



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.524

Volume 14, Issue 1, January 2025

An Experimental Study on Permeable Concrete with Partial Replacement of Cement by Fly Ash

Waseem Akram S, Yadunandan K, Shifa H, Shivaraj H

7th Semester BE, Department of Civil Engineering, SJMIT, Chitradurga, Karnataka, India

7th Semester BE, Department of Civil Engineering, SJMIT, Chitradurga, Karnataka, India

7th Semester BE, Department of Civil Engineering, SJMIT, Chitradurga, Karnataka, India

7th Semester BE, Department of Civil Engineering, SJMIT, Chitradurga, Karnataka, India

ABSTRACT: Permeable concrete is a sustainable material designed to enhance urban water management by allowing water infiltration through its structure. This study examines the performance of permeable concrete paver blocks made by partially replacing cement with fly ash and excluding fine aggregates. The primary focus is on compressive strength and water absorption to evaluate the material's structural integrity and permeability. Mixes with varying percentages of fly ash replacement were tested to identify the optimal balance between strength and water absorption. Results indicate that fly ash enhances the environmental sustainability of the concrete while maintaining sufficient compressive strength for light-load applications. Additionally, the water absorption rates confirm the material's high permeability, making it suitable for stormwater management systems. This research highlights the potential of fly ash-based permeable concrete as an eco-friendly and functional alternative for urban infrastructure.

KEYWORDS: Fly ash, Paver block, Replacement.

I. INTRODUCTION

Permeable concrete, also known as no-fines concrete, is an innovative material designed to tackle environmental and urban challenges such as stormwater runoff, urban flooding, and groundwater depletion. It is characterized by a porous structure that allows water to infiltrate through the material, thereby reducing surface runoff and promoting groundwater recharge. Unlike conventional concrete, permeable concrete is typically made with coarse aggregates, cement, and minimal or no fine aggregates, which results in an interconnected void structure that facilitates permeability.

In this study, fine aggregates are completely excluded from the mix, and cement is partially replaced with fly ash, an industrial by-product of coal combustion. Fly ash not only reduces the reliance on cement, thereby lowering CO₂ emissions, but also enhances the material's workability and durability. By incorporating fly ash, the study aims to develop eco-friendly and cost-effective paver blocks that maintain a balance between structural performance and permeability.

The main objective is:

- To assess the compressive strength of permeable concrete blocks that incorporate fly ash, determining their performance characteristics under various conditions.
- To compare the compressive strength of conventional permeable concrete with permeable concrete made using fly ash as a partial replacement for Portland cement.
- To investigate and compare the water absorption rates and permeability of conventional permeable concrete and those containing fly ash, evaluating the impact of fly ash on drainage efficiency.
- To identify potential applications for permeable concrete containing fly ash, focusing on their environmental benefits and suitability for urban infrastructure and stormwater management.

