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Construction and Maintenance Assessment of Pervious Concrete

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ABSTRACT

The information in this report focused on the construction and maintenance activities for Portland cement pervious concrete as used in selected sites in Florida, Georgia, and South Carolina. Construction specifications were suggested for Portland cement pervious concrete pavement in regional conditions typical to the States of Florida, Georgia, and South Carolina based on current construction practices and updated as a result of this research. Contractor certification is necessary. A total of 30 pervious concrete cores were extracted from actual operating pervious concrete sites and evaluated for infiltration rates before and after various rehabilitation techniques. The pervious concrete field sites investigated ranged in service life from 6 to 20 years and exhibited regionally similar structural integrity, infiltration rates, pavement cross sections and subsurface soils. The infiltration rates were performed at the same pressure head for comparative purposes. The techniques were pressure washing, vacuum sweeping and a combination of the two methods. For cores from pavements properly installed, it was found that the three methods of maintenance typically resulted in a 200% or greater increase over the original infiltration rates of the pervious concrete cores. However, it was noted that pressure washing may dislodge pollutants that cannot be captured before entering receiving waters, thus in these situations, vacuum sweeping may be the preferred method.

INTRODUCTION

Porous concrete is a unique cement-based product whose porous structure permits free passage of water through the concrete and into the soil without compromising the concrete's durability or integrity. Also referred to as enhanced porosity concrete, pervious concrete,and Portland cement pervious pavement and pervious pavement, porous concrete is a subset of abroader family of pervious pavements including porous asphalt, and various grids and paver systems. Portland cement pervious concrete is the primary interest within this report.

Portland cement pervious concrete is a discontinuous mixture of coarse aggregate, hydraulic cement and other cementitious materials, admixtures and water.

The porosity of the pervious pavements is provided by emitting all or most of the fine aggregates. Typically, Portland cement pervious concrete has a void content in the 15 to 25 percent range, which imparts the necessary percolation characteristics to the concrete. In 2001 the American Concrete Institute (ACI) formed committee 522, “Pervious Concrete” to develop and maintain standards for the design, construction, maintenance, and rehabilitation of pervious concrete such as Portland cement pervious concrete.

This recent interest in porous materials as a substitution for impervious surfaces can be attributed to desirable benefits of storm water retention and structural features of conventional pavement which Portland cement pervious concrete offers. Highly urbanized areas have a drastic impact on the ratio of impervious to pervious surface areas within a region and increase the volume of storm water in surface discharge. By substituting impervious pavement with pervious paving surfaces water is given access to filterThrough the pavement and parent soil, allowing for potential filtration of pollutants in the stormwater. The U.S.

EPA has published a Porous Pavement fact sheet (EPA, 1999) that lists the advantages of pervious pavements as follows:

- Water treatment by pollutant removal
- Less need for curbing and storm sewers
- Improved road safety because of better skid resistance.
- Recharge to local aquifers.

The disadvantages of pervious pavements include restricted use in cold regions, arid regions or regions with high wind erosion rates, and areas of sole-source aquifers (Pratt, 1997). In addition, the use of porous concrete is highly constrained, requiring deep permeable soils, restricted traffic, and adjacent land uses. Although Portland cement pervious concrete has seen increased use in recent years, there is still very limited practical documented experience with the material. Also, porous pavement sites have had a high failure rate, approximately 75 percent according to the EPA, which has been attributed to poor design, inadequate construction techniques, low permeability soil, heavy vehicular traffic and poor maintenance (EPA, 1999). Failure is determined when the pervious pavement can no longer function as a stormwater retention material due to clogging or as conventional pavement due to structural failure.

In response to the high failure rates and limited practical experience with porous concrete and with new regulations pending on “post equal pre” volume budgets for stormwater management, a current and updated assessment of the performance of pervious pavements has been conducted within this report. Specifically, an investigation has been undertaken which addresses the development of installation practices for the proper construction and maintenance of Portland cement pervious concrete. Addressed in this report is the field and laboratory Investigations performed to analyze the effectiveness of current construction methodologies and the clogging potential of installed pervious concrete systems to analyze rehabilitation techniques.

METHODOLOGY

Laboratory Investigation

In preparation of the field investigation, it was necessary to develop a testing method to assess the conditions of in-situ pervious concrete at the selected field sites. Data collected from field testing was applied in the development of the construction specifications for pervious concrete and was also used to assess the infiltration capability of pervious concrete after it had been in operation for several years. This information was also used in comparison to infiltration rates of the pervious concrete after various rehabilitation techniques had been applied.

A field test site for experimentation on the University of Central Florida campus was constructed at the Stormwater Management Academy Field Laboratory. Two test cells were designed as self-contained systems that were impermeable on all sides except for the surface. Each test cell was built six feet square and four-and-one-half feet deep from the surface of the pavement and was constructed side-by-side into the face of an existing berm. The design included an underdrain system for the removal of water and monitoring the water level in the test cells.

