RMC Research Foundation Presents:

Pervious Concrete Research Compilation:

Past, Present and Future

Compiled By:
Dr. Heather J. Brown
Concrete Industry Management Program
Middle Tennessee State University

Because even the best can become better.

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Pervious Concrete Research Compilation
Past, Present and Future

Investigator: Dr. Heather J. Brown
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RESEARCH CATEGORIES

Applications and Case Studies
Construction Techniques
Durability and Maintenance
Hydrological and Environmental Design
Mix Designs
Specifications and Test Methods
Structural Design and Properties

APPLICATIONS AND CASE STUDIES

Porous Pavements: The Overview
Bruce Ferguson, University of Georgia
Eight years of research have recently concluded with the first comprehensive review of porous pavement technology and applications resulting in the book, Porous Pavement authored by Bruce Ferguson. It defines nine families of porous paving material, each of which has distinctive costs, maintenance requirements, advantages and disadvantages for different applications, installation methods, sources of standard specifications, and performance levels.

Learning Pervious: Concrete Collaboration on a University Campus
Michael Hein, Auburn University
On the campus of Auburn University, architecture and construction students are working side by side with university facilities personnel as they learn by building with pervious concrete. Since the fall of 2003, six pervious concrete slabs projects have been successfully built including a sidewalk, a parking lot, a paved picnic area, and colored pervious arboretum walking trails. Each new project has been filled with learning opportunities as students and workers have experimented with the materials and application techniques of pervious concrete.

Case Study of a 10 Year Old Subdivision with 200 Pervious Pavement Driveways
Godwin Amekuedi, Ready Mixed Concrete Company
This presentation highlights the performance of 200 pervious pavement driveways placed in 1995 in a residential subdivision.

The Use of Pervious Concrete at Wal-Mart
A. Vance Pool, National Ready Mixed Concrete Association
This presentation highlights the use of pervious concrete at a number of Wal-Mart stores including 2 environmental "experimental" Wal-Marts.

Yen, P. T.; Sundaram, P. N.; and Godwin, W. A., 2002, "Pumped-in-Place Permeable Grout Systems, Permeation Grouting," Bechtel Corporation Technical Grant, pp. 1-44.

Permeable Pavement Use and Research at Hannibal Parking Lot in Kinston, NC -- NWQEP Notes (May 2001), W. F. Hunt, S. Stephens
Summary of runoff monitoring from a concrete grid pavers site in Eastern North Carolina. Data was collected from Hurricanes Floyd and Dennis (1999). Monitoring was conducted from June 1999 through July 2001.

ACPA, *Cement-Treated Permeable Base for Heavy-Traffic Concrete Pavements,* IS404, American Concrete Pavement

CCPC, "Pervious Concrete Driveway on 25% Slope," *Impressions,* Vol. 49, California Cement Promotion Council, June 2003, pages 5 to 6.

Ghafoori, N., and Dutta, S., "Building and Nonpavement Applications of No-Fines Concrete," *Journal of Materials in Civil Engineering,* Volume 7, Number 4, November 1995b, pages 286 to 289.

Kozeliski, F. A., "Permeable Bases Help Solve Pavement Drainage Problems," *Concrete Construction,* September 1992, pages 660 to 662.

Malhotra, V. M., "No-Fines Concrete — Its Properties and Applications," *ACI Journal,* November 1976, pages 628 to 644.

Meininger, R. C., "No-Fines Pervious Concrete for Paving," *Concrete International,* American Concrete Institute, August 1988, pages 20 to 27. Also available as NRMCA Publication No. 175.

"Pervious Concrete and Storm Water Management for Highways," Felipe Montes and Dr. Liv Haselbach, University of South Carolina

Korhonen, C. J., and Bayer, J. J., 1989, "Porous Portland Cement Concrete as an Airport Runway Overlay," *Special Report* 89-12, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N. H., 20 pp.

Malhotra, V. M., 1969, "A Low-Cost Concrete Building," *Engineering News Record*, pp. 62-63.

Tamai, M.; Mitzuguchi, H.; Hatanaka, S.; Katahira, H.; Makazawa, T.; Yanagibashi, K.; and Kunieda, M., 2004,"Design, Construction, and Recent Applications of Porous Concrete in Japan," *Proceedings of the JCI Symposium on Design, Construction, and Recent Applications of Porous Concrete*, Japan Concrete Institute, Tokyo, 15 pp.

Ghafoori, N., 1995, "Development of No-Fines Concrete Pavement Applications," *Journal of Transportation Engineering*, V. 126, No. 3, May-June, pp. 283-288.

Onstenk, E., Aguado, A., Eickschen, E., and Josa A., "Laboratory study of porous concrete for its use as top layer of concrete pavements", Proceedings of the Fifth International Conference on Concrete Pavement and Rehabilitation, Purdue University, Indiana, USA, 1993, Vol.2, pp. 125-139.

Field, R., Masters, H. and Singer, M. (1982a) An Overview of Porous Pavement Research. Water Resources Bulletin. Vol. 18 no. 2, pp. 265-270.

Field, R., Masters, H. and Singer, M. (1982b) Status of Porous Pavement Research. Water Research Vol. 16 no. 6 pp. 849-858 June 1982

CONSTRUCTION TECHNIQUES

Pervious PCC Compressive Strength in the Laboratory and the Field: The Effects of Aggregate Properties and Compactive Effort
L. K. Crouch, Tennessee Technological University
Laboratory samples using three different gradations of crushed limestone and two different gradations of gravel were compacted at six various compactive efforts using a consistent pervious concrete mixture design. Cores from four field demonstrations were also obtained. The effective air void content (voids accessible to water at the surface) and compressive strength of the pervious concrete samples were determined and compared.

