Permeable Paver Research Summary

Lake County Forest Preserves February 2003

I. BENEFITS OF PERMEABLE PAVERS

- Accommodates detention facility requirements.
- Qualifies for Credit 6 – LEED: Limits disruption of natural water flows by minimizing stormwater runoff, increases on-site infiltration, and reduces contaminants
- Qualifies for Credit 7 – LEED: Reduces heat island affect (light colored pavers).
- Long-term durability of paver units.
- Ease in repair.
- (LID, Inc.)
- Provides groundwater recharge.
- Controls erosion in streambeds and riverbanks.
- Facilitates pollutant removal.
- Reduces thermal [water] pollution.
- Eliminates standing water on pavement.

II. DISCUSSION

A. FREEZE-THAW

- Porous pavement installations have withstood freeze-thaw conditions. (Keating, 2001) (Miller, 1997) (Gutowski, 2003) (Holland, 2003)
- Porous pavement experiences less effects from frost heave than impermeable pavement. (Backstrom, 1987, 1999)
- Safety – The pavement is actually safer in the winter because it does not accumulate icy buildup. Typical pavement puddles when snow melts, the puddles then freeze again – with permeable pavement, the periodic melt enters the pavement and is not able to refreeze on the surface. (Gutowski, 2003) (Backstrom, 1987)
- The system is designed to flow the water through it – not to have the water stay for extended periods of time. It should be designed so that the water does not stay in the base longer than 12 hours* following the end of a weather cycle. (Smith, 2001)
- Pavers are installed on a sand bed without mortar. They can expand and contract with the temperature with out cracking or spalling. If unsettling occurs, the displaced pavers can be removed, the base leveled and then replaced.

*Unilock recommended time - varies depending upon source.

B. LOW-PERMEABLE SOILS

- The base is engineered to accommodate the water through depth and composition of gravel base, and drain tiles.
- Permeable pavers are feasible in low permeable soils. (Knapton, et al. 2002)

C. HIGH-HEEL SHOES

- The voids between the paving units are filled completely by the gravel material, preventing heels from entering the gaps. (UniLoc)
- Proper filling and compaction is necessary to sustain optimum performance. (Bretschneider, 1994)
- The parking lot can be designed to accommodate safe walking corridors. If a bi-surface design were used, the primary walking surface would accommodate a variety of shoes.

D. FUNDING

- Section 319 grants are available to fund these types of projects. Both the Jordon Cove and Morton Arboretum were funded through this source.
- Proposals would be due in August but could be submitted at any time prior.

E. SMC AGREEMENT

- Detention requirements would be reduced by the "Total Detention Required – Porosity of Aggregate Base"
- This project would serve as a pilot project for Lake County through the cooperation of SMC and the District.
- See attached letter.

F. MAINTENANCE – LIFE CYCLE COSTING

- Savings occur from not having to place stormwater management structures on site or to use land for detention areas because the parking lot qualifies as detention.
- Permeable pavement installations have experienced less need for repair than pervious pavements within the same installations. (Gutowski, 2003) (Holland, 2003)
- A 50-year life cycle cost comparison for the planned Morton Arboretum Parking lot (Grieco, 02):
    - All asphalt - 26,000 per year or $1,300,000.
    - All pervious pavement - $400 to $500 per year or $20,000 to $25,000.

G. Cost Comparison specific to Lake County Forest Preserves

This is a very preliminary figure based upon conceptual designs; no engineering design has been completed to date:

40,000 SF - Uni-Lock Eco-Loc Pavers – 25 years			
Item	Frequency		Cost
Installation	1 x	165,350.00	Pavers, 24" & 12" base, drain tile, excavating, hauling
		**15,000.00	Detention – excavating, hauling, topsoil, seeding, pipe
Vacuum sweep	As needed~ 2x per yr	0.00	Cooperative Agreement – Lake County DOT has Johnston vacuum sweeper
Restore permeability	1x per 4-5 yrs or as needed	1750.00	350.00 each @ 5 Service contract @ 82.00/hr. – vacuum & remove void aggregate. The District cleans, and replaces. *
Refresh base	1x per 25 yrs	8100.00	Replace base/drain as needed (reuse pavers
Total Life-cycle cost over 25 years:		190,200	

Assumption of cleaning and replacing with same aggregate.

