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Comparative Study of Permeable Pavement

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***Abstract*: Permeable pavements allows storm water runoff to filter through surface voids into an underlying stone reservoir where it is temporarily stored and infiltrated. The most commonly use permeable pavement surface are pervious concrete, porous asphalts, and permeable interlocking concrete pavers(PICP). Permeable pavements have been use for area with light traffic at commercial and residential sites to replace traditionally impervious surfaces such as low speed roads, parking lots, driveway, sidewalks, plazas, and patios. While permeable pavements can withstand truck loads, permeable pavements has not been proven in areas exposed to high repetitions of trucks or in high speed areas because its structural performance and surface stability have not yet been consistently demonstrated in such applications.**

***Keywords*: Porous asphalts, PICP, Geotextile, Hydrologic perspective, Rooftops.**

1. Introduction

Permeable Pavements, an alternative to traditional impervious pavements, are one of the most environmental friendly paving solutions that are available to builders, land scaping contractors, engineers and property owners. Permeable pavement is ideal for sites with limited space for other surface storm water these paver types provide different benefits and are applied in various outdoors areas in public, private, commercial properties. Permeable paving allows for filtrations, storage or in filteration of runoff and can eliminate surface storm water flows comparative traditional impervious paving surface like concrete and asphalts.

2. Cross-section of permeable pavements

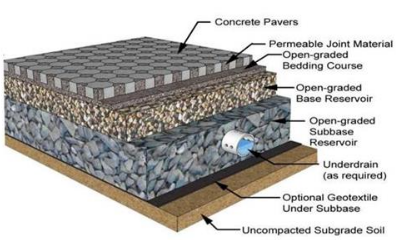

Fig. 1. Cross section permeable pavements

Permeable pavements is a method of paving that allows storm water to seep into the ground as it falls rather than running off into storm drains, waterways and eventually to water bodies. Permeable pavements functions similarly to sand filters, in that they filter the water by forcing it to pass through different aggregates size and typically some sort of filter fabric. Therefore, most of the treatment through physical (or mechanical) processes. As precipitation falls on the pavement infiltrates down into the storage basin where it is slowly released into the surrounding soils. Long term research on permeable pavers shows their effective removal of pollutants such as total suspended solids, total phosphorous, total nitrogen, zinc, motor oil, copper. In the voids spaces naturally occurring microorganisms break down.

3. Literature review

1. Permeable pavement used on sustainable drainage systems (SUDs): a synthetic review of recent literature M. Marchioni & G. Becciu Department of Civil and Environmental Engineering, Politecnico di Milano, Italy. Year 2015. Analyzing the literature it is possible to confirm the feasibility of permeable pavement as SUDs by effectively promoting runoff volume reduction and pollutants removal. However, in order to guarantee its properly performance is important to conceive the entire structure permeable, providing surface material with proper infiltration rate, an open graded base and observed the subgrade soil features regarding the infiltration rate and also use an accurate pavement design considering mechanical and hydrological features. The base should have a high void content, therefore behaves as a reservoir, but still providing the necessary mechanical strength. Even though clogging may occur, through maintenance the pavement can regain acceptable infiltration rates. To extend the design life it is important to guarantee the characteristics of the surface layer and observe the adjacent areas. There are already a number of SUDs models that comprises permeable pavement, but it stills lacks a broader tool comprising all the main aspects of the system, as outflow volume, pollutants removal, mechanical performance and design life aspects. In conclusion, permeable pavement can be a feasible solution for urban drainage and its use should be encouraged. Although the system is fully available for commercial use research is undergoing to improve specific points.
2. The Application of Permeable Pavement with Emphasis on Successful Design, Water Quality Benefits, and Identification of Knowledge and Data Gaps. Masoud Kayhanian, Department of civil Engineering and

Environmental Engineering, University of California, Davis.Peter T. Weiss, Department of Civil Engineering, Valparaiso University, Valparaiso, Indiana John S. Gulliver and Lev Khazanovich, Department of Civil, Environmental, and Geo-Engineering, University of Minnesota, Minneapolis Year June 2015.

