Arizona Memorial Porous Concrete Parking Lot
Arizona Memorial Drive, Pearl Harbor, HI

The 171-stall parking lot was completed in 2011 by Ceco Concrete Construction and includes porous concrete parking stalls with traditional concrete drive lanes. Porous concrete stalls were constructed of 3/8-inch diameter crushed, lava basalt chips binded with cement to form a 6-inch thick slab over a 6-inch thick subbase of most likely No. 57 aggregate. The porous concrete has a strength of 3,000 pounds per square inch. Material costs to construct the porous concrete were comparable to traditional concrete paving costs, at around $10-$15 per square foot. Leadership in Energy and Environmental Design (LEED) credits for stormwater and heat island effect were achieved.

Images from site visit on June 23, 2011

Porous Pavements Overview
The following description of porous pavements is taken from Bruce Ferguson's book, *Porous Pavements*, published in 2005. Several questions posed during the Arizona Memorial porous concrete parking lot tour on June 23, 2011 related to porous pavement structural support, underlying subbase and subgrade, construction, drainage, and pollutant removal are addressed below.

Porous pavements are those that have built-in networks of void spaces where water and air pass through. A porous pavement infiltrates and treats rainwater where it falls. Its pore space stores water like a detention basin. Porous pavements can allow the oils from cars and trucks to biodegrade safely, the rainwater to infiltrate the soil, the heat of the sun to dissipate, the groundwater to be replenished, the roots of trees to breathe, and the streams to flow in dry summers. Porous pavements include porous aggregate (gravel), porous turf, plastic geocells, open-jointed paving blocks, open-celled paving grids, porous concrete, porous asphalt, soft paving materials (mulch), and decks.

Drainage
A pavement's hydrology begins at the surface with rainfall or snowmelt, at least some of which infiltrates the pavement's surface. Some additional water may arrive as runoff from off-pavement areas. Water infiltrating the pavement surface may further infiltrate the subgrade soil; the remainder overflows at the elevation provided for in the pavement's construction. Storage in the pavement's reservoir takes up temporary differences between rates of inflow and outflow. Evaporation pulls water back into the atmosphere at every stage. The most common material in base reservoir construction is open-graded (single-size) aggregate such as ASTM No. 57, which tends to have a porosity of 30 to 40 percent.

Where water infiltrates from the reservoir into the subgrade, it reduces downstream storm flows and in addition maintains ground water aquifers and stream base flow. As water passes through almost any porous paving material, it is treated by filtration and the biochemical activity of microorganisms.

The presence of water reduces the bearing value of almost any subgrade soil. Porous pavements that allow moisture into the subgrade must compensate for it with correspondingly thick pavement structure to spread out the load. A thicker pavement structure requires greater construction cost, but a porous pavement has a hydrologic function that could reduce the cost of off-pavement stormwater management structures. In the mid-Atlantic area, an 18 inch base is sufficient or more than sufficient for stability over wet, uncompacted subgrade in moderately trafficked parking lots. The addition of woven geotextile to the bottom of a pavement structure can help support the pavement on soft subgrade by adding tensile strength.

Impervious Liner
Where the soil under a porous pavement would swell during moisture fluctuations, a liner stabilizes the structure. In some projects a liner turns the base course into a reservoir of harvested water. The stormwater management functions of a lined pavement are limited to detention and water-quality treatment, not soil infiltration.

Underdrains
Where water stored in a pavement reservoir discharges relatively slowly via lateral pipes, the in-pavement storage reduces downstream flooding and erosion and the required size of downstream drainage systems.

Observations in 1989 from a parking lot in Nottingham, England surfaced with concrete open-jointed blocks over an aggregate base reservoir with a perforated pipe drain above an impermeable liner showed that peak discharge was typically 30 percent that of rainfall, whereas impervious pavement would produce surface runoff at closer to 90 percent.

