

# Experimental Evaluation of Characteristics of Pervious Concrete Pavement with Fly Ash Replacement

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**ABSTRACT:** Permeable paving is a range of materials and techniques for permeable pavements with different layers that allow the movement of storm water through the surface. This system reduces the runoff, also effectively traps suspended solids and filters pollutants from the water. Examples include roads, paths that are subject to light vehicular traffic, such as parking lots, Service lanes, bicycle paths, emergency access lanes, roads and residential driveways and sidewalks. The main aim is to control storm water at the source, reduce runoff, reduce cost and improve water quality by filtering pollutants and increase ground water level, thus one way to harvest storm water. This Paper is based on design of permeable pavement by using Interlocking concrete block and pervious concrete. We have used cement concrete blocks which are widely used now a day whereas pervious concrete which is made using Portland cement, fly ash and coarse aggregate. Thus the road which is designed is eco-friendly as it harvest the water and solves the problem of disposal waste fly ash. The study is based on a laboratory model which shows actual working of paving system. It also includes cost and water quality comparison of pavement of Interlocking concrete block and previous concrete.

**KEYWORDS:** Permeable pavement, Groundwater recharge, structural capacity, replacement, fly ash, environment protection, economical analysis.

## I. INTRODUCTION

Pervious paving systems are paved areas that produce less storm water runoff than areas paved with conventional paving. This reduction in runoff is mainly caused due to infiltration water falling on the surface through the body of the pavement. This infiltration occurs either through the paving material itself or through void spaces between individual paving blocks known as pavers.

Permeable pavement is an alternative to traditional impervious surfaces that allow water coming on it to infiltrate through them into a stone reservoir where it is infiltrated into the underlying native soil or temporarily stored. They can be used for parking lots, low traffic roads, pedestrian plazas, driveways and walkways. Permeable pavement is mainly ideal for the areas where less space exists.

Porous pavement is a term used to describe different types of materials that provide a hardened surface yet facilitate water infiltration. Examples of such materials include pervious concrete, porous asphalt, and several types of pavers. A successful porous pavement system improves the infiltration capacity of pre-development site, but not affects its structural or functional requirements. There have been many studies and publications on porous pavements. One of the pioneering studies was performed by Franklin Institutes Research Laboratories in 1972. The study concluded that properly constructed porous pavements will satisfy the necessary strength and drainage requirements. However, the widespread interest on porous pavements is more of a recent trend, coinciding with the momentum of green buildings and concerns on sustainability. The use of porous pavements can assist an owner or a developer in gaining LEED credits if he or she is interested in receiving green building certification from US Green Building Council.

However, porous pavements still have great potential to be further improved and many unknown issues that need to be addressed. For example, the porous pavement system is often designed according to empirical procedures, which simply recommend default material proportions and pavement thicknesses, without considering the variations in climate, traffic loading, and material properties. The purpose of this study is to investigate the use of alternative porous pavement materials as well as to refine porous pavement design process. It is expected that the study will

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advance knowledge on porous pavement and make them more durable, economical, and environmentally friendly.

Design and construction of permeable pavement, regardless of the type of surface pavement, requires hydrological and structural analysis with both requirements being satisfied in order for the pavement to function properly. Generally, the structural design of pavement is performed to determine the thickness of different layers of pavement that are necessary to support the traffic loads while protecting the subgrade from permanent deformation. The hydrological design determines the required depth to store a design volume of infiltrated water in order to achieve storm water management objectives. An optimal permeable pavement design is one that is just strong enough to handle design traffic load and speed while maintaining the necessary porosity to provide sufficient porosity and storm water management.

## II. PERVIOUS CONCRETE PAVEMENT SYSTEM

### 2.1 Need of Pervious Concrete Pavement

- To solve traffic jam problems in highly developed areas due to problem of water logging.
- Permeable pavement can reduce the concentration of some pollutants either physically (by trapping it in pavement or soil), chemically (bacteria and other micro-organisms can breakdown and utilize some pollutants), or biologically (plants that grow in some types of pavements).
- To reduce the imbalance in natural ecosystem.

### 2.2 Objectives of Study

The overall objective of this our project is to assess the storm water drainage efficiency by using pervious pavement system from impervious surface runoff. One bench-scale study (hydraulic study) determined the flow rates. Another bench-scale study (turbidity study) will examine the role of suspended particles in pollutant removal performance of this porous pavement.

