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AN EXPERIMENTAL STUDY ON PERVIOUS CONCRETE

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Abstract: Pavement construction leads to concretization due to urbanization which caused the conversion of natural pervious ground into impervious layer. The impervious layers have reduced the groundwater recharge and increased the frequency of flash and floods along with urban heat island (UHI effects). One of the engineered ways to reduce the effect of impervious layers is by adopting pervious concrete pavement suitability.

Pervious Concrete pavement helps to increase the groundwater recharge, reduce the UHI effect, and the frequency of flash and floods. However, the urbanization and implementation of pervious concrete pavement in Indian are very minimal owing to lack of expertise and experience. Pervious Concrete is a special type of concrete that does not have fine aggregates like conventional concrete pavement. It consists of cement, coarse aggregates, water and admixtures if required. As there are no fine aggregates in the concrete matrix, the void content is more which introduces porosity, hence also called as permeable concrete and porous concrete.

Due to the introduction of voids, the compressive strength of pervious concrete is less. A lot of research work is going on to increase the compressive strength of concrete. Hence due to having low strength as compared to conventional concrete, it's usage is limited even though having a lot of advantages.

For now, it's usage is limited to parking spots and lightweight traffic roads. If the properties are improved, we can use pervious concrete for medium and heavy traffic roads. The main aim of our study is to assess the suitability of the perforated road pavement system advantageously.

***Index Terms* - Groundwater Recharge, Permeable Concrete, Porous Concrete, (UHI effects), Compressive Strength.**

I. INTRODUCTION

Pervious Concrete enhances porosity in concrete and has found to be a reliable stormwater management tool. By the 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 stormwater to pass through the pavement, into the underlying soils. In other words, pervious concrete helps to protect the surface of the road and is eco-friendly. Also, the constituents of pervious concrete are the same as that of conventional concrete, 15 to 30% of its volume consists of interconnected voids which allows water to pass through it. Europeans have also used pervious concrete for paving. Stories have passed down through the years which tell us that soldiers didn't mind walking on pervious roads during World War II because their feet would remain dry. After World War II, Pervious concrete was brought to the United States. Also, pervious concrete is light in weight, (1600 - 2000 kg/m3), due to presence of voids. It also results in a very high permeable concrete that drains water through it quickly. Pervious concrete has a ample range of applications, even though its prime use is in pavements which are in residential roads, low water crossings, low volume pavements, sidewalks and pathways, parking areas, alleys, and driveways, slope stabilization, sub-base for conventional concrete pavements etc., Private companies use it to free up valuable real estate for development, other than using expensive retention ponds to save water. Pervious concrete is also a unique and effective means to face important environmental issues and sustainable growth. When it rains, pervious concrete automatically acts as a drainage system, thereby putting water back to the groundwater table. Pervious concrete has a greater advantage in many applications. But still, it has its own limitations which must be put in effective consideration when planning its use. Structurally when higher permeability and low strength are required, then pervious concrete can be used.

1.1 Aim

To increase the compressive strength of Pervious Concrete and to find out the Mix-Ratios, strength, and porous properties of a Mix which gives optimum compressive strength and porosity.

1.2 Research Objectives

- **To minimize the runoff application of impervious pavements.**
- **To determine the effect of material proportion on the engineering properties of the pervious concrete.**
- **Investigate the performance characteristics of the pervious concrete such as porosity, compressive strength, and infiltration rate.**

II. LITERATURE REVIEW

2.1 Effect of Fly Ash and Metakaolin On Pervious Concrete Properties- Nikhil Saboo, Shekhar Shivhare, Krishna Kumar Kori, Anush K. Chandrappa (2019)

The literature is reviewed on effect of fly ash and metakaolin on pervious concrete properties. In this study, supplementary cementitious materials are the byproducts of productions which processes all from industries, several environment concerns and it is imperative to utilize for partial replacement. The research was done by the author to determine the porosity, density, compressive strength, and permeability by doing various tests. The replacement of fly ash was found to be between 5 and 15%. And as result, cement can be partial replaced by SCMs, which not only increases the workability but as well aid in achieving higher strength with lesser cement contents rendering optimal solution for usage of industrial by-products. Different method were performed like specimen preparation and curing, determination of density and porosity, permeability and compressive strength. with increase in porosity, density reduced and permeability increase.

