Use of Pervious Concrete in Pavements

Ajay Gupta
M.Tech Scholar
Department of Civil Engineering
Technocrats Institute of Technology-Excellence
Bhopal, M.P. India

Sourabh Asange
Assistant Professor
Department of Civil Engineering
Technocrats Institute of Technology-Excellence
Bhopal, M.P. India

***Abstract*—Pervious concrete pavement is a unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground, pervious concrete is helpful in recharging groundwater. In fact, the use of pervious concrete in the construction of pavement, for the hot and low rainfall places of India is seems to be significant for improving the water table. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm water management devices.**

I. INTRODUCTION

Pervious concrete is an alternative paving surface that can be used to reduce the nonpoint source pollution effects of storm water runoff from paved surfaces such as roadways and parking lots by allowing some of the rainfall to permeate into the ground below. A properly designed pervious concrete pavement system can reduce the environmental impact often associated with development. Pervious concrete pavement systems can also be used to improve the environmental performance of existing sites without compromising the business value of a property by replacing existing conventional pavements. The capability to simultaneously maintain water quality, reduce flooding, increase base flow, and preserve valuable parking areas for the property owner, especially in retrofit applications, are capabilities not easily obtained with other water quality or flood mitigation alternatives. Portland cement pervious concrete (PCPC) has an excellent performance history in the Southeastern United States, but until recently has seen limited use in environments with significant freeze-thaw cycles. Therefore, assessment of actual field performance is important. Portland cement pervious concrete (PCPC) is being used more frequently due to its benefits in reducing the quantity of runoff water, improving water quality, enhancing pavement skid resistance during storm events by rapid drainage of water, and reducing pavement noise. In the United States, PCPC typically has high porosity and low strength, which has resulted in the limited use of pervious concrete, especially in hard wet freeze environments (e.g., the Midwestern and Northeastern United States and other parts of the world). Improving the strength and freeze-thaw durability of pervious concrete will allow an increase in its use in these regions.

Benefits of Pervious Concrete Pavement

Pervious concrete has been gaining a lot of attention. Various environmental benefits such as controlling storm water runoff, restoring groundwater supplies, and reducing water and soil pollution have become focal points in many jurisdictions worldwide. Portland cement pervious concrete is a discontinuous mixture of coarse aggregate, hydraulic cement and other cementious materials, admixtures and water. By creating a permeable surface, storm water is given access to filter through the pavement and underlying soil, provided that the underlying soil is suitable for drainage.

II. COMPONENTS OF PERVIOUS CONCRETE

Pervious concrete is mainly composed by coarse aggregate, cement, and water. Small amount of fine aggregate may be added to obtain higher compressive strength. Other admixtures such as High/Middle Range Water Reducer (HRWR, MRWR), water retarder, viscosity modifying admixtures, and fibres are usually used. In some cases, fly ash is used as a substitute for Portland cement to enhance the environmental friendliness of pervious concrete.

2.1 Course Aggregate

Coarse aggregate is the main component of pervious concrete. The gradation, size, and type of coarse aggregate have been found to affect the character of pervious concrete. Coarse aggregate grading in pervious concrete normally consists of either a single sized coarse aggregate or a narrow grading from 3/4 to 3/8 in. (19~9.5 mm).

2.2 Fine Aggregate

A fine aggregate is sometimes used in pervious concrete to improve the mechanical capabilities of pervious concrete. On the other hand, the permeability will typically decrease when fine aggregate is added. However, the amount of fine aggregate is recommended to be limited within 7% of the total aggregate by weight so that permeability is satisfied.

2.3 Cement

Portland cement is another main component of pervious concrete. Type I/II cement is normally used in pervious concrete. The content of cement is dependent on the amount and size of coarse aggregate and the water content. Various amounts of cement are recommended by different agencies.

2.4 Fly Ash

Fly ash can be used in pervious concrete as a substitute for a portion of the cement. Two types of fly ash which are Class C and Class F fly ash are both able to used in pervious concrete. Currently, fly ash can replace 5-65% of the Portland cement in conventional concrete. The advantage of using fly ash is obvious: fly ash is a by-product of coal burning in power plants, its utilization saves the energy required to produce the cement. In addition, fly ash improves the flowability and workability of concrete.

2.5 Water

Water is a crucial component in pervious concrete. Enough water should be added so that cement hydration is thoroughly developed. However, too much water will settle the paste at the base of the pavement and clog the pores. Meanwhile, too much water increases the distance between particles, causing higher porosity and lower strength. The correct amount of water will maximize the strength without compromising the permeability characteristics of the pervious concrete.

2.6 Admixtures

Admixtures are sometime necessary for pervious concrete to obtain good properties. Typical admixtures used in pervious concrete include HRWR, MRWR, water retarder, viscosity modifying admixtures, air-entraining and fibers.

III. LITERATURE REVIEW

To meet the requirements of the Federal Water Pollution Control and Flood Disaster Protection Acts of the United States, the Franklin Institute Research Laboratories developed pervious asphalt pavement systems in the early 1970s (Diniz 1980).

PCPC is one of the methods used to reduce the volume of direct water runoff from pavements and to enhance the quality of stormwater (Water Environment Research Foundation 2005).

Pervious concrete pavement has been used for over 30 years in England and the United States (Youngs 2005; Maynard 1970). PCPC is also widely used in Europe and Japan for roadway applications as a surface course to improve skid resistance and reduce traffic noise (Beeldens 2001; Kajio et al. 1998).