Effect of Compaction Energy on Pervious Concrete Properties
Muhannad Suleiman, Iowa State University
This paper summarizes a study performed to investigate the effects of compaction energy on pervious concrete void ratio, compressive strength, tensile strength, unit weight, and freeze-thaw durability. Laboratory results show that compaction energy affects pervious concrete compressive strength, split tensile strength, unit weight and freeze-thaw durability.

Pervious Concrete Construction: Methods and Quality Control
John Kevern, Iowa State University
This paper describes the current state of practice in pervious concrete placement methods and presents results from a laboratory-based study to compare various placement practices and develop QA/QC criteria.

Pervious Concrete—The California Experience

Andy Youngs, California Nevada Cement Promotion Council
Over the last two years, pervious concrete usage in California has grown to over 500,000 square feet annually. Unique delivery and construction techniques have contributed to the rapid rise in pervious concrete usage in the state.

Paine, Jack. (1992) Portland Cement Pervious Pavement Construction. Concrete Construction, Vol. 37 no. 9, 4 pp.

Durability and Maintenance

Influence of Moisture Conditions on Freeze and Thaw Durability of Portland Cement Pervious Concrete
Zhifu Yang, Middle Tennessee State University
This study focuses on investigating the effects of moisture condition and freezing rate on the damage development in pervious concrete during cyclic freezing and thawing. A series of tests have been conducted in which pervious concrete specimens are preconditioned to different moisture contents and then exposed to slow or rapid freeze and thaw cycles. Resonant frequency is used to monitor the damage development in the specimens exposed to freezing and thawing. In addition, the mass change of each specimen is measured during the test.

Pervious Concrete Pavement Surface Durability in a Freeze-thaw Environment where Rain, Snow and Ice Storms are Common Occurrences
Warren Baas, Ohio Ready Mixed Concrete Association.
This presentation will provide brief viewings from known on-going research on the freeze-thaw durability of pervious concrete with a focus on observations of pervious concrete pavement installations in Ohio.

Freeze-Thaw Performance of Pervious Pavement in Minnesota
Kevin MacDonald, Cemstone
A large scale set of test panels were constructed at the MN/Road facility in the fall of 2005. Three mixtures were utilized to evaluate the freeze-thaw performance of various mixtures, as well as to monitor the hydraulic performance of the system. The pavements were instrumented for temperature and frost penetration, as were the sub-grade materials. An update of performance after the first winter, in terms of freeze-thaw resistance will be presented. In addition, the relationship between laboratory testing and field performance will be discussed.

NRMCA, Freeze-Thaw Resistance of Pervious Concrete, National Ready Mixed Concrete Association, Silver Spring, Maryland, May 2004, 17 pages.

Haselbach, Valavala, Montes (2006) *Permeability Predictions for Sand Clogged Portland Cement Pervious Concrete Pavement Systems*, accepted Elsevier Journal of Environmental Management

"Performance of Pervious Concrete Pavements" Martin Wanielista, Manoj Chopra, Joshua Spence and Craig Ballock, Stormwater Management Academy, University of Central Florida, Orlando, FL

Pindado, M. A.; Aguado, A.; and Josa, A., 1999, "Fatigue Behavior of Polymer-Modified Porous Concretes," *Cement and Concrete Research*, V. 29, No. 7, pp. 1077-1083.

Wingerter, R., and Paine, J. E., 1989, *Field Performance Investigation*, Portland Cement Pervious Pavement, Concrete and Products Association, Orlando, Fla., 16 pp.

HYDROLOGICAL AND ENVIRONMENTAL DESIGN

Study on the Surface Infiltration Rate of Permeable Pavements – submitted to the Interlocking Concrete Pavements Institute (2004), E. Z. Bean, W. F. Hunt, D. A. Bidelspach
Surface infiltration study funded by the Interlocking Concrete Pavements Institute with each site's information included in the appendix. The report was completed in June, 2004. (50 p)

Malcom, H. Rooney, *Hyrdologic Design Principles using Pervious Concrete, Final Report*, Report to Godwin Amekuedi, Unicon Concrete (now Ready Mixed Concrete), Raleigh, NC, 2002.

Valavala, S., Montes, F., Haselbach, L., 2006. *Area rated rational coefficient values for Portland cement pervious concrete pavement*. American Society of Civil Engineers (ASCE) Journal of Hydrologic Engineering, Vol. 11, Issue 3

Principles and Techniques for Hydrologic Design of Pervious Concrete Systems
Michael L. Leming, North Carolina State University
This paper describes the hydrologic design elements of a pervious concrete paving system using the "stage storage discharge" approach, including selection of an appropriate design rainfall event, integration of site characteristics and specified runoff limits, and the effects of various soil horizons. Emphasis is on "active" mitigation applications where the intent is to capture a significant portion of the runoff from an entire site, including permeable, impermeable, and vegetated areas. Results of an example feasibility study found that by using pervious concrete for a nine-acre parking lot would act hydrologically as if it were grass.