The following are result researched by the author to explore the discussion to find the improvements by replacing with fly ash and metakaolin.

- To investigate the effect of fly ash, metakaolin, and curing condition on the properties of pervious concrete.
- Addition of 2% of metakaolin reduced the porosity and increased the density.
- The rate of change in properties was higher between replacement levels of 5 and 15% for fly ash.
- Increasing cement content to produce higher strength pervious concrete, cement can be partial replaced by SCMs, which not only increases the workability.
- Achieving higher strength with lesser cement contents rendering optimal solution for usage of industrial by-products.

2.2 Experimental Analysis on High Strength Pervious Concrete-Ch. Hari Sai Priyanka1(2017)

The author researched on experimental analysis on high strength pervious concrete. As use of pervious concrete has increased significantly in the last several years, perhaps largely because it is considered an environmentally friendly, sustainable product.

This study describes the work done on determining the strength characteristics of pervious concrete, the further all the analysis was done by doing the strength tests and and comparing the characteristics of the high strength pervious concrete and conventional concrete samples. The objective was to determine the compressive strength test, split tensile strength test to determine its properties. Cubes were casted of size 150 x 150 x 150 mm for the tests. This paper also evaluates the suitability of pervious concrete for other applications such as buildings, bridges etc. the compressive strength was conducted on the compression testing machine. The tensile was determined for concrete cylinder of size 150mm dia and 300mm height.

Following conclusion are:

- The low paste content mixtures are found to have approximately 25% lower compressive energy absorption as compared to high paste content mixtures of the same strength.
- Water absorption values for high strength pervious concrete is higher than the normal concrete.
- The strength results of normal concrete, pervious concrete and high strength pervious concrete and normal concrete is compared.
- The strength of high strength pervious concrete is lesser than normal concrete, but water absorption is more for high strength pervious concrete.

2.3 Use Of Pervious Concrete In Road Pavement-Suraj F. Valvi, Anil P. Thoke, Abhijit A. Gawande, Manoj B. Godse, Prof.D.D Shelke(2017)

In this study the authors researched on the use of pervious concrete in road pavement. As pervious concrete contains little or no fine aggregates such as sand, it is sometimes referred to as “no-fines” concrete. In this study the main aim was to determine the compressive strength and permeability of the pervious concrete with casting cubes of size 150mm x 150mm x 150mm for 28 days of curing. As the durability and permeability are the important properties of pervious concrete. Pervious concrete is also used to pass through there by Reducing the Runoff from a site and Recharging Ground Water Levels. Where 43 grade of cement was used. As per IS-269-1989, fineness of cement was determined. For consistency, IS 4031 part 2 was used. Many other IS codes were used in this study to improvise work to check the results on compressive strength and permeability.

Based on the conclusions authors analyzed the study mentioned below:

- To produce high compressive strength, the smaller size of coarse aggregates should be taken.
- Pervious concrete is more suitable in rural areas as per rural requirements. Mainly to reduce the storm water runoff, to increase the ground water level.
- To get high compressive strength of pervious concrete not always depends upon the higher strength and workability.
- The use of admixtures like fly ash and silica fume, the strength of pervious concrete increases.
- OPC 53 grade cement has highest compressive strength (12.71 N/mm2) compared to any other mix proportion.
- Pervious concrete obtained by removing the fine aggregate wholly (0%) and partially as 10% and 20% replacing the coarse aggregate get higher strength.

2.4 Experimental Study on Implementation of Pervious Concrete in Pavements- Nishith M N, Gururaj Acharya, Shaik Kabeer Ahmed(2016)

The author research on the Study Experimental Study on Implementation of Pervious Concrete in Pavements. This study is based to obtain the compressive strength, flexural strength and abrasion value and porosity value of pervious concrete. The main objective of this study is to provide and improve the strength of pervious concrete. To determine the goals that needs to achieve for porosity, permeability, and strength in porous concrete mixes. The cubes for determining the tests were casted at the age of 7, 14 and 28 days of curing.

- At the age of 7, 14, 28 days, the minimum compressive strength id obtained at 0% fine aggregates.

- At 10% of mix provide high strength thus compressive strength is maximum.
- As curing period increase the compressive strength was also increased.
- The porous voids will be crested on not using more fine aggregates.
- Porosity is max at 10% fine aggregate usage with super plasticizer, and minimum at 0% fine aggregate without using super plasticizer.

