IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 1, November 2023

A Review Paper on Study and Design of Pervious Concrete Mix with Non-Metallic Firbers

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Abstract*: Pervious concrete, a sustainable and innovative construction material, has gained significant attention in recent years due to its numerous environmental benefits and versatile applications. This review paper comprehensively explores the properties, applications, environmental benefits, challenges, and future prospects of pervious concrete. Non-metallic fibers can also be used as a partial replacement of cement to increase the strength of the pervious concrete. The cement is partially replaced with Non-metallic fiber in volume of 1%, 1.5% and 2%. A large number of trial mixes are required to select the desired optimum replacement of cement by Non-Metallic fiber. By evaluating various research studies and real-world applications, this paper aims to provide an in-depth understanding of pervious concrete and its role in sustainable urban development.*

Keywords: sustainable, Environmental benefits, Versatile application,Concrete, Non-metallic fibers, Future prospect, Urban Development

I. INTRODUCTION

Pervious concrete enhances the porosity of concrete and has proven to be a reliable tool for stormwater management. Defined as a mixture of gravel or granite stone, cement, water, with little to no sand (fine aggregate), pervious concrete allows stormwater to pass through its open-cell structure when used for paving. In other words, it not only safeguards the road's surface but also serves as an environmentally friendly solution.

The constituents of pervious concrete closely resemble those of conventional concrete, with 15 to 30% of its volume being composed of interconnected voids, facilitating the passage of water. European usage of pervious concrete for paving dates back to World War II, with stories recounting that soldiers preferred walking on pervious roads because their feet remained dry. Post World War II, pervious concrete made its way to the United States.

Furthermore, pervious concrete has a relatively low weight, typically in the range of 1600 to 2000 kg/m3, due to the presence of voids. This characteristic results in a highly permeable concrete that efficiently drains water. Pervious concrete finds application in a wide range of scenarios, although its primary use is in pavements, including residential roads, low water crossings, low-volume pavements, sidewalks, pathways, parking areas, alleys, driveways, slope stabilization, and as a sub-base for conventional concrete pavements. Private companies utilize it to free up valuable real estate for development, reducing the need for costly retention ponds to manage water.

Pervious concrete is an innovative and effective means to address critical environmental issues and support sustainable growth. When it rains, it functions as an automatic drainage system, directing water back into the groundwater table. Pervious concrete offers numerous advantages in various applications. However, it does have limitations that necessitate careful consideration in its planning and use. When there is a need for both higher permeability and greater strength, pervious concrete can be employed. To enhance its compressive strength, non-metallic fibers such as glass fiber, propylene fiber, or steel fiber can be utilized. Non-metallic fiber was chosen as a replacement material due to its similarity to cement in terms of properties.

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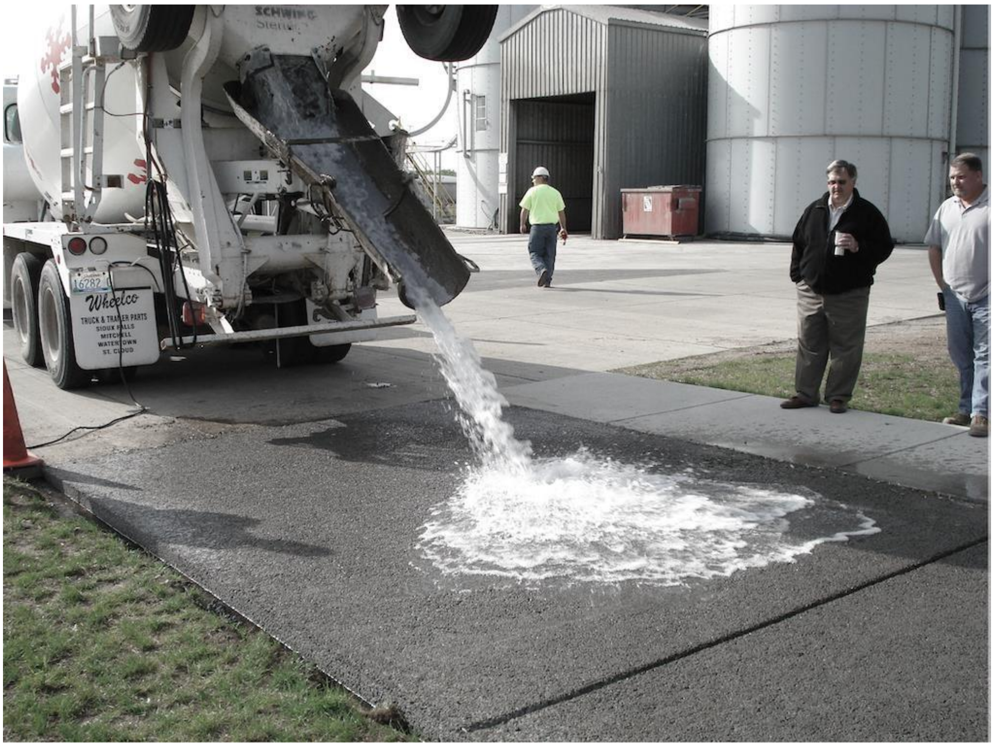