Hydraulic Performance of Pervious Concrete Pavements Montes, F. and L.M. Haselbach (2006) *Measuring Hydraulic Conductivity in Pervious Concrete:* accepted Environmental Engineering Science

Manoj Chopra, University of Central Florida
This presentation focuses on the hydraulic operations of a pervious concrete system including infiltration rates, storage capacity and clogging potential. A method of testing for the in situ infiltration rate of a pervious concrete system–an embedded single ring infiltrometer–has been developed and will be presented. The study consists of detailed analyses of several pervious concrete parking lots that have been in operation for 5 or more years.

A Field Study to Evaluate Permeable Pavement Surface Infiltration Rates, Runoff Quantity, Runoff Quality, and Exfiltrate Quality -- a Master's Thesis under the direction of Dr. William F. Hunt III, published by the Graduate School at North Carolina State University (2005), E. Z. Bean
This document Includes detailed research backgrounds, methods, results, analysis, and conclusions dealing with surface infiltration rates, water quantity and quality performance of permeable pavements. It also includes the summary of a rainfall analysis for major municipalities across North Carolina and detention pond sizing study for different areas, land uses, and soil types in North Carolina.

A Monitoring Field Study of Permeable Pavements in North Carolina -- submitted to the 8th Biennial Conference on Stormwater Research & Watershed Management Summary of water quality and quantity monitoring from three permeable pavement sites across North Carolina; one each in the Piedmont, Coastal Plain, and Coastal regions. Water quality data was collected from each site, while water quantity was only monitored from two sites. (10 p)

Monitoring Pervious Concrete for Water Quality in a Laboratory and Field Environment
Heather Brown, Middle Tennessee State University
This paper presents an in-field and laboratory study that monitored hydrocarbons and heavy metals through the pervious concrete matrix over simulated rain events as well as normal weathering cycles. With the construction of a 300,000 square foot parking lot beginning in March 2006 on MTSU campus, a better understanding of how to install collection sites for water quality testing will also be presented.

An Overview of Pervious Concrete Applications in Stormwater Management and Pavement Systems
Vernon Schaefer, Iowa State University
In this paper a summary of recent research efforts on pervious concrete mix designs for cold weather applications, reduction of road noise, stormwater management and constructability issues is discussed. In addition, the efforts to develop a comprehensive and integrated study for full depth and wearing course applications under the auspices of the National Concrete Paving Technology Center at Iowa State University are presented.
http://www.ctre.iastate.edu/reports/mix_design_pervious.pdf

- Smaller aggregate produces higher strength
- River gravel generally produces higher strength than limestone
- The use of sand increases strength while slightly decreasing void ratio and permeability
- The use of fibers increases tensile strength and permeability without affecting other PCPC properties
- Proper compaction is key to producing durable PCPC
- Sand is required to produce freeze-thaw durable PCPC using the ASTM C666A procedure
- Well designed pervious concrete can meet strength, permeability, and freeze thaw requirements for cold weather climates

Gburek, W., and Urban, J., 1980, "Storm Water Detention and Groundwater Recharge Using Porous Asphalt Experimental Site," *Proceedings: International Symposium on Urban Storm Runoff*, University of Kentucky, Lexington, Ky., pp. 89-97.

Rushton, B., 2000, "Low Impact Parking Lot Design Reduces Runoff and Pollutant Loads," Southwest Florida Water Management District, Brooksville, Fla., 225 pp.

"Water Quality Benefits of a Porous Asphalt Overlay," Pamela Kearfott, Michael E. Barrett, Joseph F. Malina, Jr., University of Texas at Austin

"The Effects of Infiltrating Storm Water on Soils and Groundwater," Scott Meyer, Timothy Ginn, Matthew Diaz, Arash Massoudiehl, Sevinc S. Sengor

Pratt, C. J. (1988) Permeable Pavement for Stormwater Quality Enhancement. Urban Stormwater Quality Enhancement, pp. 113-155.

Pratt, C. J. (1990) Permeable Pavements: Design and Maintenance. Developments in Storm Drainage-A Symp. on Infiltration and Storage of Stormwater in New Developments. pp. 136-151.

Kozeliski, F. A. (1992) Permeable Bases Help Solve Pavement Drainage Problems. Aberdeen's Concrete Construction Vol. 37 no. 9 pp. 660-2 Sept. 1992

Berry, C. and Pratt, C. (1990) Rainfall loss mechanisms in porous pavement reservoir structures. 2nd European Junior Scientist Workshop. pp. 69-76.

Neithalath, N., Weiss, W.J., and Olek, J., (2005). "Reducing the noise generated in concrete pavements through modification of the surface characteristics", PCA R&D Serial No. 2878, Portland Cement Association, Skokie, IL

Neithalath, N., (2005). "Development and characterization of acoustically efficient cementitious materials", PCA R&D Serial No. 2924, Portland Cement Association

"Development of quiet and durable portland cement concrete paving materials" and the link is: http://ntl.bts.gov/card_view.cfm?docid=24636

The concrete Producer magazine has an article titled "Silencing Concrete" in its Nov 2005 issue based on their work. "Silencing Concrete" (2005).

Article on research in enhanced porosity concrete, reported by The Concrete Producer magazine in the section "What's New", November 2005

Neithalath, N., Garcia, R., Weiss, J., and Olek, J., (2005). "Tire-Pavement Interaction Noise: Recent research on concrete pavement surface type and texture", International Journal of Concrete Pavements, Vol.1, No.1, December 2005, pp. 88-105

Nelson, P. M., "Designing porous road surfaces to reduce traffic noise", TRL Annual Review, Transportation Research Laboratories, UK, 1994.