4. Ingredients of permeable concrete

Permeable concrete mix consists of cement, coarse aggregates & water. Fine aggregates are purposely not used so as to get maximum amount of voids in it.

A. Tests on coarse aggregates

Gradation of coarse aggregate – Well graded aggregates with approximate passing as per (IS-383 Table No 2).

- o % of Flakiness Index – 7.17%
- o % of Elongation Index – 8.04%
- o Combined (F.I + E.I) – 15.17%
- o % Average Impact Value of Aggregate – 10.56%
- o % Average Crushing Value of Aggregate – 20.80%

B. Testing of concrete cube

This deals with Tests and testing procedure for fresh & hardened concrete specimen. Investigations are carried out by testing cubes 7days and 28days. Cubes were tested for Compression & Permeability.

C. Compression test- [test on cubes]

Compressive strength of concrete can be defined as the measured maximum resistance of concrete to axial loading. Compression test is the most common test used to test the hardened concrete specimens because the testing is easy to make. The specimens used in compression test were the cube of 150×150×150 mm for both size aggregates (12.5mm & 20mm). Apparatus and test Procedure of compression test the equipment used in compression test were according to IS: 509-1959 and is shown in figure testing machine: compression testing machine.

Compression strength of cubes (fc) can be calculated by following formula,

$fc = P/LB$ (N/mm^2)

Where,

P = Maximum load (N) applied to the cube

L = lengthof the cube (mm)

B = widthof the cube(mm)

Fig. 2. Compression testing machine (CTM)

The procedure is as below: The testing for the specimens should be carried out as soon as possible after taking out from the curing rank i.e. Saturated Surface Dry condition (SSD).The specimen need to get measurement before testing. The length and height of specimen is measured and recorded. Clean the uncapped surface of the specimen and place specimen in the testing machine. The axis of specimen is aligned with the centre of thrust of the seated plate. Plate is lowered until the uniform bearing is obtained. The force is applied and increased continuously at a rate equivalent to 20 MPa compressive stresses per minute until the specimen failed. Record the maximum force from the testing machine.

D. Permeability test- [test on cubes using glass jar of known volume]

To measure time taken to collect 1 Litre of water by passing through the permeable concrete cube.

Fig. 3. Glass jar for permeability test

Apparatus required: Glass Jar of size 300mm×170mm×220mm with a tap at one end, Permeable concrete specimen of size 150mm×150mm×150mm (12.5mm & 20mm size aggregate), measuring cylinder, stopwatch.

E. Procedure for test

- Fill the glass jar with water up to its full level and keep it on an even surface.
- Place the concrete block right below the tap of the jar in such a way that water falls evenly on the block.
- Put a measuring cylinder under the block to collect the percolated water.
- Open the tap of the jar and allow the water to flow through the block and collect it with the help of measuring cylinder placed below it.
- Use a stop watch to record the time required to collect 1 litre of water and write down the observations.
- Carry the procedure for more two specimens and both size aggregate to find the average time required to collect 1 litre water

Fig. 4. Collection of water by passing it through concrete block

Table 1
Observation Table

Description	Time required for collecting 1 Litre of water in seconds	
Block size & name	12.5mm	20MM
A	44.23	34
B	44.24	33
C	44.20	34.2
Block size & name	44.22 sec	33.73 sec

To measure amount of water that fills up the voids in the concrete block. Apparatus required: Glass Jar of size 300mm×170mm×220mm with a tap at one end, Permeable concrete specimen of size 150mm×150mm×150mm (12.5mm & 20mm size aggregate), measuring cylinder, stopwatch.

