



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Special Issue 3, May 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

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An Experimental Study on Behaviour of Pervious Concrete

Mrs. R.S. Gautam

Assistant Professor, Dept. of CIVIL, Sinhgad Institute of Technology & Science College, SITS, Pune, India

B Pranav, N Yashasvi, P Mansi, P Prasad, R Ravindra

UG Student [SITS], Dept. of CIVIL, Sinhgad Institute of Technology & Science College, SITS, Pune, India

ABSTRACT: Pervious concrete, characterized by its high porosity and interconnected void structure, offers promising solutions for sustainable urban development, particularly in mitigating stormwater runoff and improving groundwater recharge. This study presents an experimental investigation into the mechanical behaviour and hydraulic performance of pervious concrete under different loading conditions.

The research focuses on evaluating the compressive strength, permeability, and durability properties of pervious concrete mixtures designed with varying proportions of aggregate gradations, cement content, and admixtures. Laboratory experiments are conducted to assess the effect of compaction methods on the porosity and permeability of pervious concrete specimens.

The experimental results provide insights into the behaviour of pervious concrete under loading scenarios, aiding in the optimization of mix designs and construction practices for durable and resilient pervious concrete pavements. The findings contribute to the advancement of sustainable infrastructure development and the promotion of pervious concrete as a viable solution for urban stormwater management.

KEYWORDS: Pervious concrete, Porous pavement, Sustainable urban development, Stormwater management Groundwater recharge, Compressive strength, Permeability, Aggregate gradation, Cement content, Admixtures, Compaction methods, Mechanical behaviour, Hydraulic performance, Curing conditions, Infiltration capacity, Runoff reduction, Environmental sustainability, Urban drainage.

I.INTRODUCTION

Pervious concrete has emerged as a sustainable solution for addressing challenges related to urban stormwater management and groundwater recharge. Characterized by its high porosity and interconnected void structure, pervious concrete offers unique properties that enable the infiltration of rainwater into the ground, reducing surface runoff and alleviating the burden on conventional drainage systems. In recent years, the adoption of pervious concrete pavements and porous pavement systems has gained momentum worldwide, driven by increasing concerns over urban flooding, water pollution, and the degradation of natural water resources.

The significance of pervious concrete lies in its ability to mitigate the adverse impacts of urbanization on the hydrological cycle by promoting infiltration, filtration, and groundwater replenishment. Unlike traditional impervious surfaces, such as asphalt and concrete, pervious concrete allows rainwater to percolate through the pavement surface and into the underlying soil layers, where it is naturally filtered and stored. This not only reduces the volume and velocity of stormwater runoff but also helps to recharge aquifers and maintain baseflow in rivers and streams.

Despite its potential benefits, the performance of pervious concrete is influenced by various factors, including material properties, mixture design, construction practices, and environmental conditions. Therefore, a comprehensive understanding of the behaviour of pervious concrete under different loading conditions is essential for optimizing its design, improving its durability, and enhancing its effectiveness in stormwater management applications.

This study aims to investigate the mechanical behaviour and hydraulic performance of pervious concrete through an experimental approach. The research focuses on evaluating key properties such as compressive strength, permeability, and durability under varying loading scenarios, including static and dynamic loading conditions. Additionally, the study examines the influence of material composition, compaction methods, moisture content, and curing conditions on the structural response and hydraulic conductivity of pervious concrete pavements.

By elucidating the behaviour of pervious concrete under real-world conditions, this research contributes to the development of sustainable infrastructure solutions that mitigate urban flooding, protect water quality, and promote resilient communities in the face of climate change and urbanization pressures.

II. LITERATURE SURVEY

Priya Jagtap, Oshin Victor, Rakesh Verma (Volume-9, Issue-9; Sep, 2022)

This research looked at “Experimental study of pervious concrete”. In the construction sector, concrete is a widely utilized building material. Pervious concrete is a high-porosity concrete used for concrete flatwork applications that allows water from precipitation and other sources to pass directly through, decreasing runoff and permitting groundwater recharge. The main objective is to determine the strength of pervious concrete by introducing admixture. The results of an experimental inquiry on pervious concrete are given and analysed in this overview. The amount of general-purpose water in pervious concrete has been minimized by utilizing super plasticizer to enhance the strength of pervious concrete and to develop inexpensive pervious concrete. The mix design for pervious concrete was prepared, concrete specimen samples were manufactured, and tests were performed on pervious concrete specimens to determine the strength of pervious concrete and compare it to conventional concrete.

