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**RESEARCH PROJECT TITLE**

An Integrated Study of Pervious  
Concrete Mixture Design for Wearing  
Course Applications

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# An Integrated Study of Pervious Concrete Mixture Design for Wearing Course Applications

tech transfer summary

Portland cement pervious concrete (PCPC) has great potential to reduce roadway noise, improve splash and spray, and improve friction as a surface wearing course.

## Background/Problem Statement

A pervious concrete mix design for a surface wearing course must meet the criteria of adequate strength and durability under site-specific loading and environmental conditions. To date, two key issues that have impeded the use of pervious concrete in the US are that strengths of pervious concrete have been lower than necessary for required applications and the freeze-thaw durability of pervious concrete has been suspect.

However, the overall conclusion that can be drawn from recent work by the National Concrete Pavement Technology (CP Tech) Center at Iowa State University is that well-designed pervious concrete mixes can achieve strength, permeability, and freeze-thaw resistance to allow use in cold weather climates.

## Objectives of the Integrated Study

This project represents the largest and most comprehensive study to date on portland cement pervious concrete (PCPC). The integrated research objectives included finding optimal pervious concrete mix designs for wearing course sections in pavement applications. Information for the wearing course sections needed to address the issues of noise and skid resistance, assuming adequate strength and durability were developed.



Completed surface of pervious overlay covered with two layers of plastic

The constructability issues were also very critical. Of paramount importance for the research was to determine techniques for construction that utilized existing pavement equipment.

## Summary of Research Approach and Methods

A comprehensive study was undertaken to investigate the use of PCPC in overlay applications. The project was designed to begin with pervious concrete best practices and then to address the unanswered questions in a systematic fashion to allow a successful overlay project.

Consequently, the first portion of the integrated project involved a combination of test method development, fundamental material property investigations, and a constructability study before actual construction could take place.

After completing the first portion of the study, a pervious concrete overlay was designed and constructed on the MnROAD Low Volume Road, a cold region pavement test track near Albertville, Minnesota. Hence, the second portion of the project involved full-scale construction and long-term testing before reporting successes, failures, and lessons learned.

This MnROAD overlay represented the first wet-on-dry concrete overlay and has been in place for more than three years. The overlay has been a success and is performing remarkably well in regard to its surface durability, hydraulic performance, and low noise.

The research results were designed to be widely accessible and easily applied by designers, producers, contractors, and owners. (Each chapter of the report is written as a standalone document that may be read and understood on its own.)



*RapidAir tests determine entrained air void structure*

## Summary of Key Findings

### Pervious Concrete Air Entrainment

Air entrainment is common in traditional concrete and improves durability. PCPC has a more complicated void system than traditional concrete, containing not only the small-sized entrapped and entrained air in the paste or mortar but also porosity, the larger-sized interconnected void space between the paste-coated aggregate particles.

Consequently, questions persisted about the role of air entrainment and its measurement in PCPC. The studies conducted show that the RapidAir test is an effective means of determining the entrained air void structure in PCPC. Air entrainment increased past volume and improved the workability and durability of pervious concrete. It is recommended that air entrainment continue to be used in pervious concrete mixtures.

### Measuring Pervious Concrete Workability

Slump is not an effective means to quantify pervious concrete workability. Given that pervious concrete for slip form placement is a combination of a self-consolidating concrete and a stiff slip-formable concrete, questions persisted on workability measurement. The current method of forming a ball with the plastic pervious concrete is impossible to specify due to the lack of quantifiable values and individual bias.

A new test method based on gyratory compaction was developed to characterize the workability of pervious concrete. The new test method produces consistent concrete specimens, and the output from the test quantifies the workability and compactibility of pervious concrete. The researchers developed suggested ranges of the workability parameters that can be used to assist in designing pervious concrete mixtures for specific compaction methods and to allow quantification of placeability for overlay mixture development.

### Pervious Concrete Overlay Mixture Development

To ensure good performance during both the construction and service periods, a PCPC mixture for a pavement overlay must possess the following properties:



*New gyratory compaction test method characterizes pervious concrete workability*

- High workability for ease of placement
- Uniform porosity or void structure throughout the pavement for noise reduction
- Adequate bond with underlying pavement and proper strength for traffic load
- Sufficient resistance to wearing, aggregate polishing, and freeze-thaw damage

A systematic study using a large number of mix designs was conducted to investigate effects of a wide variety of concrete materials and mixture proportions on PCPC performance, including concrete workability, compaction density, strength, freeze-thaw durability, and overlay bond strength.

