# Pervious Concrete Pavement Systems

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## 1.Abstract

Pervious concrete is a type of concrete with high porosity. It is used for concrete flatworks application that allows the water to pass through it, thereby reducing the runoff from a site and allowing ground water recharge. The high porosity is attained by highly interconnected voids content. Pervious concrete has water to cementitious material ratio of 0.36. The mixture is composed of cementitious materials, coarse aggregates and water with no fine aggregates. In this paper works porous concrete with fly ash as a blended material is tested for strength and permeability for assessing the adaptability of fly ash as a substitute material to cement. The percentage of fly ash is varied from 10% and 20%. Various tests like compressive strength, tensile strength and water permeability are done on the specimens and results are discussed. Current climatic changes are occurring due to various human and industrial activities. In particular, the effects of urbanisation and growing threat of global warming have likely caused increasing precipitation in many geographic regions. For many years, Portland cement pervious concrete (PCPC) has been making an important contribution, as a sustainable urban drainage system (SUDS), on improving environmental conditions. This type of porous concrete can help minimizing flooding risks, recharging ground water, reducing run off and peak flows, alleviating the precipitation load on overstressed drainage systems and improving water quality by capturing pollutants. The benefits of using PCPC in order to attenuate storm water problems are quite essential mainly in urban areas where most surfaces typically consist of relatively impervious concrete or asphalt pavements, causing elevated levels of surface runoff. In addition, PCPC can reduce the absorption of solar radiation and urban heat storage potential which can lead to temperate urban conditions, and thus protecting the environment and health and safety of living things. However, PCPC requires regular maintenance to prevent any clogging of the pores by sediments and vegetation.

## 2. Introduction

Pervious concrete which is also known as the no-fines, porous, gap-graded, and permeable concrete and Enhance porosity concrete have been found to be a reliable storm water management tool. By definition, pervious concrete is a mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate). When pervious concrete is used for paving, the open cell structures allow storm water to filter through the pavement and into the underlying soils. In other words, pervious concrete helps in protecting the surface of the pavement and its environment.

As stated above, pervious concrete has the same basic constituents as conventional concrete, 15-30% of its volume consists of interconnected void network, which allows water to pass through the concrete. Pervious concrete can allow the passage of 11.35-18.97 liters of water per minute through its open cells for each square foot (0.0929$m^2$) of surface area which is far greater than most rain occurrences.

## 3. Objectives

1. To prepare Pervious and Conventional concrete block
2. To perform Compressive strength test on Pervious and conventional concrete block and compare them
3. To perform permeability test on Pervious and conventional concrete block and compare them

## 4.Literature Review

Construction of pervious concrete pavement stretch, Ahmedabad, India, A Case study – Tejas Joshi, Urmil Dave (2021)
The pervious nature of the pavement is suggested to act as a drainage pipe and the water accumulated on the road or pavements drains out immediately. Therefore, an attempt has been made for the construction of PCP in this present study. The PCP was constructed at Nirma University campus, Ahmedabad, India for study purpose. The size of PCP stretch was 3 m × 10 m. The details of construction methodology and material used for the construction of PCP are included in this paper. In addition to that, properties of pervious concrete (PC) such as void ratio, compressive strength, permeability and density were evaluated and compared with field investigation results. The 28 days results of PC field cores and cast specimens achieved similar range for compressive strength and void ratio. Moreover, maintenance schedule was prepared for the supervision of PCP. The infiltration rate was measured at different intervals to determine if there was clogging in the PCP.

Effect of the rheological properties of fresh binder on the compressive strength of pervious concrete – Sungwoo Park , Suhawn Ju, Hyeong-Ki Kim, Yo-Seob Seo, Sukhoon Pyo (2022)
This paper investigates the effect of the rheological properties of fresh binder on the compressive strength of pervious concrete. This study measured the plastic viscosity, yield stress, adhesion energy of fresh binder using a rotational rheometer; and the data were compared with the compressive strength of the pervious concrete.