The primary objectives of the ongoing hydraulic bench-scale study are to:

- Test the use of different percentage of fly ash replacement with cement to improve the properties of concrete and find the percentage which gives maximum strength.
- Determine the flow rate of water through the system.
- Compare the total suspended solids (TSS) of the influent storm water with that of the effluent.
- Economic analysis of pervious concrete pavement and permeable interlocking concrete pavement.

### 2.3 Applications

- Low volume roads, driveways, sidewalks
- Parking Lots, Noise Barrier
- Swimming pool decks, Slope stabilization
- Tennis courts
- Hydraulic structures

## III. RESEARCH REVIEW

Beeldens A et.al.<sup>[1]</sup> stated that To ensure the combination of the bearing capacity and the water storage of the pavement, a special design is applied where both parameters are assigned respectively to the base and the sub base layer. This paper describes various thickness to be adopted under different foundations. She also determined the thickness based under different loading conditions.

Siddharth Talsania et.al.<sup>[2]</sup> investigated that to increase the strength and permeability of pervious concrete and decrease the cost of pervious concrete can be done by replacing cement with various industrial waste materials such as waste glass powder, hypo sludge, ceramic waste and rice husk ash. This paper describes the literature which is based on pervious concrete in which fly ash, silica fume and ground granulated blast furnace slag is partially replaced by cement in pervious concrete and various industrial waste such as waste glass powder, hypo sludge, ceramic waste, rice husk ash partially replaced by cement in concrete.

Darshan Shah et.al.<sup>[3]</sup> states that pervious concrete pavement becomes more suitable in rural areas to meet requirements such as to reduce storm water runoff, to increase ground water level, to eliminate the costly storm water management

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practices. Also his study concludes that there is considerable saving in cost about 193 Rs/m<sup>2</sup> for construction of pavement.

Tomas U. Ganiron et.al.<sup>[4]</sup> concluded that the pervious concrete with fly ash replacement gives high strength than Portland cement concrete.

B. Hung et.al.<sup>[5]</sup> concluded that the compressive strength and indirect tensile strength of pervious concrete with larger size aggregate was larger, which can have smaller air void. Also the permeability increases with increase in aggregate size.

## IV. EXPERIMENTAL WORK

The design of permeable pavements requires the consideration of both structural and hydrological components as shown in Figure 1. The structural design of the pavement is completed to determine the thickness of the various pavement components that are necessary to support the intended design traffic while protecting the subgrade from permanent deformation.

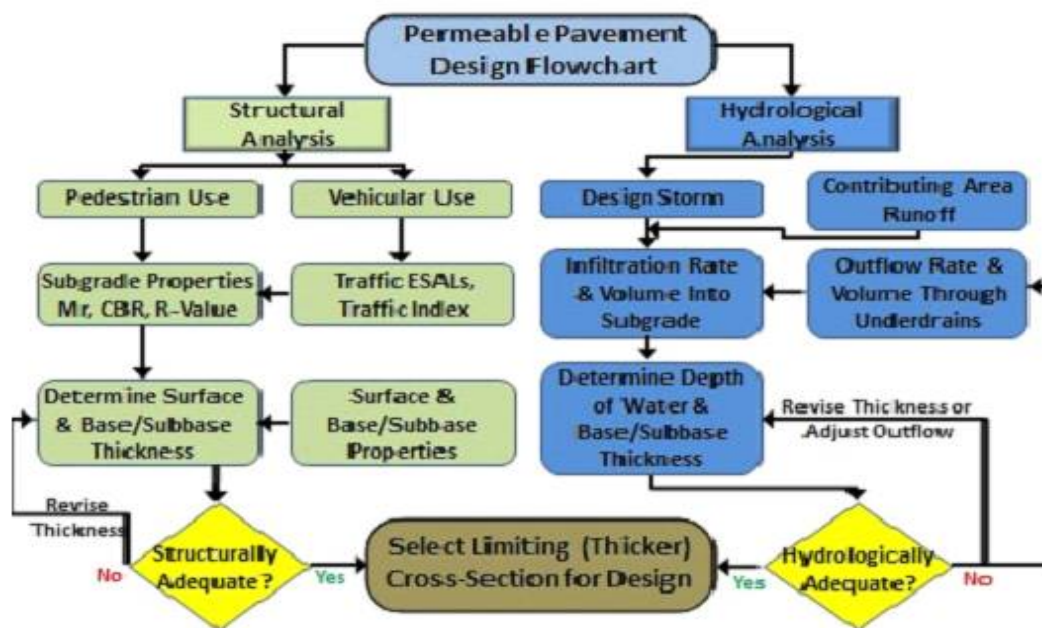


Fig -1: Flow Chart

### 4.1 Design Of Sub Grade Thickness

According to Beeldens theory of permeable pavement, determination of subgrade and base course thickness for various types of traffic conditions are classified in a standardize format, which is given in chart below.

