Portland Tries Permeable Interlocking Concrete Street Pavements

Known for its leadership in environment stewardship, The City of Portland, Oregon, placed over 19,000 sf (1,765 m^2) of permeable interlocking concrete pavements in its Westmoreland neighborhood.

Portland, Oregon, (population 551,000) endeavors to maintain its reputation as an environmentally friendly and innovative city. Last November, the city government confirmed its commitment to both by constructing a permeable interlocking concrete pavement (PICP) pilot project using some 19,000 sf (1,765 m^2) in its Westmoreland neighborhood. The well-kept, 80-plus year old neighborhood required water line reconstruction following installation of large-diameter sanitary sewer pipes in 2003. Rather than merely repave the streets with asphalt, the City's Bureau of Environmental Services and the Portland Office of Transportation conceived a demonstration project with PICP on three blocks. The $412,000 project included about $100,000 of water line work. The City leveraged the costs for installing the PICP with an $80,000 grant from the U.S. Environment Protection Agency Innovative Wet Weather Program.

However, this wasn't the first permeable interlocking concrete pavement project for the City. Permeable pavers had been used in a municipal arts center and at other locations. See Figure 1. The Westmoreland project, however, was the first time permeable interlocking concrete pavers (PICPs) were installed in a city public right-of-way.

According to Steve Townsen, P.E., Head of Engineering Services for Transportation and the Acting City Engineer, different pavement slopes and pavement configurations were employed to evaluate the long-term impact slopes would have on runoff and drainage. One city block has been paved the full width in permeable pavers with a centerline crown and cross slopes of 2% (see photo above). Two other streets have 6 ft 10 in. (2.1 m) parking strips paved with PICP on each curb side and a 12 ft (3.7 m) center lane paved in asphalt. See Figure 2.

The PICP is flat on these two streets. The asphalt center lane on one has a centerline crown and 2% slope in each direction. The asphalt strip on the other street slopes 2% to one side. Open-graded

Figure 1. The City of Portland is not new to permeable pavements. The Multnomah Arts Center parking lot was one of the early projects.

Figure 2. The permeable pavers receive runoff into an open-grade aggregate base, or "drainage blanket," that extends under the asphalt across the entire street. This boosts water storage and infiltration capacity.

Figure 3. Portland has been reducing flows to combined sewer systems by disconnecting downspouts that daylight to street outlets like the one shown here. PICP offers another way to reduce combined sewer flows. The metal ring in the curb was a regional tradition that facilitates horse parking.

Figure 4. Deteriorated concrete curbs and driveway aprons were replaced. The existing storm drainage inlets and pipes were left in place for use as an overflow drain during heavy rainfall.

base (called a "drainage blanket") extends completely under the PICP pavement and streets with the asphalt center lane and PICP curb lanes. In other words, the drainage blanket offers additional storage and infiltration under the asphalt center lanes.

PICP as Traffic Calming?

The City left the storm sewers in place since they didn't require replacement. According to Mr. Townsen, "The storm sewer inlets can act as an overflow device if the permeable pavements were to become plugged or are completely full of runoff." He noted that, "The neighbors were delighted with the results." This was verified by the editor and a consulting engineer for the project walking the neighborhood in March 2005 and informally asking residents for their opinions. Neighbors expressed satisfaction with the pavement. One resident wanted the asphalt center lane paved with permeable units to further slow down vehicles.

Reducing Combined Sewer Overflows

The experimental project demonstrated a new method for reducing runoff into the city's combined sanitary and storm sewer system. Like many cities with aging combined sewer systems, when combined pipe flows reach capacity during rainstorms, some untreated sewage

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Figure 5. Mechanical installation equipment places the permeable pavers in the final laying pattern over the bedding course.

Figure 6. The bedding material was an Oregon DOT standard for small size, open graded stone.

Figure 7. The drainage blanket of open-graded stone base ranged in size from 4 in. (100 mm) to 1/16 in. (2 mm), an Oregon DOT standard for large size, open-graded stone.

overflows into the Willamette River. Any means to reduce stormwater flowing to the combined sewer system helps reduce combined sewer overflows (CSOs). A common approach is to disconnect downspouts from pipes, allowing water to infiltrate. The City initiated a program encouraging residents to do this. With infiltration offered by PICP, the City has another tool for reducing CSOs and water pollution.

Construction

The pavement consists of 3 1/8 in. (80 mm) thick permeable interlocking concrete pavers. Mechanical installation was used on most of the project with portions of pavers hand installed along the curbs on the sides of the 6 ft 10 in. (2.1 m) wide PICP strips. Since many of the curbs and driveways aprons were as old as the neighborhood, some had to be replaced. If curbs weren't replaced, pavers were cut and fitted around existing curbs pushed a few inches into the street by the trees.

Figure 8. The drainage blanket base runs under the curbs across the width of the street. Geotextile was placed over the top of the drainage blanket in the asphalt center strip and dense-graded base compacted into place as shown here. Temporary driveways built with base and plywood allowed access to residents' driveways.

Figure 5 shows mechanical installation equipment set the paving units on a 3 in. (75 mm) thick bed of small size, open-graded stone (ODOT 02610.10) ranging is size from 9 mm to about ½ mm in size. The same material was used to fill the openings in the pavers. A layer of geotextile separated the bedding layer from the open-graded drainage blanket (ODOT 00360.11). The size of the base aggregate ranged from 100 mm to 2 mm. Figures 6 and 7 illustrate the stone bedding and drainage blanket base.

