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CENews.com Feature Article | Posted: Monday, June 30, 2008

Controlling runoff beautifully

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Pervious concrete has become a superstar among environmentally friendly pavements

Water runoff from pavements carries pollutants into waterways and creates erosion problems. For decades, engineers have dealt with these issues by designing gutters, swales, and retention ponds to redirect, channel, and collect runoff. Lately, a different approach to the challenge has been gaining attention: Don't let the water run off.

The rising star of runoff control is pervious concrete. Water flows through it, not over it. Stormwater percolates into the ground beneath, recharging the natural water table instead of running off and causing erosion. Natural bacteria in the soil break down water-borne organic pollutants. The U.S. Environmental Protection Agency (EPA) has designated porous pavement as a best management practice for stormwater runoff.

Pervious concrete can protect fragile environments and provide a low-cost, low-maintenance solution to the EPA's runoff pollutant regulations. It can also make an aesthetic contribution to a project by including color in the concrete. Pervious concrete has been used in the United States for almost 40 years. Increased awareness of environmental issues, however, has recently given it celebrity status as a solution to pollution and erosion associated with pavement runoff.

In a demonstration of drainage, 1,800 gallons of water are released, far exceeding the heaviest rainfall possible. Photo: Standard Concrete, Santa Ana, Calif.

It can be considered a type of dry detention pond. The material's volume contains 15- to 40-percent void space, and water soaks directly into it almost immediately. A properly designed pavement-plus-subbase holds several inches of stormwater that can then be absorbed into the ground during a period of hours.

The first flush from a storm—the first 1 to 1.5 inches of rainfall—carries away 90 percent of pollutants found on pavements. It can pollute streams and rivers if it is allowed to flow into waterways untreated. When water is returned into the ground, as it is with a pervious pavement, natural bacteria break down organic compounds. (Applications where inorganic pollutants are a factor, therefore, may not be appropriate for pervious pavement.)

Pervious pavement's voids are created by making concrete without fine aggregate. Mixtures are designed with just enough cement paste to coat the coarse aggregate, but not to fill all the spaces between the aggregate. For strength, and to keep the paste from flowing and filling the voids, a low water/cementitious material (w/c) ratio is required. About 0.3 is typical.

The pavement cures to a solid matrix with a network of interconnected voids. The percentage of void space is partially dependent on the size of aggregate used: 3/8-inch aggregate produces 15- to 25-percent void content; 1/2-inch rock yields 30- to 40-percent void content and a noticeably coarser surface. Larger aggregate can be used, but the texture is so rough that it is not suitable for many paving applications.

How it works

The concrete is usually placed over a base of coarse aggregate. The combined volume of voids in the concrete and the base form a detention system with a calculable capacity. A typical design—6 inches of pervious pavement with 20-percent voids over 6 inches of 1-inch rock with 40-percent voids—can absorb and hold 3.6 inches of water: (6 x 0.20) + (6 x 0.40) = 1.2 + 2.4 = 3.6 inches.

When properly designed and placed, pervious pavement can drain at 3 to 8 gallons per square foot per minute. The example 3.6-inch accumulation is then held within the pavement system. Depth of concrete and base can be adjusted to accommodate design assumptions of rainfall and the percolation capacity of the subgrade. A subgrade absorption rate of 0.5 inches of water per hour is considered a minimum.

According to Byron Klemaske, vice president of T.B. Penick & Sons, San Diego, a contractor specializing in pervious pavement, the material is used for both vehicular and pedestrian traffic. It can also be used for some street pavements, for tree wells, and even sea walls. Pervious pavements are also used to collect and redirect stormwater into holding tanks for irrigation.

Klemaske noted that the majority of Penick's pervious pavements have been integrally colored. This prevalence of color, even for driveways and parking areas, may seem odd, but not to Nick Paris, vice president marketing for Davis Colors, Los Angeles, a supplier of concrete pigments.

