From the Editor **David R. Smith**

Do the Math

As the market for permeable interlocking concrete pavement (PICP) grows, ICPI members and staff find ourselves making an increasing number of presentations to design professionals and stormwater agencies. As with any new technology and eventual paradigm shift, a pattern of frequently asked questions emerges:

- What about freeze and thaw, won't PICP heave?
- To what extent does the system capture oils?
- How quickly does the surface clog?

The answers to these involve math-based principles and relationships discovered through research. The answer to the first question is fairly straightforward. Water expands 9% when it freezes. Depending on the layer within PICP, the void or open space among the aggregates is roughly between 20% and 40%, certainly well over 9%. Therefore, when water freezes, it has ample room to expand as ice while moving into spaces among the stones. Base heaving is not a threat. In fact, it has not been reported as ever occurring.

The answer to the second question involves a bit more math. PICP has joints or openings filled with open-graded stone. When oil drips from vehicle engines, it drips on this stone and provides an opportunity for oil to spread over the stone surfaces. As the oil spreads on the stone surfaces, it also breaks down from bacteria over a period of days.

An interesting research paper develops some working relationships between PICP and oil capture. It is a 1999 paper by Christopher Pratt, "Developments in Permeable Pavements: Further Observations on Mineral Oil Degradation" in the *Proceedings* of the Standing Conference on Stormwater Source Control, XVII, 1999, Coventry University, UK. Pratt set up PICP in a large laboratory test container and introduced oil to determine how much was being captured. The test bed consisted of permeable pavers, open-graded bedding and base stone.

Pratt concluded that the bedding stone can hold about 16 g of oil per pound of bedding stone. Assuming 120 lbs/ft^3 at a 2 in. depth, the weight per square foot is about 20 lbs. Using Pratt's estimate on oil holding capacity, this calculates to about 320 g of oil held in each square foot of bedding stone or about 0.8 lbs of oil (about 0.11 gal of oil assuming 6.8 lbs/gal).

Pratt further estimated that about a pound of base/subbase stone captures 3 grams of oil. Let's assume that a PICP base/subbase is 12 in. deep. Assuming 120 lbs/ft^3, the estimated amount of oil captured would be about 360 g or about 0.74 lbs (0.1 gal).

Adding the capture rates for each pavement component, the total is about 1.7 lbs (~770 g) of oil captured per square foot (about a quart/sf). Obviously, Pratt conducted laboratory research in controlled conditions because of the more difficult task of measuring oil capture by each layer in the field. Even if Pratt's laboratory-generated numbers are off by 50%, a conservative estimate for PICP oil capture of 0.13 gal/sf is encouraging. And we are not counting the oil that remains on the concrete paver surface, also eventually degrading from bacteria.

Let's turn to answering the surface clogging question. For any permeable pavement, the rate of clogging depends on the intensity of PICP use and sediment deposited by vehicles or eroded onto the surface. Under ordinary use, clogging does not shut down surface infiltration. ICPI recommends vacuum sweeping the surface once or twice annually, adjusting the schedule depending on sediment deposition. Vacuuming can maintain high surface infiltration rates.

Some folks criticize PICP for its small joints that are perceived as easily clogged. The real question is what is the long term the surface infiltration rate of all of these systems? What should be used for design? Porous asphalt and pervious concrete have very high initial surface infiltration rates. That's because the surfacing materials consist of ASTM No. 8 stone or materials with similar gradations. This stone has an infiltration rate of over 1,000 in./hr. Field surface infiltration measurement of new installations have confirmed this.

For PICP, the initial surface infiltration rate is also quite high. North Carolina State University measured PICP sites and found rates over 1,000 in./hr. All initial rates are subject to decrease over time in all types of permeable pavements. So how does one estimate a reasonable long-term surface infiltration rate for PICP? The estimate starts with the percent of open surface area which varies by paver design.

Let's assume that a PICP system has 10% total open surface area. The permeability of the joint filling material is 1,000 in./hr. Therefore surface infiltration of a PICP with 10% open area is 1,000 in./hr. x 0.10=100 in./hr. Several researchers have separately documented that all permeable pavements experience a decrease in surface infiltration rate over their life. A conservative, projected lifetime surface infiltration rate suggested by one PICP researcher is 85% of the initial rate or 15%. Applying this to 100 in./hr x 0.15 = 15 in./hr. So the worst case infiltration rate is 15 in./hr. This rate can accommodate just about all rainstorms. The researcher is Soenke Borgwardt, who has tested the surface infiltration on many older PICP projects and found this general pattern.

So the answers to these FAQs are found in numerical relationships backed by research findings. What backs up the numbers is PICP's positive field performance with respect to heaving, oil capture and surface infiltration. Doing the math helps explore those relationships and better positions PICP as the preferred choice for reducing runoff and pollutants. By the way, please accept my apologies for the Imperial units in this article. I just couldn't do the math for the metric equivalents. ❖