Some PICPs don't use geotextile between these two layers of aggregate when the bedding layer 'chokes' or meshes into the base surface. For the Portland streets, there was some concern that gradation of the two aggregate layers would not mesh well. Since that was the case, geotextile was used to prevent loss of the bedding layer into a base with large aggregate sizes. In addition, geotextile was placed between the soil subgrade and the open-graded base. Storm drainage considerations established the 10 in. (250 mm) thick open-graded granular drainage blanket. With most street traffic coming from passenger cars, vehicular loads were not a factor in determining the base thickness.

Prior to construction, Portland's Bureau of Environmental Services conducted three infiltration tests to determine a design infiltration rate for the silty soil. The tests utilized a double-ring infiltrometer similar to that recommended by ICPI to assess soil infiltration rates. While higher infiltration rates were measured, a conservative design infiltration rate of 1 in./hour or 7 x 10-6 m/sec. was assumed for the design and modeling. The soil subgrade was not compacted prior to conducting the tests nor compacted as part of the construction process.

The cost of the PICP, bedding and filler stone and geotextile was about $102,000. After replacing the water lines, the aggregate drainage blanket was placed. Compaction consisted of several passes of a vibratory roller. Header curbs to restrain the asphalt and PICP were poured, cured and more drainage blanket installed as needed. Geotextile was placed over the drainage blanket, dense-graded base

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Figure 9. A makeshift screed levels the bedding course for the permeable pavers.

Figure 10. The width of new curb was set to accommodate mechanical placement of two paver layer widths within the 6 ft – 10 in. (2.1 m) wide parking strips. Some adjustments were necessary to fit the layers within the new curbs and the mostly uneven old curbs adjacent to the residences.

Figure 11. Installed pavers were compacted, the openings filled with the bedding stone and compacted to about 3/8 in. (10 mm) above the new concrete curbs.

compacted and 4 in. (100 mm) thick asphalt placed in the center of the streets. Temporary driveways were built with base and plywood to enable access to residences along the streets. See Figure 8.

Geotextile was placed over the drainage layer in the PICP locations, then the 3 in. (75 mm) thick bedding layer placed and screeded to receive the pavers. Once installed, the pavers were compacted, openings filled, then compacted again. See Figures 9, 10 and 11. The PICP installer, manufacturer and project consulting engineer were ICPI members.

Modeling and Monitoring

How effective is the project? According to project manager Steve Burger, P.E., Senior Engineer with Portland's Bureau of Environmental Services, the PICP is designed to handle a 10-year (SCS/NRCS Type 1a) storm. He modeled inflows and outflows using 10 and 25-year storms (i.e. storms with a 10% and 4% chance of happening annually.) The modeling included runoff contributed by adjacent driveways and roof areas as well as runoff from the streets themselves. Using a 1 in./hour soil infiltration rate, his modeling indicated a modest amount of overflow from the PICP during a 25-year storm and none during a 10-year storm. This confirms that PICPs are designed to handle frequently recurring storms. This is an important factor as storms of this nature can be the ones with the highest concentrations of pollutants.

As part of the US EPA grant, the city will monitor the project using observation wells built into the lower elevations of the streets. These consist of vertical perforated pipes that enable measuring the rate of water infiltrating into the soil. See Figure 12.

In addition, there is a 10 ft (3 m) long horizontal perforated pipe buried 12 in. (0.3 m) in the soil below the base that drains into one of the utility structures. This enables sampling and testing pollutants in water filtered through the base and soil and collected by the drain pipe. So far, monitoring infiltration and sampling water have been impossible. According to Mr. Burger, "The permeable pavement system drains so well that we haven't been able to measure infiltration rates or sample water that has passed through the base and soil to analyze it for pollutants."

Maintenance

Mr. Townsen noted that the first cleaning of the permeable pavers was done in February 2005. Portland streets are typically cleaned four to six times annually with municipal-duty, high-suction street cleaning equipment. He and Mr. Burger said that a sweeper was used first to loosen the dirt and leaves in the openings and then a vacuum sweeper followed behind the sweeper. The suction level on the vacuum machine was reduced to prevent intake of the small stones in the openings of the PICP. A water spray was not used as it would have likely loosened fines and enabled them to flow into the PICP.

Now in use for over six months, the project appears to be a success. Late in November 2004, a Portland television station reporter christened the PICP by dumping a five-gallon (19 l) bucket of water on the pavers. The water disappeared immediately into the pavement openings. The "baptism" broadcast on the evening news gave dramatic proof of the pavement's high infiltration capacity.

"We don't have any current plans to pave any future projects, but this is another tool in our toolbox on how to dispose of stormwater, Mr. Townsen said. That tool not only disposes of stormwater, it creates a unique neighborhood character, one that fits well into the ethos of environmental stewardship that characterizes Portland. ❖

Figure 12. Capped, 4 ft (1.2 m) deep, 6 in. (150 mm) diameter perforated pipes serve as wells to monitor infiltration rates.

Neighborhood participation: a do-it-yourself resident replaced his front walk with spare pavers and bedding material.