The test cells were constructed with plywood and lined with an impermeable rubber liner. The fill soil used in the cells was a Type A hydrologic soil classified as a fine sand or A-3 soil using the AASHTO soil classification system. The soil was compacted in 8 inch lifts to a minimum of 92% of the Standard Proctor maximum unit weight of 104 lb/ft^3. The soil had a hydraulic conductivity of approximately 12 inches per hour as determined by permeability testing prior to compaction. After compaction, the infiltration rate was approximately two inchesper hour as determined by application of a double-ring infiltrometers test (ASTM D 3385-94). One cell contains a five-inch deep reservoir of $^3/_8$ to ½ inch coarse aggregate, and both cells have a five- inch thick pervious concrete slab. Depicted in Figure 3 is the installation of the pervious concrete in the test cells as well as a double-ring infiltrometer test being performed on the compacted subsoil.

Figure 3: Stormwater Academy Porous Concrete Test Cell Installation

Test cells were used to conduct the initial evaluation of various in-situ testing methods which included the use of double-ring and single-ring infiltration tests that were potential methods of evaluating the flow rates into pervious concrete in the field investigation portion of this study. The test cells could not be used for the additional purpose as a system to evaluate mass balance in a pervious concrete system due to leakage.

A double-ring infiltrometer (ASTM D3385-03) was the first method evaluated to calculate the in-situ infiltration rate of the porous concrete, a procedure used in similar pervious concrete field investigations (Bean, 2005). The double-ring infiltrometer is a cylindrical or square metal frame with no bottom so that the water is directed downward as shown in Figure 4. The walls of the infiltrometer reduce the effect of lateral infiltration. There is no standard dimensions for infiltrometers but studies have found that the larger the diameter, the lower the error (Minton, 2002).

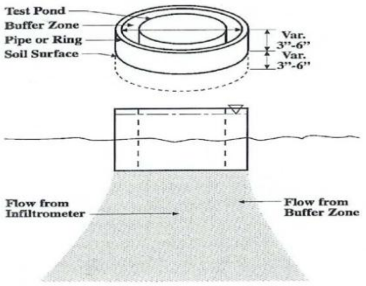

Figure 4: Double-Ring Infiltrometer (Minton, 2002)

The IFSTTAR APT facility

The IFSTTAR accelerated pavement testing facility (APT), in Nantes, is an outdoor circular carousel dedicated to full-scale pavement experiments, carried out with public and/or private partners. The carousel consists of a central tower and four arms (each 20 m long) equipped with wheels, running on a circular test track (Figure 4). The experimental circular pavement has a mean radius of 17.5 m and a width of 6m, and thus a total length of approximately 110 m. The position of the loading module can be adjusted for different radii on each arm, for instance to test simultaneously the effect of different load configurations. During loading, a lateral wandering of the loads can be applied to simulate the lateral distribution of loads of real traffic (Autret et al., 1988; Autret and Gramsammer, 1990; Gramsammer et al., 1999).

CONCLUSION

As presented in the literature review, glass fiber grid based reinforcement systems have been used for about 30 years, and have been the subject of many studies. Concerning laboratory behaviour, two main grid properties have to be evaluated: the adhesion of the grid to the asphalt material, and the resistance to cracking of the grid reinforced asphalt layer. Two main tests, which are relatively easy to perform, are largely used to evaluate these properties: the Leutner shear test to characterize adhesion and the four point bending test to characterize resistance to cracking. Another important property of glass fiber grids is their resistance to damage during construction, and a laboratory test simulating construction damage is also in development.

Laboratory tests on glass fiber grid reinforcement systems have shown mixed results, and it was shown that poor performance is mainly due to problems of bonding between the grid and the asphalt material. Various solutions have been proposed to improve the bonding, including association of the grid with a non woven geotextile and tack coat, or with a special adhesive film. The size of the grid mesh is also important: a too small size, in comparison with the maximum aggregate size, prevents the interlock of the aggregates from the two asphalt layers, and can lead to debonding.

In situ, glass fiber grids can be used for local repairs or for full width pavement reinforcement. Many results of field experiments have been reported, and have shown, in general, the efficiency of glass fiber grids for improving the resistance to cracking. Cases where poor performance was observed are mainly due to problems of bonding between the grid and the asphalt layers. Therefore, proper installation is essential to ensure an effective reinforcement.

If the efficiency of properly selected and installed glass fiber grids has been proven, the mechanisms of action of these reinforcements are still not fully understood, and the design of reinforced pavements remains mainly empirical. No practical, widely accepted, method for design of pavement overlays reinforced by glass-fiber grids is available, and this remains an important subject for research.

Full scale tests on grid reinforced pavements carried out on the IFSTTAR Accelerated pavement testing facility have improved the knowledge of the behavior of these systems, and confirmed some of the conclusions of the literature review.

The test with new low traffic pavement structures has confirmed that a glass fiber grid, placed near the bottom of the asphalt layer, significantly improves the fatigue life, provided that there is good bonding with the asphalt layer. The results of this experiment also indicated no significant effect of the grid on pavement deflection, and resistance to rutting. To confirm the lack of influence on rutting, further tests could be performed at higher temperatures, and with the grid placed in the upper part of the asphalt layer

The test of maintenance techniques, performed in the FORMAT project, proved the efficiency of grid reinforcement, to improve the performance of thin asphalt overlays (only 2.5 cm thick).

Finally, the last part of the paper presented a solution of instrumentation of glass fiber grids by strain gages, to monitor their performance. First tests performed in a new pavement, have shown the possibility to measure the strains of the glass grid under traffic loading. First measurements indicated that in the new pavement, levels of strain in the grid and in the unreinforced asphalt layer are very similar. The experiment will be continued, to follow the behaviour of the grid during the whole life of the pavement.

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