International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 10 | Oct - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Study of mechanical properties of pervious concrete as a pavement material by partial replacement of GGBS in cement with addition of cellouse fibers

Dodde Swarna Priya, [2] Dr. P. Balakrishna, Ph. D

[1]M. Tech Student, Department of Civil Engineering, MVR College of Engineering and Technology (autonomous) paritala, India.

[2]Associate professor and Head of the Department (HOD), Department of Civil Engineering, MVR College of Engineering and Technology, paritala, India.

---***---

Abstract - Among all the transportation systems roadways is the most used transportation system. But in the present scenario roads face a lot of problems like potholes, cracks and many other distresses. Not even these but water is also the main enemy to the pavement which causes deformations and changes the texture of subgrade soil resulting in large variation in performance. The total Impervious Surface Change (ISC) for India between 2000 and 2020 is 2274.62 km (about 1413.38 mi) [2]. This is one of the most considerable problems due to rapid urbanization where there is a tremendous increase in construction of black topped and different types of impervious pavements. This has an adverse effect on the environment as the storm water becomes stagnant over the surface of the pavement due to inadequate drainage conditions. The necessity for reducing stagnation and the surface runoff has given the inception of pervious pavement surface. Pervious concrete pavement is a special type of its kind with high porosity with no or minimal fines which allow water to percolate through it and thus the water which is accumulated over the surface can be collected and used for various purposes. The present work studied the mechanical properties and permeability of pervious concrete of mix 3:1 aggregate cement ratio. The control mix is altered by partially replacing 30% of cement with Ground Granulated Blast Furnace Slag (GGBS), included Cellulose fibers of 5% of weight of the cementitious material and combination of both in one mix and compared the results obtained. The properties such as compressive strength, indirect tensile strength, flexural strength and permeability are assessed by performing tests. It was observed that there is an increase in Compressive Strength, Split Tensile Strength, Flexure Strength and decrease in the permeability in the altered pervious concrete mixes when compared to the Pervious concrete with no additives.

Keywords: pervious concrete, impervious surface change, urbanization, pavement drainage, stormwater management, mechanical properties, compressive strength, split tensile strength, flexural strength, permeability, Ground Granulated Blast Furnace Slag (GGBS), cellulose fibers, sustainable pavements.

1.Introduction

Pavements are the hard and smooth layered surface that allows or bear travel in an area. There are two types of pavements based on design considerations.

1. Flexible Pavement
2. Rigid Pavement

1.1Rigid Pavement

The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil

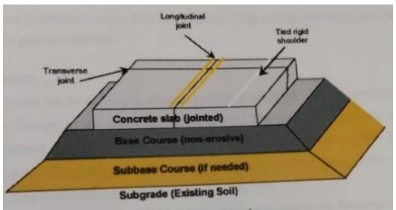


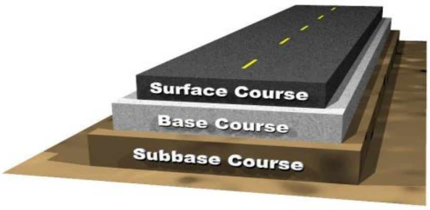
Fig 1.1.Rigid Pavement

1.2 Rigid Pavement

Minor variations in sub grade strength have little influence on the structural capacity of a rigid pavement. In the design of a rigid pavement, the flexural strength of concrete is the major factor and not the strength of sub grade. Due to this property of pavement, when the sub grade deflects beneath the rigid pavement, the concrete slab is able to bridge over the localized failures and areas of inadequate support from subgrade because of slab action.

Flexible Pavement

Flexible pavement can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are examples of flexible pavements



1.3 Pervious concrete

Pervious concrete is an open-graded or "no-fines" concrete that allows rainwater to percolate through to the underlying sub-base. Its primary ingredients include aggregate, Portland cement, admixtures, and optionally fine aggregate and water. The key distinction lies in its void space, typically ranging from 15-25%. With anticipated increases in oil prices driving up asphalt pavement costs, pervious concrete emerges as a sustainable alternative. Many streets are paved with cement concrete, which often exceeds the necessary strength for low-volume roads. Pervious concrete provides a viable solution, offering a sustainable, multipurpose pavement option that requires less construction space and cost.