A novel approach to evalute the clogging resistance of pervious concrete – Jiwei Cai, Jin-ge Chen, Junli Shi, Qing Tian, Gelong Xu, Yun Du (2022)
In this paper, the pervious concrete is proportioned by introducing a parameter of filling ratio, and the influences of filling ratio and W/C ratio on compressive strength and permeability of pervious concrete are investigated. In order to simulate the actual situation of pervious concrete clogging phenomenon, a novel method with saturated slurry (soil suspension) as clogging media is proposed in this paper. Here we will evaluate clogging resistance. The image processing is used to determine the pore characteristics and to interpret the formation mechanism of permeability and clogging resistance of pervious concrete.

Experimental Study on behavior of Pervious Concrete in Strength and Permeability by Changing Different Parameters - Sujeet Kumar Sah and Shaik Niyazuddin Guntakalb and Dr. S. Senthil Selvan (2018)
Types of concrete that permits water to penetrate through it because of its high void or porosity is known as pervious concrete. These studies look into the impact of size of aggregate (20mm and 10mm), w/c ratio (0.32 & 0.28), super plasticizers and different percentage of fibre (i.e 1% & 2%) on the behavior of pervious concrete and were described the resemblance with 4 criteria: Compressive strength, split tensile strength, flexural strength, and permeability test. The result indicates that there is moderate increase in strength with decrease in w/c ratio from 0.32 to 0.28 & moreover super plasticizer (conplast sp 430) gives good strength. Addition of fibre i.e 1% by weight of cement showed a significant role in increase in strength.

An Experimental Study on Pervious Concrete - G.Amirthagadeshwaran, S.Ramesh, K.Selvi (2022)
In this paper works porous concrete with fly ash as a blended material is tested for strength and permeability for assessing the adaptability of fly ash as a substitute material to cement. The percentage of fly ash is varied from 10% and 20%. Various tests like compressive strength, tensile strength and water permeability are done on the specimens and results are discussed. As the pervious concrete with 10% and 20% replacement of fly ash gives slight increase in compressive strength, split tensile strength and decrease coefficient of permeability. Hence this material can be used for road pavement at the places of low volume of traffic road, parking lots, play grounds etc which helps in recharging.

## 5.Materials Used

Cement – Grade 53
Coarse Aggregate – 10mm to 25mm
Fine Aggregate --
Usually no fine aggregate is used in pervious concret but the research papers we studied suggest that An optimization of 10%-20% of fine sand to coarse aggregate has been shown to increase compressive strength from 14 to 19 MPa. We preffered to not to use the fine aggregate as it may affect the permeability of concrte pavement
water
While any potable water can be used for mixing, the amount of water is critical for the formation of the voils in pervious concrete. Water-to-cement ratios can range from 0.27 to 0.30 with ratios as high as 0.40. Careful control of water is critical A mix design with little water can create a very weak binder. This will create a very dry mix that is susceptible to spalling and crumbling. A mix design with too much water can collapse the void space, making an almost impenetrable concrete surface.

## 6.Mix design of pervious concrete

Void Content:

At a void content lower than 15%, there is no significant percolation through the concrete due to insufficient interconnectivity between the voids to allow for rapid percolation, So, concrete mixtures are typically designed for 20% void content in order to attain sufficient strength and infiltration rate.

Unit Weight or Density:

The density of pervious concrete depends on the properties and proportions of the materials used, and on the compaction procedures used in placement. In-place densities on the order of 1600 kg/m² to 2100 kg/m² are common, which is in the upper range of lightweight concretes. A pavement 125 mm thick with 20% voids will be able to store 25 mm of a sustained rainstorm in its voids, which covers the vast majority of rainfall events in the U.S. When placed on a 150mm thick layer of open-graded gravel or crushed rock sub base, the storage capacity increases to as much as 75 men of precipitation.