FIG. Pervious Concrete.

1.1 Objective

- Minimizing runoff is achieved through the application of impervious pavements.
- The study aims to assess the impact of material proportions on the engineering properties of pervious concrete.
- Research investigates the performance attributes of pervious concrete, encompassing porosity, compressive strength, and infiltration rate.
- The research delves into the influence of fibers on the strength of pervious concrete.

II. LITERATURE REVIEW

Experimental Analysis on High Strength Pervious Concrete--Ch. Hari Sai Priyanka [2017];

In 2017, Ch. Hari Sai Priyanka conducted an experimental analysis of high-strength pervious concrete. The increased use of pervious concrete in recent years is primarily attributed to its reputation as an environmentally friendly and sustainable construction material. This study focuses on assessing the strength characteristics of pervious concrete through a series of strength tests and comparing these properties with those of conventional concrete samples. The main objectives included conducting compressive strength tests and split tensile strength tests to determine the material's properties. Cubes with dimensions of 150 x 150 x 150 mm were used for these tests.

Furthermore, this research also explored the suitability of pervious concrete for various applications, including in buildings and bridges. Compressive strength testing was carried out using a compression testing machine, while tensile strength was determined for concrete cylinders with dimensions of 150 mm in diameter and 300 mm in height.

The key findings and conclusions from this study are as follows:

Mixtures with low paste content exhibited approximately 25% lower compressive energy absorption compared to mixtures with high paste content at the same strength level.

High-strength pervious concrete displayed higher water absorption values when compared to normal concrete.

Strength results were compared among normal concrete, pervious concrete, high-strength pervious concrete, and normal concrete.

High-strength pervious concrete exhibited lower strength properties in comparison to normal concrete, although it had higher water absorption characteristics.

Use Of Pervious Concrete in Road PavementSuraj F. Valvi, Anil P. Thoke, Abhijit Gawande, Manoj Godse, Prof. D. D Shelke [2017];

In their research conducted by Suraj F. Valvi, Anil P. Thoke, Abhijit Gawande, Manoj Godse, and Prof. D.D. Shelke in 2017, the focus was on investigating the application of pervious concrete in road pavement. Pervious concrete, often referred to as "no-fines" concrete, is characterized by its minimal or absence of fine aggregates like sand. The primary objectives of this study included assessing the compressive strength and permeability of pervious concrete by casting cubes with dimensions of 150mm x 150mm x 150mm and curing them for 28 days. Both durability and permeability are vital properties of pervious concrete. The study employed 43-grade cement and adhered to the guidelines outlined in IS-269-1989 for determining the fineness of cement and IS 4031 part 2 for consistency testing. Various other IS codes were also utilized to enhance the research and validate the findings related to compressive strength and permeability.

The conclusions drawn by the authors can be summarized as follows:

To achieve higher compressive strength, it is advisable to use smaller coarse aggregates.

Pervious concrete is particularly well-suited for rural areas, catering to the specific needs of such regions. Its primary benefits include reducing stormwater runoff and increasing groundwater levels.

Attaining high compressive strength in pervious concrete does not solely rely on greater strength and workability; other factors play a role.