Bhavin Shah, Apurva Patel (Volume-8, Issue-3, Mar 2021)

This article looked at a “Experimental Study on Pervious Concrete” This study is concluded based on the results from this experimental research on pervious concrete; the following conclusions have been drawn: Compressive strength of concrete mainly depends on porosity of concrete, age of binding material and type of admixture

Mukund Chougale, Saahil Dehankar, Atharva Karmore, (Volume-8, Issue-5, May 2020)

This study looked at the “AN EXPERIMENTAL STUDY ON PERVIOUS CONCRETE” 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.

Sujeet Kumar Saha and Shaik Niyazuddin Guntakal and Dr. S. Senthil Selvan (Volume-13, Number 2018)

He conducted research on “Experimental Study on behavior of Pervious Concrete in Strength and Permeability by Changing Different Parameters” 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 (auramix 400 & conplast sp 430) 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. However porosity was the most consider shrewd potency of porous concrete in calculating efficiency of porous concrete which was affected by addition of certain percentage of fibre. The result of this investigation provided useful information about effectiveness of w/c ratio, super plasticizer, fibre and compaction to achieve the optimal strength drain ability balance, adequate for the different urban uses.

A.Ayyappan, D.Dinesh kumar, G.Sangeetha, S.Roshini, M.Sivasangari (Volume 3, March 2018)

This study looked at the “Pervious concrete is a special type of concrete with a high porosity used for concrete flatwork applications that allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing groundwater recharge. It is also called as porous concrete, permeable concrete, no fines concrete and porous pavement. Pervious concrete is made using large aggregates with little to no fine aggregates. The concrete paste then coats the aggregates and allows water to pass through the concrete slab. This type of concrete having a high void content of about 30%, is becoming popular nowadays due to its potential to reduce the runoff to the drainage systems which can provide a water flow rate around 0.34 cm/second. It is an important application for sustainable construction and is one of many low impact development techniques used by builders to protect water quality. Pervious concrete also find its effective application in low loading intensity parking pavements, footpaths,

walkways and highways. The pervious concrete is considered as an Environmental Protection Agency (EPA) for providing pollution control, storm management and suitable development. It is a composite material produced by mixing cement, inert matrix of sand and gravel or crushed stone. This concrete has a light colour and open-cell structure because of which they do not absorb heat from the sun; they also do not radiate the heat back into the atmosphere, which reduces heating in the environment. Pervious concrete has low installation costs. In addition, it filters the storm water thus reducing the number of pollutants entering the rivers and ponds. Pervious concrete also improves the growth of trees. In the present study the behaviour of pervious concrete has been studied experimentally. The water-cement ratio was kept at different ratios 0.35, 0.40, 0.45. Different properties of pervious concrete e.g. workability, compressive strength, split tensile strength, flexural strength test at 7, 14 & 28 days have been studied experimentally. The mix proportions with aggregates size (4.75 mm to 10 mm) gives higher strength when compared to mixes with aggregates size (10 mm to 20 mm) and (4.75 mm to 20 mm) respectively.