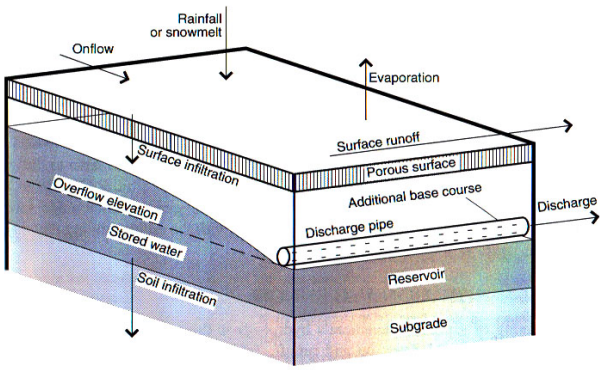

Image of Hydrologic features of porous pavement

Pollutant Removal
In general, porous pavements are effective at treating the particulates, oils, nutrients, and bacteria that occur in the course of pavements' normal use and maintenance. The treatment involves the removal of solid particles and their attached chemical ions from water, and bringing oil into contact with microorganisms for biochemical degradation. The pores house a microecosystem that filters and biodegrades the pollutants that occurs generically on residential, commercial, and office pavements; the underlying soil ecosystem is a backup treatment system that assures high treatment levels.

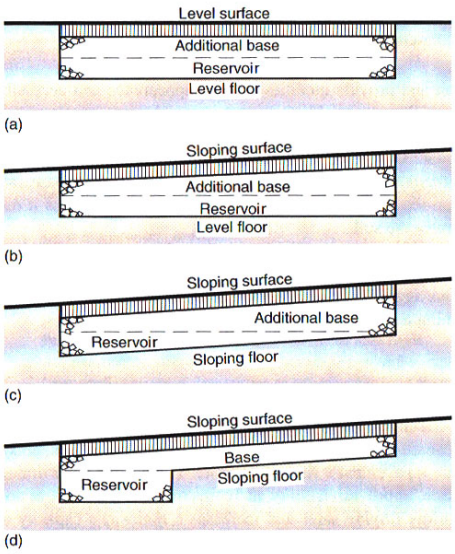

FIGURE 2.3 Reservoir in level and sloping pavements.

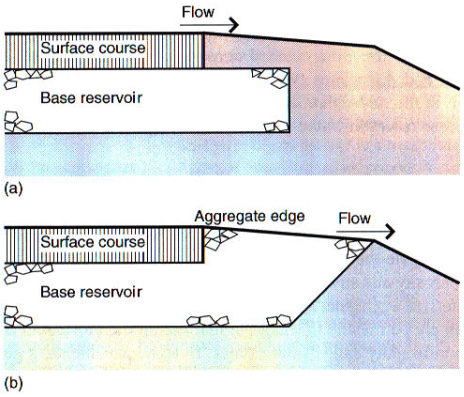

FIGURE 2.6 Arrangements for reservoir overflow at a pavement surface.

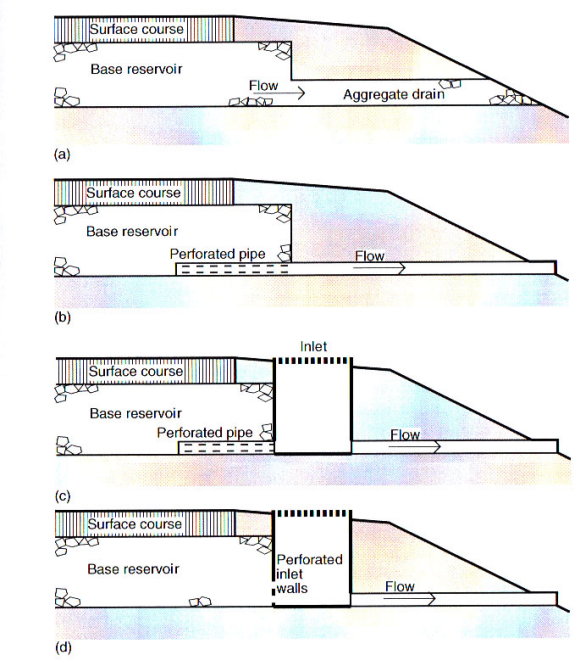

FIGURE 2.4 Examples of lateral discharge from the bottom of a pavement reservoir.