Nissoux, J-L., Gnagne, C., Marzin, J., Lefebvre, J-P., and Pipien, G., "A pervious cement concrete wearing course below 73 dB(A)", Proceedings of the Fifth International Conference on Concrete Pavement and Rehabilitation, Purdue University, Indiana, USA, 1993, Vol.2, pp. 269-284.

Booth, Derek B., and Jennifer Leavitt. 1999. Field evaluation of permeable pavement systems for improved stormwater management." *APA Journal* 65, no. 3.

MIX DESIGNS

Development of Mix Proportion for Functional and Durable Pervious Concrete
Kejin Wang, Iowa State University
Pervious concrete mixes made with various types and amounts of aggregates, cementitious materials, and chemical admixtures were evaluated, and the effects of the mix proportions on the concrete porosity, water permeability, strength, and freezing-thawing durability were studied. Based on results, performance-based criteria are proposed for proportioning functional and durable pervious concrete mixes.

Practical Application of Pervious Concrete: Mix Designs that are Workable
Rick Blackburn, Axim Italcementi Group
This paper focuses on the development of a practical pervious concrete mix designs that are workable for placement by hand and machine with an emphasis on compaction. The effect of compaction on porosity and 28 day flexural strength are presented.

Making Pervious Concrete Placement Easy Using a Novel Admixture System
Mark Bury and Christine Mawby, BASF Admixtures, Inc. (formerly Degussa Admixtures, Inc.)
Through laboratory and field testing, an admixture system (consisting of a polycarboxylate-based water-reducer, cement hydration controlling admixture, and viscosity-modifying admixture) has been developed to improve workability. This paper will offer a description of the chemical admixtures used to improve the mixing, handling, and performance of pervious concrete. Test data will be presented, along with two test methods used to evaluate the performance of pervious concrete.

Fiber Reinforced Pervious Pavement
Greg Moody, CEMEX
Polypropylene fibers are proposed as shrinkage and thermal reinforcement for pervious concrete in this presentation. Flexural testing of fiber reinforced pervious concrete in accordance with ASTM C 1399 showed that polypropylene fibers can attain residual flexural strength equal to temperature and shrinkage reinforcement. The addition of fibers was found to increase the spacing of the coarse aggregates, thus increasing the void content. The addition of sand allowed for adjustment of the void content and to maintain the desired compressive strength.

Jain, O. P., "Proportioning No-Fines Concrete," *Indian Concrete Journal,* May 1966, pages 183 to 189.

SI Concrete Systems, 2002, "Fiber Reinforced Pervious Concrete," *Project* 2120-36, Chattanooga, Tenn., Oct. 25.

Byproduct Utilization study to reduce pH of stormwater, Heather Brown, TCA Conference, January 2004.

"Effect of Aggregate Type and Gradation on Pervious PCC", Proceedings of the 13th Annual Symposium Aggregates: Asphalt Concrete, Portland Cement Concrete, Bases & Fines; International Center for Aggregate Research, April 10-13, 2005, Austin, Texas

SPECIFICATIONS AND TEST METHODS

Neithalath, N., Weiss, J., and Olek, J., (2006). "Characterizing Enhanced Porosity Concrete using electrical impedance to predict acoustic and hydraulic performance", Cement and Concrete Research
This paper presents a unique non-destructive method to determine the permeability of pervious concrete from electrical conductivity measurements. Combining the normalized electrical conductivity of pervious concrete determined using either alternating or direct currents with the porosity of the material, and applying it in a modified version of Kozeny-Carman equation, a new parameter called hydraulic connectivity factor is introduced. Using this factor, and the porosity, the hydraulic conductivity or permeability of pervious concrete is determined.

Determining Pervious PCC Permeability with a Simple Triaxial Flexible-Wall Constant Head Permeameter
L. K. Crouch, Tennessee Technological University
A simple triaxial flexible-wall constant head permeameter was constructed for determining the permeability of pervious concrete in the range of 0.001 to 10 cm/sec (1 to 14,000 inches/hour). Laboratory samples using three different gradations of crushed limestone and two different gradations of creek gravel were compacted at six different compactive efforts using a consistent pervious concrete mixture design. The effective air void content and constant head permeability of both the field and laboratory pervious concrete mixtures was determined.

Haselbach, L.M., and Freeman, R.M., Effectively Estimating In-situ Porosity of Pervious Concrete from Cores, submitted to the Journal of ASTM International, December 2005

"Measuring the Effective Air Void Content of Portland Cement Pervious Pavements," ASTM Journal of Cement, Concrete, and Aggregates, CCA, Vol. 25, No. 1, June 2003

Structural Design and Properties

Developing a Structural Design Method for Pervious Concrete Pavement
Norbert Delatte, Cleveland State University
This paper will review the current state of the practice on structural design of pervious concrete pavements, and outline a methodology for moving forward to develop a new, more appropriate structural design method. Design methods should identify the failure mechanisms for pervious concrete pavements, as well as the layer properties and thickness and joint detailing necessary to prevent failure.

Estimating Pervious PCC Pavement Design Inputs with Compressive Strength and Effective Void Content
Ryan Hewitt, Tennessee Technological University
This study uses a two-fold approach to obtain information on pervious concrete static modulus of elasticity (ASTM C 469), split tensile strength (ASTM C 496) and flexural strength (ASTM C 78). In the first approach existing correlations for normal concrete were applied to pervious concrete field and laboratory data. Secondly, the impact of effective void content on these properties was determined.

