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APPLICATION OF PERVIOUS CONCRETE IN CONSTRUCTION OF RIGID PAVEMENTS - A REVIEW

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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.

Keywords: Cement, Concrete, Voids, Density, Compressive Strength and Hydraulic Conductivity.

Introduction
Pervious concrete or porous concrete or no fines concrete is an amazing concrete made up of interconnected voided structure, which allows the water percolation through it and also maintains the structural performance. Pervious concrete being a specific material is a considerably permeable material formed by cutting the quantity of fine aggregates in the concrete composition. Enhancement in permeability usually leads to decreased strength performance (ACI 2010). The properties of pervious concrete depend upon the composition as well as the methodology of construction. Pervious concrete was first developed in 1980s in Japan for its eco-friendly advantages. Generally, the water permeability and porosity of the pervious concrete lies in the range of 15-30% and 1.4-12.4 mm/s respectively (ACI 2010). Likewise, the compressive strength of pervious concrete is approximately 2.8 to 28 MPa, which is quite less than that of normal concrete (17-40 MPa) (ACI 2010). Despite having low compressive strength, the pervious concrete is still preferred globally having numerous environmental benefits viz. controlling storm water run-off, slope stabilisations, pedestrian pathways, parking lots and light vehicular lots.

Benefits of Pervious Concrete Pavement
Pervious concrete has been gaining a lot of attention. Various environmental benefits like controlling storm water runoff, restoring groundwater supplies, and reducingwater and soil pollution have become focal points in many jurisdictions worldwide. Portland cement pervious concrete (PCPC) isa irregular mixture of coarse aggregate, hydraulic cementand other cementious materials with admixtures and water. Bycreating 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.

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.

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).

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.

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 differentagencies.

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.

Water

Water is a crucial component in pervious concrete. Enough water should be added so that cement hydration is thoroughly developed. However, excess amount of water settles the paste at the base of the pavement and chock the pores. Also, excess amount of water increases the distance between the particles, thus causing increased porosity and lower strength. The accurate amount of water thus maximize the strength of concrete without affecting the permeability characteristics of the porous concrete.

Admixtures

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

Literature Review

Non-management of urban rainwater in developing countries has serious consequences. Inadequate disposal of rain water during monsoons leads to unnecessary deaths and diseases and loss of homes, property and livelihoods. Poor storm water management also pollutes the environment and squanders limit limited freshwater resources. Storm water management is a bit difficult for developing countries due to lack of resources (Parkinson and Ole, 2005)

Joseph Lim (2016) discussed the different method used for storm water management in urban areas. Type of storm water management system are downspout disconnection, storm water green streets, bios wales, green roofs, blue roofs, permeable surfaces, rain gardens, surface detention systems, rain barrels and cisterns and wet detention basin. These methods are already applied in all the cities of U.S. The permeable surfaces method is more effective than the different methods of storm water management mentioned above for disposal of water collected in urban areas during monsoon in India.

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 utilized since last 30 years in England and the United States (Youngs 2005; Maynard 1970). PCPC is also broadly exercised in Europe and Japan for roadway

applications as a surface course to get better 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 permit storm water to infiltrate through the pavement and decrease or eliminate the requirement 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).
This can be achieved by construction of detention ponds and vegetative buffers (WERF 2005). Again, the porous concrete is an effective technology for achieving this kind of reductions in storm water runoff and also initially treating the storm water. The open structure of PCPC is having other benefits also, which includes the following: (1) improvement in skid resistance, (2) reduction in noise levels, (3) rapid melting of snow, and (4) prevents the faulting on sidewalks and recreational trails by allowing trees to grow with no root heave (Tennis et al. 2004; Ferguson 2005).
Yang and Jiang, (2003) used a low strength pervious concrete pavement material for roadways. The porous concrete pavement materials which composed of a surface course and a base course had been made. The compressive strength of prepared material reached up-to 45 MPa and the flexural strength 7MPa. The abrasion resistance, permeability, and the freezing and thawing durability of the materials were found to be very good. It has been observed that pervious material can be applied for both the footpath and the low traffic 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 porous concrete systems which is completely covered with the extra fine sand in a by using simulated rainfalls. This experiments results correlated very well with the theoretically determined permeability of the porous concrete system for porous concrete systems completely covered on the surface by sand. The results thus obtained are significant in designing and developing pervious concrete as a pavement surface for the watershed management systems and for controlling the quantity of the runoff.
According to Leming et al. (2007) ability of pervious concrete to simultaneously preserve water quality, decrease flooding, increase base flow, and preserve valuable parking areas for the property owner, particularly in retrofit applications, are capabilities not simply obtained with other water quality or flood mitigation substitutes. Pervious concrete also offers a unique leadership opportunity for stewardship in context-sensitive construction and Low-Impact Development. This document explains the fundamental hydrological behaviour of porous concrete pavement systems and expresses basic design methodologies suitable for a variety of the sites and conditions. This document also discusses limitations of these methodologies in brief.
Portland cement pervious concrete (PCPC) has been utilized by Kevern et al. (2009) which permits storm water to pass through the pavement into an aggregate base beneath to infiltrate. Until now, the temperature response of the entire system (aggregate base, concrete and natural soil) was not known. Since PCPC is an infiltration-based BMP, once a frost line forms under the base the infiltrating capacity is lessened or eliminated. PCPC also is suggested for use in hot climates as a cooler pavement substitute to conventional concrete or asphalt. To quantify the temperature behaviour of a pervious concrete system, a fully observed parking lot—composed of half traditional concrete and half PCPC—was constructed at Iowa State University as component of the Iowa Pervious Concrete Storm water Project. Sensors were installed through the profile of both pavements and into the underlying soil. The outcomes show that insulation from the aggregate base underneath the pervious concrete substantially