Fig 1.water percolating through the pervious concrete cube

To create pervious concrete pavement, the concrete is placed over an aggregate base, with a filter fabric used to separate the underlying soil and prevent clogging of the concrete's pores. Typically, single-sized coarse aggregates are employed, which provide large voids, making the concrete lightweight and architecturally attractive. These aggregates are held together by a thin layer of cement paste, imparting strength. Advantages of pervious concrete include lower density (1600-2000 kg/m³), reduced cost due to lower cement content, lower thermal conductivity, minimal drying shrinkage, and better insulating properties. Due to its low bond strength, reinforcement is not used with pervious concrete.

Fig.2 Pervious concrete vs Conventional concrete

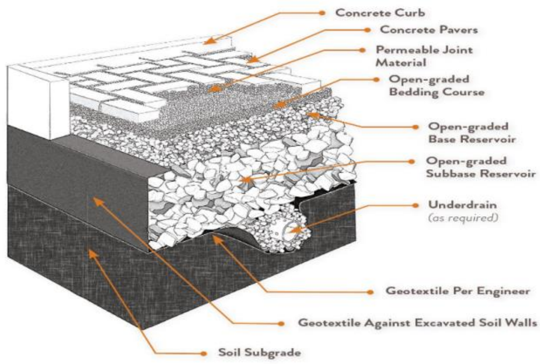


Fig.3 Sectional view of pervious concrete pavement

1.4The sectional view of pervious concrete pavement illustrates several key layers:

1. Pervious Concrete Layer: The top layer, allowing water to percolate through.
2. Filter Fabric: Separates the pervious concrete from the soil, preventing clogging.
3. Aggregate Base: Provides structural support and enhances drainage.
4. Subgrade Soil: The foundational layer supporting the pavement.

These layers collectively ensure effective drainage and durability in the pavement system. As shown in fig.

2. Objectives

Pervious concrete has been predominantly used in non-pavements applications with only a limited use in pavements applications. The purpose of this project is to assess the suitability of pervious concrete to be used for the construction of road pavements.

The main objectives of this study as follows

- To develop initial mix design to evaluate possible alternatives using different water- cement ratios and aggregate-cement ratios.

- To investigate the properties of pervious concrete with GGBS, natural fibers like Cellulose and both.
- To conduct the necessary tests to assess the strength and permeability.
- To analyze the results obtained and conclude the effectiveness of no fines concrete as a pavement material.

3.SCOPE OF THE PRESENT STUDY:

The scope of the proposed work encompasses the following aspects:
The current study focuses on evaluating the strength and permeability characteristics of pervious concrete mixes, specifically examining the effects of Ground Granulated Blast-Furnace Slag (GGBS), cellulose fiber, and their combined influence on the concrete's performance. This investigation aims to provide insights into how these materials can enhance the overall properties of pervious concrete, promoting its sustainability and effectiveness in various applications.
Additionally, the study is limited to a single mix proportion, specifically a 3:1 aggregate-to-cement (A-C) ratio. By concentrating on this specific mix design, the research aims to establish a baseline for assessing the performance of pervious concrete and its potential benefits. This focused approach allows for a thorough analysis of the interactions between the different components, providing valuable data for future studies and practical applications in pavement engineering.

4.Materials and Methodology

4.1 Material Used:

1.cement
2. coarse aggregates
3.chemical admixtures
4.water
5.fine aggregates
6. Chemical admixtures

Structural concrete is among the most widely utilized construction materials globally, recognized for its versatility and effectiveness in various conditions. One of concrete's unique advantages is its ability to be delivered in a plastic state, allowing it to be molded into virtually any form or shape. This flexibility enables a wide range of applications, from highways and bridges to buildings and even ships. In this study, we focus on the mechanical properties of pervious concrete, often referred to as "no-fines" concrete. Pervious concrete is characterized by its open-graded structure, consisting of hydraulic cement, coarse aggregates, chemical admixtures, and water, with little or no fine aggregates. When combined, the cement and water create a paste that binds the coarse aggregates, resulting in a hardened product with interconnected pores that facilitate water percolation.

In our experimental work, Ground Granulated Blast-Furnace Slag (GGBS) is employed as a mineral admixture, and cellulose fiber is introduced as a fiber reinforcement to examine their effects on the mechanical properties of pervious concrete.

Cement serves as a critical binder in concrete, a material that sets and hardens independently and binds other materials together. The term "cement" dates back to the Romans, who used "opus caementicium" to describe a masonry-like material made from crushed rock and burnt lime. Today, cement is primarily produced by heating limestone and other materials in a kiln to create clinker, which is then ground with gypsum to form Ordinary Portland Cement (OPC). OPC is essential for concrete production, providing the binding agent that holds together the aggregate components.