Water-Cement Ratio:

The water-cementitious material ratio (w/cm) is an important consideration for obtaining desired strength and void structure in pervious concrete. A high wiem reduces the adhesion of the paste to the aggregate and causes the paste to flow and fill the voids even when lightly compacted. A low w/em will prevent good mixing and tend to cause balling in the mixer, prevent an even distribution of cement paste, and therefore reduce the ultimate strength and durability of the concrete. w/em in the range of 0.26 to 0.40 provides the best aggregate coating and paste stability. The conventional w/cm-versus-compressive strength relationship for normal concrete does not apply to pervious concrete. Careful control of aggregate moisture and wiem is important to produce consistent pervious concrete.

Cement Content:

The total cementitious material content of a pervious concrete mixture is important for the development of compressive strength and void structure. An insufficient cementitious content can result in reduced paste coating of the aggregate and reduced compressive strength. The optimaan cementitious material content is strongly dependent on aggregate size and gradation but is typically between 267 and 415 kg/m3. The above guidelines can be used to develop trial batches. ASTM C1688 provides the tests to be conducted in the laboratory to observe if the target void contents are attained

## 7. Mix Design Criteria:

Pervious concrete uses the same materials as conventional concrete, except that there is usually little or no fine aggregate. The quantity, proportions, and mixing techniques affect many properties of pervious concrete, in particular the void structure and strength. Usually single sized coarse aggregate up to 20 mm size normally adopted. Larger size aggregates provide a rougher concrete finish while smaller size aggregates provide smoother surface that may be better suited for some application such as pedestrian pathways. Although the coarse aggregate size 6 mm to 20 man are used, the most common being 10 mm fairly uniform size is used. The aggregates may be rounded like gravel or angular Eke crushed stone

Since the pervious concrete is highly permeable, the voids between aggregate particles cannot be entirely filled by cement paste. Use of smaller size aggregates can increase the number of aggregate particles per unit volume of concrete. As the aggregate particle increase the specific surface and thus increases the binding area. This results in the improved strength of pervious concrete. However, the major thrust for using pervious concrete stems from its capability to drain and potentially de-pollute enormous amounts of water in short time, thus reducing the runoff rates. The physical and mechanical properties of pervious concretes are reported elsewhere

The use of larger size aggregates reduces clogging of pores in the pervious concrete. The water permeation capacity or drainage properties are closely related to the porosity with coefficient of permeability to about 0.01m's is recommended. A drainage rate of 100 to 270 lit/m²/min has been reported for pervious concrete with a porosity ranging from 17% to 28% . Recently it is suggested that the aggregate sizes of pervious concrete should be between 9.5 men and 19 min and no firse aggregate should be used.

The binder normally used in ordinary Portland cement (OPC). Pozzolanic materials like fly ash, blast furnace slag and silica fume can also be used. However, use of pozzolanic materials will affect setting time, strength, porosity and permeability of the resulting concrete. Addition of fine aggregate will reduce the porosity and increase the strength of concrete.

Chemical admixtures like water reducing admixture, retarders, hydration stabilizing admixtures, viscosity modifying admistures and intermal curing admixtures are used.

Pervious concrete uses same materials as conventional concrete, except that there are usually No or little fine aggregates. The size of the coarse aggregate used is kept fairly uniform in size to minimize surface roughness and for a better aesthetic, however sizes can vary from 6.25 mm to 12.5 mm. Water to cement ratio should be within 0.27 to 0.34. Ordinary Portland cement and blended cements can be used in pervious concrete. Water reducing admixtures and retarders can be used in pervious concrete.

## 8 .TESTING

### 8.1Compression Test

Compression test is used to know the characteristics of the concrete block. It gives the compressive strength of the concrete block. Compressive strength is the ability of material or structure to carry out the loads on its surface without any crack or deflection. The value of compression test depends upon the water-cement ratio, cement strength, quality of concrete material, quality control during the production of concrete. The compression is done after the mixing, placing, and curing of concrete block, the specimens are tested after the 7 or 28 days of curing. To obtain the proper reading of compressive strength the blocks should completely dry. To obtain the more proper value of compressive strength, take the average value of three blocks, which eliminate the error by manmade or machine.