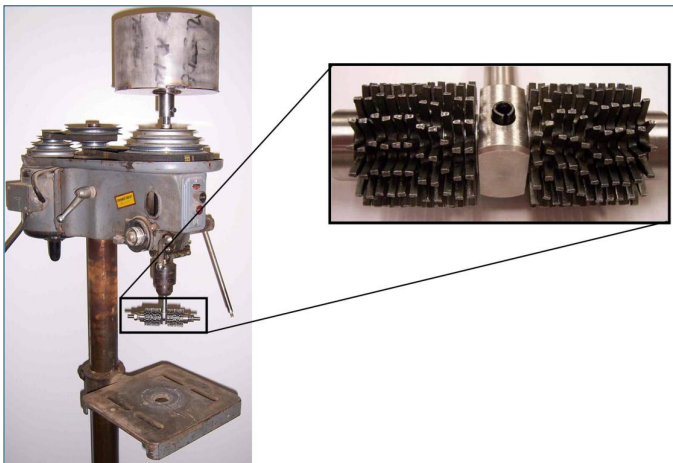
The results indicate that PCPC mixtures can be designed to be highly workable, sufficiently strong, permeable, and possessing excellent freeze-thaw durability making them suitable for pavement overlays. Such overlays will not only function well structurally for carrying designed traffic loads but also perform well environmentally for noise reduction, skid resistance, and splash and spray reduction.

### **Pervious Concrete Curing and Surface Durability**

Concrete curing is required to maintain sufficient moisture to allow cement hydration and concrete microstructure development, and curing has been shown to impact concrete durability and strength. While many techniques exist to control moisture loss in traditional concrete, most are not appropriate for pervious concrete.

Curing is especially important for pervious concrete because the high porosity and bottom exposure of the slab may allow rapid loss of moisture from the fresh concrete due to evaporation. The current method of curing PCPC involves covering the fresh concrete with plastic sheets and allowing the pavement to cure for seven days before removal of the plastic.

The effect of nine different curing methods or curing materials was evaluated for effect on pervious concrete



*Abrasion apparatus and cutting head used for abrasion tests*

properties, including flexural strength and surface abrasion resistance. The samples cured under plastic had the best abrasion and resistance as well as the highest flexural strength, and it was shown that seven days of curing was sufficient for strength gain.

Of the other methods, soybean oil has the potential to be an effective curing compound, supplementing or possibly replacing plastic. Additional studying of curing methods will be necessary for large-scale use of pervious concrete in roadway applications and as new products and techniques emerge.

### **Pervious Concrete Durability to Deicers**

In cold weather regions, deicers are applied to a pavement surface to help prevent icing. The relatively high permeability of PCPC allows melting water to drain into the stormwater system, thus reducing the potential for surface icing due to ponded water.

Sand is sometimes applied to pavement in the event that the temperature drops below a level at which deicers can prevent freezing. Because of the nature of PCPC, deicing chemicals cannot be ponded at the top of the sample and will pass through the surface; therefore, current methods of evaluation of concrete resistance through immersion of the sample do not accurately reflect typical field conditions.

A drained test method was developed to better simulate PCPC field conditions. The drained test provides improved results compared to the saturated tests and provides a good alternative to simulate deicer damage to pervious concretes. Three deicer solutions were compared with distilled water and samples tested for freeze-thaw durability, surface condition, and compressive strength.

Samples without latex polymer had much less mass loss than those using a latex polymer. For a given concrete mixture, sodium chloride or calcium-magnesium acetate performed better than calcium chloride, with less damage.

### **Design Considerations to Reduce Potential Clogging**

Clogging of PCPC leading to potential problems in serviceability has been regarded as one of the primary drawbacks of all permeable pavement systems. A suite of clogging tests was conducted using design porosities of 15, 20, and 25 percent and three sediments: sand, silty clay, and blended sand and silty clay.

