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Quality, Testing and Engineering Applications of Pervious Concrete- A State of Art

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Abstract: *Porous concrete pavements have become popular as an effective storm water management device to control the storm water runoff in pavement. The objective of this paper is to study a pre-review on Porous concrete pavement and its previous laboratory study. To improve the strength of the porous concrete, various additives have been study as a part of porous concrete mix. Porous concrete is a special type of cementitious material composed of gap graded aggregates, Coated with a thin layer of cement paste and bonded by the cement paste layers partially being in contact (Ramadhansyah Putra Jaya). As the use of pervious concrete becomes more prevalent throughout the United States, the issue of construct ability will become more of a concern. A number of practices exist to place pervious concrete, without any theoretical underpinnings or correlation to laboratory scale studies.*

I. Introduction

As we know water covers 71% of the Earth's surface but only 2.5% of the Earth's water is fresh water, and 98.8% of that water is in the form of ice and as groundwater. Hence we have to save the water for our future generation. There are various methods and technologies are available for conserving the rain water, recycling the used water or waste water such as Rain Water Harvesting, Efficient Energy Building, Green Building, Wet & Pond Method and Porous Concrete method. . There are various ways to save water, from that use of porous concrete pavement is one of the best method adopted now-a-days. Pervious concrete pavement is unique and effective means to address important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground due to its design properties, pervious concrete is instrumental in recharging ground water, reducing storm water runoff. In other words we call it as a “RAIN WATER HARVESTING CONCRETE”.

By definition, pervious concrete is a mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate) with or without admixtures. Porous concrete also called as pervious concrete, No-fines concrete and Permeable concrete Pervious concrete has the same basic constituents as conventional concrete that is, 15% -30% of its volume consists of interconnected void network, which allows water to pass through the concrete. Pervious concrete is a unique and effective means to address important environmental issues and sustainable growth. When it rains, pervious concrete automatically acts as a drainage system, thereby putting water back where it belongs. Pervious concrete is rough textured, and has a honeycombed surface, with moderate amount of surface raveling which occurs on heavily travelled roadways (S. O. Ajamu1, 2012).

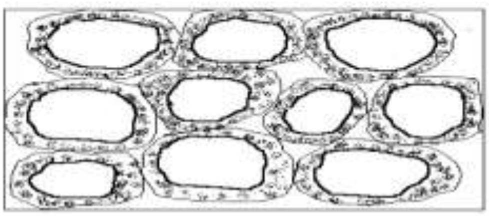

Figure 1: Pervious concrete

II. Design of Permeable Pavements

Designing permeable pavements is more complex than that of traditional asphalt or concrete roadway surfaces. Pervious concrete in particular has been used in multiple non-roadway applications including; sidewalks, parking lots, airport runways, greenhouse floors, sea wall structures, and permeable drain tubing (Ghafoori and Dutta, 1995b).

Permeable pavement systems (PPS) are suitable for a wide variety of residential, commercial and industrial applications, yet are confined to light duty and infrequent usage, even though the capabilities of these systems allow for a much wider usage range. The general principle of PPS is simply to collect, treat and infiltrate any surface runoff to support groundwater recharge. (P. Grabowiecki, 2008).

Permeable pavements work by controlling the release of surface water to the natural environment. This is achieved by a technique known as Attenuation, which basically means slowing down or braking. Surface water is collected by the pavement and then 'held in storage' while it is slowly released to the environment in a controlled manner, minimizing the risk of inundation or flooding. Permeable pavement designs vary greatly. PPS have many potential benefits such as reduction of runoff, recharging of groundwater, saving water by recycling and prevention of pollution.

