

# Pervious Concrete Performance in Freeze-Thaw Environments

By Norbert Delatte, Cleveland State University

*Cleveland State University researchers studied 24 pervious concrete pavements in Ohio, Indiana, Kentucky, Pennsylvania and Colorado. They found that most of the properly constructed pavements performed well in freeze-thaw environments and required little maintenance.*



## INTRODUCTION

Portland Cement Pervious Concrete (PCPC) is a material of increasing interest for parking lots and other applications. PCPC typically consists of coarse aggregates, portland cement, water and various admixtures. Similar materials are used for cement-stabilized drainage layers in highway and airport pavements. In a research project funded by the Ready Mixed Concrete (RMC) Research & Education Foundation, in-service PCPC pavements were inspected in the field, and cores were removed in order to investigate properties in the laboratory. Field evaluation methods included visual inspection, two surface infiltration measurements and indirect transmission ultrasonic pulse velocity (UPV). Laboratory testing methods included void ratio, unit weight, compressive strength, splitting tensile strength, hydraulic conductivity (sometimes referred to as permeability), and direct transmission UPV. Because it is compacted on the surface with screeds or rollers, PCPC generally has higher strength, lower void ratio, and lower permeability at the surface than at the bottom. Therefore, the properties of the top and bottom parts of the core samples were compared. Generally, the PCPC installations evaluated under this research project have performed well in freeze-thaw environments with little maintenance required. No visual indicators of freeze-thaw damage were observed. With the exception of some installations where the pore structure was unintentionally sealed during construction with wet mixtures or over compaction, nearly all sites showed fair to good infiltration capability based on drain time measurements.

## RESEARCH BACKGROUND

Portland Cement Pervious Concrete (PCPC) has an excellent performance history in the Southeastern U.S., but until recently has seen limited use in environments with significant freeze-thaw cycles. Therefore, assessment of actual field performance is important. This research project documented field observations, and nondestructive testing results of PCPC sites located in the states of Ohio, Kentucky, Indiana, Colorado and Pennsylvania. PCPC is most often used as a pavement for parking lots. Field performance depends on the quality of the mixture as well as proper control of construction and curing. In addition to field observations and nondestructive testing, laboratory testing was performed on cores removed from some of the test sites. Generally, the PCPC installations evaluated have performed well in freeze-thaw environments with little maintenance required.

The research goals included developing recommendations as to how to build PCPC pavements in freeze-thaw environments, and how to prevent clogging. Observations suggest that providing sufficient drainage under PCPC pavements to keep them from becoming saturated in freezing weather, as recommended by the National Ready Mixed Concrete Association (NRMCA) in its publication, *Freeze-Thaw Resistance of Pervious Concrete*, is likely to be effective. Site specific observations of clogging patterns provided insight into sources of clogging and how these may be avoided.

## FIELD AND LABORATORY TESTING

Construction, use and maintenance information was obtained during the site visits.

This included mixture constituents and proportions, admixtures, type of compaction used and any difficulties noted during construction. Most of the sites had not yet had maintenance treatments performed. Information about vehicle traffic, including heavy vehicle overloads, was also obtained.

The field investigation plan encompassed a thorough visual inspection for signs of distress, two types of surface infiltration measurements and ultrasonic pulse velocity (UPV) testing at the Ohio, Kentucky and Indiana sites. At the Colorado and Pennsylvania sites, only one type of surface infiltration test was made. Visual inspection documented cracking and surface raveling, as well as areas that appeared to be clogged. One type of field infiltration test, developed during this research project, used the time to drain a 4 by 8 inch plastic cylinder through a 3/4-inch opening down into the pavement. The UPV was used in indirect transmission mode, because only the surface of the pavement was accessible.

At six of the sites, it was possible to extract cores for laboratory testing. The cores were brought back to the laboratory and tested for void ratio, hydraulic conductivity and direct transmission UPV. Direct transmission is considered to be more reliable than indirect transmission for UPV. Once these tests were completed, some of the specimens were tested for compressive or splitting tensile strength. Some of the cores were cut into top and bottom specimens, to compare the properties through the pavement thickness. Significant differences were observed between cores from pavements that used gravel and crushed limestone coarse aggregates. The use of gravel as a coarse aggregate may facilitate more effective and uniform compaction. The hydraulic conductivity results were plotted against the drainage times, so that in the future the field test may be used to estimate PCPC infiltration capability.

## SUMMARY OF OBSERVATIONS

Observations from test sites address raveling, cracking, clogging, results of maintenance and test results.

- Raveling often appeared early after construction, but decreased as the pervious concrete aged and the top loose rocks were removed. Most raveling was a product of excessively low water to cement ratio, poor compaction or dry weather conditions during placement. Tooled contraction joints raveled more than saw cut joints.
- Major causes of cracking were heavy vehicle traffic, lack of contraction joints, or a large

distance between joints. Joint spacing should probably follow recommendations for conventional concrete until more definitive rules for PCPC joint spacing can be developed.