From the traffic study conducted it was observed that proposed road is subjected to Heavy vehicals less than 20/day and Light vehicals less than 500/day. Whereas Pune city comes under moderate rainfall region, therefore selected thickness is as follows:

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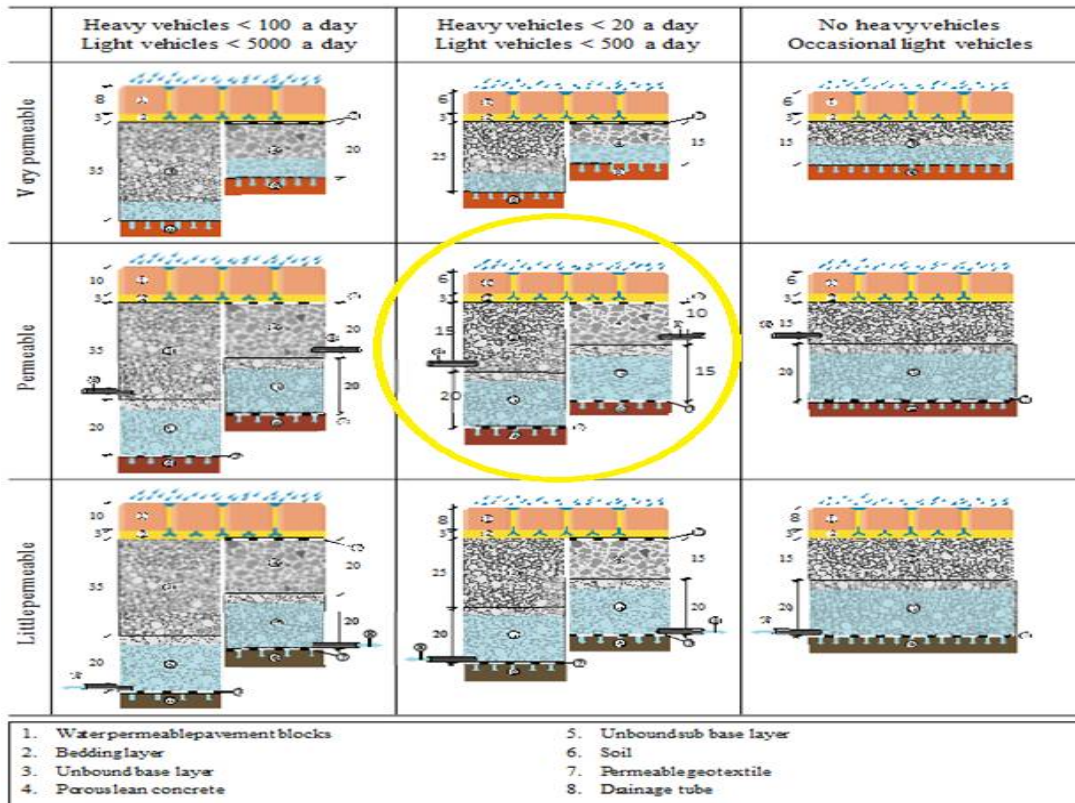


Fig -2: Thickness Chart

## 4.2 Mix Proportion Of Pervious Concrete

Concrete mix proportion is a process of optimization of several desirable characteristics based on the product requirement. The characteristics to be optimized are economy, strength, durability and placeability. Typical proportions of pervious concrete are taken from website of pervious concrete. The typical ranges of materials proportions in pervious concrete are as below:

- Cementitious Materials** : 267 to 326 Kg/m<sup>3</sup>
- Coarse Aggregate** : 1190 to 1480 Kg/m<sup>3</sup>
- Fine Aggregate** : 0 to 297 Kg/m<sup>3</sup>
- Total Aggregate** : 1190 to 1777 Kg/m<sup>3</sup>
- Water/Cement Ratio** : 0.27 to 0.36

So, by referring this we have adopted the proportions of various materials. The proportions of material used in concrete are given in Table 1.