II. LITERATURE SURVEY

(1) M. Jemimah Carmichael (2021):- In the recent times, the permeable concrete has grasped an attention of the civil engineering research community to address the drainage issues in the transportation sectors. Even though the surface nature appears to be rough and non-uniform, but it can effectively drain out the water through its interconnecting pore like structure in a large volume. The constituents of this concrete were as like conventional concrete but the difference is in the quantity of fine aggregate. It has been only little quantity and even some times there is no fine aggregate part also. In this paper, the work is planned to estimate the properties of compression and tension strength of permeable concrete which is prepared with cement and nano fly ash. In this work, the cement (C) to coarse aggregate (C.A) mix ratios were adopted was 1:4, 1:6 and 1:8 with respect to various water - binder ratios 0.32, 0.33 and 0.34. For each of these mixes, the cement was replaced from 0% to 50% with nano fly ash materials. The above. mentioned strength tests were performed at 7th and 28th days of age of curing and it has a b c Share Cite compared with the permeable concrete with conventional cement. From the test results, it was found that 1:6 mix, 0.34 water - binder ratio, 40% replacement fraction of cement through nano fly ash was found be optimum among the other mixing compositions. (2). A. Oner (2005) :- This paper presents a laboratory study on the strength development of concrete containing fly ash and optimum use of fly ash in concrete. Fly ash was added according to the partial replacement method in mixtures. A total of 28 mixtures with different mix designs were prepared. 4 of them were prepared as control mixtures with 250, 300, 350, and 400 kg/m cement content in order to calculate the Bolomey and Feret coefficients (K , K). Four groups of mixtures were prepared, each group containing six mix designs and using the cement content of one of the control mixture as the base for the mix design. In each group 20% of the cement content of the control mixture was removed, resulting in starting mixtures with 200, 240, 280, and 320 kg/m cement content. Fly ash in the amount of approximately 15%, 25%, 33%, 42%, 50%, and 58% of the rest of the cement content was added as partial cement replacement. All specimens were moist cured for 28 and 180 days before compressive strength testing. The efficiency and the maximum content of fly ash that gives the maximum compressive strength were obtained by using Bolomey and Feret strength a b a Share Cite 3 B F 3 equations. Hence, the maximum amount of usable fly ash amount with the optimum efficiency was determined. This study showed that strength increases with increasing amount of fly ash up to an optimum value, beyond which strength starts to decrease with further addition of fly ash. The optimum value of fly ash for the four test groups is about 40% of cement. Fly ash/cement ratio is an important factor determining the efficiency of fly ash. (3). Elnaz Khankhaje (2023) :- Disposing fly ash in to landfill of coal fire power plant initiated environmental and health problems. A lot of researchers have conducted research to study the addition of fly ash (FA) as cement replacement in pervious concrete (PC). The aim of this paper was to review the impact of adding FA as partial substitution of cement in PC. The experimental outcomes from different previous studies have indicated that the void content and permeability of PC decreased with adding FA due to filler effect of FA. The optimum substitution level of cement with FA was obtained to be 10–30%. However, with increasing the level of replacement affects the hydration procedure resulting lower strength. PC containing FA showed higher abrasion resistance and lower drying shrinkage compared to normal PC. It can be concluded that using FA as partial substitution of cement would be environmentally friendly in association with more sustainable PC. (4). Amit Mittal (2011) :- The utilization of fly ash in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvements in the long term durability of concrete combined with ecological benefits. Technological improvements in thermal power plant operations and fly ash collection systems have resulted in improving the consistency of fly ash. To study the effect of partial replacement of cement by fly ash, studies have been conducted on concrete mixes with 300 to 500 kg/cum cementitious material at 20%, 30%, 40% and 50% replacement levels. In this paper the effect of fly ash on workability, setting time, density, air content, compressive strength, modulus of elasticity, shrinkage and permeability by Rapid Chloride Permeability Test (RCPT) are studied. Based on this study, compressive strength vs W/Cm curves have been plotted so that concrete mixes of grade M 15 to M 45 with different percentage of fly ash can be directly designed. (5). Mr. A. Gunaseelan, Mr. K. M. Ramalingam (2016) :- More than 88 million tons of fly ash is generated in India each year. Most of the fly ash is of Class F type. The percentage utilization is around 10 to 15%. To increase its percentage utilization, an extensive investigation was carried out to use it in concrete. This article presents the results of an experimental investigation dealing with concrete incorporating high volumes of Class F fly ash. Portland cement was replaced with three percentages (40%, 45%, and 50%) of Class F fly ash. Tests were performed for fresh concrete properties: slump, air content, unit weight, and temperature. Compressive, splitting tensile and flexural strengths were determined up to 28 days of testing. Test results indicated that the use of high volumes of Class F fly ash as a partial replacement of cement in concrete decreased its 28-day compressive, splitting tensile strength and flexural strengths of the concrete. Based on the test results, it was concluded that Class F fly ash can be suitably used up to 50% level of cement replacement in concrete for use in precast elements and reinforced cement concrete construction.