The fine-grained silty clay had almost no effect on the ability of water to flow through specimens at typical stormwater concentrations. The results with sand and blended materials show that clogging is only an issue at the lowest porosity and primarily for the blended materials. In most cases, sufficient permeability remains after clogging that reduced waterflow through the pervious concrete will not be an operational issue for pervious pavements.

Several rehabilitation methods were examined. Clogging by sand can best be alleviated using dry vacuuming, while clogging by blended materials can best be alleviated using power washing followed by vacuuming..

### **Pervious Concrete Overlay Construction**

The pervious concrete overlay constructed on the MnROAD Low Volume Road in October 2008 was over concrete originally placed in July 1993. The PCPC overlay was nominally four inches thick with formed joints approximately over the original skewed joints.

The original mix design development work envisioned machine placement of the overlay. Because of weather delays and equipment availability, a powered roller-screed was used for placement. The construction used hand placement of the material, roller screeding, jointing with a mechanical cutter, and curing under plastic for seven days. The construction did leave some surface irregularities in the form of stretch markings and surface sealing.

### **Pervious Concrete Overlay Field Durability and Performance**

Condition surveys of the overlay were conducted in 2009, 2010, and 2011. The primary distress to the overlay pavement was joint deterioration. With a minor amount of cracking, the joint deterioration is believed to be the result of the method of joint placement; saw cutting the joints would have resulted in less deterioration. The joint deterioration increased each year and is likely due to the effects of snowplow operations.

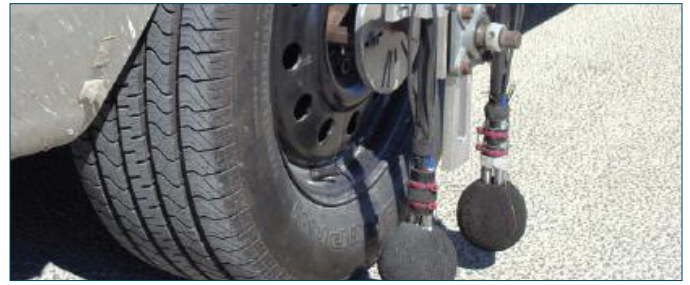
The flow characteristics have been measured each year, with high infiltration results and good consistency from year to year. Operations during rain events indicate that the pervious overlay quickly removes rainwater from the pavement surface and that the water migrates laterally to the side of the pavement, indicating pervious concrete is a successful tool for mitigating splash and spray as well as reducing hydroplaning difficulties.

### **Pervious Concrete Overlay Noise Characteristics**

Noise measurements have been conducted on the overlay at MnROAD and reveal a remarkably quiet pavement. (While



*MnRoad National Research and Technology Center*



*On-board sound intensity measurements compare noise levels*

traditional concrete noise levels range from around 100 to 110 decibels adjusted (dBA), values for this pervious concrete in 2009 and 2010 ranged between 96 and 98 dBA, making the pervious overlay one of the quietest concrete pavements in place.)

## **Implementation Readiness**

This research project answered many questions surrounding pervious concrete construction and applications. The mixture design was a success. However, areas were identified in the construction process that can be improved in future applications.

A logical next step is to construct a pervious concrete overlay for use as a general roadway application, improving on this research project. Like any new technology, limited, publically-accessible trial sections must be constructed to prove to state and municipal owners that the technology is durable and viable in specific environmental conditions.

Future related research of particular interest would be addressing design requirements for minimized clogging in particular areas and observing constructed sections. Long-term noise generation is also an area of interest, with investigation into wear and normal surface deterioration impacts on surface characteristics.

This project was designed for slip-form paving, which did not end up occurring. Mechanized placement should produce a more uniform final surface and improve overall durability. A logical next step would be to use mechanized placement.

## **Implementation Benefits**

The results of the studies conducted for this project show that a pervious concrete overlay can be designed, constructed, operated, and maintained. A pervious concrete overlay has several inherent advantages, including reduced splash and spray and reduced hydroplaning potential, as well as being a very quiet pavement.

The good performance of this overlay in a particularly harsh freeze-thaw climate in Minnesota shows pervious concrete is durable and can be successfully used in freeze-thaw climates with truck traffic and heavy snow plowing.