Table – 1 : Proportion of Different Materials

Sr. No.	Material	Proportion
1.	Cement	300.00 Kg.
2.	Coarse Aggregate	1650.00 Kg.
3.	Admixture (0.40%)	1.20 Lit.
4.	Water	120 Lit.
5.	W/c Ratio	0.40

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## Mix Proportion For 1 m<sup>3</sup> Concrete

<b>Cement : C.A.</b>	<b>1 : 5.50</b>
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As per IS 456:2000, Arbitrary method of design for M15 grade concrete the ratio of proportions Cement : F.A. : C.A. is 1:2:4 i.e. for Cement : Aggregate it is 1:6. So we can say that the above Mix is of M15 grade concrete.

In this work we are using different sizes of coarse aggregate with different percentages. We have used 5 different trial mixes with different sizes of aggregate with different percentages. The proportions of 5 trial mixes are given below in Table 2.

Table – 2 : Trial Mixes

Mix No.	Cement (Kg.)	CA 20 mm (Kg.)	CA 10mm (Kg.)	CA 6mm (Kg.)	Natural Sand (Kg.)	W/C Ratio
1.	300.0	825.0	825.0	0.0	0.0	0.40
2.	300.0	412.5	1237.5	0.0	0.0	0.40
3.	300.0	825.0	577.5	0.0	247.5	0.40
4.	300.0	825.0	412.5	412.5	0.0	0.40
5.	300.0	0.0	1250.0	0.0	0.0	0.40

### 4.3 Construction of Working Model

- 1) Transparent Fiber Box
  - Transparent fiber box having size 32.5 cm X 37.5 cm X 35 cm.
  - The layers of permeable pavement rest in the Transparent fiber box.
  - We used Transparent fiber box so we can clearly see the layers.
- 2) Perforated UPVC pipe
  - We used the PVC pipe of 2” diameter & 0.60 m in length which having holes of 7 mm diameter at 60 degrees for collecting water & disposed off to natural source of water
- 3) Aggregate
  - 20 mm diameter of crushed stone aggregate of angular shape of 12cm thick.
  - It acts as a foundation for permeable road pavement and also supports the under drainage pipe.
- 4) Plastic Paper
  - Plain transparent plastic paper.
  - It acts as a seal to make layer below pipe impermeable so as to increase water collection through pipe and to allow less amount of water to percolate in base layer.
- 5) Waste mosquito net used as geo-synthetic sheet
  - It act as a separator so as fine aggregate does not interlock to the coarser aggregate & helps water to percolate easily.
- 6) Crushed Stone Aggregate
  - 10 cm layer of 10 mm diameter crushed stone aggregate.
  - This aggregates helps to transfer surface water to sub base, without affecting stability of road

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## Case – I

In case when there is application of PICP for parking area i.e. where surface void ratio is upto 20%. This 20% surface opening can be filled by porous bitumen or compacted clays or even by grass, so as to avoid surface erosion.



Fig -3: Permeable paving block system

## Case – II

In case when there is application of porous concrete for parking area i.e. where surface void ratio is between 15-25 %.



Fig -5: Porous concrete system

### 7) Bucket

- This bucket is use as source of water.
- It have the holes at bottom of 3mm in diameter & having specified distance. Approximately 15L of water were rained over each tray every 5 days for 2 weeks.

## V. RESULTS

### 5.1 Compressive Strength Test

By using 5 trial mixes we have casted 3 cubes of each trial mix. After that we have tested this cubes for 7, 14, 28 days compressive strength. After the results, we have selected the mix having good strength as well as maximum void ratio. Then we replace the cement content of this mix by 10%, 20%, 30% weight of fly ash.

Table – 3 : 28 Days Compressive Strength of Normal Concrete

Mix No.	Weight of cube (Kg)	Load (kN)	Strength (MPa)
1.	7.72	335.00	14.89
2.	7.85	397.00	17.64
3.	8.90	458.00	20.36
4.	7.96	385.00	17.11
5.	7.36	232.00	10.31

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Table – 4 : 28 Days Compressive Strength with Fly Ash Replacement

Sr.no	Fly Ash Replacement	Weight of cube (Kg)	Load (kN)	Strength (MPa)
1.	10 %	8.22	409.00	18.18
2.	20 %	8.36	387.00	17.20
3.	30 %	8.10	349.00	15.51

## 5.2 Total Suspended Solids Test

CASE I – Interlocking Concrete Block Pavement



Chart -1: Duration Vs TSS Removal Efficiency

In study, it was observed that TSS removal efficiency is 40% at initial stage is reduced to 33% as time passes for Interlocking Concrete Block Pavement. Hence from above study, we can say that duration of infiltration is inversely proportional to TSS removal.