III. Material

The pavement material or wearing surface, receives the traffic wear and transfers its load to the base, while at the same time serving as the base's protective cover. Pavements are classified as either flexible or rigid. Flexible pavements are resilient surfaces that distribute loads down to the sub base in a radiant manner. Flexible pavements generally have thin wearing surfaces and thick bases. Rigid pavements distribute imposed loads over a broader area than do flexible pavements and therefore require thicker wearing surfaces and thinner bases. Asphalt and concrete are the most common paving materials found in the developed landscape. However, there are other strong, durable pavements that can add variety to the built landscape and help reduce pavement's imperviousness. The following is a review of selected paving materials:

Asphalts

Bituminous concrete or asphalt is composed of aggregates bound together with asphalt cement. Depending on: how it is constructed, the traffic it will bear, the climate it must endure, and the maintenance it receives, typical asphalt pavement has a life expectancy of 20 years before it needs resurfacing. Conventional hot mixes of asphalt are impervious to water as long as the total air void content is kept below 7 percent. Some mixtures often referred to as, “pop corn,” use larger sized aggregate to increase the air voids and thus make the pavement more porous. Porous asphalt pavements need to be washed with high pressure sprays or vacuumed to keep soil particles from collecting in and clogging the voids. Porous mixtures have been used on parking lots, driveways, sidewalks, local roads and temporary roads and ramps.

Concrete

Concrete consists of binding material called cement, composed of lime, silica, alumina and gypsum, that is mixed with sand, aggregate and water. Concrete can be mixed in bulk and placed in forms to achieve any desired shape. Concrete surfaces can be used year round for multiple purposes. Concrete surface maintenance costs are very low. As concrete pavers do not rely on continuity for structural integrity, cuts can easily be made for surface or underground utility repair. Concrete pavers come in many colors, shapes and patterns that can be used to mark traffic and parking lanes and pedestrian walkways.

Brick

Brick from kiln-fired clay or shale has been used as paving for thousands of years. The Romans used brick to build their roads and since the colonial era, brick has been used in America for pathways, sidewalks and as a building material. Brick is graded by its' weather resistance, measured by porosity. When properly installed, brick pavement is stable and durable, however, it is generally more costly to install than bulk paving materials such as concrete and asphalt. Paver bricks, specially made for outdoor and street use, are different from those used on historic brick walks and streets in that they have a slip resistant surface and are very dense to resist freeze/thaw damage. There are three basic types of brick paving systems: flexible brick over a flexible base, flexible brick over a rigid or semi rigid base and rigid brick on a rigid concrete base.

Stone

Stone is a durable paving surface that is available in either natural or synthetic form. Natural paving stone is graded based on its' hardness, porosity and abrasion resistance. It is available either in cut or uncut form in various degrees of smoothness. While providing a slightly irregular surface, crushed stone can be used where a porous material is desired for roads, driveways, paths or parking lots with light traffic. It is also used as a durable, decorative ground cover and to reduce erosion and promote infiltration in areas receiving roof and surface runoff. The advantages of crushed stone are its relatively low installation cost, high porosity and enhancement of community character. Crushed stone also has some disadvantages including: dust generation and weed growth, rutting from tires, displacement of stone during snow plowing, stones getting caught in snow blowers and lawn mowers and need to periodically replenish displaced stones.

Tile

Tiles are baked clay of various shapes, colors and finishes. Tile is often graded on its' weather resistance. Tile can be glazed or unglazed. Glazing increases tile's imperviousness. Tile's small unit size makes it easy to work with, particularly where space is limited or hard to reach. When used as a paving surface, tile is laid similar to brick and stone.

Wood

Wood and wood products are used in the construction of decks, walks and steps. At one time, wood was used to surface roads, resulting in what was commonly known as "plank roads." Wood is strong and durable for its weight. Wood used outdoors must be non-splintering, stiff, strong and resistant to decay, wear and warp.

Earth Materials

Earth materials used for paving include sand, gravel, soil, granular products, and turf. The volume of earth materials is determined by its state in the earth moving process. Sand is often used as a sub base for other paving material such as brick and paver blocks. Depending on how the paving material is laid in the sand and the sub base used, sand surfaces can be porous or impervious. Gravel has been used for years as a road and path surface. The Design Guide also lists the advantages and disadvantages of gravel roads. Advantages of gravel roads include: less costly to construct than paved roads, easier to maintain as they require less equipment and equipment used is easier and less expensive to operate, surface damage is easier and less expansive to correct and they discourage speeding and preserve the area's rural character. Disadvantages include they generate dust, require more frequent maintenance, can become impassable with frequent snow or rain and create greater wear and tear on vehicles than paved roads.Soil, while not commonly used as a surface material by itself, can be bound with various stabilizers to decrease its muddy or dusty. The most common form of stabilized soil is soil cement, a mixture of existing soil and 5 to 16 percent Portland cement. No aggregate or sand is used, so costs are less than those of concrete or asphalt are qualities and to harden it.

