POROUS PAVEMENT
Pavement That Leaks

New Commentary, by A. Richard Miller

Also see this other MMS web page.

In 1997, porous pavement is an economically and environmentally sound paving alternative which should be seriously addressed before paving or repaving any parking lot. Unfortunately, engineers and planners have heard more about poor examples of porous paving than about good ones. Thus they often recommend against its use for wrong reasons.

One good porous pavement installation was installed by the Commonwealth of Massachusetts at Walden Pond as a demonstration project in 1977. Twenty years later, a *long* time for one paving job on that busy parking lot, it *still* looks good and works well. And, as many of the doubting engineers will confirm,Walden Pond is in a *worst* climate condition for this material. Obviously, a warmer climate would create less freezing of rainwater (freezing expands water into ice, the mechanism which breaks down pavement). But a colder climate wouldn't be as severe either, because the snow and ice would be less likely to remelt and then refreeze. Eastern Massachusetts has more freeze-thaw cycling during a winter than most other parts of the world. But this porous pavement *does* work in eastern Massachusetts, and it will work in most climates worldwide.

The good porous pavement installation at Walden Pond in 1977 did not happen by accident. It was a special Technology Transfer demonstration project. It followed best-practice methodology generated by a 1972 U.S. Environmental Protection Agency project, it benefitted from an unusual amount of professional engineering supervision and analysis, and it generated technical documentation. It also generated a public information sign at the entrance to the Walden Pond parking areas, and finally in 1989 it generated a matching, public-education brochure. The remainder of this Porous Pavement webpage *is* that 1989 brochure. Read it, and consider how porous pavement can help *your* community.

POROUS PAVEMENT
Pavement That Leaks

by A. Richard Miller, 1989
A volunteer project for the Massachusetts Executive Office of Environmental Affairs

Porous pavement is an innovative technique which can lead to environmental and economic improvements in the way we pave our parking areas and roads. The demonstration project at Walden Pond State Reservation - the parking surfaces beyond the entrance booth - is New England's first look at porous pavement and has been working well since 1977.

A demonstration project of the Massachusetts Executive Office of Environmental Affairs, John P. DeVillars, Secretary:
Dept. of Environmental Quality Engineering, Daniel S. Greenbaum, Commissioner
Division of Water Pollution Control, Cornelius J. O'Leary, Acting Director

In cooperation with the
Dept. of Environmental Management, James Gutensohn, Commissioner
Division of Forests & Parks, Richard A. Kendall, Director

Conventional Pavement Causes Problems

Our nation has come a long way since early cobblestone streets kept our feet out of the mud. However, we have been too successful. Not only have we managed to keep our feet dry, we have succeeded in keeping the rain water from the soil. Modern conventional paving materials are impervious to the passage of water. And although it is not apparent, this causes some serious problems.

The most obvious problem with conventional pavement is *runoff*. If rainwater cannot soak into the ground where it falls, it will run downhill. On a small scale we can see this at home when water runs off the driveway onto the lawn, maybe leaving a small eroded area. Multiply this effect over the expanse of a shopping center or an entire metropolitan area and you begin to understand the size of the problem. As water collects downstream, along with everything from soil and fertilizer to cigarette butts and oil spills, it causes flash flooding and wash-down of debris and pollutants.

How is this runoff handled? Usually storm drains are built into paved areas to channel runoff to some downstream location, such as your favorite river or pond. In New England cities, combined storm and sanitary sewers are unfortunately common. Because most sewage treatment plants have inadequate capacity to treat all the water fed into them by "combined sewers" during storms, the combined runoff and sewage must overflow through bypasses and relief valves to the region's rivers, ponds, and harbors. This contaminant- and nutrient-loaded water makes our surface waters unhealthy and accelerates their *eutrophication* (a nutrient enrichment process which grows green "pea-soup" algae and aquatic weeds). Remember that we must pay not only for the construction of these storm drains but, where combined sewers exist, also for the cost of greatly increased treatment-plant capacity to clean the huge volumes of combined sewage and stormwater which are produced during storms.

Another consideration is the replenishment of our *groundwater sources*. Groundwater provides much of the drinking water in New England, keeps our trees and plants healthy, and helps to maintain the flow into our rivers and ponds. Water recharged from land surfaces is naturally stored in the ground and gradually released to streams. This groundwater discharge sustains base streamflow between rain storms and is the critical element controlling natural low streamflows during the growing season. As we have paved over more and more land, we have bypassed the natural process which lets rainwater soak into the ground where it falls. This prevents our environment from helping us.