** *Preliminary calculation. Based upon total detention requirement - % porosity of base.*

40,000 SF - Asphalt Parking Lot - LCFP costs – 25 years			
Item	Frequency		Cost
Installation	1x	109,000.00	3" asphalt, 12" base, striping, excavating, hauling
		25,000.00	Detention – excavating, hauling, topsoil, seeding, pipe
Crack Sealing	1 x per yr	6250.00	250.00 / yr @ 25 x
Seal Coat	1 x per 5 yrs	100,000.00	20,000.00 / 5 yrs @ 5 x
Striping	1 x per 5 yrs	3125.00	625.00 @ 5x 6.00 / space 12.00 / HC space 96 spaces w/4 HC
Patching	As needed	500.00	1x / 5 yrs @ 100.00/patch
Replace paving surface	1 x per 20 yrs	32,000.00	1x Asphalt surface and striping
Total Life-cycle cost over 25 years:		275,875	

H. LONG-TERM VIABILITY OF PAVERS

- Tests have shown that if lost, permeability can be restored. (Dierkis et al, 2002) (James, 2001, 2002)
- Tests and case studies have shown that pavement remains permeable over time. (Brattebo et al, 2002) (Dierkes et al, 2002) (Gutowski, 2003) (Holland, 2003) (Miller, 1997)

- Permeable pavement has lasted as long or longer than impermeable asphalt. (Gutowski, 2003) (Holland, 2003)

III. CASE STUDIES

A. Naval District Washington

- "Low Impact Development Projects"
- Retrofit pilot project to restore and maintain the water quality of the Anacostia and Potomac Rivers and the Chesapeake Bay.
- Retrofitted parking lot included: permeable pavers in the parking lanes, bioretention islands, sand filters, gutter strips.

B. Annsville Creek Paddlesport Center - New York State Parks

Ken Allen, Landscape Architect
NYS Office of Parks, Recreation and Historic Preservation

- Governor of New York directly approved use of permeable pavers.
- No puddling, ponding, or heaving through snow and rain.
- *"The pavers were installed in November of 2001 and are working wonderfully. No problems through the winters and pouring rains of spring. No heaving, no clogging, no ponding."*

C. Morris Arboretum – University of Pennsylvania, Philadelphia

Bob Gutowski, Director of Programs

- ***Designed by Cahill Associates and Andropogon Associates, Inc.***
- The parking lot has lasted for 10 years.
- Mr. Gutowski "*advocates and promotes*" the use of permeable pavement.
- The parking lot does not heave and won't heave if it is designed well.
- Periodically the parking lot needs to be vacuumed (say after a leaf fall)
- Maintenance is not a problem

- They have patched the non-porous entry drive and have not needed to patch the porous pavement.

D. Jordan Cove project
Waterford, CT

- Working with different agencies, including EPA to research applicability of permeable pavers
- Works to a 0.68" infiltration rate where standards require first 0.5"
- Received a grant to cover the expense above and beyond the ordinary expense.
- Use steamers to keep out weeds
- Helps alleviate the heat island effect
- Factory entrance drive in MA uses these blocks that withstand heavy truck use

E. Walden Pond State Reservation, MA

- Miller, Richard. "Porous Pavement – Pavement That Leaks". 1989 & 1997.
- Porous pavement parking lot was installed in 1977 to address environmental concerns.
- Twenty years later, the pavement is still functioning and looks good.
- Important to design the subbase correctly.
- This pavement works well in a freeze-thaw environment.

F. Siemens Health Services. Philadelphia Pennsylvania. (Holland, 2003)

- Pervious pavement has been in place since 1982 and is still performing well.
- Imperious pavement has had to be replaced while the original pervious pavement remains.