Porous Pavements

Permeable pavements are alternatives to traditional impervious asphalt and concrete pavements. Interconnected void spaces in the pavement allow for water to infiltrate into a subsurface storage zone during rainfall events. In areas underlain with highly permeable soils, the captured water infiltrates into the sub-soil. In areas containing soils of lower permeability, water can leave the pavement through an underdrain system. Water that passes through and leaves the pavement is referred to as exfiltrate. Nearly all permeable pavement types have the same general structures as in Figure 2 .

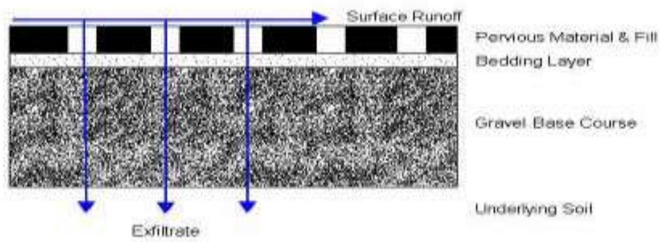

Figure 2: cross section of a typical block paver permeable pavement installation without under drains

Pervious material and fill are considered surface layer or cover. This is the top layer that drivers and users see. It is identified by the type of pavement used, such as permeable concrete, permeable interlocking concrete pavers filled with gravel, or segmental plastic pavers to be filled with grass. More on pavement type follows in this section. They are several different types of permeable pavement exist, and the main differences among each pavement type are in the total pore space, spatial arrangement of the underlying pervious layers, and structural strength. The most common types include permeable concrete (PC), permeable asphalt (PA), permeable interlocking concrete pavers (PICP), concrete grid pavers (CGP), and plastic grid pavers (PG).

(a) (b) (c) (d) (e)

Figure 3: (a) Permeable Concrete. (b) Permeable Asphalt. (c) Permeable interlocking concrete pavers with pea gravel fill. (d) Concrete grid pavers with topsoil and grass fill. (e) Plastic reinforcement grid pavers with earth and grass fill.

Plastic Grid Pavers feature a system of 100 percent recycled molded, interlocking plastic grids that support a strong, attractive, porous surface of 100 percent grass or crushed stone. The plastic grids are flexible, allowing use on uneven sites without grading. The grid rings or cells transfer surface loads to the underlying base course material. This prevents surface rutting, compaction of grass roots, and displacement of soil or stone due to traffic. Plastic grid pavers do not require curbs, curtain drains, detention or retention ponds or any other associated drainage facility making them competitively priced with asphalt and concrete paving when their required associated drainage facilities are cost factored.

Concrete Grid Pavement first appeared in the early 1960s when concrete building blocks were placed in the ground, hollow side up, to handle overflow parking at a cultural center near Stuttgart, Germany. Since then concrete grids have been used for embankment stabilization and as ditch liners. There are two types of concrete grid pavers: lattice and castellated. Lattice pavers produce a flat, continuous, patterned, concrete surface when installed. Castellated grid pavers feature protruding cement knobs on their surface that make the grass surface appear continuous when installed.

Aggregate

There were significant relationship between density and porosity, density and permeability, and porosity and permeability. Smaller sized aggregates resulted in greater retention of compost on the specimens and less reduction in permeability after removing the compost from the specimen surface. The PPS comprises four distinct components.

- pavers and bedding layer
- unsaturated zone of the base material
- saturated zone of the base material
- sub-grade.

IV. Method of Evolution

Flow test

To secure the required workability of the concrete, to prevent the separation of ingredients during the forming process, and to form continuous pores after the hardening process we have to check the result of flow test.