Procedure for test:

- Measure the volume of glass cylinder and amount of water required to fill the cylinder (A) to its full level and note down the observations.
- Measure the volume of concrete block (B) and note down.
- Now place the concrete block in the empty glass jar.
- Start pouring water in the glass jar by keeping a record of quantity of water poured.
- Fill the glass jar to the full level and note down the amount of water poured (C).
- Carry this for more two cubes and both size aggregates.
- Note down the observations.

Fig. 5. Concrete blocks placed in glass jar

Volume of water filled in glass jar to full level (A) = 11500 ml
Volume of concrete block (B) = 3.375
Volume that should be required to fill the remaining space in jar after placing the block in jar (C) = 8125 ml

Table 2
Observation table

Description	Actual volume of water filled after placing the concrete block in jar. (D) ml		Actual volume of water filled after placing the concrete block in jar. (D) ml	
Block size & name	12.5mm	20mm	12.5mm	20mm
A	8300	8500	175	375
B	8320	8490	195	365
C	8290	8485	165	360
Average volume of voids	-	-	178 ml	ml

5. Benefits of permeable pavements

In urbanized areas, we have been forced to deal with runoff water by building large sewer systems that channel this water directly to lakes, rivers, and other surface water rather than into the groundwater. Because of the toxins this runoff picks up as it travels, expensive water purification systems are often built to clean the water before it re-enters the natural water cycle. As water runoff increases and is channeled to travel in straight paths, a watershed community will find very serious impacts. In order to overcome such and such inconveniences, an established permeable pavement allows:

- Urban Heat Island Effect Reduction: Porous materials have less thermal Conductivity and thermal capacity than traditional impervious pavement, thereby reducing the urban heat island effect.
- Quiet Streets: Porous surfaces absorb sound energy and dissipate air pressure around tires before any noise is generated. Tire noise is lower in loudness and pitch for a porous surface than a corresponding dense pavement.
- Trees: Permeable pavements may give urban trees the rooting space they need to grow to full size. A "structural-soil" pavement base combines structural aggregate with soil; a porous surface admits vital air and water to the rooting zone. This integrates healthy ecology and thriving cities, with the living tree canopy above, the city's traffic on the ground, and living tree roots below. The benefits of permeable on urban tree growth have not been conclusively demonstrated and many researchers have observed tree growth is not increased if construction practices compact materials before permeable pavements are installed.
- Winter Performance: Snow plough and deucing costs are reduced due to rapid snow and ice melt drainage. Puddling and flooding on parking lots is also reduced. And also imparts:
- Reduction in erosion
- Declined toxic load
- Lesser sediment load
- Presents pleasant temperature

- Subjugation in flooding

6. Limitations of permeable pavements

- As there are no fine aggregates to fill the voids in this concrete, it has high permeability than normal concrete. Thus, it is not a good idea to construct reinforced concrete with no fines concrete, as the reinforcement can easily get corroded.
- To make this concrete impermeable, extra coat of masonry plaster is required, which increase the cost.
- No fines concrete cannot be tested for workability by using tests for normal concrete such as slump or compaction factor test. Values of workability and its test methods are unknown.
- They are not as strong as traditional or asphalt pavements. If you put consistent pressure (like heavy vehicle breaking) on it, then the pores of the pavement will collapse. Due to this, permeable pavement isn't ideal for building airport runways and highways.
- The maintenance requirements of permeable pavement are quite different.

7. Conclusion

By stopping storm water from pooling and flowing away, porous paving can help recharge underlying aquifers and reduces peak flows and flooding. That means that streams flow more consistently and at cooler temperatures, contributing to healthy ecosystems. Permeable pavers have been gaining popularity because of their proven benefits such as reduced installation costs, increased water quality, decreased storm water runoff, and prevention of soil erosion and flooding. The various applications also mean that it's possible to use them not only in one specific outdoor area but in several areas in a property. They also eliminate the need to install costly retention and drainage systems, while at the same time help property owners save on pricey compliance regulations. All of these great benefits ultimately make permeable pavers among the most preferred paving options in use today.

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