Concrete is created by mixing aggregates—both fine and coarse—with cement and water. Its popularity stems from its versatility, allowing for innovative applications and design techniques. Concrete hardens due to hydration, a chemical reaction where water interacts with cement, leading to the formation of a stone-like material. This composite is utilized in various structures, including pavements, bridges, and residential buildings.

The quality of aggregates significantly impacts concrete performance. Good gradation of aggregates reduces shrinkage and enhances economy by minimizing voids, requiring less paste to fill them. The aggregates should be hard, strong, and durable, free from impurities, and well-graded to ensure optimal performance.

Water is another vital component, participating actively in the chemical reactions that produce strength in concrete. The quality of water used for mixing is crucial; generally, potable water is recommended.

Admixtures are additional ingredients used to modify the properties of concrete, which may include chemical and mineral admixtures. Chemical admixtures, like water reducers and air-entraining agents, improve workability and strength, while mineral admixtures such as fly ash and GGBS enhance durability and sustainability by partially replacing Portland cement.

Fiber reinforcement is another innovative approach to improve concrete properties. Fiber-reinforced concrete (FRC) incorporates various types of fibers, including steel, glass, and cellulose, which enhance the material's structural integrity and help control plastic shrinkage and crack propagation.

Lastly, the mix design of pervious concrete is a crucial process that involves selecting suitable ingredients and determining optimal proportions to achieve desired compressive strength and workability. Traditional slump tests may not be effective for pervious concrete due to its lightweight nature; instead, the workability is often assessed by the ability to form a cohesive ball by hand. This unique approach underscores the importance of careful water content management in achieving the desired properties of pervious concrete.

4.2 Properties of materials used in the experimental work:

The materials used in experimental work are:

- Cement
- Coarse aggregate
- Water

4.2.1 Cement

The most common cement used in construction is ordinary Portland cement confirming to IS: 12269-1987.This type of cement is typically used in construction and is readily available from a variety of sources. The cement is fresh and uniform colour. The cement is free from lumps and foreign matter. The typical fineness of cement ranges from 350 to 500 sq.m/kg. The type of cement used all throughout the experiment was Ordinary Portland Cement of grade 53 (OPC-53). This is the most common type of cement used in general concrete construction where there is no exposure to sulphates in the soil or in the ground water.

S.No	Property	Experimental values
1	Finnes of cement	6.50%
2	Specific gravity	3.10
3	Normal Consistency	29%
4	Initial Setting Time	50 min
5	Final Setting Time	320 min

Table.1. Physical Properties of cement

4.2.2Coarse Aggregate

Well-graded cubical or rounded aggregates are desirable. Aggregates should be of uniform quality with respect to shape and grading. The crushed coarse aggregate of maximum size 10mm, 100% of it passing through 10 mm IS sieve and retaining on 4.75mm IS sieve. The results of various tests on CA are given below.

Table.2. Sieve Analysis of Coarse Aggregate

S. No	**Sieve size (mm)**	**Weight Retained (gram)**	**% weight Retained**	**Cumulative % Retained**
1	20	0	0	0
2	12.5	0	0	0
3	10	14	1.4	1.4
4	4.75	979	97.9	99.3

The single size aggregate is taken for the whole research work as the single sized aggregate would give us better permeable concrete**.**

Table.3. Physical Properties of Coarse Aggregate

S. No	Property	Value
1.	Specific gravity	2.77
2.	Bulk density	
	Loose	14.90kN/m^3
	Compacted	16.7kN/m^3
3.	Water absorption	0.5%

4.	Fineness modulus	7.00%

4.3 Water

This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc: In general, the water, which is fit for drinking, should be used for making concrete. The results of various tests on water are given below.

4.4 Granulated Blast Furnace Slag

In order to fulfill its commitment to the sustainable development of the whole society, the concrete of tomorrow will not only be more durable, but also should be developed to satisfy socioeconomic needs at the lowest environmental impact.

So, the problem is related to environment, problem is related to cost minimization but structural engineer will give the solution by proper analyzing the properties of concrete made by using industrial waste material.

GGBS means the ground granulated blast furnace slag is a by-product of the manufacturing of pig iron. Iron ore, coke and Lime-stone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500 °C to 1600 °C.

The molten slag has a composition close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched rapidly, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size, which is known as ground granulated blast furnace slag (GGBS).