Total void ratio measurement

The total void ratio was obtained by dividing the difference between the weight (W1) of the cylinder specimen in the water and that (W2) measured following air drying for 24 h by the specimen volume.
The equation used to obtain this value is as follows:

$$A= (1- ((W2-W1)/\varrho_w)/(V1))/ 100\%$$

Where:
A=Total void ratio of the porous concrete, %
W1=underwater weight of cylinder specimen, kg;
W2=weight of cylinder specimen dried in air for 24 h, kg;
V1=Specimen volume, mm3; qw=density of water, (kg/mm3).

pH Measurement

For finding out nature of water we have to determine the pH Of water, whether it is alkaline or acidic. pH value 7 is neutral value of pH, more than 7 it is said to be alkaline water and less than 7 it is said to be acidic in nature.

DO (Dissolved Oxygen, Mg/l) measurement

To measure the amount of microorganisms attached to the panel, the DO consumption (mg/l) have measured.

Specific Gravity

The specific gravity of an aggregate is defined as the ratio of the solid in a given volume of sample to the mass of an equal volume of water at the same temperature. The specific gravity is require for the calculation of yield of concrete or of the quantity of aggregate required for a given volume of concrete. The specific gravity is given by

Specific gravity = c/(a-b)

Where,
a – mass of saturated surface dry aggregate in air
b – mass of saturated surface dry aggregate in water
c- mass of oven dry aggregate in air.

Bulk Density

The bulk density of an aggregate is defined as the mass of the material in a given volume and is expressed is defined as the mass of the material in a given volume and is expressed in kilogram/litre. The bulk density of particle can be used for judging the quantity of aggregate by comparing it with normal density for that type of aggregate.

Voids

The empty spaces between the aggregate particles are termed voids. It is the difference between thr gross volume of aggregate mass and the volume occupied by the particle alone. The void ratio of an ag regate can be calculated from the specific gravity and bulk density of aggregate mass as follows

Void ratio = 1- (bulk density / apparent specific gravity)

Moisture content of aggregate

The surface moisture expressed as a percentage of the weight of the saturated surface dry aggregate is termed as moisture content. The determination of moisture contain of an aggregate is necessary in order to determine the net water-cement ratio for a batch of concrete.

Compressive strength of concrete

The determination of Compressive strength of concrete is important for know the load bearing capacity of concrete.

Pollutants

Impervious surfaces have a high potential for introducing pollution to watercourses. Possible water quality
Variables of concern include the following

- Sediment and suspended solids (including phosphorus and some metals)
- Organic waste with high biochemical oxygen demand.
- Dissolved nutrients and pollutants (including nitrogen, heavy metals, solvents, herbicides and pesticides).
- Oil and grease and Faecal pathogens.

Permeable pavements have a good track record at removing suspended solids and nitrogen. The assessment of the microbiological water quality has been an important process in preventing waterborne diseases. The two most common alternate tests carried out are for coliforms and Escherichia coli, or faecal coliforms.

Sustainable Drainage Systems

Traditional systems capture storm runoff, and subsequently distribute it to nearby watercourses or sewer systems. Some of these systems have become ineffective and inefficient. Instead of focusing on 'end-of-pipe' treatment, the traditional approach of wastewater treatment by optimizing the resource utilization and development of novel and more productive technologies.
Reductions in suspended solids, biochemical oxygen demand, chemical oxygen demand and ammonia levels in comparison to highway gullies not only demonstrate the high treatment efficiency of PPS, but also that there is no need for frequent maintenance, unlike with gully pots.

V. Application And Challenges

Permeable pavement systems (PPS) are suitable for a wide variety of residential, commercial and industrial applications, yet are confined to light duty and infrequent usage, even though the capabilities of these systems allow for a much wider range of usage. Where there is any concern about the possible migration of pollutants into the groundwater, permeable pavement should be constructed with an impermeable membrane, and the treated storm water should subsequently be discharged into a suitable drainage system. Common applications of permeable pavement are as follows:

- Vehicular access: residential driveways, service and access driveways, roadway shoulders, crossovers, fire lanes and utility access.
- Slope stabilisation and erosion control.
- Golf courses (cart paths and parking).
- Parking (church, employee, overflow and event).
- Pedestrian access.
- Bicycle and equestrian trails.
- Land irrigation.