G. Dominican University, River Forest, IL (Beulow, 2002)

- Installed pavers Aug 15, 2002 to address storm water issues. The storm water on-site retention requirements were so cost prohibitive that this was a feasible solution.
- Applied to a 300-car parking lot and drive that winds through the trees. It's a very highly trafficked parking lot.
- The pavers have a one-inch void that is filled with an aggregate material. The voids must be periodically vacuumed out and refilled to maintain permeability.
- The parking lot must be kept free of debris such as leaves and mud. (sweeping)

H. The Morton Arboretum
Lisle, IL
Planned – *Conservation Design Forum* (Grieco, 2002)

- Purpose to demonstrate bmp's for storm water management for parking lots in an urban environment
- Funded the installation through grants from state.
- As part of grant will host 2 symposiums, provide website access and on-site interpretation
- Including, storage in the underplayed strata, porous pavers, swales w/ a native plant regime, water movement through a level spreader to wetlands
- 500 car lot
- Must keep lot free of debris, vacuum out filler material periodically and reapply periodically to maintain permeability
- Studied life cycle costs and this material is far less expensive than asphalt
- Have not yet located vacuum device yet – planning on addressing that in two years.
- Will construct summer 2003

IV. ANNOTATED BIBILIOGRAPHY

Allen, Ken. Landscape Architect. New York State Office of Parks, Recreation and Historic Preservation. Telephone conversation – 1/27/03.

- Annsville Creek Paddlesport Center –Hudson River
- Installed November 2001 – works great.
- They put in permeable pavement because they could not put in subsurface drainage structures.
- 2 gradations of crushed stone with drain pipes.
- No problems
- Multi-agency coordination effort – ok'd by the Governor

Backstrom, Magnus. <u>Porous Pavement in a Cold Climate</u>. University of Technology – Sweden. 1999.

- "Porous pavement was more resistant to freezing than a conventional impermeable pavement due to higher water content in the underlying soil which increased the ground's latent heat."
- The air in the pavement insulates the ground, which delayed the ground's freezing, which decreased frost heave damage.
- Air released from the pavement helped to melt frost.
- Concluded that freeze thaw did not pose operational setbacks because the porous pavement was more resistant to freezing than impermeable; pavement thawing is a quick process; frost penetration depth is decreased and the frost period is shortened from impermeable pavement creating a lower risk for frost damage.

Backstrom, Magnus. "Ground Temperatures in Porous Pavement During Freezing and Thawing Conditions" Div. Of Sanitary Engineering. Lulea University of Technology. S0971 87 Lulea, Sweden.

- Meltwater infiltrates into the pavement, standing water is eliminated which reduces the danger of ice on pavement.
- Permeable pavement is more resistant to freezing and frost damage than impermeable pavements because of an absence of stormwater pipes and manholes within the pavement itself.
- Presents a case study in Luea, northern Sweden.
- Frost heave in permeable pavements was equal to or less than the impermeable pavement. The heave measured was distributed evenly throughout the pavement with no irregular heaving noticed.

Beulow, Dan. Dominican University. River Forest, IL.

- Telephone interview 2002. See above.

Brattebo, Ben and Derek Booth. "Permeable Parking Lot Demonstration Project – The Six-Year Follow-Up". Center for Urban Water Resources Management, University of Washington. DRAFT Sept. 11, 2002.

- The study purpose was to evaluate the long-term effectiveness of permeable pavements. Four permeable systems were installed, including Uni Eco-Stone.
- All pavements retained permeability over two-year test period.
- Uni Eco-Stone maintained durability over 6-year period – no signs of rutting, settling or shifting.
- Pavement successfully filtered pollutants.
- Successful test did not account for higher volume rains or extended freezing temperatures that other areas may experience.

Bretschneider, Professor Burkhard. "Expert Opinion on Uni Eco-Stone-Pedestrian Use". 1994.

- Tested Eco-Stone for safety and walking including high heel shoes.
- Proper filling and compaction was important for a good performance.

Dierkes, Carsten, Lothar Kuhlman, Jaya Kandasamy, George Angelis. "Pollution Retention Capability and Maintenance of Permeable Pavements". 9th International Conference on Urban Drainage, Portland, Oregon. 8-13 September 2002.

- Purpose to study the pollution retention capacity and to assess the success of cleaning clogged pavements.
- Fifteen years after construction a permeable paver grocery store parking lot remained permeable and filtered pollutants.
- Tested a schoolyard paving system. After six years the pavement had become clogged. Following cleaning by the "geoCLEANING" machine, the pavement exceeded infiltration capacity requirements.
- Permeable pavers are a long-term viable sustainable solution if planning construction and maintenance are done properly.

Grieco, Ralph. The Morton Arboretum. Facsimile dated 10/29/02.

- Provided project-planning information for their proposed parking lot including cost comparisons and project descriptions.

- See above.

Gutowski, Bob. Director of Projects. Morris Arboretum – University of Pennsylvania. Telephone conversation – 1/28/03. (215) 247-5777.