III. MATERIALS

Used Procurement of Materials

CEMENT

The cement which will be used for the investigation is Ordinary Portland Cement (O.P.C) of 43 grade. Ordinary Portland cement (O.P.C): This is the basic type of cement which is used on large scale in all general types of construction works. The details regarding the composition and properties of this type of cement are given in IS: 269. These cements are available in different grades viz. 33, 43 and 53 grade. 43 grade O.P.C is used in the project. In this type of cement, the 28 days cement strength is expected to have a minimum value of 43Mpa.



Fig.: Cement

Sl.No.	Oxides	Percent Content
1	CaO	60.84
2	SiO ₂	16.34
3	Al ₂ O ₃	6.95
4	Fe ₂ O ₃	5.38
5	MgO	2.32
6	S ₂ O ₃	1.99
7	K ₂ O	2.73
8	Na ₂ O	1.50

Table: 1-Grade Portland Cement Chemical Composition (IS: 12269-1987)

FLYASH

Fly ash is a fine, powdery material that is a byproduct of burning pulverized coal in thermal power plants. During the combustion process, the heat vaporizes the mineral matter in the coal, which then condenses and solidifies into tiny particles as it cools. These particles are carried out of the boiler with the flue gas and are captured by air pollution control devices, primarily electrostatic precipitators or fabric filters.



Fig.: Fly ash

POTABLE WATER

Potable Water: Generally, potable (drinkable) water is considered suitable for concrete mixing. It is free from impurities that could adversely affect the concrete's strength, durability, and appearance.



Fig.: Potable water

COARSE AGGREGATE

In the present study the natural coarse aggregates produced by crushing stones was procured from the local quarry. The coarse aggregates were 10mm down size also called chips. The specifications of IS:2386-1963 were followed while using the coarse aggregates for the study.



Fig.: Coarse Aggregate

IV. PRELIMINARY TESTS & RESULTS

1. SPECIFIC GRAVITY TEST ON CEMENT

Description of item	Trial 1	Trial 2	Trial 3
Weight of sample taken gms	64	64	64
Initial height of flask in mm W1	0	0	0
Final height of flask in mm W2	20.4	20.5	20.6
Displacement volume in cm ³ (W=W2-W1)	20.4	20.5	20.6
Specific gravity of cement G	3.13	3.12	3.10
Average specific gravity of cement G	3.11		

2. Normal Consistency Test on Cement

TRIAL	Mass of Cement (grams)	Percentage of Water Added	Vicat's Needle Penetration
1	400	30%	9.5 mm
2	400	28%	8.0 mm
3	400	26%	6.0 mm
4	400	24%	4.5 mm

3. SPECIFIC GRAVITY TEST ON FLY ASH

Description of item	Trial 1	Trial 2	Trial 3
Weight of sample taken gms	40	40	40
Initial height of flask in mm W1 g	0	0	0
Final height of flask in mm W3 g	12	11	14
Displacement volume in cm ³ (W=W2-W1)	12	11	14

Specific gravity of Fly ash G	3.3	3.63	2.85
Average specific gravity of Fly ash G	3.26		

4. NORMAL CONSISTENCY TEST FLY ASH

TRIAL	Mass of fly ash (grams)	Percentage of Water Added	Vicat's Needle Penetration
1	300	28%	6 mm
2	300	30%	17 mm
3	300	32%	28 mm
4	300	34%	30 mm

5. Specific Gravity Test on Coarse Aggregate

W1- Weight of empty pycnometer with lid	0.627kg
W2- Weight of pycnometer + C.A	1.107kg
W3 -Weight of pycnometer + C.A +water	1.771kg
W4-Weight of pycnometer +water	1.482kg
Specific gravity	2.606

6. Coarse Aggregate Sieve Analysis Details

Sieve Size (mm)	Empty Weight (M1) (Kg)	Weight Of The Sieve +Weight of coarse aggregate (M2) (Kg)	Weight of coarse aggregate (M2- M1) (Kg)	%Retained In Each $M2-M1 * 100 M$ (%)	Cumulative (%)	% FINES S
40	0.880	0.880	0	0	0	100
25	0.820	1.140	0.320	6.4	6.4	93.6