Laboratory and Analytical Study of Permeability and Strength Properties of Pervious Concrete
Baoshan Huang, University of Tennessee
This paper presents a study in which the effects of aggregate gradations on the permeability and mechanical properties of pervious concrete were investigated. Pervious concrete with three aggregate gradations were characterized through laboratory tests. Air voids distributions were evaluated through image analysis. Theoretical and laboratory methods were employed to evaluate the permeability properties of the concrete mixtures. The mechanical properties of the concrete mixtures were characterized through the modulus of elasticity, compressive and split tensile strength tests.

Analysis of the Behavior of Filtration vs. Compressive Strength Ratio in Pervious Concrete
Jose Juan Flores, Cement and Concrete Technology Center, CEMEX
This paper characterizes different mixture designs using a proposed test which measures the filtering capabilities in relation to compressive and flexural strengths. The tests analyze the individual and accumulated influence of different factors that take part in the filterable concrete design, such as cement content, the addition of different percentages of sand, or the use of additives that modify the fresh-state properties.

Pervious Concrete Durability Testing
Scott Erickson, Quality Concrete
This paper presents results of a full-scale accelerated load test on a driveway into an aggregate and ready mix plant in Oregon. The trucks are 5-axle concrete mixers with a legal capacity of 70,500 pounds and 8 axle dump truck and trailer combinations with a legal capacity of 105,500 pounds. The pavement is divided in multiple test areas that range from four inch to ten-inch thick sections of pavement on an engineered base.

Strength Measurements of Field-Placed Pervious Concrete L. Haselbach, C. Pierce, K. Pulis, F. Montes, and S. Valavala , Resubmitted early 2006 with revisions to ACI Materials Journal.

Yang, J., and Jiang, G., "Experimental study on properties of pervious concrete pavement materials", Cement and Concrete Research, Vol. 33, 2003, pp. 381-386.

Mulligan, A., 2005, "Attainable Compressive Strength of Pervious Concrete Paving Systems," Masters thesis, University of Central Florida, 132 pp.

Ghafoori, N., and Dutta, S., "Laboratory Investigation of Compacted No-Fines Concrete for Paving Materials," *Journal of Materials in Civil Engineering,* Volume 7, Number 3, August 1995a, pages 183 to 191.

CURRENT FUNDED RESEARCH ACTIVITY

Stormwater Management and Development of a Long-Term Maintenance Guideline For Pervious Concrete Pavements (Completion date of Summer 2006)
University of Central Florida
RMC Research Foundation Funding
The use of pervious concrete pavements continues to grow as builders and communities move toward sustainable development. One of the environmental benefits of pervious pavements is its stormwater management properties. However, without proper maintenance, pervious pavement may become clogged and lose some of its permeability.
Additional research is also needed to ensure acceptance of the use of pervious pavements. This research addresses three main issues that are of interest to both the staff in water management districts and the concrete industry for widespread acceptance of pervious pavements: namely, 1. the design cross-section to ensure adequate infiltration, 2. credit for replacement of impervious areas, and 3. operational and maintenance issues.

Long-Term Field Performance of Pervious Concrete Pavements
Cleveland State University (Completion date of fall 2007)
RMC Research Foundation Funding
Pervious concrete pavements are growing in popularity but study of their long-term performance is still needed in order to evaluate and improve them. An updated evaluation of the long-term field performance of pervious concrete pavement will be helpful not only to the concrete industry but also to design and permitting communities and end users. The study will evaluate current pervious concrete pavements of various ages with differing soils, environmental conditions, and geographical locations. The final report will include recommendations for changes in designs, construction, and maintenance of pervious concrete pavements.

Investigation into the Effect of Aggregate on the Freeze-thaw Durability of Pervious Concrete
John Kevern and Drs. Kejin Wang and Vernon Schaefer
Iowa State University

PCA Funding
The durability of pervious concrete in northern states is questioned by many specifiers. Preliminary research at Iowa state shows that aggregate type and grading have significant impacts on frost resistance. This project will characterize aggregate properties that improve frost resistance.

Serviceability of Pervious Concrete Pavements
Luis Mata and Dr. Michael Leming, North Carolina State University
PCA Funding
As the market for pervious concrete continues to grow, so does the need to demonstrate and improve its serviceability. This project evaluates sedimentation rates on porosity and the effect of various porosities on frost resistance.

Pervious Concrete for Solid/Liquid Separation and Waste Remediation
Joe David Luck and Dr. Stephen Workman, University of Kentucky
PCA Funded
This project will demonstrate that pervious concrete can be used for solid/liquid waste separation and remediation in agricultural applications.

Demonstration of Integrated Pervious Pavement System for Management of Stormwater Quality and Quantity
Center for Transportation Research and Education Iowa State University
Iowa Department of Natural Resources Funded
Abstract: The overall goal of integrated pervious pavement systems is two-fold: 1) to reduce volume of direct runoff from the pavement surface by direct infiltration of the water through the pavement surface and into the subbase/subgrade; and 2) to provide enhancement of stormwater quality by directing the sheet flow of water through the pervious concrete and underlying porous subbase structure. This project is focused on the design of PC pervious concrete for use in the cold wet-freeze environment found in Iowa and the Upper Midwest. It will evaluate the mix design for durability, porosity, and improved stormwater runoff management.