- Advocates and promotes permeable pavement.
- The pavement can't be swept, it should be vacuumed.
- Pavement is designed with a recharge basin.
- Expecting the pavement to last as long as conventional concrete.
- Saves dollars than on stormwater structures.

Holland, Keith. Facilities Director. Siemens Health Services Corp. Malvern, PA. Telephone conversation 1/29/03. (610) 219-6300.

- Pervious pavement has been in place since 1982 and is still performing well.
- Imperious pavement has had to be replaced while the original pervious pavement remains.
- Water doesn't sit in it or on it so it isn't affected by the freeze.
- They sweep it two times per year.
- Can't put gravel or salts or on it. They use the pellets.

James, William. "Green Roads: Research Into Permeable Pavers". Stormwater. March/April 2002.

- An investigation of infiltration capacity, pavement leachate, and runoff temperature.
- Tests showed that the infiltration capacities can be regenerated by street sweeping and vacuuming.
- Pavers reduced the water temperature and amount of heated run-off.

James, William. "Eco Sensitive Roads: Alternative Pavements Could Reduce Contaminated Runoff". Copyright 2001 by American Society of Agricultural Engineers.

- Permeable pavers slow stormwater run-off, reduce run-off water temperatures, and filters pollutants.
- Research has shown the infiltration capacity of permeable paver systems can be regenerated through proper maintenance.

Keating, Janis. "Porous Pavement". Stormwater. March/April 2001.

- Example cases indicate that porous pavement (not pavers) provides a viable paving material.
- The pavement withstands freeze-thaw climates.
- It's very important that the snowplow blade is in the correct position to prevent damage to the surface.

Kluh, Susanne, Marco E. Metzger, Dean F. Messer, Jack E. Hazelrigg, and Minoo B. Madon. "Stormwater, BMPs, and Vectors: The Impact of New BMP Construction on Local Public Health Agencies". Stormwater. March/April 2002.

- BMPs can be modified to prevent mosquito breeding if it becomes a problem.
- Water retention should not exceed 72 hours.
- Monitoring is needed to make sure that vectors stay under control.

Knapton, Professor J, ID Cook, D. Morrell. "A New Design Method for Permeable Pavements Surfaced with Pavers". Highways and Transportation. January/February 2002.

- UK has clay soils, which limit the ability for water to percolate from the pavement into the soils, and they lose strength when wet.
- Series of tests were conducted that concluded that pavers are suitable as an infiltration medium.
- System must be designed as detention system.
- Design should accommodate poor soils and specific site conditions. Should consider hydraulic patterns, traffic loading characteristics, properties of the subgrade, and the ground beneath the pavement.
- Base design should accommodate certain period of rainfall.
- Deliberate cascading of water through construction material is radical so it should be designed for stability.

Low Impact Development Center, Inc. "Watershed Benefits of Permeable Pavers". www.lid_stormwater.net/permeable_pavers/permpavers_benfits.htm

- Discusses the benefits of permeable pavers.
- Summarizes research into the subject (Florida, Washington State, & University of Guelph).

Miller, Richard. "Porous Pavement – Pavement That Leaks", 1989, 1997. www.millermicro.com/porpave.html

- See above – Walden Pond.

Smith, David R. Permeable Interlocking Concrete Pavements: Selection, Design, Construction, Maintenance, 2nd Ed. 2001. Interlocking Concrete Pavement Institute.

- Maintenance – after 20 – 25 years the base and/or drain materials may need to be repaired or replaced. The pavers can be removed and then reused at this time.
- The pavement can be plowed.
- If it a paver cracks, it can be replaced.

ToolBase Services. Permeable Pavement. www.toolbase.org/tertiaryT.asp?DocumentID=2160&CategoryID=38

- The paving system must be installed properly – especially the substrate to hold the water while it absorbs or in poorly drained areas.

Uni-Group U.S.A. Uni Eco-Stone Guide and Research Summary. 2002

- Summarizes research regarding performance of permeable pavers.

Zollinger, Dan G. Assoc. Prof., Su Ling Cao, Daryl Poduska. Drainage Design and Performance Guidelines for Uni Eco-Stone Permeable Pavement. The Department of Civil Engineering, The Texas A&M University System. 1988.

- Provides design details for different pavement designs.