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Porous Concrete Sidewalks
- How to build sidewalks and not stormwater ponds

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Abstract

Building sidewalks typically triggers stormwater mitigations requirements. Sometimes the cost of creating the stormwater mitigation for a new sidewalk can exceed the cost of constructing the sidewalk. Using permeable pavements is one way to create sidewalks without triggering stormwater mitigation requirements.

The City of Olympia, Washington has installed over 7,500 square yards or about two miles of porous concrete sidewalk to date, with more projects coming each year. We have experience with three different types of porous concrete materials over an eight-year period. Materials range from the regular "no-fines" porous concrete to a new form of 100 percent sand "all-fines" concrete.

This paper presents the lessons learned and current state of porous sidewalk technology in Olympia. Our experience with different materials, design, construction, and maintenance is provided along with construction and operating costs.

Sidewalks in Olympia, Washington

A 2000 survey of residents in Olympia found that sidewalks and walking facilities are the top choice for neighborhood public improvements. In 2003, citizen volunteers completed an inventory of arterials, major collectors, and neighborhood collectors that did not have sidewalks. These streets compose 42 percent of the City's street system. The inventory found 84 miles of missing sidewalks on these high-volume streets. At previous funding levels, it would take the City 180 years to construct the needed sidewalks.

In 2004, a funding measure was placed on the ballot for parks and sidewalks facilities. Voters approved an increase of the private utility tax resulting in approximately $1 million dollars annually for sidewalk construction.

Sidewalk construction typically triggers the installation of stormwater controls. These stormwater controls often require the acquisition of additional right-of-way or land. The total cost for the stormwater mitigation can exceed the cost of the sidewalk construction. The land required for stormwater controls can be expansive, on retrofit projects, it is sometimes simply not available. Porous concrete does not generate increased stormwater runoff and therefore does not trigger the need for stormwater controls. Porous concrete allows Olympia to build sidewalks without building costly stormwater ponds.

Current State of Porous Concrete Technology

Porous concrete is a type of concrete that has sufficient interconnected voids to allow water to pass through the material. Historically, porous concrete started as "no-fines" concrete, a regular concrete material without fine aggregates. This lack of fines results in an increase in the amount of voids. There now exists varieties of porous concrete that use fine and sand aggregate which results in a smoother surfaced porous concrete.

The defining feature of all porous concrete is the low water-to-cement ratio used during mixing. Traditional concrete has a water-to-cement ratio that allows the cement to form a slurry and bond the aggregate together. The slurry fills all of the voids between the aggregate. Porous concrete reduces the water-to-cement ratio such that the cement forms a paste. The goal of the mixing process is to coat the aggregate with the cement paste and then compress or consolidate the material to increase bonding strength. Given that the original aggregate has a large amount of voids between them, the addition of the paste does not completely fill the voids. This results in the presence of voids connected completely through the porous concrete.

Three major groups of porous concrete will be discussed. Each is categorized by the name of the admixture used in the material: Regular (no admixtures), Stoney Creek, and Percocrete. The major difference between the groups is the size of the aggregate that can be used in the material. The more expensive the admixture, the smaller the aggregate that can be used. The smaller the aggregate used, the smoother the surface texture of the porous concrete. Table 1 below provides a summary of the general properties of the three porous concrete groups:

Table 1: Porous Concrete Properties

Porous Concrete Group	Typical Smallest Aggregate Size	Surface Texture	Material Cost	Finish Technique
Regular	3/8-inch	Coarse	Lowest cost	Roller or self-consolidating
Stoney Creek	¼-inch	Medium	Medium cost	Self-consolidating or slip form
Percocrete	Sand + ½-inch	Smooth	Most expensive	Plate compactor

Typical strength of most porous concrete is 2,000 to 3,000 pounds per square inch (psi) compressive strength and 200 to 300 ponds flexural strength. Some mixtures can have significantly more or less strength depending on the materials used in the design. The following general characteristics apply to mix designs. Fractured aggregate has a higher strength then naturally round aggregate. Aggregates that are a blend of different aggregate sizes result in stronger porous concrete but have less voids content. Porous concrete that has a higher water-to-cement ratio is stronger than materials with a lower water-to-cement ratio. Materials with a higher water-to-cement ratio have more cement slurry and have lower voids and lower infiltration rates.

Void contents of porous concrete range between 10 percent and 20 percent. Generally, at least 15 percent voids are needed in the final material to create a product that is highly porous. Aggregate used in the material need to start out with at least 30 percent voids. The more uniform the aggregate size, the more voids there are in the material. This relationship holds true for sand and rock aggregate. Thus, sand materials can have similar voids contents to large aggregate.