- Clogging was mainly caused by sediment and debris that had been carried onto the pervious concrete. In some areas, clogging was caused during the installation process by paste smudging across the surface, over compaction, wet mixes or high water to cement ratio.
- Vacuuming and pressure washing successfully restored appearance and permeability of the pervious concrete at some sites.
- Surface infiltration results indicate that the concrete with an average value less than one minute and a small standard deviation suggest acceptable infiltration capability.
- Field UPV testing was inconclusive.
- Laboratory tests on cored samples suggest a strong relationship between compressive and tensile strengths and the ultrasonic pulse velocity.

## RESEARCH RESULTS

Generally, the PCPC installations evaluated under this research project have performed well in freeze-thaw environments with little maintenance required. No visual indicators of freeze-thaw damage were observed. With the exception of some installations where the pore structure was sealed during construction with wet mixtures or over-compaction, nearly all sites showed fair to good infiltration capability based on drain time measurements. Most of the sites visited do not yet require maintenance.

Because use of PCPC in this region began fairly recently, the sites visited are less than four years old. Although they are performing well now, it would be useful to revisit them periodically in the future. If future visits are made, the results reported in this research will provide a useful baseline for comparing performance.

## Designing and Building Freeze-Thaw Durable PCPC Pavements

None of the sites investigated showed any sign of freeze-thaw damage. The damage observed was either due to early age raveling or to structural overload. This was probably because the sites were adequately drained and therefore the pervious concrete was not saturated when the temperature was below freezing.

In conventional concrete, however, freeze-thaw damage may take many years to become apparent. It eventually results in disintegration. Therefore, in pervious concrete, freeze-thaw damage would be expected to take the form of widespread raveling progressing through the thickness of the pavement. This was not observed at any of the sites visited.

In the laboratory, the relative dynamic modulus determined using a sonometer is used to calculate the durability factor of a concrete specimen. Because UPV works on very similar principles to a sonometer, UPV should be able to detect freeze-thaw damage in the field as a reduction in wave velocity. However, this requires further work.

In addition, this research validated the result found in other studies that there is a considerable difference between the void ratio at the top and at the bottom of a PCPC pavement. Generally, the top is much better compacted.

## Field Investigation Techniques

This research employed a number of field investigation techniques that may be of value to future researchers engaged in similar studies.

### *Visual Observations*

It has been suggested that one of the most powerful and useful investigative tools is the eye connected to the brain of a knowledgeable engineer. Visual observations can identify structural and nonstructural problems in PCPC pavements and can often identify locations most likely to be clogged and sources of clogging material.

### *Drain Time Testing*

The 4 x 8 inch plastic cylinder mold drain time test has been found to correlate reasonably well to hydraulic conductivity. This test may be used to assess infiltration capability of newly built pavements or to determine whether maintenance is needed. It would be useful to track results over time, in order to assess the need for and effectiveness of different maintenance treatments.

### *Ultrasonic Pulse Velocity*

Laboratory UPV results, found by direct transmission, correlate very well with hydraulic conductivity and strength of PCPC. Field indirect transmission UPV results have so far been less reliable, but results may be improved with future research.

### *Testing of Cores*

Unfortunately, at this time cores remain the best way to measure thickness, strength



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and void ratio of PCPC pavements. In order to avoid the damage and expense of core removal, it would be desirable to develop other test methods. Of course, the new test methods would first have to be calibrated to cores. NDT methods such as UPV show promise, but require further development.

#### **Future Research**

The main drawback of the present study has been the relatively recent construction of PCPC pavements in this area. As these pavements are subjected to weather and traffic, the performance trends will become clearer. For the sites investigated in this project, the test results provide a benchmark for comparison with future test results.

As new materials, mixtures and construction methods are used for PCPC, the methods outlined in this report should be used to document the initial condition after construction. Thus, the longterm effect of new technologies on PCPC performance may be assessed.

More information is provided in two MSCE Theses published in December 2007 at Cleveland State University. These may be obtained as PDF files by emailing [n.delatte@csuohio.edu](mailto:n.delatte@csuohio.edu).

#### **RECOMMENDATIONS**

It is necessary to use care during construction to avoid sealing off the surface. The National Ready Mixed Concrete Association recommends the use of certified contractors and has developed a Pervious Concrete Contractor Certification Program, the text of which was also funded by the RMC Research & Education Foundation.

A properly designed pervious concrete pavement system will allow water to flow through and will not become saturated. This is important, because the damage due to freezing and thawing is likely to occur mainly when the pavement is saturated and these conditions can be avoided.

With proper attention to design, mixtures and construction, it is possible to make wider use of pervious concrete throughout the U.S. It is important to be careful in locating pervious concrete pavements so that soil from landscaping and other debris does not clog them.

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