Porous Concrete Overview

Porous concrete is made by binding open-graded aggregate with Portland cement. Most of the volume of concrete is aggregate; the cement binds the aggregate particles together. Porous concrete is chemically identical to dense concrete; the defining difference is that porous concrete is made with open-graded aggregate, which creates the voids in the concrete structure.

A porous concrete slab, like one of dense concrete, is structurally rigid; it distributes traffic loads over large subgrade areas. Its strength is principally in compression, not tension. The compressive strength of properly made porous concrete containing No. 89 aggregate is commonly 2000 pounds per square inch or more.

Porous concrete's strength and durability have been adequate for the moderate traffic loads of numerous Florida parking lots where the material has been in place for more than 15 years. Six inches is probably the minimum thickness for any porous concrete slab bearing light vehicular traffic. Six inches of porous concrete can have the same strength as 1.5 inches of asphalt concrete with 5 inches of aggregate base. Properly installed porous concrete is appropriate for both low traffic loads of driveways and walkways, and moderate traffic loads such as those of commercial parking lots and residential streets.

Subbase

An aggregate layer under a rigid slab is referred to as a "subbase," perhaps because it does not interact with the slab to form a single structure, the way an aggregate base does under a flexible surface. In operation a subbase distributes load on the subgrade with relatively little expense, holds a slab in alignment across incipient cracks, and protects subgrade from frost penetration. An Army-Air Force manual suggests an aggregate subbase under rigid slabs where the subgrade's Unified classification is OH, CH, CL, MH, ML, or OL, and on SM and SC soils where the water table is high or where soil drainage will be slow.

The thickness of the subbase can be increased to compensate for great traffic load or soft subgrade, or to provide stormwater storage. In Florida parking lots the thickness of subbase has typically been determined more by hydraulic storage than by structural concerns as a result of Florida's combination of intense rainfall, stable soils, and shallow frost. In porous concrete control joints should be spaced no farther apart than 20 feet.

Porous Concrete History

Porous concrete was first used in pavements following World War II. California used it to make drainage layers under dense concrete highway surfaces. Switzerland and other jurisdictions in Europe reportedly used it in surface courses. Subsequently it was used for overlays on dense concrete roadways to improve drainage and traction, and for well-drained tennis courts and highway shoulders. The use of porous concrete pavement specifically for its environmental effects started in the 1970s in Florida, where stringent requirements for stormwater retention had been established.

Porous concrete is advocated as a best management practice by the EPA (Hun-Dorris 2005).

Porous Concrete Installed in Fine-textured Subgrades

Since 1996 porous concrete pavements have been installed on fine-textured subgrades outside the southeastern Coastal Plain. Although these pavements cannot percolate large quantities of rainwater into the soil during intense storms, they demonstrate that porous concrete pavements are structurally possible on fine-textured soil and that durable benefits of detention, water-quality amelioration, tree preservation, and gradual long-term infiltration are achievable.

Porous Concrete Cost Savings

In 1999 the West Coast acquired its first known installation of porous concrete. It is a 1500 foot long sidewalk along North Street in Olympia, Washington. Olympia's porous concrete material cost $5 more per square yard than dense concrete would have, and $10,000 more in engineering. However, because there had been no sidewalk in this area previously, this was a new development requiring rigorous stormwater control. The porous concrete saved $110,000 for off-pavement land acquisition and detention pond construction, making a large net saving.

References

Ferguson, Bruce. (2005). *Porous Pavements*. Boca Raton, Florida: CRC Press.

Hun-Dorris, Tara. (2005). "Advances in Porous Pavement." March-April. stormh2o.com.

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