Pervious Concrete

An Online Continuing Education Course for Engineers

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Pervious Concrete

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INTRODUCTION

Figure 1. Pervious concrete; source - NRMCA

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. With regard to quantity, high runoff can exceed the infrastructure's capacity to store and convey it, causing erosion and overflows, particularly combined sewer overflows. With regard to 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 in order to protect water quality and associated aquatic habitat.

One such LID practice is using **pervious concrete** (Figure 1) in lieu of conventional concrete for flatwork applications like residential roads, parking lots, and walkways. For any site, pervious concrete must successfully perform in two roles:

- hydrologic to maximize storage & infiltration; and minimize runoff

- structural to handle vehicle loads on the surface

Professional Organizations

Numerous professional organizations have published documents that contribute to the design, construction, maintenance, and knowledge of pervious concrete. The list below is not exhaustive, but it does highlight the prominent ones.   Their contributions to this course are listed in the chapter "References."

- American Concrete Institute (ACI): construction specification 522.1
- American Concrete Pavement Association (ACPA): PerviousPave design software
- ASTM International: test methods for product acceptance
- National Ready Mixed Concrete Association (NRMCA): contractor certification; mixture proportioning software; “Pervious Pavement” website
- Portland Cement Association (PCA): engineering bulletins

THE BASICS

Pervious concrete is a high-porosity concrete with void content typically ranging from 15% to 25%. It has very limited or no fine aggregate; and has just enough cementitious paste to coat the narrowly-graded coarse aggregates while preserving the interconnectivity of the voids.

These material characteristics, in turn, drive construction considerations that are distinctly different from conventional concrete:

a) Pervious concrete mix is stiff with negligible slump (< ¾").
b) Tests for compressive strength, slump, and air content do not apply.
c) To preserve permeability, the surface is neither sealed nor finished with float or trowel.
d) Joints do not use dowels.
e) Curing is much more critical.
f) Product acceptance is based on density - not compressive strength.

Figure 2 shows a basic cross-section of a pervious concrete system, which shall be explained from bottom to top.

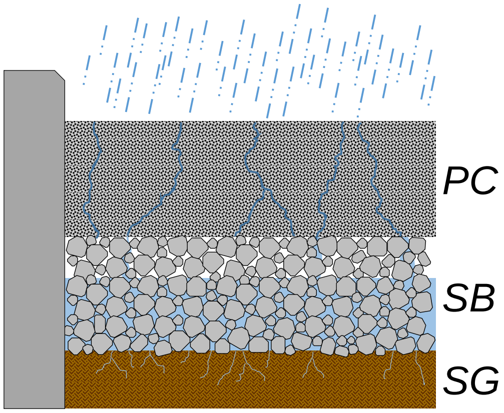

Figure 2. Simple cross-section of pervious concrete system showing percolation of stormwater through the pervious concrete (PC) down to the subbase (SB). Water further percolates through the subgrade (SG), if permeable.

Subgrade

Just as in conventional pavement, the subgrade in pervious concrete is critical because it must have structural capacity to support the layers above it. Furthermore, its elevation and slope will, in turn, affect the elevation and slope of the overlying layers.

Specifically for pervious concrete, an important hydrologic property of the subgrade is its infiltration rate. Infiltration rate of the subgrade determines whether or not additional appurtenances like underdrains and liners are necessary to promote drainage on site. Less permeable subgrades require a thicker subbase.

Compaction of the subgrade presents a dilemma to the designer. Although compaction may yield higher strength, it will reduce the subgrade's permeability and its hydrologic performance. Hence, the designer must consider the tradeoff in structural vs. hydrologic merits with compacting the subgrade.

Subbase

The subbase is immediately above the subgrade, typically 6 to 12 inches thick, and comprised of compacted, clean open-graded stone (ASTM No. 67, for example). The subbase serves several purposes:

- Hydrologically, it acts as a storage chamber for surface water until it either infiltrates the subgrade or enters drainage pipes.
- It protects the pervious concrete from freeze-thaw damage. The open-graded, coarse aggregate creates abundant voids to accommodate expansion of water when it freezes.
- It protects the pervious concrete from sulfate attack. The subbase acts as an isolation barrier between the overlying pervious concrete and the underlying soil.

A note on semantics: some sources say "base" for this layer instead of "subbase." For this course, the author uses "subbase" as the preferred term because the American Concrete Institute uses it in 522.1-13 *Specification for Pervious Concrete Pavement*, which is the definitive publication for this type of pavement.

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The pavement itself, typically ranging from 6 to 12 inches thick, owes its permeability to the near or total absence of fine aggregate (i.e. sand). The coarse aggregate is open-graded, such as ASTM No. 89, and it is coated with sufficient cement to bind the stones together. This renders an extensive matrix of interconnected voids that enables water to drain via gravity from the surface and down through the pavement to the subbase.

BENEFITS

Stormwater Management

The US EPA recognizes pervious concrete as a Best Management Practice (BMP) for providing first-flush pollution control and stormwater management. Usage of pervious concrete in lieu of conventional pavement at a site 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. Pervious concrete not only addresses the runoff *quantity*, but also *quality*. The subsurface aggregate filters suspended and dissolved contaminants, enabling discharges to other waterways to stay below Total Maximum Daily Loads (TMDLs). Petroleum contaminants from vehicles can adsorb onto the aggregate and then degrade via long-term microbial digestion (i.e. natural attenuation).

Pervious concrete can also yield additional runoff control by allowing more vegetated area within the project footprint. Its porosity makes water & air more available to plant roots than impervious pavement, so trees & shrubs can better thrive. More vegetation means more stormwater absorption and less runoff.

The permeability of pervious concrete also means that stormwater will not puddle on the surface, which is a particular nuisance for pedestrians.

Winter Liability

The top concern of property managers is liability. Managers typically instruct their maintenance personnel to salt and plow when snow begins to lay on the surface. In many cases, that minimal amount of snow will melt either in direct sunlight or when temperatures even slightly rise. With pervious concrete, snow melts and infiltrates the pavement – it does not refreeze on the surface, as it would on an impervious surface. Hence, prevention of slick surfaces reduces liability from pedestrians slipping & falling. Additionally, studies show that the ground beneath the pervious concrete system is less susceptible to freezing due to the insulating properties of the air space in the aggregate base. This is very beneficial to property managers who are concerned about safety and liability.

Site Utilization

Pervious concrete may provide sufficient storage and infiltration of stormwater to reduce or eliminate the need for detention/retention ponds, culverts, sewers, and other drainage infrastructure. As part of a larger project, these reductions in project scope can substantially reduce development footprint; which in turn preserves existing vegetation, lowers construction costs, and simplifies permitting.

Heat Island Reduction

Conventional asphalt pavement contains bituminous binder that gives the pavement a darker hue; therefore, it tends to absorb solar radiation, especially in the summer. Over time, the pavement heats up and then radiates heat to the surroundings. This is an urban phenomenon called *heat island effect*. Pervious concrete is better than asphalt in mitigating heat island effect for two reasons:

- *No dark bitumen*. Compared to asphaltic pavement, pervious concrete is lighter in color and has higher solar reflectance index (SRI). Hence, it absorbs less solar radiation.
- *Less heat storage*. Convective air flow in the voids contributes to cooling. Water in the voids can absorb heat and then evaporate.
- *Viable vegetation*. As mentioned before, pervious concrete better promotes on-site vegetation because it makes water & air available to roots. More vegetation means more shade and less solar absorption.

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 recycled or locally sourced materials and for providing more vegetated area (“green space”).