Fig 4.Ground Granulated Blast Furnace Slag Cellulose fiber

4.5 Cellulose fiber

Cellulose fiber (short-cut strands of very fine denier monofilament) is added to the concrete during batching. Thousands of individual fibersare then evenly dispersed throughout the concrete during the mixing process creating a matrix-like structure. Small quantities of fiber in the mix may increase the cohesion and prevent sedimentation due to their interlocking water may be reduced

Fig 5. Cellulose fiber

4.6 Tests on hardened concrete

4.6.1 Compressive strength Test

The following test procedure was undertaken during the compression test:

- The testing of test specimens was undertaken as soon as possible after being removed from the curing tank.
- All specimens were tested in a wet condition and excess water removed from the surface.
- The dimensions of the test specimens were measured and recorded.
- The plates were cleaned when necessary to ensure no obstruction from small particles or grit.
- Any loose particles were removed from the uncapped bearing surfaces of the specimens.
- It was ensured there was no trace of lubricant on the bearing surfaces.
- The 150 x 150 mm plate was placed on top and bottom of the beam directly opposite each other.
- The specimens were centered on the bottom platen of the testing machine.
- The upper platen was lowered until uniform pressure was provided on the specimen.
- A force was applied at the required rate shown by the rotating disc on the testing machine.
- . The maximum force applied to the cylinder was recorded and the compressive strength calculated

Compressive strength = $\frac{P}{A}$

Where, P = maximum load in kg applied to the specimen

A = cross sectional area of the cube on which load is applied (100mm

Fig 6. Compression Testing Machine

5. RESULTS & DISCUSSIONS

In this chapter, the experimental results are presented and discussed. The compressive strength, Split Tensile strength, permeability, flexural strength, Young's modulus test results are tabulated and the variation of mean strength is plotted against curing period in the following figures

5.1. Preliminary test results of trial mixes

The trial mixes were used to determine the most suitable mixture for the analysis. The twelve different samples were mixed and compressive strength was found out at the age of 7 days, *14* days and 28 days curing period. The results are tabulated in the Table 5.1.

Table 5.1. Compressive strength for different mix proportions

S. No	Aggregate	cement	Water cement ratio	Compressive strength (MPa)
1.	3	1	0.4	17.76
2.	4	1	0.4	14.08
3.	6	1	0.4	12.25
4.	3	1	0.35	24.70
5.	4	1	0.35	17.89
6.	6	1	0.35	14.25
7.	3	1	0.30	26.60
8.	4	1	0.30	19.20
9.	6	1	0.30	17.40
10.	3	1	0.28	16.65
11.	4	1	0.28	12.48
12.	6	1	0.28	10.35

5.2 Compressive strength of Pervious Concrete

The Compressive strength of Pervious Concrete was calculated and the corresponding strength was tabulated in Table 5.2. The variation of the Compressive strength with curing was plotted in Fig.

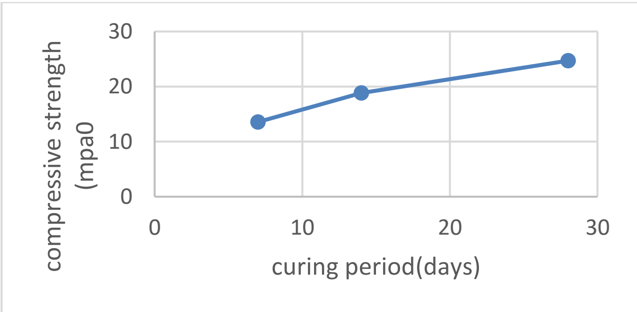
Fig 5.1. Compressive strength of Pervious Concrete vs. Curing period

From Fig 5.1, it was observed that there is an increase of 38.84%, 82.08% in Compressive

strength at the age of 14 days and 28 days curing period respectively when compared to the compressive strength at curing period of 7 days.

Table 5.2 Compressive strength of Pervious Concrete (PC)

Curing period (days)	Compressive strength (MPa)
7	13.563
14	18.832
28	24.695



5.2 Compressive strength of Pervious Concrete with Cellulose Fiber

The Compressive strength of Pervious Concrete with Cellulose Fiber was calculated and *the* corresponding mean strength was tabulated in Table 5.3. The variation of the Compressive strength with curing period was plotted in Fig.5.2.