CASE – II Pervious Concrete System

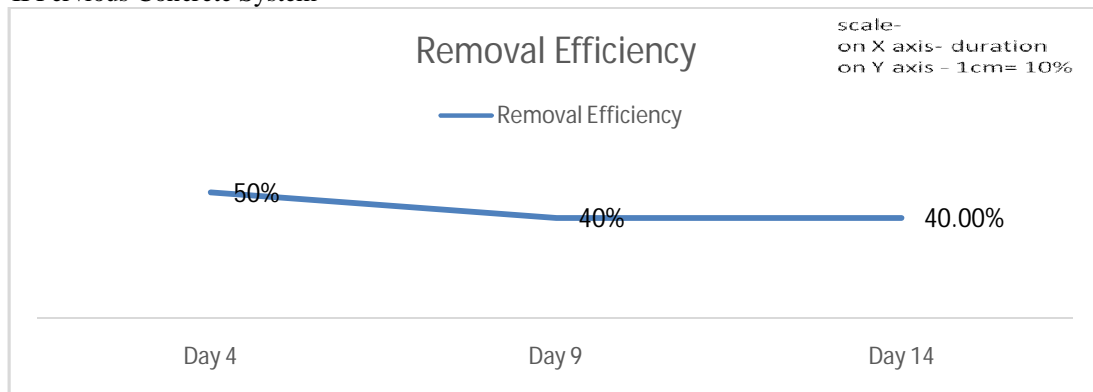


Chart -2: Duration Vs TSS Removal Efficiency

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In study, it was observed that TSS removal efficiency is 50% at initial stage is reduced to 40% as time passes for Pervious Concrete Pavement. Hence from above study, we can say that duration of infiltration is inversely proportional to TSS removal.

The graph says that concrete pavements are good to assess the pollutant removal with much good percolation rate the hydrological bench scale study carried on system of concrete pavement also state that there is high frequency of system failure due to clogging.

### 5.3 Cost Comparison

Table – 5 : Cost of Construction of Permeable Pavement

Type of pavement	Pervious Concrete	Interlocking Block Pavers
Construction Cost	200.04 Rs/m <sup>2</sup>	313.00 Rs/m <sup>2</sup>

Table – 6 : Cost of Normal Concrete

Material	Quantity	Rate	Amount
Cement	298 Kg.	5.40	1609.20
Fine Aggregate	0.26 m <sup>3</sup>	1500.00	390.00
Coarse Aggregate	0.50 m <sup>3</sup>	820.00	410.00
Water	149 Lit.	0.15	22.35
<b>Total</b>			<b>2431.55</b>

Table – 6 : Cost of Pervious Concrete

Material	Quantity	Rate	Amount
Cement	270 Kg.	5.40	1458.00
Fly Ash	30 Kg.	1.90	57.00
Fine Aggregate	0.00 m <sup>3</sup>	1500.00	0.00
Coarse Aggregate	0.57 m <sup>3</sup>	820.00	467.40
Water	120 Lit.	0.15	18.00
<b>Total</b>			<b>2000.40</b>

## VI. CONCLUSION

The conclusion obtained from our model study of various pervious system are summarized as follows:

- From testing of concrete it has been shown that, the pervious concrete has good compressive strength to serve it's intended purpose.
- The pervious concrete with 10% fly ash removal gives high compressive strength than the pervious concrete with no replacement.
- It has been shown that, porous paver systems remove TSS from storm water runoff. It has also been shown that the use of a mosquito net as a separator in a previous pavement system has both advantages and disadvantages (higher TSS removal vs. slower infiltration rates, higher possibility of clogging due to higher retention of solids).
- Also in the model we are using fly ash as replacement for cement. It is clear that by using waste material by partially replacement of cement in pervious concrete, overall cost of making of concrete can reduce. It can reduce the disposal problems of waste materials thus reducing it's impact on the environment.



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- The Cost Pervious concrete is less than conventional concrete. Also the construction cost of pervious concrete pavement is less than interlocking block pavers.

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