III. PROPOSED METHODOLOGY AND DISCUSSION

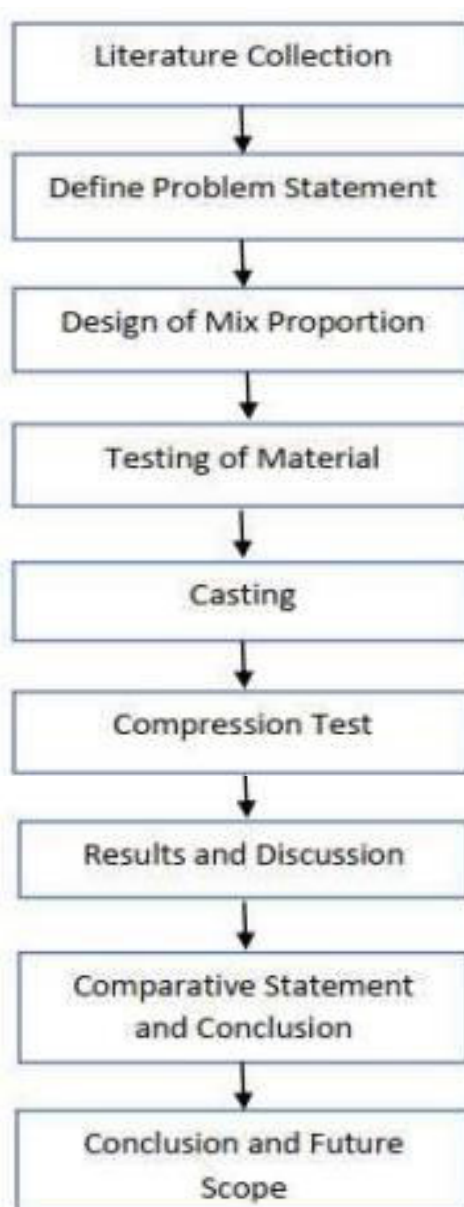


Fig.no.1. Flow chart

STIPULATIONS FOR PROPORTIONING

- a) Grade designation : M20
- b) Type of cement : OPC 53 grade conforming to IS 269
- c) Type of mineral admixture : GGBB conforming to IS 16714
- d) Maximum nominal size of aggregate : 6mm And 10mm
- e) Type of aggregate : Crushed angular aggregate

TEST DATA FOR MATERIALS

- a) Cement used : OPC 53 grade conforming to IS 269
- b) Specific gravity of cement : 3.15
- c) Fly ash : Conforming to IS 16714
- d) Specific gravity of fly ash : 2.88
- e) Specific gravity of Coarse aggregate
10mm (at SSD condition) : 2.90
- f) Water absorption 1) Coarse aggregate 10mm : 1.21
- g) The aggregates are considered dry free surface moisture is zero or nil.

MIX DESIGN

$$f'_{ck} = f_{ck} + 1.65 S$$

whichever is higher.

Where, f'_{ck} = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days,

S = standard deviation

From IRC:44-2017 Table 18, standard deviation, $S = 4\text{N/mm}^2$.

Therefore, target strength using both equations, that is

$$f'_{ck} = f_{ck} + 1.65 S$$

$$f'_{ck} = 20 + 1.65 \times 4 = 26.6 \text{ N/mm}^2$$

Therefore, target strength will be 26.6 N/mm^2 .

Selection Of Water-Cement Ratio

From IRC:44-2017 Clause 6.3.3, The water-cementitious material ratio (w/cm) is an important consideration for obtaining desired strength and void structure in pervious concrete. A high w/cm 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/cm 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. Experience has shown that w/cm in the range of 0.26 to 0.45 will provide the best aggregate coating and paste stability

Hence, we select the W/C ratio = 0.30

SELECTION OF WATER CONTENT

As per previous Trials Data Adopted water content will be – 90kg

CALCULATION OF CEMENTATIOUS CONTENT

Water-cement ratio = 0.30

$$\begin{aligned} \text{Cementatious content} &= 90/0.3 \\ &= 300.0 \text{ kg/m}^3 \end{aligned}$$

Cement @ 53.33 percent of total cementitious material content = $300 \times 53.33\text{percent} = 160 \text{ kg/m}^3$

To proportion a mix containing GGBS the following steps are suggested:

GGBS @ 46.67 percent of total cementitious material content = $300 \times 46.67\text{percent} = 140 \text{ kg/m}^3$

MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows:

1. Total Volume = 1 m^3
2. Volume of entrapped air in wet concrete = 0.4 m^3
3. Volume of cement

$$\begin{aligned} &= \frac{\text{Mass of Cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000} \\ &= \frac{160}{3.15} \times \frac{1}{1000} \\ &= 0.0507 \text{ kg/m}^3 \end{aligned}$$

4. Volume of GGBS

$$\begin{aligned} &= \frac{\text{Mass of GGBS}}{\text{Specific gravity of GGBS}} \times \frac{1}{1000} \\ &= \frac{140}{2.88} \times \frac{1}{1000} \\ &= 0.0486 \text{ m}^3 \end{aligned}$$



5. Volume of water

$$= \frac{\text{Mass of Water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$$

$$= \frac{90}{1} \times \frac{1}{1000} = 0.09 \text{ m}^3$$

6. Volume of all in aggregate

$$\begin{aligned} &= [(1-2)-(3+4+5)] \\ &= [(1-0.4)-(0.0507+0.0486+0.09)] \\ &= 0.4107 \text{ m}^3 \end{aligned}$$

7. Mass of coarse aggregate

$$\begin{aligned} &= F \times \text{percentage of 20 mm aggregates} \times \text{Specific gravity of coarse aggregate 10 mm} \times 1000 \\ &= 0.4107 \times 1 \times 2.90 \times 1000 \\ &= 1193 \text{ kg/m}^3 \end{aligned}$$

MIX PROPORTIONS

Cement	= 160kg/m³
GGBS	= 140 kg/m³
Water	= 90 kg/m³
Coarse Aggregate 10 mm	= 1193 kg/m³

Mix proportion 1 of M20 grade pervious concrete, replacing the cement by 46.67% of GGBS, for 6 mm Coarse Aggregate:

Cement	GGBS	Coarse aggregate 6 mm	Water
5.76 Kg	5.04 Kg	42.51 Kg	3.674 Kg

Mix proportion 2 of M20 grade pervious concrete, replacing the cement by 46.67% of GGBS, for 10 mm Coarse Aggregate:

Cement	GGBS	Coarse aggregate 10 mm	Water
5.76 Kg	5.04 Kg	42.51 Kg	3.674 Kg



Compare Above Mix Design Proportion With 100% Cement Without Using GGBS.