We Americans now use more water than we really need, and are beginning to recognize the limits of our water resources. Although New England's annual rainfall is about 40 inches, which translates to over one million gallons per acre, we in eastern Massachusetts still have water shortage and pollution problems. When we retain rainwater in the local hydrologic cycle instead of letting it go "down the drain", we can reduce the need for large, expensive water diversion projects, sewers and sewage treatment plants.

Porous pavement can reduce some of these negative effects of our urban lifestyle.

What Is Porous Pavement?

The form of porous pavement used in the Walden Pond demonstration looks and acts like conventional asphalt pavement, but it is *permeable* - it allows water to leak through. It is made and applied with conventional asphalt paving equipment. Only the recipe is changed: conventional asphalt pavement is a mixture of large and small stone particles bonded together with asphalt tar; for porous pavement, *the smaller particles are left out and the percentage of tar is reduced.* This provides bonding while leaving spaces through which the water may pass.

In laboratory tests, porous pavement was able to pass "rainfalls" *over 60 inches per hour*, more than sixty times greater than our typical "downpour". Of course the ability to handle water in real applications relies

on the ability of the underlying soils to absorb the water. For engineers, this translates to how much additional water-holding sub-base, if any, must be provided under the pavement to store the water until it can soak in.

Since the early 1970's, porous pavement parking lots have been installed successfully in other states (Delaware, Pennsylvania and Texas) with encouraging results for road use and local water retention. In England, it was laid over a conventional airport runway surface; this combination improved landing safety and withstood the abuse of commercial aircraft landings.

The Walden Pond demonstration project uses suitable combinations of pavement thickness and sub-base depth for the soils and weather of our New England environment. This installation proves that *properly used and installed porous pavement withstands the extreme freeze/thaw cycling of New England winters*. After more than ten years, *no potholes* were observed.

For home driveways, loose gravel acts like porous pavement. So will a mat of concrete slabs cast into open patterns, with soil and grass filling the holes - a durable driveway which you can mow!

Is Porous Pavement Appropriate For All Applications?

Certainly not all, but *it fits many situations*. The Walden Pond project has established cost information and design criteria for parking lot uses in the New England area

Where underlying soils are sufficiently permeable, it should be appropriate for all but very small applications, where "special mix" costs cannot be absorbed. Other installations may require expensive sub-base preparations, yet still be cost effective. In some soils (extensive clay and rock perhaps), porous pavement will not be advantageous. Finally, as with septic system installations, attention must be given to potential harm through ground water pollution (from dripped oil, road salt, etc.). However, since the usual alternative is to run vehicle pollutants directly into water bodies via storm drains, the filtration, buffering, and bacterial breakdown processes in the soil should make porous pavement the better choice in all but some very special cases. The Walden Pond demonstration has determined that the water which has passed through the porous pavement is of good quality.

Highway Maintenance

Although initial installations have been confined to parking lot surfaces, use of porous pavement for street and highway surfaces is a future area for investigation which may offer great savings due to the elimination of expensive storm drain systems.

During our long, cold New England winters, we put salt on the highways to improve driving conditions. Its melting action softens the ice for the snowplow and prevents new ice from forming. But the salt is harmful to our vegetation and drinking water, and it rusts our cars and corrodes concrete bridge decks. When ice is sanded instead of salted, a thaw and refreeze could leave the sand useless under the ice. Porous pavement reduces this problem; ice thawing on the road drains through into the ground, providing a safe road while reducing or eliminating the need for salting. This greatly reduces the cost of winter highway maintenance. Porous pavement will reduce or eliminate spring potholes, which are caused by the freezing and expansion of water trapped within road cracks. Under laboratory conditions and at Walden Pond, repeated freeze/thaw testing on porous pavement has shown no ill effects. Lane markings are less apt to disappear in headlight glare on porous pavement highways, because water doesn't puddle on the road and because the rougher surface is more visible to the motorist at oblique angles. The pavement even can be colored, for better traffic flow control and aesthetic appeal.

Ecological Benefits

Restoration of soil moisture is important to support the trees and plants which give us shade, beauty, and oxygen to breathe. Conventional pavement diverts rain away from large areas; then, the large expenses of dry soil under the parking lots and highways "sponge" water away from the still-fertile adjacent soils, making it more difficult for our plants to survive.

Is Porous Pavement Expensive?

No, because it is made from the usual paving materials by the existing equipment; and, the benefits could make it a real bargain. Considering only installation costs, porous pavement is expected to cost no more than conventional pavement on low-traffic applications such as parking lots (although a premium of up to 20% might be charged for the first few "special" installations). For large highways on sufficiently permeable subsoils, porous pavement, if applicable, should be less expensive than conventional surfaces since it can greatly reduce the need for storm drains. Curbing and gutters would be needed only where safety is a consideration, or to prevent silty areas from washing onto the pavement and clogging its pores.