Clarkson University and Purdue University contact: Narayanan Neithalath

- Non-destructive determination of porosity of pervious concrete
- Influence of pore structure on transport of water and hydrocarbons through pervious concrete.

University of Tennessee
Investigating soil exfiltration and long term subgrade support
TCA Funded

Middle Tennessee State University
Investigating current state of all existing pervious concrete in TN using NRMCA survey method.
TCA Funded

SUMMARY AND FUTURE RESEARCH NEEDS

Applications and Case Studies

- Applications have been focused on parking lots and pedestrian pavements. More field applications of pervious overlays, low volume streets, highway shoulders, medians and swales needs to be researched for additional concrete opportunities

Construction Techniques

- With the wide variety of placement techniques (plate compactor, vibratory screed, roller, high density paver), an attempt to standardize the equipment used is important. Compactive effort affects many properties of pervious concrete that are used for QA/QC purposes
- As pervious pavement applications widen, attention will eventually turn to quicker turnaround on opening pervious pavements. No research has been focused in that area.

Durability and Maintenance

- Freeze thaw has been researched by multiple laboratories. A modified laboratory method would be better suited for a properly designed pervious system where water should not reside in the pervious layer if located in a f/t environment.
- Clogging, whether surface or within, needs to be further researched in terms of being able to monitor volume loss over time and the maintenance techniques that can be used to recapture volume. Removing cores for clogging observation is not a perfect science since water is used to remove cores which could disturb some of the sediment loading.
- Additional design elements due to heavy sediment loading to prevent failure of pavement
- Raveling of the surface is a problem with many pervious pavements in service. Further research could be performed in this area.

Hydrological and Environmental Design

- Adsorption of grease and oil into pervious concrete pores and its long term impact.
- Comparison of filtering and purification effects of water running through pervious concrete vs. pervious asphalt
- Growth and decomposition of biomass and aerobic digestion in a pervious system
- Leaching of concrete materials into the groundwater and soils

Mix Designs

- Admixture research for various construction techniques and concrete properties
- Byproduct research – cement kiln dust, high carbon ash, etc.

Specifications and Test Methods

- Field test method for permeability
- Nondestructive test methods

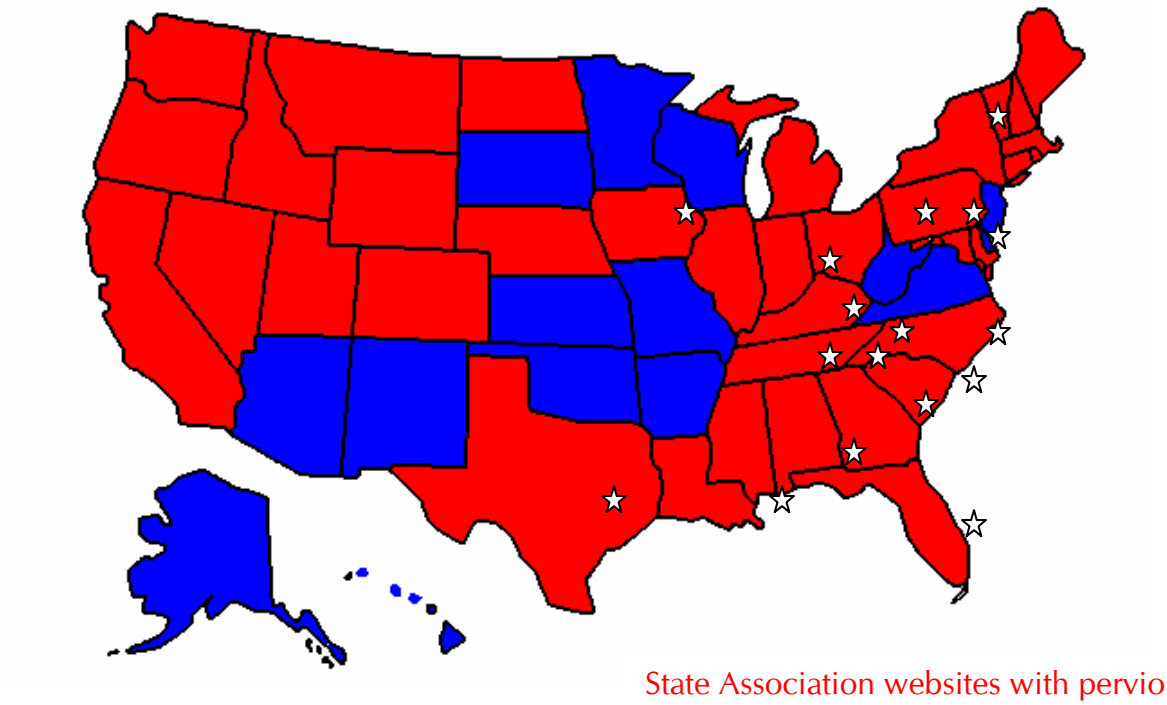
- Development of observation wells for water quality testing

Structural Design and Properties

- Work has started on developing a structural design method for pervious pavements and should be further emphasized

** This list is solely the opinion of the investigator and other research areas should be considered if a lack thereof exists.