The incorporation of additives such as fly ash and silica fume contributes to enhanced strength in pervious concrete.

Among the various cement types, OPC 53-grade cement exhibited the highest compressive strength (12.71 N/mm^2) compared to other mix proportions.

Pervious concrete, obtained by entirely removing fine aggregates (0%) or partially by replacing 10% and 20% of the coarse aggregates, demonstrates superior strength.

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

The authors, Nitin M. N, Gururaj Acharya, and Shaik Kabeer Ahmed, conducted an experimental study in 2016 focused on implementing pervious concrete in pavements. The primary objective of this research was to assess and enhance the compressive strength, flexural strength, abrasion value, and porosity of pervious concrete. The study aimed to establish the necessary criteria for achieving specific goals related to porosity, permeability, and strength in porous concrete mixes. To conduct these tests, concrete cubes were cast and examined at the ages of 7, 14, and 28 days of curing.One significant finding of the study is that at the ages of 7, 14, and 28 days, the lowest compressive strength was consistently observed when utilizing 0% fine aggregates.

Kolli. Ramujee (2013);

In their research conducted by Kolli. Ramujee,The tests for compressive strength and splitting tensile strength indicated that the strengths increased in direct correlation with the rise in the volume ratios of Polypropylene Fibers when compared to the control mix without any admixtures.

A.V. Pradeepa (2014);

Experimental findings demonstrate that the mechanical properties were improved through the reinforcement of GGBF Slag with Glass Fiber Polymer. Notably, the specimen containing 15% GGBF Slag, the highest percentage among all specimens, exhibited superior tensile strength, compressive strength, flexural strength, impact strength, and hardness.

Chandana Priya.C (2016);

The investigation involved an examination of the mechanical properties of a composite made by replacing different weight percentages (0%, 20%, and 40%) of fly ash with the addition of glass fiber at four distinct volume fractions (0%, 0.5%, 1%, and 1.5%). This addition resulted in a notable increase in compressive strength, with improvements ranging from 20% to 25%.

III. REQUIRED MATERIALS

Cement

The cement used in pervious concrete is typically Portland cement, which is commonly available in various grades such as 33, 43, or 53. Among these, higher-grade Portland cement, like 53 Grade, is often preferred for its superior compressive strength. This cement plays a crucial role in binding the aggregates in pervious concrete while allowing for the necessary porosity that characterizes this type of concrete.

The choice of cement in pervious concrete is influenced by factors like strength requirements, durability, and regional availability. Portland cement provides the necessary binding properties to hold the mixture together while still allowing for the passage of water, making it a suitable choice for creating pervious concrete pavements and surfaces.

Fig. Cement.

Aggregate-

Aggregates used in pervious concrete are a crucial component that provides the necessary structural support and permeability. Pervious concrete is designed to allow water to pass through its interconnected voids while maintaining sufficient strength. Here's a brief note on the aggregates used in pervious concrete:

1. **Coarse Aggregate:** Pervious concrete primarily consists of a single-sized coarse aggregate, typically ranging in size from 3/8 inch to 3/4 inch (10 mm to 19 mm). The coarse aggregate forms the main structural framework of the concrete.
2. **Gradation:** The gradation of the coarse aggregate is critical in pervious concrete. It should be well-graded to create a matrix of voids within the concrete. A specific particle size distribution is designed to achieve the desired porosity and permeability.
3. **Absence of Fine Particles:** Pervious concrete minimizes the use of fine particles (sand) in the mix. This is because fine particles can clog the voids and reduce the permeability of the concrete.
4. **Clean and Free-Draining:** The coarse aggregate used in pervious concrete should be clean, free from contaminants, and well-draining. Contaminants can adversely affect the durability and permeability of the concrete.
5. **Void Ratio:** The choice of aggregate and its gradation determines the void ratio of the pervious concrete mix. A higher void ratio results in increased permeability but maysacrifice some structural strength.

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Fig. Aggregates.

Glass Fiber–

Glass fibers in pervious concrete serve as reinforcement to enhance its mechanical properties. These fibers are typically made from glass and are dispersed throughout the concrete mixture. They add strength, reduce cracking, and improve the overall durability of the pervious concrete.