Porous pavement also promises many secondary benefits: its use can benefit local water supplies by returning to local ground water up to one million gallons per acre per year in New England; sewage treatment plants need less capacity where combined sewer overflow problems are reduced; damage from downstream flooding is reduced; and highway safety should be improved. Although these desirable benefits are not priced into construction contract costs, their economic and social values are real and significant.

The Recipe for Walden Pond's Porous Pavement

Of the various good combinations tested at Walden Pond, the best is the one on the lot to the left as you pass the entrance booth. Here are its specifications:

Well-drained underlying soil. Minimum thickness of the asphalt concrete is 2.5 inches, mix composition per Table 1, asphalt content 4.5 to 5.58, asphalt type AC-20 viscosity grade. Various types of base course are suitable; Figure 1 and Table 1 describe the most effective one at Walden Pond.

Runoff from adjoining areas should be prevented or minimized by grading the surrounding landscape away from the site, or by installing trenches to collect the runoff. To minimize the spillage of construction material onto the finished porous pavement, schedule construction activities so all ground preparation and earth work is completed prior to the installation of the pavement. Snow removal methods should include plowing, but no sand and, as elsewhere, no more salt than is necessary. Impacts of porous pavements on the local hydrology and water quality are site-specific, and should be evaluated on a case-by-case basis.

Successful porous pavement projects require more than the right mix. Provide design and installation supervision to assure that suitable sub-base exists or is prepared, that excessive silt is prevented from draining onto the surface, and that the mix is properly prepared and installed. Good porous pavement surfaces should last as long as conventional pavement, and with many additional benefits.

Table 1 - **Mix Composition of Porous Pavement and Crushed-Stone Base Courses**

Course	Square-Opening Sieve	Percent Passing (by Weight)
POROUS PAVEMENT	1/2 inch 3/8 inch No. 4 No. 8 No. 16 No. 200 Asphalt	100 90-100 35-50 15-32 0-15 0-3 4.5-5.5%
BASE COURSE TYPE A	1/2 inch 3/8 inch	100 0-5
BASE COURSE TYPE B	2-1/2 inch 2 inch 1-1/2 inch 1 inch 3/4 inch	100 95-100 35-70 0-15 0-5

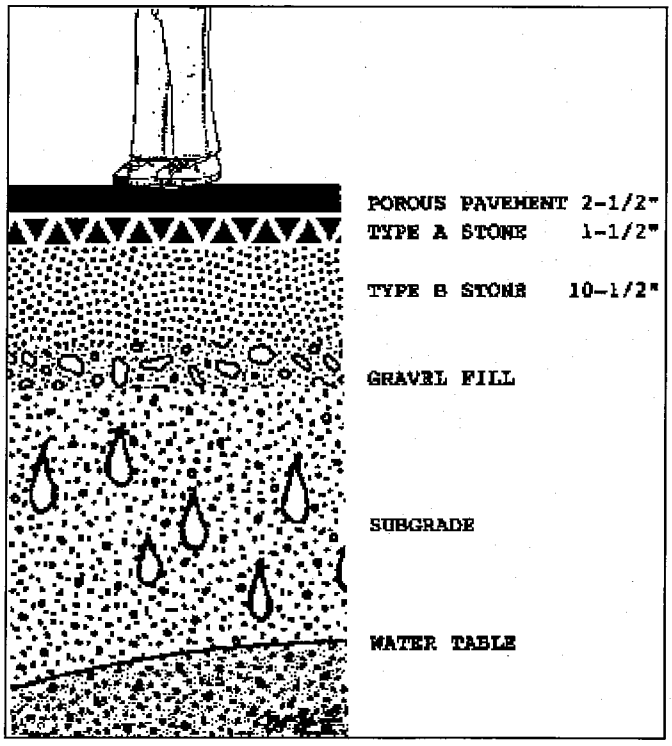

Figure 1 - Cross-section of Porous Pavement, including Base Courses

Credits & References

This brochure was written by A. Richard Miller (508/653-6136; TheMillers@millermicro.com) as Executive Director of the *Lake Cochituate Watershed Association*; the typesetting was volunteered by *Miller Microcomputer Services*, Natick, Massachusetts 01760. The LCWA has supported further development of porous pavement in New England since 1972, based on *Investigations of Porous Pavements for Urban Runoff*

Control, by *Franklin Institute Research Laboratories* (Water Pollution Control Research Series 11034 DUY, US EPA, March, 1972; due to EPA's Web site design, you must search there for "11034DUY0372").