State Association Efforts



State Association websites with pervious links, training or research
State Association websites with no pervious links, training or research

☆ Denotes University that performs pervious research

Alabama

Auburn University Research
http://www.bsc.auburn.edu/cp/fall03/pdf/Pervious%20Sidewalk.pdf#search='alabama%20pervious%20concrete%20research'

http://www.aces.edu/dept/extcomm/newspaper/jan22a04.html

Alabama's association offers a CEU 1 hour class on pervious that is available through the below listed link. It is a free internet learning module.
http://www.alconcrete.org/education/ceu_pervious.com

http://www.alconcrete.org/concreteParking/pervious.cfm

Alaska

No pervious links found

Arizona

No pervious links

Arkansas

No pervious links

California

Costs and Needs explanation can be found at:
http://www.scrpa.com/mportal.aspx?tabindex=1&tabid=10096

California Nevada Cement Promotion Council
http://www.cncpc.org/pages/perevious.html

NRMCA Pervious Certification Offered by Concrete Promotion Council of Northern California and Southern California Ready Mixed Concrete Association

Colorado

NRMCA is hosting conference in Denver on pervious.

Only two major known applications in entire state. CRMCA is interested in hosting more about pervious, as many contractors are weighing the differences between that and asphalt.

Connecticut

http://www.fhiplan.com/PDF/NW%20Parking%20Study/Northwest%20Connecticut%20Parking%20Study%20Phase%20I%20Final%20Report.pdf

Delaware

No pervious links found

Florida

University of Central Florida research

http://www.stormwater.ucf.edu/chopra_publications/mulligan_ann_m_200508_ms.pdf

http://www.stormwaterauthority.org/assets/28parking.pdf

http://www.csra.com/Florida/PerviousPavement.htm

Concrete Pavement Construction Training CD is now available at www.fcpa.org

Georgia

http://www.pervious.info/

Georgia Concrete & Products Association
http://www.gcpa.org/specification.htm
http://www.gcpa.org/pervious_concrete_pavement.htm

Cool Communities Rome, GA
http://www.coolcommunities.org/
http://www.coolcommunities.org/cool_pavements.htm

University of Georgia research

NRMCA Pervious Certification is offered by Georgia Concrete and Products Association

Hawaii

No pervious links found

Idaho

NRMCA Pervious Certification offered by ACI Intermountain Chapter

Illinois

Association website has links to resources

Indiana

http://www.irmca.com/Topics/pervious.asp

Purdue University research

Iowa

Iowa State University Center for Transportation Research and Education

NRMCA Pervious Certification is offered by Iowa Ready Mixed Concrete Association

Kansas

No pervious links found

Kentucky

University of Kentucky research

NRMCA Pervious Certification is offered by Kentucky Ready Mixed Concrete Association

Louisiana

http://www.caal.org/frame.htm

Louisiana State University research

Maine

NRMCA Pervious Certification offered by Northern New England Concrete Promotion Association (NNECPA)

Maryland

http://www.marylandconcrete.com/

University of Maryland research

Massachusetts

NRMCA Pervious Certification offered by Massachusetts Concrete Aggregate Producers Association

Michigan

NRMCA Pervious Certification offered by Michigan Concrete Association

Minnesota

Not performing much research on pervious, but they are really promoting concrete parking lots which will for sure spark more on pervious soon.

http://www.armofmn.com/resources.html

http://armofmn.com/pdf/resources/ConcreteParkingLotsinMN.pdf

Mississippi

http://www.mississippiconcrete.com/pervious.cfm

NRMCA Pervious Certification offered by Mississippi Concrete Industries Association

Missouri

No pervious links found

Montana

NRMCA Pervious Certification offered by ACI Intermountain Chapter

Nebraska

Lincoln, NE field evaluation of pervious concrete in collaboration with NAHB and PATH
http://toolbase.org/tertiaryT.asp?TrackID=&CategoryID=1505&DocumentID=4711

NRMCA Pervious Certification offered by ACI Intermountain Chapter

Nevada

http://www.lasvegasconcrete.com/categories/DB081315-AE6D-F223-E7CD268910624692/pervious_concrete.htm

California Nevada Cement Promotion Council
http://www.cncpc.org/pages/perevious.html

New Hampshire

NRMCA Pervious Certification offered by Northern New England Concrete Promotion Association (NNECPA)

New Jersey

No pervious links found

New Mexico

No pervious links found

New York

http://www.nyconcrete.com/home.asp

Clarkson University research

North Carolina

http://www.crmca.com/node/12

NC State University research
http://www.bae.ncsu.edu/topic/permeable-pavement/research.html

North Dakota

No pervious links found

Ohio

Cleveland State University research

NRMCA Pervious Certification offered by Ohio Ready Mixed Concrete Association

http://www.highbeam.com/doc/1G1:143154468/Pervious+concrete+on+wheels+at+Ohio+Expo.html?refid=SEO

Oklahoma

No pervious links found

Oregon

NRMCA Pervious Certification offered by Washington Aggregates & Concrete Association (WACA) in Metro Portland

Pennsylvania

http://www.paconcrete.com/streets/pervious.html
General research is being conducted and its uses are being promoted

Pennsylvania Concrete Promotional Council
http://paconcrete.com/pacocrete/streetsandroads/pervious.asp

Pennsylvania State University research

Rhode Island

NRMCA Pervious Certification offered by Massachusetts Concrete Aggregate Producers Association

South Carolina

http://www.crmca.com/node/12

University of South Carolina research

South Dakota

No pervious links found

Tennessee

http://www.trmca.org/

NRMCA Pervious Certification offered by Tennessee Concrete Association

Middle Tennessee State University, Tennessee Technological University, University of Tennessee research