Currently, full-depth PCPC is used in the United States for parking lots, pathways, and, in some cases, low-volume roads for storm water applications (Tennis et al. 2004). PCPC is used to allow storm water to infiltrate through the pavement and reduce or eliminate the need for additional control structures, such as retention ponds. The large surface area of PCPC also helps clean a majority of the pollutants in the storm water and allows the natural attenuation of microbes to reduce their concentration. Instead of accumulating in nearby surface waters, the pollutants are trapped in the pavement system, thereby increasing overall water quality.

Private owners and public agencies are required to reduce the amount of storm water runoff and reduce the contaminants in the runoff water to near pre-development levels (Federal Register 2004).

These reductions can be achieved by detention ponds and vegetative buffers (WERF 2005). However, pervious concrete is an effective tool for achieving these reductions in storm water runoff and initially treating storm water. The open structure of PCPC also has other benefits, including the following: (1) improved skid resistance, (2) reduced noise levels, (3) fast melting of snow, and (4) prevention of faulting on sidewalks and recreational trails by allowing trees to grow with no root heave (Kajio et al. 1998; Tennis et al. 2004).

Yang and Jiang, (2003) used a low strength pervious concrete pavement material for roadways. The pervious pavement materials that composed of a surface layer and a base layer had been made. The compressive strength of the prepared material reached up-to 50 MPa and the flexural strength 6MPa. The water penetration, abrasion resistance, and freezing and thawing durability of the materials are found to be very good. It has been observed that pervious material can be applied to both the footpath and the vehicle road. It is an environment-friendly pavement material.

A theoretical relation has been developed between the effective permeability of a sand-clogged pervious concrete block, the permeability of sand, and the porosity of the unclogged block by Haselbach et al. (2006). . Permeability had been measured for Portland cement pervious concrete systems fully covered with extra fine sand in a flume using simulated rainfalls. The experimental results correlated well with the theoretical calculated permeability of the pervious concrete system for pervious concrete systems fully covered on the surface with sand. The results obtained are important in designing and evaluating pervious concrete as a paving surface within watershed management systems for controlling the quantity of runoff.

Kevern et al. (2012) performed a study on a site in Iowa where both a pervious concrete and a traditional concrete paving system have been installed and where temperatures were recorded within the systems for extended time periods. The analyses cover days with negligible antecedent precipitation and high air temperatures, which are extreme conditions for UHI impact. This paper compares the increase in overall heat stored during several diurnal heating cycles in both of these systems. These analyses include not only the temperatures at various depths, but also the heat stored based on the bulk mass of the various layers in each system and below grade. Results suggest that pervious concrete pavement systems store less energy than do traditional systems and can help mitigate UHIs

According to Leming et al. (2007) capability of pervious concrete to simultaneously maintain water quality, reduce flooding, increase base flow, and preserve valuable parking areas for the property owner, especially in retrofit applications, are capabilities not easily obtained with other water quality or flood mitigation alternatives. Pervious concrete also provides a unique leadership opportunity for stewardship in context-sensitive construction and Low-Impact Development (LID). This document describes the fundamental hydrologic behavior of pervious concrete pavement systems and demonstrates basic design methodologies appropriate for a variety of sites and circumstances. This document also briefly discusses limitations of these methodologies.

IV. CONCLUSION

- By capturing rainwater and allowing it to seep into the ground, pervious concrete is helpful in recharging groundwater.
- A pervious concrete mixture contains little or no sand, creating a substantial void content.
- Water is a crucial component in pervious concrete. Enough water should be added so that cement hydration is thoroughly developed. However, too much water will settle the paste at the base of the pavement and clog the pores.

REFERENCES

1. Beeldens, A., D. Van Gemert, and C. Caestecker. 2003. Porous Concrete: Laboratory Versus
2. Diniz E. V. 1980. *Porous Pavement: Phase I – Design and Operational Criteria*. EPA-600/2-80- 125. Cincinnati, OH: Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.
3. Federal Register. 2004. Effluent Limitations Guidelines and New Source Performance Standards for the Construction and Development Category. Federal Register 69.80. Ferguson, B. K. 2005. *Porous Pavements*. New York: Taylor and Francis Group.
4. Haselbach, L. M., Valavala, S., & Montes, F. (2006). Permeability predictions for sand-clogged Portland cement pervious concrete pavement systems. *Journal of environmental management*, *81*(1), 42-49.
5. Kajio, S., S. Tanaka, R. Tomita, E. Noda, and S. Hashimoto. 1998. Properties of Porous Concrete with High Strength. *Proceedings 8th International Symposium on Concrete Roads*: 171–177.
6. Kevern, J., Schaefer, V., & Wang, K. (2009). Temperature behavior of pervious concrete systems. *Transportation Research Record: Journal of the Transportation Research Board*, (2098), 94-101.
7. Leming, M. L., Malcom, H. R., & Tennis, P. D. (2007). Hydrologic design of pervious concrete.
8. Maynard, D.P. 1970. A Fine No-Fines Road. *Concrete Construction*: 116.
9. Tennis, P.D., M.L. Leming, and D.J. Akers. 2004. *Pervious Concrete Pavements*. Special publication by the Portland Cement Association and the National Ready Mixed Concrete Association.
10. Water Environment Research Foundation (WERF). 2005. International Storm water Best Management Practices Database. http://www.bmpdatabase.org.
11. Yang, J., & Jiang, G. (2003). Experimental study on properties of pervious concrete pavement materials. *Cement and Concrete Research*, *33*(3), 381-386.
12. Youngs, A. 2005. Pervious Concrete: It's for Real. Presentation at the Pervious Concrete and Parking Area Design Workshop, Omaha, NE.