III. RESEARCH MATERIALS AND METHODOLOGY

3.1 Materials for Trial Mix

3.1.1 Cement- Ordinary Portland Cement, grade 43 confirming to IS 8112: 1989 is used in this project.

3.1.2 Aggregates- Locally available crushed stone coarse aggregates of nominal size 10mm and 20mm are used for the trial. Following table shows the physical properties of coarse aggregates.

Table 1 Physical properties of coarse aggregate

Size	Specific Gravity	Water Absorption %	Flakiness Index %	Elongation Index %	Crushing Value%	Impact Value %
10. mm	2.92	1.10	9.48	14.28	11.76	5.76
20 mm	2.92	1.01	8.21	10.49	12.34	5.40

3.1.3- Admixture- In our project we have used naphthalene-based superplasticizer which are also known as high range water reducers are synthetic water-soluble organic compounds that reduce the amount of water required to achieve certain stability of concrete, reduce water-cement ratio, reduce water content and increase slump. The use of superplasticizers reduces the quantity of mixing water required to produce a concrete mix of given consistency by 25 to 30%. Superplasticizers dosage is usually 0.5-3% of the weight of cement.

3.1.4 Water- For casting and curing water used is free from organic matter and portable water is used as per clause no. 5.4 of IS 456-2000.

3.2 Methodology

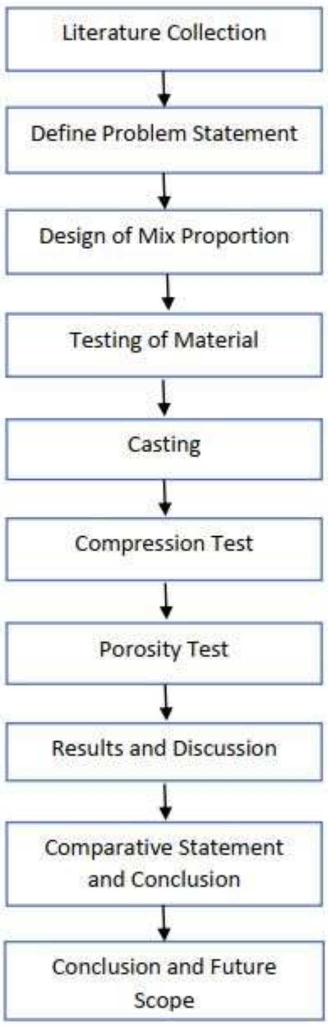

Figure 1 Methodology

3.3 Mix Design

3.3.1 Mix proportion of M30 grade Pervious Concrete for 10mm Coarse Aggregate:

- Type of cement: OPC 43(Ordinary Portland Cement) grade 43, confirming to IS 8112:1989.
- Specific gravity of cement: 3.15
- Maximum nominal size of aggregate: 10mm
- Specific gravity of aggregates: 2.92
- Water absorption of coarse aggregate: 1.10
- Type of aggregate: Crushed angular aggregate
- Free moisture of coarse aggregate: Nil
- Exposure condition: Severe

Step 1: Determining the Target Strength for Mix-Proportioning
$f'_{ck} = f_{ck} + 1.65 \times s$
$= 30 + 1.65 \times 5 = 38.25$ N/mm^2(s=5, as per the table 1 from IS 456)
Step 2: Water-Cement Ratio
Maximum water-cement ratio = 0.45 (as per table.5 of IS 456)
Adopt Water-Cement ratio = 0.4
Step 3: Selection of Water Content
Maximum water content for 10 mm aggregate = 208 Kg/m^3 (for 25 to 50 slump)
Here, we are using the superplasticizer as a admixture, so we can reduce water content by 23%.
Water content = 208-(23/100)× 208 kg/m^3
∴ Water content = 160.14 kg/m^3
Step 4: Calculation of Cement Content
Water-Cement Ratio = 0.4
Water content from Step 3 i.e. 160.14 liters
Cement Content = Water content / "w-c ratio" = (160.14/0.40) = 400.35 kgs
From Table 5 of IS 456,
Minimum cement Content for moderate exposure condition = 360 kg/m3
400.35 kg/m3 > 360 kg/m3, hence, OK.
Step 5: Proportion of Volume of Coarse Aggregate and Fine Aggregate Content
As we are calculating mix-proportions for pervious concrete i.e., no fines concrete. We will take the proportion of volume of fine aggregate =0 and coarse aggregates=1.
Step 6: Estimation of Concrete Mix Calculations
The mix calculations per unit volume of concrete shall be as follows:
a) Volume of concrete = 1 m^3
b) Volume of cement = (Mass of cement / Specific gravity of cement) x (1/1000) = (400.35/3.15) x (1/1000) = 0.127 m^3
c) Volume of water = (Mass of water / Specific gravity of water) x (1/1000) = (160.16/1) x (1/1000) = 0.16016 m^3
d) Total Volume of Aggregates = 1- (b+c) =1- (0.127+0.16016) = 0.713 m^3
Note:

- *There is no Indian Standard code for calculating the mix proportions for pervious concrete.*
- *Since, we are not using fine aggregates, our foremost aim of introducing the porosity is achieved.*
- *So, to compensate the amount of fine aggregates we are assuming the porosity after the casting of cube will be 20%*

∴ Total Volume of Aggregates = (0.713-0.2) m^3 =0.512 m^3

1. Mass of coarse aggregates = Total volume of aggregates X Volume of Coarse Aggregate X Specific Gravity of Coarse Aggregate X 1000 = 0.512 X 1 × 2.92 X 1000 = 1495.04 kg/m^3
2. Mass of fine aggregates = Total volume of aggregates X Volume of Fine Aggregate X Specific Gravity of Coarse Aggregate X 1000 = 0.512 X 0 = 0 kg/m^3

Step7: Concrete Mix Proportions
Cement = 400.35 kg/m^3
Water = 160.16 kg/m^3
Coarse aggregate = 1495.04 kg/m^3
Water-cement ratio = 0.40
∴ Mix Proportions = Cement: Coarse Aggregate = 1:3.73
For Mix 1 we have made concrete equivalent to volume of 9 standard cubes of (15 × 15 × 15) cms.
Hence, total proportion required for casting Mix 1 are as follows:
Volume of 1 cube = 3.375×10^{-3} m^3
Volume of 9 cube = 0.030375 m^3
Cement = 0.030375 × 400.35=12.16 kg
Coarse aggregate = 0.030375 × 1495.04 = 45.41 kg
Water = 0.030375 × 160.15 = 4.86 kg
Step-8: Moisture Correction:
Moisture Content = 1.01 %
Corrected Value of Coarse Aggregate = 45.41 + 0.4541 = 45.8641kg
Corrected Value of Water Content = 4.86 – 0.4541 = 4.4059 kg
Final quantity of materials required for casting 9 cubes of Mix 1 are

Cement	Coarse aggregate	Water
12.16 kg	45.68 kg	4.40 kg

For the other three trials we have used the same process for Mix Design

3.3.2 Mix proportion of M30 grade pervious concrete, replacing the cement by 30% of Fly Ash, for 10mm Coarse Aggregate:

Flyash	Cement	Coarse aggregate	Water
3.65 kg	8.51 kg	45.86 kg	4.40 kg

3.3.3 Mix proportion of M30 grade Pervious Concrete for 20mm Coarse Aggregate:

Cement	Coarse aggregate	Water
12.16 kg	45.86 kg	4.40 kg

3.3.4 Mix Proportion of M30 grade Pervious Concrete by using Coarse Aggregates in a ratio (30:70) of (10mm:20mm) Aggregates:

Cement	Coarse Aggregate		Water
	20 mm	10 mm	
12.43 kg	33.04 kg	14.16 g	3.88 kg

IV. TESTING

4.1 Compression 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.

4.2 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 is calculated using the equation of falling head method.

V. RESULTS AND DISCUSSION

5.1 Compressive Strength Results

Table 2 Comparison of Compressive Strength for different Mix

Mix	Water-Cement Ratio	Day of Curing	
		7 day	28 day
Mix-1	0.40	7.03 N/mm^2	19.32 N/mm^2
Mix-2	0.40	7.2 N/mm^2	19.14 N/mm^2
Mix-3	0.35	9.4 N/mm^2	20.67 N/mm^2
Mix-4	0.35	11.62 N/mm^2	23.04 N/mm^2