In the laboratory, pervious concrete mixtures have been found to develop compressive strengths in the range of 3.5 MPa to 28 MPa, which is suitable for a wide range of applications. Typical values are about 17 MPa. As with any concrete, the properties and combinations of specific materials, as well as placement techniques and environmental conditions, will dictate the actual in-place strength. However, currently there is no ASTM test standard for compressive strength of pervious concrete.

Testing variability measured with various draft test methods has been found to be high and therefore compressive strength is not recommended as an acceptance criterion, Rather, it is recommended that a target void content (between 15% to 25%) as measured by ASTM C 1688: Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete be specified for quality assurance and acceptance

## 8.2 Permeability Test

For measuring the permeability of pervious concrete, the falling head method is used. A 300 mm water heads were adopted for measuring the permeability. For measuring the permeability of pervious concrete cylinder of size 150 x 150 mm are cast. Cylinders are cast in the PVC pipe. In this study permeability of pervious concrete is measured at the end of the 28 days. Permeability of pervious concrete iscalculated using the equation of falling head method.

The permeability of pervious concrete was determined using a falling head permeability set up Figure 8. Water was allowed to flow through the sample, through a connected standpipe which provides the water head. Before starting the flow measurement, the samples were wrapped with polythene insikle the cylinder. Then the test started by allowing water to flow through the sample until the water in the standpipe reached a given lower level A constant time of 5seconds was taken for the water to fall from one head to another in the standpipe. The standpipe was refilled and the test was repeated when water reached a lower.

the concrete permeability limitation is not a critical design criterion. Consider a passive pervious concrete pavement system overlying a well-draining soil. Designers should ensure that permeability is sufficient to accommodate all rain falling on the surface of the pervious concrete. For example, with a permeability of 140 L/m³/min, a rainfall in excess of 0.24 cm's would be required before permeability becomes a limiting factor. The permeability of pervious concretes is not a practical controlling factor in design. However, the flow rate through the sub grade may be more restrictive.

## 9. Result and Conclusion

## 9.1 Results

Mix 1 -- Mix proportion of M30 grade Pervious Concrete for 10mm Coarse Aggregate:
Cement – 8.51 kg Coarse Aggregate -- 45.86kg Water – 4.40kg

Mix 2 -- Mix proportion of M30 grade Pervious Concrete for 20mm Coarse Aggregate:
Cement – 12.16kg Coarse Aggregate – 45.86kg Wate – 3.88kg

For Compression test on Pervious concrete block

Mix –1 W/C Ratio 0.40

Compressive strength on $7^{th}$ day of curing 7.2 N/mm2

Compressive strength on $28^{th}$ day of curing 19.14 N/mm2

Mix –2 W/C Ratio 0.35

Compressive strength on $7^{th}$ day of curing 9.4 N/mm2

Compressive strength on $28^{th}$ day of curing 20.67 N/mm2

Permeability test results
Mix 1 – Permeability coefficient(k) = 5.84
Mix 2 – Permeability coefficient(k) = 6.50

## 9.2 Conclusions

- Compressive strength and permeability are inversely proportional to each other. As the porosity increases, compressive strength
- decreases.
- We also concluded that reduction in aggregate size, decreases the porosity, because of its inter-relation with no fine aggregate
- property.
- Compressive strength and void ratio are inversely proportional as the void ratio increases, compressive strength decreases.
- Also, the reduction of aggregate size affects the compressive strength of pervious concrete. More strength is achieved as the
- aggregate size decreases.
- Pervious concrete pavement is unsuitable for heavy-duty roads.
- Currently, pervious concrete gives low compressive strength. Therefore, it is used for parking lots, sidewalks, and on highway
- shoulders and median.
- We concluded that aggregate of size 10-12.5 mm gives the good compressive strength and optimum porosity in pervious concrete.

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