20	0.850	2.080	1.24	24.8	31.2	68.8
16	0.920	3.060	2.140	42.8	74	26
12.5	0.760	1.74	0.980	19.6	93.6	6.4
10	0.780	0.988	0.200	4	97.6	2.4
4.75	0.820	0.92	0.100	2	99.6	0.4
PAN	0.720	0.74	0.020	0.4	100	0

7. Coarse Aggregate Impact Test Details

OBSERVATION	Trial 1(gms)	Trial 2(gms)	Trial 3(gms)
Total weight of the aggregate filling the cylinder metal measure (W1)	320	325	318
Weight of aggregate passing through 2.36 mm sieve (W2)	55	57	50
Aggregate impact = $W2/W1 \times 100$	17.18	17.5	15.7

V. METHODOLOGY

METHODOLOGY

➤ Material Selection:

- Use Ordinary Portland Cement, coarse aggregates (10-20 mm), and Class F fly ash.
- Completely exclude fine aggregates to maintain permeability.

➤ Mix Proportions:

- Design concrete mixes with varying percentages of fly ash replacing cement (e.g., 10%, 20%, 30%).
- Determine the water-cement ratio suitable for achieving workability without compromising permeability.

➤ Batching and Mixing:

- Weigh materials accurately for each mix proportion.
- Mix cement, fly ash, coarse aggregate, and water thoroughly to achieve a uniform blend.

➤ Casting Specimens:

- Prepare cube molds (150 mm × 150 mm × 150 mm) for compressive strength testing.
- Cast paver blocks in standard dimensions for water absorption tests.

➤ Curing:

- Cure specimens in water for 7, 14, and 28 days to evaluate strength progression.

➤ Testing Procedures:

- **Compressive Strength Test:** Perform tests on cubes using a compression testing machine as per IS 516.
- **Water Absorption Test:** Measure dry weight of paver blocks, immerse them in water for 24 hours, then weigh again to calculate absorption percentage.

➤ **Data Analysis:**

- Compare compressive strength and water absorption values for different fly ash replacement levels.
- Determine the optimal mix design that provides sufficient strength and permeability.

➤ **Result Interpretation:**

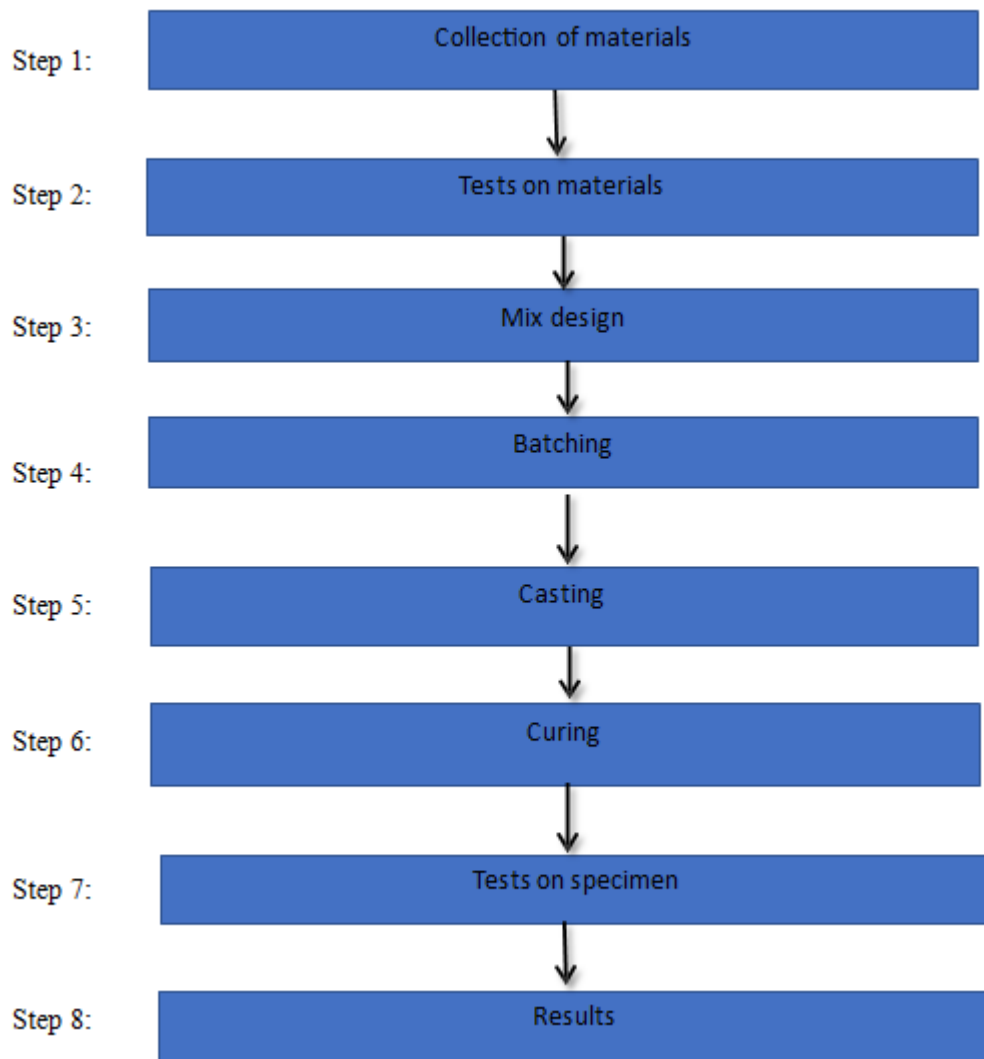
- Evaluate the relationship between fly ash content and concrete performance.
- Assess the feasibility of using the mix for light-load applications like walkways and pavements.