Large expanses of colored pervious concrete are being installed at Olympic venues in and around Beijing. When liquid pigments are used, the water content of the mix must be adjusted to account for liquid in the pigments, keeping the w/c ratio accurate. Photo: Bunyan Industries, USA

Paris sees a logical connection. "When the people behind a project are concerned about an environmentally responsible runoff solution, it's not surprising that they also care about aesthetic harmony with the surroundings," he said. "Color can be used to make concrete blend better with the natural features of the site, making it less visually intrusive. Alternatively, bright or contrasting colors can make concrete stand out as an artistic contribution. Hardscaping sometimes creates social and political tensions between developers and communities. A bit of color can be an easy and economical way to defuse the situation." (See "Pervious pavement goes platinum")

Pervious concrete pavement can make other environmental contributions. Concrete pavement is more light-reflective than asphalt and can reduce the urban heat island effect. Light-colored concrete improves reflectivity even further. Klemaske observed this as one of the main motives in pigmented installations: "Many projects use light colors because it helps earn LEED points."

Pervious concrete contributes to an additional LEED point because it is generally made from locally extracted and processed materials. It can also be made with recycled content such as fly ash or blast furnace slag. These materials darken concrete, and must be taken into account if color is a concern.

Designing for traffic loads

Because of the open nature of the matrix, the attainable compressive strength is lower than would normally be expected from such a low w/c ratio. According to the National Ready Mixed Concrete Association (NRMCA), which certifies pervious pavement contractors, compressive strength is typically in the range of 2,500 to 3,000 pounds per square inch (psi), and NRMCA recommends assuming 2,500 psi. However, a study conducted jointly by the Florida Department of Transportation (FDOT), the Florida Department of Environmental Protection, and Rinker Materials concluded that 1,700 psi was a more realistic figure.

Measurement of compressive strength is complicated by the fact that no standard testing method exists. ASTM Committee C-09 Subcommittee 49 is working on one, but according to ASTM Staff Manager Scott Orthey, it could be several years before it is finalized.

The difficulty of designing compressive strength testing is due to the way pervious pavement is made. To preserve the void structure, the concrete is not vibrated during placement. In fact, to minimize consolidation, workers shouldn't even walk through it or on top of it before curing. The mixture is screeded and then the top surface is lightly compacted—about 3/8 inch—locking together the rocks to produce a more even surface with minimized raveling. Understandably, a standard test cylinder would not replicate the properties that the material acquires in use.

The most commonly used guide is simply the experience of hundreds of installations. Typically, 6 inches of pervious concrete provides suitable strength for parking lots and residential driveways; 8 to 10 inches is appropriate for low-volume streets and commercial driveways. High-volume streets or pavements expecting heavy truck traffic should probably not use pervious pavement. Ten inches of pervious concrete is considered the maximum thickness that can be properly placed and compacted. The Portland Cement Association (PCA) recommends using its Streetpave software to aid in structural design.

Freeze-thaw performance has received much study. NRMCA issued recommendations with documented case studies that address this issue. The material has performed well in areas experiencing dry freeze, hard dry freeze, or wet freeze. No special design is needed, although 4 to 8 inches of aggregate base is recommended, and clogging of voids must be avoided or cleaned out.

For areas experiencing hard wet freeze, the recommended aggregate base depth increases to 24 inches. Air entraining admixtures may also help protect the paste in these conditions. Perforated PVC pipe can also be placed in the aggregate base to drain water. In areas where the groundwater table rises to less than 3 feet from the surface, or where there is substantial moisture flow from surrounding higher ground, pervious pavement is not recommended.

Cost of materials and overall placement for pervious pavements varies considerably by region. Little or no premium exists in regions such as the Southeastern United States and the West Coast where pervious pavement is widely used and experienced producers and contractors are prevalent.. In Santa Ana, Calif., for instance, materials cost is roughly even with conventional concrete, according to Renee Hernandez, general sales manager for Santa Ana-based Standard Concrete Products, Inc. In places where experience and supply are limited, however, materials and placement can cost as much as 30-to 50-percent more. Integral coloring generally adds 50 cents to $4 per square foot, depending on color intensity.