Table 5.3. Comparison of Compressive strength of different mixes

Curing period (Days)	PC (MPa)	PC+CF (MPa)	PC+GGBS (MPa)	PC+CF+GGBS (MPa)
7	12.33	13.563	26.279	14.16
14	17.66	18.832	20.295	20.33
28	24.695	25.66	26.279	27.66

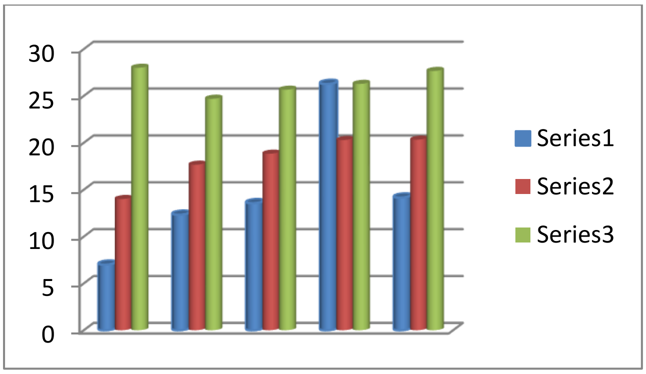


Fig 7. Comparison of Compressive strength

From Fig.7, it was observed that there is an increase in Compressive strength of 10% in case of Pervious Concrete with Cellulose fiber, 17.04% in case of Pervious Concrete with GGBS and 14.18% in Pervious Concrete with both Cellulose fiber and GGBS respectively when compared to that of Pervious Concrete with no additives at 7 days curing period. Similarly, it was observed that there is an increase in Compressive strength of 6.63% in case of Pervious Concrete with Cellulose fiber, 14.92% in case of Pervious Concrete with GGBS and 15.11% in Pervious Concrete with both Cellulose fiber and GGBS respectively when compared to that of Pervious Concrete with no additives at 14 days curing period. It was observed that there is an increase in Compressive strength of 3.90**% in** case of Pervious Concrete with Cellulose fiber, 6.41% in case of Pervious Concrete with GGBS and 12% in Pervious Concrete with both Cellulose fiber and GGBS respectively when compared to that of Pervious Concrete with no additives at 28 days curing period.

6. REFERENCES

1. ACI Committee 522, Pervious Concrete, 522R-06, American Concrete Institute, Farmington Hills, MI (2006)

2. Ammar A.Muttar "Improving the Mechanical Properties of No-fines concrete, Journal of Babylon University/Engineering Sciences, Volume 21, No. 2 (2013).

3. Darshan S.Shah and Jayeskumar Pitroda "An experimental study on hardened properties of pervious concrete", Journal of International Academic Research for Multidisciplinary, Volume.2, No.3, April (2014).

4. Ghafoori. N and Shivaji Dutta "Building and non pavement applications of no-fines concrete", Journal of Material in Civil Engineering, Vol. 7, No. 4, November (1995).

5. Guruji .A.L, Rana. A.V "Ground Water Recharging through Pervious Concrete Pavement", International Conference on: "Engineering: Issues, opportunities and Challenges for Development (2015).

6. Huda Nema Khalifa, "Effect of Adding Cellulose as Fiber and Crystal on Some Mechanical Properties of Concrete", International Journal of Current Engineering and Technology, Volume.5, No.6, December (2015)

7. Hussam A.A.Rehman "Some properties of fiber reinforced No-fine concrete", Al- Qadisiya Journal for Engineering Sciences, Volume 5, No.4 (2012). -

8. Malhotra V.M "No-Fines Concrete Its Properties and Applications", ACI Journal, Volume.73. No. 11, November (1976)

9. Meininger, R.C "No-fines pervious concrete for paving", Concrete International, August, Vol. 10, No. 8 (1988)

10. Neetu.B. Yadav, Jayesh.A.Shah, and Rushabh.A.Shah "Pervious concrete: Solution for low Cost Construction", Journal of Innovative Science and Modern Engineering, Volume. 1, No. 10, September (2013).

11. NRMCA- Pervious Concrete Pavement, Retrieved 06/2009 fromwww.perviouspavement.org (2009)

12. *Panshi* Wang, Chengquan Huang and Eric C. Brown de Colstoun "Mapping 2000-2010 Impervious Surface Change in India Using Global Land Survey Landsat Data", Remote
Sens Journal, April (2015)

13. Paul Klieger, "Further Studies on the Effect of Entrained Air on Strength and Durability of Concrete with Various Sizes of Aggregate", Vol. 25, No. 11 (2003)

14. Sargaphuti.M, Shah S. P, and Vinson K. D "Shrinkage Cracking and Durability Characteristics of Cellulose

Fiber Reinforced Concrete", ACI Materials Journal (1993).
15. Selvaraj. M, Amirthavarshini. M "Some Aspects of Pervious concrete", International
Journal of Engineering and Applied Sciences, Volume.3, No.1, January (2015).