Porous Asphalt Pavements for Stormwater Management

Figure 1. Construction of the UNH porous asphalt lot, October, 2004.

Figure 2. Infiltration of 30 gallons per minute from a 2-inch hose at UNH.

By Robert M. Roseen, P.E., Ph.D. and Thomas P. Ballestero, Ph.D., P.E.

Porous pavements are being recognized as an innovative stormwater management strategy that is both feasible and cost effective. In keeping with EPA requirements for Phase II of the Clean Water Act and the Total Maximum Daily Load (TMDL) program, municipalities are beginning to require improved stormwater management. These practices are designed to limit additional contaminant loading, in some instances to reduce existing loadings, and to limit effective impervious cover. This is a high standard that simply cannot be met with most conventional stormwater management practices using curb and gutters, and stormwater ponds and swales.

In northern climates, the selection of stormwater management strategies is further complicated by the need to consider the functionality of systems in cold weather. Recent research has demonstrated that stormwater management systems using infiltration and filtration mechanisms, when properly designed, have demonstrated cold-climate performance exceeding conventional practices by measures of both water quality and hydraulics.

One of the greatest benefits of the use of porous pavements is the capital cost savings when compared with other common stormwater management approaches. Eliminating curbing, catch basins, and stormwater ponds can result in great savings. Porous pavements also have the benefit of a reduced need for deicing and anti-icing practices. This benefit is significant both in the potential economic savings for winter maintenance and the environmental benefits. Chloride-laden stormwater runoff, from winter-treatments, is toxic to aquatic life, degrades drinking water supplies, and cannot be reduced from runoff by treatment but rather only through reduced application. For standard pavements, reduced salt application is balanced with public safety.

Background

Increased contaminant loading from developed land uses with elevated levels of imperviousness is clear (USEPA 1983; Pitt et al 2004; NCHRP 2006), and conventional stormwater management is doing only a modest job at mitigating impacts. Accumulation of heavy metals, organics, and inorganic compounds can be acute in urban snow runoff (Sansalone et al 1996, 2002; Glenn, 2002), further accentuating the need for effective winter stormwater management in northern climates. Low impact development stormwater designs and, in

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particular porous pavements, have been shown to be extremely effective at reducing contaminants from impervious surfaces (Ferguson, 2003; Dietz and Clausen, 2007; Dietz, 2007) in northern climates (Roseen, et al 2006), and for reducing peak flow, lag time, and runoff volume (Hood et al, 2007). Porous pavements in cold climates have been found to be more resistant to freezing than standard pavements, due largely to the disconnection to subsurface moisture and from rapid thawing due to the infiltration of meltwater (Backstrom 2000).

Study Area The study area is located in Durham, N.H., at the University of New Hampshire Stormwater Center (UNHSC). The porous asphalt test facility was constructed as two equivalently sized parking lots: one with standard dense-mix asphalt and the other with porous asphalt. The impervious lot generates surface runoff whose characteristics can then be compared to the flow from the bottom of the porous asphalt lot. The lots are used for commuter parking and routine bus traffic. The area is frequently plowed and salted during the winter months. The climatology is coastal, cool temperate with an average annual precipitation of 48 inches (122 cm). The mean annual air temperature is 48°F, with the average low in January of 16°F, and the average high in July of 82°F.

Design and Durability The mix design for porous asphalts has been in use for decades as open-graded friction course (OGFC), a pavement mix with a void content commonly in the 18-20 percent range. For porous pavement systems, the primary difference is that the open-graded mix is placed as a full-depth (4”) pavement designed to infiltrate into the subbase. Specifications can be found at a variety of places including industry associations (NAPA, 2002, 2003), stormwater manuals (PADEP, 2006), and watershed assistance groups (UNHSC, 2007). Structural durability and life cycle are major concerns when selecting pavement type.

The principal cause of parking lot pavement breakdown in northern climates is freeze-thaw cycling. Parking lots in these areas have a typical lifespan of around 15 years. By design, an open graded, well-drained porous pavement system incorporating significant depth will have a longer life cycle from reduced freeze-thaw susceptibility and greater load-bearing capacity than conventional parking lot pavements. Design guidelines for freeze-thaw consideration reflect frost depth ranges from 48-52” from coast to inland. For porous pavements, greater depth of frost is not the concern but rather the increase in the rate of cycling between freeze and thaw. This rate is highest near the coast.

It is important to understand that porous asphalt as a stormwater management system is just that: a system. This system includes porous asphalt at the surface, a stone (choker course) immediately below, and the finer filter material (sand to gravel). A significant degree of water quality improvement occurs in this filter course. In low-permeabile soil, the filter course will need to be underlain by a drainage layer consisting of stone and drainage pipe. For the UNH site, this drainage layer was constructed in order to monitor and sample the water that passes through the porous asphalt system.

Hydraulics The winter performance of porous asphalt pavements tends to be one of the greatest concerns by design professionals. Recent findings by researchers show, however, that there are fewer problems with the functioning of the porous asphalt than with the performance of conventional technologies like swales and ponds. Researchers at the University of New Hampshire Stormwater Center have been monitoring the hydraulic and water quality performance of many different stormwater technologies since 2004. The winter hydraulic performance of porous asphalt has been one of the most significant findings. In fact, it has been found that surface infiltration rates are not negatively impacted from frost penetration but are actually higher during winter months than in summer.