To preserve the void structure, pervious concrete must not be consolidated by vibration. Instead, it is struck off and then slightly compacted by rolling the surface. This powered roller-screed does both operations in two or three passes. Photo: Steven H. Miller, courtesy of Davis Colors

The extra cost of pervious pavement, however, is often recovered in whole or in part by savings elsewhere in the project through elimination of other runoff-control structures. In some projects, extra buildable land made available by eliminating a retention pond can result in significant net profit.

In the long term, a small, but on-going maintenance cost is incurred for vacuuming or pressure-washing the pavement two to four times per year to prevent void clogging. In some locations, there may also be on-going savings because of reduced use of the local sewage system.

Other design considerations

For pervious concrete to function properly, the void structure must remain unclogged. Conditions that can lead to clogging must be anticipated and avoided. For instance, pervious pavement should be higher than surrounding ground to avoid dirt being washed onto the pavement.

Debris from trees can also clog voids, but it can usually be removed by vacuuming or pressure-washing, a maintenance cost to anticipate.

The w/c ratio is critical. When liquid pigments are used, the water content of the mix must be adjusted to account for liquid in the pigments to keep the w/c ratio accurate.

Suggested specifications require the presence of certified Pervious Concrete Technicians or Pervious Concrete Craftsmen on any sizeable project. Certification is administered by the NRMCA.

For further information, including specification language, see PCA publications CD063 "Pervious Concrete: Hydrological design and resources" and SP021 "Color and texture in architectural concrete." Both are available at www.cement.org. Certification information is available at www.nrmca.org/certifications/pervious.

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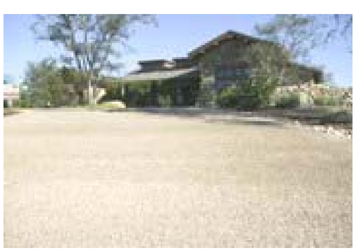
Pervious pavement goes platinum

Pervious pavement recently helped a project achieve Platinum LEED certification, the highest eco-friendly construction designation under the U.S. Green Building Council's Leadership in Energy and Environmental Design program. Black Mountain Ranch House is a sustainably designed building at the center of the Del Sur master-planned community in north San Diego. The building currently serves as a welcome center and sales office for the development, but will later become the community center. The Del Sur project will comprise 3,050 homes in nine neighborhoods. It has been in development for almost 20 years, a process lengthened, in part, because of opposition from environmental activists.

Environmentally conscious design of the Ranch House includes both functional harmony with nature and visual harmony with the surrounding landscape and the architectural traditions of San Diego. Sustainable construction figured into virtually every aspect of the project, including the native stone that was excavated from the site to construct the building's walls, and 10,220 square feet of pervious concrete walkways, driveways, and parking lot surrounding the building.



Black Mountain Ranch House is the 28th building in the world to obtain Platinum LEED status, an achievement due in part to the pervious parking area, driveway, and walkways. Photo: Davis Colors

The pervious pavement was integrally colored to blend with adjacent earth tones and the native stone. The landscape design firm of Wimmer, Yamada and Caughey, San Diego, worked with architectural color consultant Ann Matteson of Newport Beach, Calif., and Davis Colors to develop an appropriate color. They modified a standard color to a special blend that could be consistently and cost-effectively mixed using Davis' Chameleon liquid pigment dosing system, an automated system well-suited to replicating custom colors accurately from one batch to the next. The final color, dubbed Del Sur Buff, is being used in both pervious and conventional concrete throughout the development.

The developer's extra effort to mitigate environmental impact yielded tangible positive results. The good will they built with the surrounding community ultimately proved instrumental in getting voter approval for the entire development. One of the former environmentalist opponents even organized a regional "GreenBuilt" tour in September 2007 that featured Black Mountain Ranch House. The tour raised awareness of the project and introduced potential buyers to the site.