Texas

http://www.tx-taca.org/Links.htm

University of Texas at Austin research

Utah

NRMCA Pervious Certification offered by ACI Intermountain Chapter

Vermont

NRMCA Pervious Certification offered by Northern New England Concrete Promotion Association (NNECPA)

Virginia

No pervious links found

Washington

http://www.washingtonconcrete.org/industry/pervious/pervious_pavement.php

http://www.psat.wa.gov/

NRMCA Pervious Certification offered by Washington Aggregates & Concrete Association (WACA)

West Virginia

No pervious links found

Wisconsin

No pervious links found

Wyoming

NRMCA Pervious Certification offered by ACI Intermountain Chapter

Proprietary Pervious Companies

1. Advanced Pavement Technologies

2. Bosse Concrete Products

3. Cahill Associates

    Stormwater Management with Porous Pavements, written by Tom Cahill, Michele Adams, and Courtney Marm, in the March-April 2005 issue of Government Engineering (http://www.govengr.com/stormwater.htm).

    Pavements that are Stormwater Management Friendly: Porous Asphalt with Infiltration Beds, written by Tom Cahill, Michele Adams, and Kent Hanson, in the September 2004 issue of Land Development Today (http://www.landdevelopmenttoday.com/Article90.htm - website registration required to access article).

    Stormwater Design and Sustainable Development, contributions from Tom Cahill, President of Cahill Associates, in the Nov/Dec 2003 issue of Stormwater Magazine http://www.forester.net/sw_0311_stormwater.html).

    Porous Asphalt: The Right Choice for Porous Pavements, written by Tom Cahill, Michele Adams with assistance from Courtney Marm, all of Cahill Associates, in the Sep/Oct 2003 issue of Hot Mix Asphalt Technology - the journal of the National Asphalt Pavement Association.
    Download the PDF here (http://www.thcahill.com/documents/NAPA-AsphaltTheRightChoiceForPorousPavements.pdf).

Porous Asphalt Pavement with Recharge Beds: 20 Years and Still Working, written by one of our principal engineers, Michele Adams, in the May/June 2003 issue of Stormwater Magazine. Link to article (http://www.forester.net/sw_0305_porous.html)

Thinking Green with Porous Asphalt, written by Dan Brown, with contributions by Wesley Horner, principal planner with Cahill Associates, in the May/June 2003 issue of Hot Mix Asphalt Technology - the journal of the National Asphalt Pavement Association. Download the PDF here (http://www.thcahill.com/documents/NAPA-ThinkingGreenwithPorousAsphalt.pdf).

Porous paving, green roofs can ease impact of development on water supplies, written by Bill Bergstrom, Associated Press, with input from Tom Cahill, for the June 14, 2002 issue of Environmental News Network.

4. Capitol Ornamental Concrete Specialties, Inc.
5. Central Concrete
6. Charger Enterprises, Inc.
7. Dare Concrete, Inc.
8. E.P. Henry
9. Eco-$mart, Inc.
10. Ecocreto
11. GridTech
12. Hanover Architectural Products
13. Hastings Pavement Co.
14. Inteq Corp.
15. Invisible Structures, Inc.
16. KB Industries, Inc.
17. Mat Factory, Inc.
18. National Diversified Sales Inc.
19. Nicolock

20. Pavestone

21. PCI Systems, LLC

22. Presto Products Company

23. RK Manufacturing, Inc.

24. Soil Stabilization Products Company

25. Stan Reese Concrete

26. Stoney Creek Materials

27. Uni-Group USA

Associate Companies

- Axim Italcementi Group
- BASF Admixtures, Inc.
- Cemen Tech
- CEMEX
- Cemstone
- Durafiber Inc.
- Grace Construction Products
- Headwaters Resources
- Lafarge North America
- Quality Concrete
- Euclid Chemical Company
- Putzmeister America, Inc.
- Ready Mixed Concrete Company
- Rinker
- Propex Concrete Systems
- Sika Corporation
- Tarmac America

Additional Resources

The following links are from a websites dedicated to promoting, educating, and explaining the fundamentals and incentives of using pervious concrete.

www.concreteparking.org/pervious/how%20is%20PC%20installed.htm

www.concreteparking.org/pervious/pervious.htm

www.concretetechnologyforum.org/documents/CIP%2038.pdf

www.landdevelopmenttoday.com/Article327.htm

www.edcmag.com/CDA/Articles/Concrete_Supplement/ccf285e92e697010VgnVCM100000f932a8c0

Concrete Promotion Council
http://cpcnc.org/index_files/page0006.html

National Ready Mixed Concrete Association
http://www.nrmca.org/search/default.asp

http://www.nrmca.org/success%20story/

Southeast Cement Association (PCA)
http://www.secement.org/pervious_concrete.htm

Tarmac Ready Mix Concrete (What The Experts Are Saying About Pervious Concrete)
http://tarmacamerica.com/products/readymix/experts.html

http://www.millermicro.com/porpave.html

http://www.win.tue.nl/macsinet/WG/WG11.html

http://www.eos.uoguelph.ca/webfiles/wjames/homepage/Research/pavrefs.html

Tennis, P. D.; Leming, M. L.; and Akers, D. J., Pervious Concrete Pavements, EB302, Portland Cement Association, Skokie, Illinois, and National Ready Mixed Concrete Association, Silver Spring, Maryland, 2004, 25 pages.