Surface infiltration rates have been recorded monthly for three years and show a repeating trend of oscillating infiltration rates of about 2000 cm/hr in the winter to 1000 cm/hr in the summer. The infiltration capacity remains high during winter, even when there is significant frost penetration, sometimes in excess of 12 inches. The porous asphalt does freeze, however it generally freezes as a porous medium and not a solid block. Freezing rain and rain on snow can freeze at the surface. Minor salting and plowing at such times can return the surface to high infiltration.

The well-drained nature of the parking lot subbase ensures that the void space remains open, even during periods of prolonged freezing. While the filter may indeed freeze, it does not freeze solid and infiltration capacity is preserved. Monitoring of frost depth penetration before and after winter runoff has shown that chloride-laden meltwater serves to thaw the frozen filter media.

During the three-year period of monitoring, there has been no surface runoff from the parking lot. During this period, the Northeast region has experienced an increase in extreme

Figure 3. Comparison of dense-mix asphalt (left) and porous asphalt (right) on the same day, one hour after plowing.

storm events with two 100-year storms in the past three years. Runoff has occurred as designed through the subdrainage with an average of 88 percent peak flow reduction and increased lag times of 460 percent. Because impervious surfaces increase runoff quantities and velocities, slowing down the runoff (measured by lag time) is an important facet of stormwater management. The net water balance for the site was a 25 percent reduction in volume, with little or no runoff during the hottest months. **This has been accomplished for a site with relatively poor infiltrating soils (hydrologic soil group C) where infiltration as stormwater management is often not considered.** This is a substantial accomplishment in that for many infiltration systems the design guidance recommends limiting to sites with >0.5 inches/hour infiltration rates, and this site does not qualify under those guidelines. This design guidance appears to be most appropriate for infiltration systems with high ratios of watershed area to filter area, such as bioretention or sand filters (>25:1). However, for porous pavements the watershed area to filter area ratio should be a maximum of 5 to 1. Poorly infiltrating soils can be easily accommodated with design variations allowing storage for extended infiltration.

Hydraulic Parameter	Performance
Peak Reduction	88%
Lag Time	460%
Volume Reduction	25%

Water Quality At the base of the UNHSC system is drainage pipe that drains into a swale. In this pipe, water flow rate and water quality (temperature, conductivity, dissolved oxygen, pH, and turbidity) are monitored real time (every five minutes). In addition, an automated sampler collects one-liter water samples in Teflon bags at various intervals during storms. These water samples are sent to a certified lab for analysis of water quality. The water quality performance for the porous pavement system has been exceptional and has not varied seasonally. The porous asphalt design tested at UNHSC is distinctive in its use of a medium-grained sand for a reservoir base and filter course. This refinement enhances its effectiveness in treating water quality. Typical performance efficiencies have exceeded 95 percent for total suspended solids (TSS), total zinc (TZ), and total petroleum hydrocarbons in the diesel range (TPH) and approximately 42 percent for total phosphorous (TP).

The UNHSC has focused on these parameters because each is considered a common measure of stormwater pollution, each is a common pollutant in national water quality impairments (303D listings of the Clean Water Act), and each is always measured in the runoff on the UNHSC impervious asphalt lot. The source of TPH is most likely from vehicle drippings and atmospheric deposition. No nitrogen removal occurred as would be expected from a non-vegetated system (if nitrogen were a concern, it could be addressed with a small vegetated system located at the subdrain outlet).

Contaminant	Influent Concentration (ug/l)	Effluent Concentration (ug/l)	Removal Efficiency (%)
Total Suspended Solids (TSS)	20,000	200	99
Total Zinc (TZ)	67	2	97
Total Petroleum Hydrocarbons (TPH)	10	0.1	99
Total Phosphorus (TP)	86	50	42

Chloride and Winter Maintenance Winter pavement maintenance requires a substantial effort and entails substantial cost in

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northern climates. In New Hampshire, routine plowing, anti-icing and deicing is common for more than four months a year. Maintenance strategies for improving efficiency and effectiveness of winter practices are valuable. Winter research conducted at the UNHSC on porous asphalt has shown that salt application can be reduced by 75 percent and the porous asphalt can still meet two important winter measures: friction, and snow and ice cover. Studies examined porous and non-porous parking lots and evaluated reduced salt application rates. The areas were evaluated for the degree (percentage) of snow and ice cover, and the friction factor (measured by a standardized test method – ASTM E303-93). A 75 percent reduction was possible based on snow and ice cover (with only 25 percent of the salt, the snow and ice cover on the porous asphalt was the same as on dense-mix asphalt), whereas a 100 percent reduction was determined for the friction factor (porous asphalt, even with no salt, has higher frictional resistance than dense-mix asphalt with 100 percent of the normal salt application). Therefore, a sizable reduction in salt application rate is possible for porous asphalt without compromising braking distance or increasing the chance of slipping and falling.

Summary Porous asphalt systems can be an extremely effective approach to stormwater management even in northern climates. Unlike retention ponds, they do not require large amounts of additional space. Instead, rainfall drains through the pavement surface and infiltrates directly into the subsurface. This significantly reduces runoff volume, decreases its temperature, improves water quality, and essentially eliminates impervious surface. It also speeds snow and ice melt, dramatically reducing the salt required for winter maintenance. The use of porous asphalt for parking lots is one watershed-based strategy that can provide solutions both for new developments and for areas being redeveloped.

***Dr. Robert Roseen, P.E.**, is an assistant research professor of civil engineering at University of New Hampshire and the UNH Stormwater Center Director. **Dr. Thomas P. Ballestero, P.E.,** is an associate professor of civil engineering at UNH and the lead scientist for the UNH Stormwater Center.*

For more information about the UNH Stormwater Center, go to http://www.unh.edu/erg/cstev.

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