Mix proportion 1 of M20 grade pervious concrete, 100% cement and 6 mm Coarse Aggregate:

Cement	Coarse aggregate 6 mm	Water
10.8 Kg	42.51 Kg	3.674 Kg

Mix proportion 1 of M20 grade pervious concrete, 100% cement and 10 mm Coarse Aggregate:

Cement	Coarse aggregate 10 mm	Water
10.8 Kg	42.51 Kg	3.674 Kg

CASTING:-

The concrete mix is prepared according to the design specifications and poured into molds to form test specimens, typically 150 X 150 X 150 mm cubical in shape. The concrete is then compacted by Tampping Rod and ensure a uniform distribution of materials.

CURING:-

Curing is a process where the concrete is kept moist to facilitate the chemical reaction between water and cement, known as hydration. This process is crucial for the development of strength. The specimens are usually cured for specified periods, commonly 7 or 28 days.

TESTING:-

After curing, the specimens are tested in a compression testing machine. The machine applies a gradually increasing load on the specimen until it fails. The maximum load carried by the specimen before failure is recorded.

Compression Test :-A compression test is used to determine the characteristics of a concrete block. It gives the compressive strength of the concrete block, which is the ability of the material or structure to bear loads on its surface without cracking or bending. The value of the compression test depends on factors such as the water-cement ratio, cement strength, quality of concrete materials, and quality control during the production of concrete. The compression test is conducted after mixing, placing, and curing the concrete block, typically after 7 or 28 days of curing. For accurate readings of compressive strength, the blocks should be completely dry. To obtain a more precise value of compressive strength, it is recommended to take the average value of three blocks, which helps to eliminate errors caused by human or machine factors.



Fig No.2 Casting



Fig No.3 Curing



Fig No.4 Testing

EFFICIENT DISCUSSION

The experimental results provide valuable insights into the behavior and performance of pervious concrete under various loading conditions. The discussion section interprets the findings and discusses their implications in the context of sustainable urban development and stormwater management. Here are some key points to consider:

1. **Mechanical Properties:** The compressive strength tests reveal the influence of aggregate gradation, cement content, and compaction methods on the structural integrity of pervious concrete. The discussion highlights the importance of balancing strength requirements with permeability considerations in pavement design.
2. **Structural Response:** Static and dynamic loading tests assess the deformation behavior and load-bearing capacity of pervious concrete under realistic traffic conditions. The discussion evaluates the suitability of pervious concrete for different pavement applications and traffic intensities.
3. **Stormwater Management:** Hydrological evaluations quantify the ability of pervious concrete to attenuate peak flows, capture pollutants, and promote groundwater recharge. The discussion emphasizes the role of pervious concrete in mitigating urban flooding and enhancing water quality in urban environments.
4. **Sustainability Considerations:** The study discusses the environmental benefits and lifecycle implications of pervious concrete compared to conventional pavement materials. Considerations such as embodied energy, carbon footprint, and long-term maintenance are addressed to support informed decision-making in sustainable infrastructure development.

IV. RESULT

Result For replacing the cement by 46.67% of GGBS, for 6mm & 10 mm Coarse Aggregate:

MIX	DAY OF CURING	
	7 Day Strength	28 Day Strength
MIX 1 6 mm	6.6 N/mm ²	13.33 N/mm ²
MIX 2 10 mm	10.6 N/mm ²	20.66 N/mm ²



Result For Using 100% cement , for 6mm & 10 mm Coarse Aggregate (Conventional Pervious Concrete)

MIX	DAY OF CURING	
	7 Day Strength	28 Day Strength
MIX 1 6 mm	5.7 N/mm ²	11.11 N/mm ²
MIX 2 10 mm	8.8 N/mm ²	18.22 N/mm ²

V.CONCLUSION

In this Paper, a Detailed study on Pervious Concrete and Enhancing Compression Strength and durability using GGBS (Ground Granulated Blast-furnace Slag) Replacing Cement upto 50%, This helps to increase Compression Strength, More than 100% cement using Conventional Concrete.

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