VI. Innovation And Future Research

Concerning porous pavements, silica fume and super plasticizer can be added to standard porous concrete ingredients. This usually improves the compressive strength of the porous pavement to allow for higher loads depending on the application. (Yang J, Guoliang, 2003)

The demand for fresh drinking water is continuously rising with the passing years as a direct effect of population explosion. This hence warrants a situation that necessitates conservation and augmentation of fresh water from every possible sector. For the given rooftop area of 11107 sq.m, about 706 cubic metre of rainwater was found with a collection efficiency of 90%. The results of the qualitative analysis carried the study in terms of provision of necessary treatments in the form of two slow sand filters. (Rama R. Rudrappa Shetahalli,Jan 15)

With concern to porous concrete, phosphate and nitrogen can added to improve its strength and water quality. Results from this study show that porous concrete using industrial byproducts is able to purify water efficiently. (Sung-Bum Park, 2003).

An additional layer of heat-bonded geotextile was introduced to the Form pave sub-base. This liner slowed down the release of small oil spillages, and their subsequent transport through the system (Newman AP,2004).

Furthermore, M. Scholz, P. Grabowiecki, 2007 worked with Form pave and Water Furnace Europe to develop a heating/cooling system, which can be installed within the sub-base of modern PPS. The energy gained from the below-ground pump can be used for heating or cooling buildings. Natural energy can be used to heat water and subsequently reduce industrial and domestic energy bills. The system is safe, reliable and energy efficient, because heat energy is transferred from the earth to heat and cool work and domestic environments, which would otherwise rely on fossil fuels that are becoming scarce and more expensive.

Treating the clay sub grade beneath pervious concrete plots with boreholes, ripping, and trenching greatly increased the infiltration rate compared to the control plots. All treated plots showed average infiltration rates sufficient to drain the plots in three days or less. None of the control plots drained adequately. There was no temporal trend to the infiltration rates collected from three drainage experiments undertaken during a period of nearly a year following plot construction. At the 5% level of significance, the hypothesis that average infiltration rates for control<borehole< ripped< trenched was rejected only for the case of borehole< ripped. The average infiltration rates were 0.8 cmd (control), 4.6 cmd (borehole), 10.0 cm d (ripped), and 25.8 cm d (trenched). (J.S. Tyner, W.C. Wright, P.A. Dobbs, 2009).

Porous concrete pavement is one of the solution of storm water runoff. The main problem of porous concrete pavement are the strength itself. Silica is a major inorganic element in the rice husk. By grinding a controlled temperature burning rice husk ash into nano size, it will use as cement replacement to improve the strength. Different percentage cement replacement of Nano-silica from Rice Husk Ash at lo%, 20%, 30%, 40% and 50% will be evaluate to determine the optimum of nano-silica in porous concrete mixes. Hardened porous concrete characteristics will be evaluate by conducting compressive strength test, flexural strength test, tensile splitting test, shear strength test and also water permeability test (Ramadhansyah P.J).

The self-sustainability of these relatively new systems in comparison to traditional pavements requires further assessment. Moreover, the long-term impact of permeable pavement system on the environment is still unclear. Further research on the short- and long-term effects of contaminants that remain in the permeable pavement should be undertaken.

Finally, as porous pavement becoming established as environmental friendly engineering techniques, so we have to implement it in our life.

VII. Conclusion

This review paper summarized the diffuse literature on permeable and porous pavement systems. Permeable pavement systems (PPS) have become an important integral part of sustainable urban drainage systems despite the lack of corresponding high-quality research in comparison to other research areas. Design, maintenance and water quality control aspects relevant to the practitioner were outlined for permeable and porous pavement systems. In this paper author gives the various aspects of porous concrete, its tests, material use their quality etc. Recent innovations were highlighted and explained, and their potential for further research work was outlined.

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