Glass fibers are preferred for their corrosion resistance and ability to maintain their structural integrity in the presence of moisture. They also contribute to increased flexural strength, impact resistance, and toughness of the concrete. This makes pervious concrete with glass fiber reinforcement suitable for various applications, particularly in areas where additional strength and resistance to environmental factors are necessary.

In summary, glass fibers play a vital role in strengthening and enhancing the performance of pervious concrete, making it more robust and durable for applications like pavements, walkways, and other load-bearing structures.

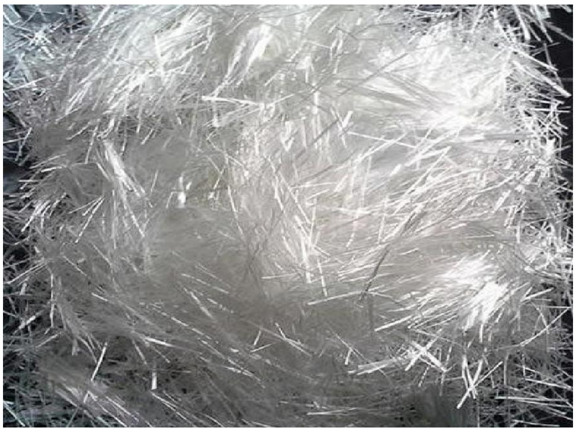

Fig. Glass fibres

The specifications of the glass fiber:

- Filament diameter: 14μm / 0.000550 • Specific gravity of glass fiber is 2.68g/cm3
- Moisture (%): 0.50max.
- Material: Alkali resistant glass
- Softening point: 8600C (15800 F)
- Modulus of elasticity: 72Gpa 3.2

DOI: 10.48175/IJARSCT-13611

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Water

Water is a critical component in the mixture of pervious concrete. It serves multiple purposes in the creation and functionality of pervious concrete pavements and surfaces. During the mixing process, water acts as a binder, facilitating the hydration of the cement and helping to hold the aggregates together.

The proper balance of water during the mixing phase is crucial to ensure that the concrete maintains its structural integrity while still allowing for the desired level of porosity to achieve its water-draining capabilities. Too much water can reduce strength, while too little can hinder the material's workability. Therefore, controlling and managing the water content is essential for creating durable and functional pervious concrete surfaces.

Selection of Material

	GLASS FIBER	POLYPROPYLENE
TENSILE STRENGTH	1200-1700MPa	550-70 MPa
COMPRESSION STRENGTH	1080MPa	as % increases compressive strength increases
SPECIFIC GRAVITY	2.7 g/cm^3	0.91 g/cm^3
SHAPE	irregular pieces	Wavy
NATURE	It does not absorb water	It has hydrophobic nature
PRICE	40 Rs/kg	140 Rs/kg
SOURCE	Industries	Chemical industry
		

FIG. Comparison of glass fiber and polypropylene

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IV. CONCLUSION

Based on the theory and observations from our experiments, we can draw the following conclusions:
The compressive strength of pervious concrete is influenced by concrete porosity, and the choice of binder material, which includes the type of cement, significantly impacts the strength.
Several key factors play a vital role in determining the strength of pervious concrete:
a) Coarse aggregate size.
b) Water-cement ratio.
c) Aggregate-to-cement ratio.
In terms of mix design, the void ratio and unit weight are essential parameters for pervious concrete.
Porosity is directly proportional to the void ratio. An increase in void ratio results in higher porosity.
Compressive strength and permeability exhibit an inverse relationship. As porosity increases, compressive strength decreases.
A reduction in aggregate size leads to a decrease in porosity due to the absence of fine aggregates.
Compressive strength and void ratio also display an inverse relationship. An increase in the void ratio results in decreased compressive strength.
Reducing aggregate size positively affects the compressive strength of pervious concrete. Smaller aggregates lead to higher strength.
Pervious concrete pavements are not suitable for heavy-duty roads.
Pervious concrete, currently characterized by lower compressive strength, is typically used in applications like parking lots, sidewalks, and on highway shoulders and medians.
We found that aggregates in the size range of 10-12.5 mm provide a good balance between compressive strength and optimum porosity in pervious concrete.

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