge.

Regarding water quality, many suspended and dissolved contaminants are filtered as the stormwater percolates downward through the porous asphalt, stone reservoir, and subgrade soil. Further degradation of organic compound is possible via long-term microbial digestion (i.e. natural attenuation). Such filtration and treatment of contaminants may enable discharges into receiving waterways to stay below Total Maximum Daily Loads (TMDLs).

The permeability of PAP also means that stormwater will not puddle on the surface, which is a nuisance for pedestrians. Liability from slipping on ice is reduced because when snow melts it often infiltrates rather than refreezing should temperatures drop.

2. Cost and Site Utilization

PAP may provide sufficient storage and infiltration of stormwater to reduce or eliminate the need for detention/retention ponds, culverts, sewers, pipes, and other drainage infrastructure. As part of a larger project, these reductions in project scope can lower life-cycle costs and substantially reduce development footprint.

3. Sustainability Certification

Reduction in both stormwater runoff and heat island effect may earn points toward certification for projects that are registered with industry-recognized rating systems, such as the U.S. Green Building Council (USGBC) Leadership in Energy & Environmental Design (LEED). Additional points are possible for using locally available aggregate.

4. Winter

The gradation of aggregate in the stone reservoir renders considerable voids between stones. These voids render a capillary barrier that attenuates vertical movement of water as well as provide space for water to expand upon freezing. Hence, the risk of damage from frost heaving is significantly reduced. Furthermore, snow and ice melts faster on PAP than conventional pavement, thereby reducing usage of deicing salts.

5. Traffic Safety

Because water cannot accumulate on the surface of PAP, there is less tire spray and therefore better wet-weather visibility. Hydroplaning is also mitigated.

Limitations & Considerations

- Erosion and sedimentation control of adjacent areas is crucial. Potential clogging with dirt and organic debris requiring specialized maintenance such as vacuuming or other cleaning mechanisms.
- Related to the previous bullet, PAP is not appropriate for dirty sites that are subject to fines and dust deposited by rain, wind, or vehicles. Accumulation of fine particles can clog the PAP aggregate voids and degrade the pavement's ability to store and exfiltrate surface water.
- PAP is not appropriate for sites designated to store hazardous materials. Any spills or leaks of HAZMAT can easily penetrate PICP and contaminate the subsurface. Impervious pavement with spill containment is preferable.
- Sloped pavements require extra design considerations; such as terraced parking, underground berms, and drainage pipes at low points.

DESIGN

The essential purpose of PAP design is to determine thicknesses of the constituent layers. As such, design is performed with three approaches:

- Site considerations to ensure that the site is acceptable
- Hydrologic design to ensure the porous pavement meets the potential stormwater runoff demands
- Structural design to ensure that the porous pavement withstands the anticipated traffic loading.

Most often, thickness of the stone reservoir will be controlled by the water quantity (hydrologic design) and soil infiltration rates (site considerations); while the porous asphalt surface layer will be determined by the traffic loads (structural design).

Site Considerations

The location of porous pavements should be considered early during the design process. Contrary to conventional construction pavement siting, porous pavements perform best on upland soils (Cahill et al. 2005). Additional site considerations include soil types, depth of bedrock, pavement slope, and additional sources of runoff. General site guidelines include the following:

- Avoid building on landfills or areas that may be subject to hazardous material spills, such as fueling areas.
- Soil infiltration rates of 0.1 to 10 inches/hour (0.5 inches/hour is recommended by EPA). Do not place over known sinkholes.
- Minimum depth to bedrock or seasonal high water should be greater than 2 feet.
- Frost depth should be considered. The University of New Hampshire Stormwater Center (UNHSC) 2014 design specification recommends that the total thickness of the pavement - measured from the asphalt surface to the bottom of the stone reservoir – should be at least 65% of the local frost depth. Other projects have used lesser pavement thicknesses without damage from frost heave, such Swarthmore College, PA and Walden Pond Visitor Center, MA.
- The bottom of the infiltration bed should be flat to maximize the infiltration area and reduce the amount of stone required. For roads, it may be necessary to construct berms under the pavement surface to retain water on slopes and install drains/overflows at low points.
- Porous pavements work best on flat or gently sloping areas; as such, the slope of the porous pavement surface should be less than 5%. For slopes, greater than 5%, the parking areas should be terraced with berms in between.
- Impervious to pervious areas should be less than a 5:1 ratio for most conditions or 3:1 for sinkhole-susceptible areas (karst formations).
- Early in the design process, look for opportunities to use the stone reservoir to infiltrate stormwater from nearby impervious areas on the site, as shown by the example in Figure 2. Stormwater runoff from the roof (A) and driveway (B) are conveyed directly to the stone reservoir, where a perforated pipe (D) distributes the stormwater evenly in the reservoir. Simultaneously, the reservoir also receives stormwater from direct precipitation on the porous asphalt surface (C). Stormwater then infiltrates the uncompacted subgrade (E). Such consolidation of site runoff with direct precipitation on the porous asphalt has huge potential to reduce costs for additional drainage infrastructure. However, the ability to do this depends upon volume of runoff from impervious areas, porous pavement area, and infiltration rate. Sediment control devices should be used to prevent transporting silt, sand, and other fine matter into the reservoir.