The Walden Pond demonstration project was proposed by the LCWA and the *Walden Pond Advisory Council*. It is a joint effort of the *Massachusetts Department of Environmental Quality Engineering* (now, Mass. Dept. of Environmental Protection), *Division of Water Pollution Control*, and the *Massachusetts Department of Environmental Management*. The MDEM assisted in the preparation of the construction specifications and supervised the pavement installation. The pavement was installed by *Warren Brothers Company, Inc*. Engineering work and research services have been provided by the *Northeastern University Department of Civil Engineering*, Boston, Massachusetts 02115 (*Installation and Evaluation of Permeable Pavement at Walden Pond State Reservation*, Final Report February 1986, Irvine W. Wei, Ph.D. (617/373-3368; I.Wei@coe.neu.edu).

Reference copies of the above-mentioned reports are kept in the Headquarters Building at Walden Pond State Reservation. For further information on porous pavement and on the Walden Pond demonstration project, please contact Arthur Screpetis, Mass. Department of Environmental Protection Central Regional Office (CERO), 627 Main Street, Worcester, MA 01608 (508/767-2875; Arthur.Screpetis@state.ma.us).

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Please E-mail your feedback on this Webpage to Dick and Jill Miller at
TheMillers@millermicro.com

Porous Paving Design
Compared to Impervious Pavement Standards

Porous pavements by their very nature are designed to move water through their cross section - vertically and horizontally, without loss of structural integrity. This is in direct opposition to design training and construction materials and methods developed since the early 1900's, where totally impervious pavement sections were the supreme objective.

Must all pavements be constructed to impervious standards? No! Are all pavements appropriate for porous standards? No! However, there are appropriate applications for each, and the designer must determine which pavement is best suited to each project, or portion of project. A critical element to remember is that each pavement, whether porous or impervious, must be designed to meet project criteria.

Porous pavements are generally appropriate for applications where traffic moves slowly (less than 30 mph) and/or infrequently, such as with firelanes, service drives, overflow or all day parking, pedestrian areas, etc.

Porous pavement design incorporates more than just the surface "wearing" course, as is the usual case with porous asphalt or porous concrete, where the primary objective to remove water from contact between tires and the pavement surface. The base course, or primary structural layer, should also be designed for porosity to meet environmental and stormwater management objectives, as well as the occasional aesthetic design criteria. Depth of base course is still determined by evaluating the design load to be supported, and the load capacity of the subsoil (native or fill).

Eliminate "Fines"

The one significant difference between porous and non-porous pavement is the presence of "fines", or material that will pass a 200 mesh screen. Also classified as clay or silt size particles, fines will enhance compaction, reduce voids (air spaces), and restrict water movement through the pavement cross section. By the simple action of removing (or restricting) fines from the base course material, porosity is achieved.

Structural integrity is maintained by a wide range of particle sizes, varying from fine sand to 1.5" diameter stone, usually crushed to provide angular surfaces which interlock better than rounded surfaces. Sand and smaller stone help to fill large voids and prevent larger stone from rotation or other gross movement.

If local gravel material sources do not have standard mixtures that meet the low fines requirement, we have clients that have successfully prepared their own base course mixtures by blending 3/4"-1" crushed drainage rock (at 66%) with concrete sand (at 34%) by using a front end loader to do the blending into piles on a hard surface.