➤ **Conclusion and Recommendations:**

- Highlight the potential of fly ash-based permeable concrete for sustainable construction.
- Suggest further research to optimize performance and scalability for urban applications.

METHODOLOGY FLOW CHART

METHODOLOGY

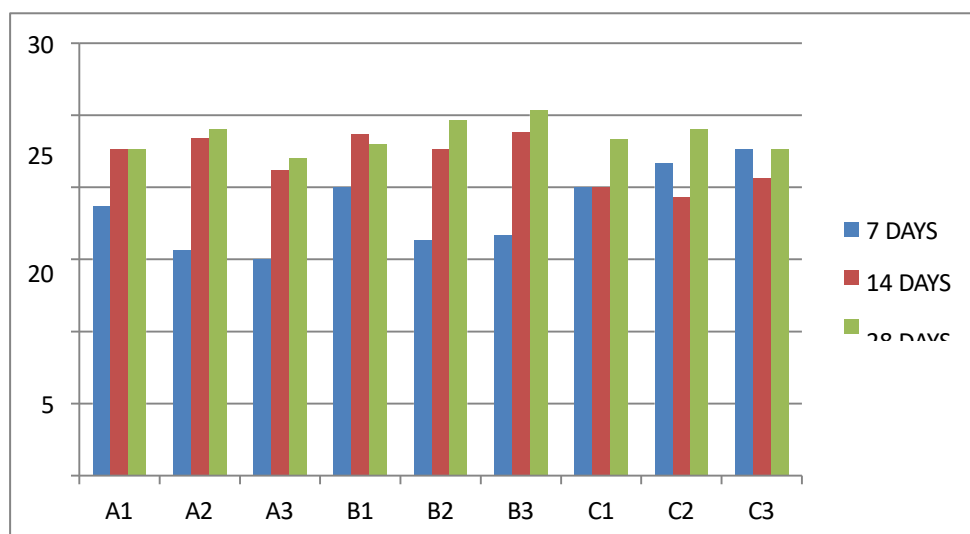


VI. EXPERIMENTAL TESTS AND RESULT

1. COMPRESSIVE STRENGTH TEST DETAILS

TYPE		COMPRESSIVE STRENGTH		
		7 DAYS	14 DAYS	21 DAYS
CONVENTIONAL PAVER BLOCKS	A1	18.66	22.66	22.66
	A2	15.66	23.4	24
	A3	15.20	21.17	22
20%FLY ASH REPLACEMENT WITH CEMENT	B1	20	23.67	23
	B2	16.33	22.66	24.66
	B3	16.66	23.84	25.33
40% FLY ASH REPLACEMENT WITH CEMENT	C1	20	20	23.33
	C2	21.66	19.33	24
	C3	22.66	20.66	22.66