Benefits of Porous Concrete

The major benefit of porous concrete is the ability of water to completely pass through the material. Rainfall can then be infiltrated into the soils underlying the pavement. Infiltration not only reduces or eliminates the need for stormwater mitigation, it also recharges groundwater. Initial infiltration rates of porous concrete range from the 10's to 1000's of inches per hour. Infiltration rates of the underlying soil may actually be more limiting. While some clogging of the surface pores is inevitable, porous pavement only fails when it does not pass typical rainfall intensities of the region. In Olympia, typical rainfall intensities are less than one inch per hour. Given this precipitation intensity, infiltration of the porous pavement is not a limiting factor.

The large voids content of porous concrete allows the material to be able to withstand freezing and thawing. Even when samples are completely soaked in water and rapidly frozen, there are air voids left within the material that allows for ice crystal expansion without effecting the concrete.

The voids content of porous concrete allows water and air to flow through the material. The flow of air and water is a two-way process. During rainstorm events, water is able to flow into the underlying soils. Between rainstorm events, water is able to leave the underlying soils and evaporates back into the air. Air is continually able to exchange between the underlying soil and the atmosphere.

Porous pavement also stays cooler than traditional concrete materials. A significant benefit of porous concrete is the reduction of the heat island effect associated with traditional concrete materials. Porous concrete materials are slower to heat up and faster to cool down than traditional concrete. A disadvantage of this property is that porous concrete sidewalks can freeze sooner than traditional pavements. When air temperatures are just below freezing, porous concrete sidewalks can freeze and allow ice to accumulate on the surface while traditional concrete may remain unfrozen. This effect is reversed when air and soil temperatures result in thawing of pavements.

Porous Concrete Sidewalks In Olympia

The City of Olympia installed its first 1,500 feet of porous concrete sidewalk in 1999 along North Street in East Olympia. The sidewalk was adjacent to an existing roadway. Due to the stormwater regulations and price of land in Olympia at the time, the sidewalk saved an estimated $140,000 in initial construction cost. Maintenance costs were unknown.

A survey of residents using that sidewalk in 2000 found that 52 percent of sidewalk users liked the appearance of the Regular porous concrete surface; 25 percent did not. When asked about the walking surface, 49 percent said it was less slippery, while 9 percent said it was more slippery than a regular sidewalk. If the price was comparable to traditional concrete, 52 percent said they would consider using it at their homes verses 15 percent who would not. When asked if the City of Olympia should encourage developers and builders to use porous pavements 72 percent said yes, while 11 percent said no.

Since 2000, there have been advances in the use of finer aggregates in porous concrete. These finer aggregates result in smoother surfaces with more and smaller surface voids then compared to Regular porous concrete. This finer aggregate porous concrete may be less prone to clogging. The appearance is also more appealing to the public.

Olympia also installed a section of Stoney Creek porous concrete sidewalk in 2004. Stoney Creek uses ¼-inch sized aggregate. The concrete is also self-consolidating, meaning that after screeding no additional surface rolling or compressing is needed. The surface texture of Stoney Creek is much smoother than Regular porous concrete. Cleaning of Stoney Creek previous concrete should be easier and more effective than Regular porous concrete.

Percocrete porous concrete uses sand aggregate and is similar to regular concrete in texture. The surface voids of Percocrete porous concrete are smaller than most of the leaf litter material that falls on a sidewalk. For this reason, Percocrete porous concrete may be the least susceptible to surface clogging. Olympia has been using Percocrete previous concrete in sidewalks since 2004 and plans to continue to use it in the future.

Maintaining Porous Concrete Sidewalks

Olympia started to explore ways to clean the North Street sidewalk five years after the sidewalk was built. Without any maintenance, some sections of the Regular porous concrete were clean and free of debris; other sections were almost completely clogged and had moss growing on the surface. Clogging of the pavement was dependant on the amount of leaf litter it received. Where there were trees adjacent to the pavement, it contained moss. Where there were no trees, the pavement was clean. Where homeowners mowed the grass and discharged the lawn clippings onto the sidewalk, it was clogged. After five years of doing nothing, it was evident that porous pavements need some form of regular maintenance if the infiltration capacity was to be maintained.

The City has tried many different types of cleaning machines on the North Street sidewalk. The initial cleaning was performed by pressure washing. Pressure washing is an expensive maintenance technique and should only be used as a last resort to revitalize clogged pavements. A cleaning machine that combines pressure washing and vacuum extraction of the wash water was also tried on the North Street sidewalk. This cleaner