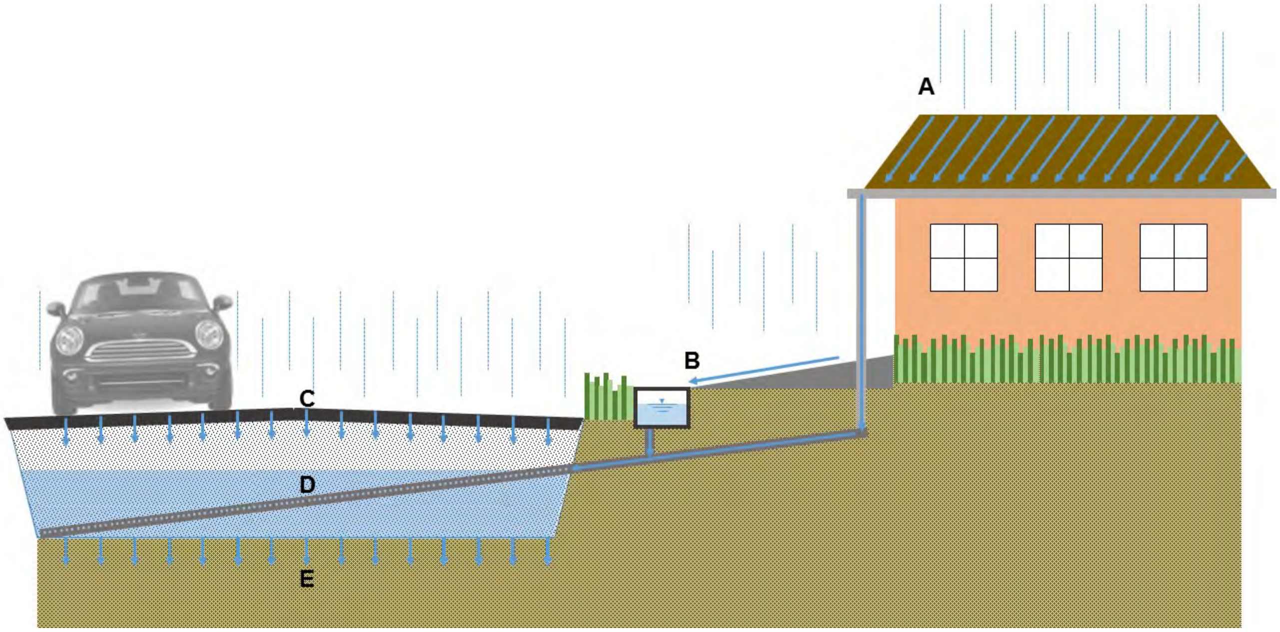

Figure 2. Consolidating runoff from impervious surfaces (A & B) with surface infiltration (C).

Hydrologic Design

Hydrologic design determines what layer thicknesses are requir sufficiently infiltrate,
store, and release the expected inflow of w ainfall and excess
stormwater runoff fro es information regarding
the layer thicknesses n intensity levels. Per
the National Asphalt P should drain within 12
and 72 hours.

The hydrologic design c ensed engineer. The
two most common met /NCRS Curve Number
method and the Rationa ded for evaluation of
porous pavement syster d the scope of this
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Overflow and Alternate

Porous pavements are oft m precipitation at
the site. Therefore, overfl ored stormwater
from reaching the surface perforated pipes in the stone
reservoir that are connecte arge pipe as shown in Figure 2. It is also recommended

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