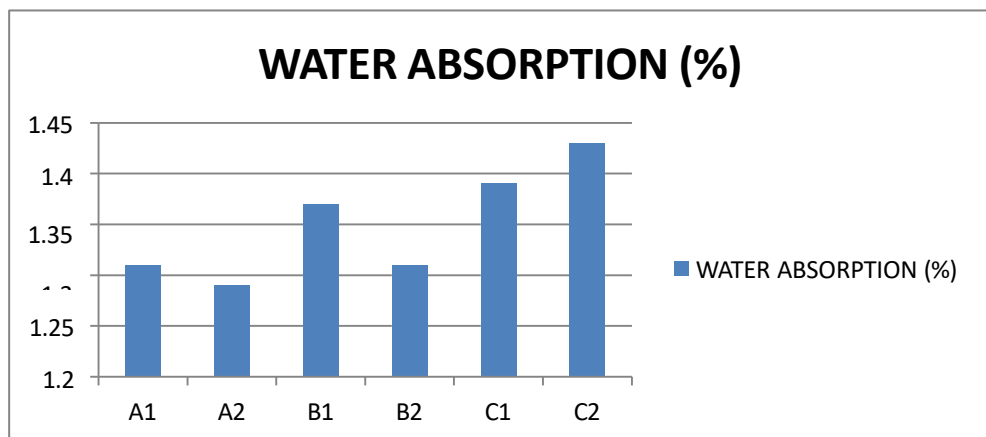
2. COMPARITIVE OF COMPRESSIVE STRENGTH CONVENTIONAL,20% FLY ASH &40% FLY ASH REPLACED PAVER BLOCKS



3. WATER ABSORPTION TEST DETAILS

TYP E	WATER ABSORPTION (%)
	28-days
A-1	1.31
A-2	1.29
B-1	1.37
B-2	1.31
C-1	1.39
C-2	1.43

4. WATER ABSORPTION TEST



VII. CONCLUSION

This study demonstrated the feasibility of using fly ash as a partial replacement for cement in the production of permeable concrete paver blocks. The results showed that eliminating fine aggregates and incorporating fly ash achieved the desired permeability and maintained sufficient compressive strength for light-load applications. Optimal replacement levels of fly ash improved the eco-friendliness of the material while reducing reliance on cement and addressing industrial waste management.

The water absorption tests confirmed that the paver blocks have adequate permeability, making them suitable for stormwater management and groundwater recharge in urban areas. This research highlights the potential of fly ash-based permeable concrete as a sustainable and cost-effective solution for infrastructure applications such as pavements, parking lots, and walkways. Further studies are recommended to explore long-term durability and large-scale implementation in various environmental conditions.

REFERENCES

1. **M. Jemimah carmiacha etal (2021)** :- Effect of partial replacement of cement with nano fly ash on permeable concrete: A strength study Volume 43, Part 2, 2021, Pages 2109-2116
2. **A. Oner (2005) Etal** :- An experimental study on strength development of concrete containing fly ash and optimum usage of fly ash in concrete. Volume 35, Issue 6, June 2005, Pages 1165-1171
3. **Elnaz khankhaje Etal (2023)** :- Properties of pervious concrete incorporating fly ash as partial replacement of cement: A review 14, 2003.
4. **Amit mittal Etal (2022)** :- Experimental study on use of fly ash in concrete.
5. **Mr. A Gunaseelan Mr. K.M Ramalingan (2016)** :- Experimental Study on Performance of High Volume Fly Ash Concrete IJIRST –International Journal for Innovative Research in Science & Technology| Volume 2 | Issue 12 | May 2016



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details