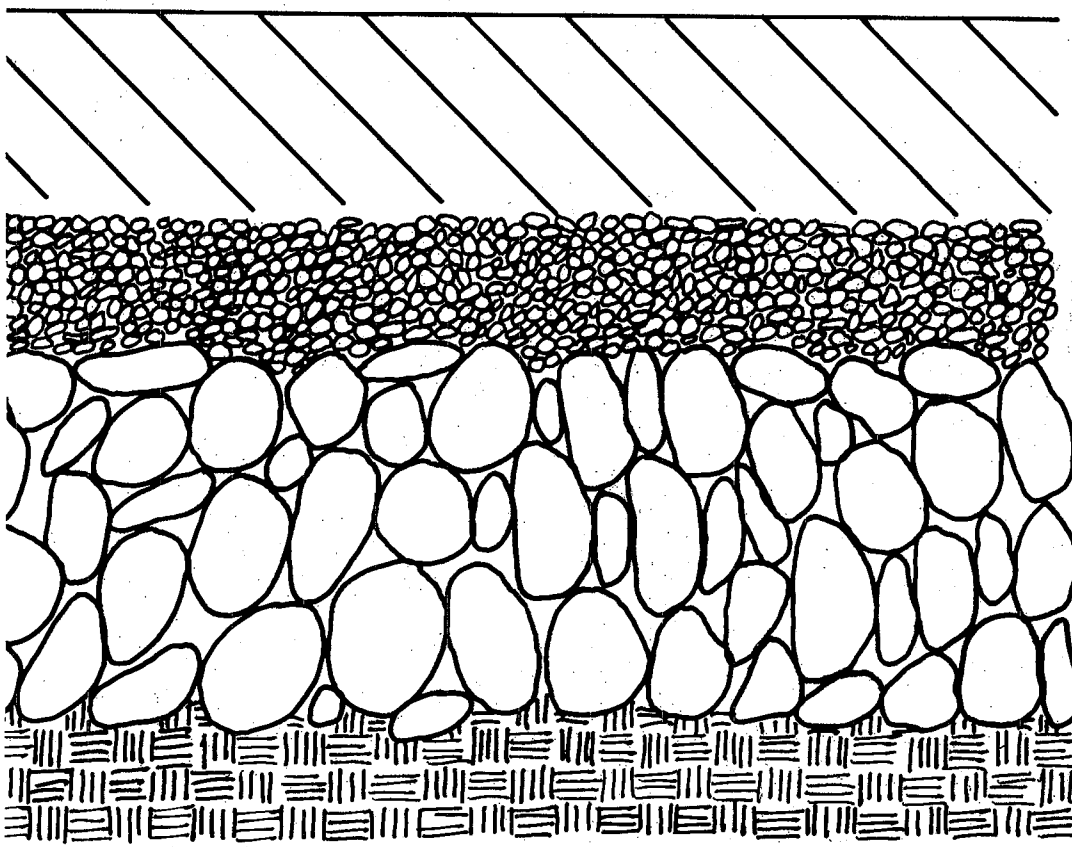
Horticultural Demands

Some variations of porous pavements, such as our Grasspave2 system, must also meet horticultural requirements in order for the vegetation to survive and flourish. This demand is met mostly by the sand sized particles and stability of the larger stone to prevent movement of the root zone once established. Sand will allow water movement, including capillary (vertical), and air access to the root zone.

Compaction

We have been promoting porous pavements since 1982, and have found that if the base course material is compacted to 95% Modified Proctor, both structural and horticultural criteria can be satisfied. Ω

William Bohnhoff, Invisible Structures, Inc. April 1999



POROUS ASPHALT COURSE
1/2" TO 3/4" AGGREGATE
ASPHALTIC MIX (1.27 - 1.91 cm.)

FILTER COURSE
1/2" CRUSHED STONE (1.27 cm)
2" THICK (5.08 cm)

RESERVOIR COURSE
(2.54 - 5.08 cm)
1" TO 2" CRUSHED STONE VOIDS
VOLUME IS DESIGNED FOR RUNOFF
DETENTION

THICKNESS IS BASED ON STORAGE
REQUIRED AND FROST PENETRA-
TION

EXISTING SOIL
MINIMAL COMPACTION TO RETAIN
POROSITY AND PERMEABILITY

FIGURE 2

POROUS ASPHALT PAVING TYPICAL SECTION

Draft concept language for Pervious Paving By-law
Scheduled for Town Meeting April 2009,
Scheduled Hearing Date: February 17, 2009

This adjustment to zoning language in Acton Zoning By-law 2008 would allow pervious paving to be an option in appropriate areas throughout Town. Appropriate sites may include: parking lots, overflow parking, accessory drives, fire truck access roads, sidewalks, patios, bike paths, walking trails and other suitable uses.

The intent of this adjustment is to encourage flexibility in site plan design, and to keep Acton current with the green building and low impact design initiatives gaining ground throughout New England as well as nationally.

A quick perusal suggests language will need to be adjusted in:

- **Section 3** Accessory Use Regulations; 3.8.1.5 Common Drives, l) – This specifics a minimum of 3" of bituminous concrete for shared drives. (*remove this requirement*)

- **Section 4** Overlay Districts; 4.3.3.8 Groundwater Protection District, Impervious Cover (*add pervious paving as a definition to the groundwater protection district*).

- **Section 6** Parking Standards; 6.7 Parking Lot Design Requirements (*include suitable pervious pavement as a cover option*)

References:

http://transtoolkit.mapc.org/Parking/Strategies/mitigating_environmental_impacts.htm#Pervious_surfaces

http://www.papionrd.org/howtohelp_pdfpages/NRD%20PerviousPaving%20NRCS.pdf

http://www.lakesuperiorstreams.org/stormwater/toolkit/paving.html

http://www.crwa.org/projects/greenstreets/Brook%20Street%20Workshop%202.pdf