setbacks the formation of a frost layer and permeability is restored when melt water is present. It was also examined that in direct sunlight, the pervious pavement became hotter than normal concrete, whereas the daily low temperature of the two was similar, signifying less heat storage capacity in the previous concrete.

McCain and Dewoolkar (2010) used 374 kg/m3 cement content and 1660 kg/m3 aggregate. Aggregate–cement ratio used as 4.43:1. Author also used chemical admixture such as viscosity modifying admixture, an air entraining admixture, a high range water reducer and a stabilizer. For the development of mixture design 10 mm size of coarse aggregate was used. Autor presented the compressive strength and permeability results for pervious concrete. It was observed that w/c played very important role for the development of mixture design of pervious concrete.

A site study has been performed by Kevern et al. (2012) in Iowa in which both a pervious concrete and a conventional concrete paving system have been installed and where temperatures were measured within the systems for longer time periods. The analyses cover days with slight antecedent precipitation and high air temperatures, which are extreme conditions for UHI impact. This paper contrasts the increase in overall heat stored during numerous diurnal heating cycles in both of these systems. These analyses comprise not only the temperatures at diverse depths, but also the heat stored based on the bulk mass of the various layers in every system and under grade. Results propose that pervious concrete pavement systems store less energy than do conventional systems and can help lessen UHIs.

Liu et al. (2018) carried out experimental study on performance on pervious concrete. A high performance pervious concrete is developed using cement, silica fume and super plasticizers. Coarse aggregate size 4.75mm – 9.5 mm and a/c ratio 4:1 was used for the investigation work. It is observed that using silica fume enhances the properties of pervious concrete

Yu et al. (2019) investigated the influence of aggregate size on the compressive strength of pervious concrete. Coarse aggregates ranges from 2.36 mm -4.75 mm, 4.75 mm-6 mm, 6 mm -8 mm, 4.75 mm –9.5 mm, 8 mm-9.5 mm, 10 mm -12.5 mm and 10 mm- 15 mm were used for the research investigation. Cement content and coarse aggregate content 378 kg/m3 and 1703 kg/m3 were used. It was noticed that for coarse aggregate size beyond 7mm, the increase of aggregate size does not have any influence on compressive strength of pervious concrete.

Oz Hatice (2018) investigated the properties of pervious concrete using acidic pumice as coarse aggregates. The coarse aggregate sizes of 10mm-12mm crushed limestone and acidic pumice were used. Total 12 mixes of pervious concrete were produced with constant water to cement ratio of 0.30. Cement content 300 kg/m3 and 420 kg/m3 were used for the mixture proportioning of pervious concrete. Pervious concrete properties such as compressive strength, flexural strength, split tensile strength, void ratio and permeability were evaluated and compared. It was found that use of acidic pumice aggregate reduce the compressive strength, flexural strength and split tensile strength of pervious concrete.

Toghroli et al. (2020) investigated the properties of pervious concrete after incorporation of two different types of fibers. Waste plastic fibers and steel fibers were incorporated at 1% and 2% fraction of the total volume. Pervious concrete mixes with 2% steel fibers were showing the best results in terms of mechanical properties. It was due to the fact that the dispersion of waste plastic fibers was not proper as compared to that of steel fibers.

Zhu et al. (2020) investigated the properties of pervious concrete after incorporation of three different types of fibers. Polypropylene fibers, Copper coated steel fibers and polypropylene thick fibers. The natural aggregates were replaced by RCA and recycled fine sand. Three different types of w/c ratios, 0.25, 0.30 and 0.35, were selected to be varied for the comparative analysis. The w/c ratio of 0.30 came out to be the best among all. The pervious concrete mixes with polypropylene thick fibers were having the best results in terms of mechanical properties.

Yu et al. (2021) proposed a new modified mix design for pervious concrete mixes. This mix design was based on the Mohr-Coulomb failure criterion. With the subsequent decrease in the paste thickness, the cohesion firstly increased and then it decreased. Similar permeability along with improved strength can be achieved in pervious concretes through the new mix design proposed.

Hwang and Cortés (2021) utilised the FA and milled glass waste powder in pervious concrete to enhance the properties. The results established that the combination of FA and Glass powder optimised pervious concrete and enhanced the strength properties. Therefore, FA being an industrial by-product and glass powder as waste material can be combined to produce a sustainable green pervious concrete with sufficient amount of compressive strength.

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 isthoroughly developed. However, too much water will settle the paste at the base of the pavement and clog the pores.

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