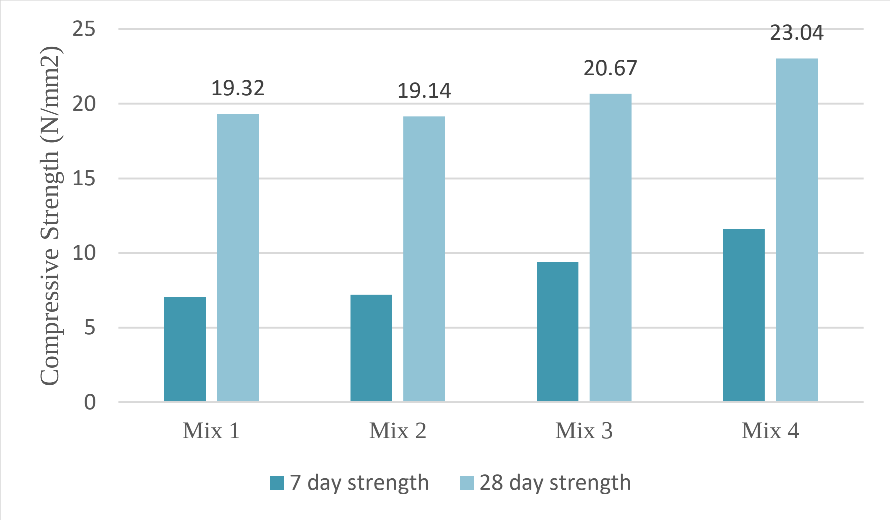

Figure 2 Comparison of Compressive Strength for different Mix

5.2 Permeability Test Results

Table 3 Comparison of Permeability Coefficient (k) for different Mix

Mix	Permeability Coefficient k mm/sec
Mix-1	6.29
Mix-2	5.84
Mix-3	6.50
Mix-4	5.58

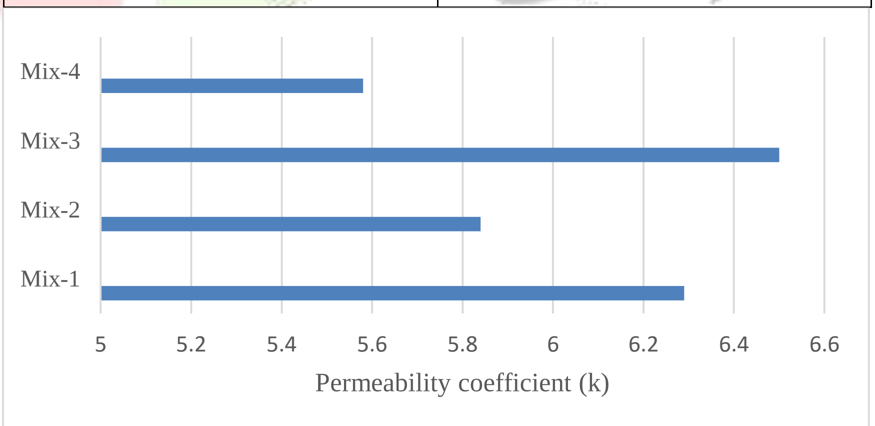

Fig.3 Comparison of Permeability Coefficient (k) for different Mix

V. Scope of Study

If the compressive strength of pervious concrete is increased successfully, then it can be used to construct pervious concrete pavement instead of a rigid pavement of conventional concrete, which will be very beneficial. It can be used to avoid the accumulation of water over road pavements, which leads to traffic delay so it helps to reduce traffic density during the rainy season. Pervious concrete, if used on pavement will help to reduce the quantity of runoff water, enhance skid resistance, and can further be used as a tool for rainwater harvesting to increase groundwater level.

VI. Conclusion

- Compressive strength of pervious concrete depends upon the porosity of concrete, binder material (a type of cement), showed huge influence on the strength of pervious concrete.
- Using up to 30% Fly ash as a cement replacement has the same effect as using pure concrete for making pervious concrete.
- Replacement of Fly ash with cement reduces the energy-intensive manufacturing of Portland cement. This reduction in energy leads to fewer emissions of greenhouse gases.
- Following terms plays a crucial role in the strength of pervious concrete:
  a) Size of coarse aggregate
  b) Water-cement ratio
  c) Aggregate to cement ratio
- The void ratio and unit weight are two important parameters of pervious concrete in the context of mix design.
- The porosity is directly proportional to the void ratio. As the void ratio increases porosity also increases.
- 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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