

# Development of Sustainable Cement Tiles with Partial Replacement of Cement and Sand with Fly Ash, GGBs and Glass Powder

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**Abstract -** The increasing demand for construction materials has resulted in excessive consumption of natural resources and higher environmental impacts, particularly from cement production. This study focuses on the development of sustainable cement tiles by partially replacing Ordinary Portland cement and natural sand with alternative materials such as fly ash, ground granulated blast furnace slag (GGBS), and glass powder. Cement tile specimens were prepared with controlled replacement levels and tested to evaluate their mechanical and physical properties. Experimental investigations included tests for compressive strength, water absorption, abrasion resistance, and surface finish in accordance with relevant standards. The results indicate that the use of Fly Ash and GGBS as partial cement replacements improves long-term strength due to enhanced pozzolanic activity, while finely ground glass powder effectively substitutes natural sand and improves particle packing. The optimized mix achieved performance comparable to conventional tiles while reducing cement consumption and environmental impact, supporting sustainable construction practices.

**Keywords:** Fly Ash, Cement, Sand, Glass Powder, GGBS, Sustainable Construction.

## I. INTRODUCTION

The construction industry faces increasing challenges due to excessive use of natural resources and environmental concerns. Cement tiles are widely used for flooring and paving applications, but their production requires large quantities of cement and natural sand. To promote sustainability and partial replacement of conventional materials has gained significant attention. This project focuses on the development of sustainable cement tiles by partially replacing cement and fine aggregate. An experimental study is carried out to evaluate the strength and basic properties of the modified cement tiles and to compare their performance with conventional cement tiles.

## II. METHODOLOGY:

- Collection of Materials
- Preparation of Mix Design
- Mixing of Materials
- Casting of Specimens
- Curing of Specimens
- Testing of Specimens

## III. COLLECTION OF MATERIALS:

### 1. Cement

Ordinary Portland Cement (OPC) of 53 grade was used throughout this experimental investigation as the primary binding material. OPC 53 grade is widely preferred in structural and high-strength concrete applications due to its high early strength development and superior compressive strength characteristics. It conforms to the requirements specified in IS 12269:2013, which governs the physical and chemical properties of 53 grade Ordinary Portland Cement in India.

In this investigation, OPC 53 grade was selected to ensure uniformity in the experimental work and to obtain reliable

strength and durability characteristics for the prepared specimens.



Fig- 1 : Cement

Table-1: Properties of Cement

S.NO	Description	Values	Required Value (IS Code)
1	Normal consistency	31%	26% – 33% (Typical range)
2	Specific gravity	3.14	~3.15
3	Fineness	95%	≥ 90% (for OPC, sieve test)
4	Initial setting time	94 minutes	≥ 30 minutes
5	final setting time	197 minutes	≤ 600 minutes



Fig-2: Sand

Table-2: Properties of Sand

S.NO	Description	Values	Required Value (IS-383)
1	Specific Gravity	2.65	2.5 – 3.0 (Typical range)
2	Fineness Modulus (FM)	2.71	2.2 – 3.2 (Zone II preferred)
3	Bulk Density	1680 kg/m <sup>3</sup>	1450 – 1750 kg/m <sup>3</sup>
4	Water Absorption	1 %	≤ 3%
5	Moisture Content	2.5 %	Varies (should be accounted in mix)
6	Silt Content	2 %	≤ 8% (as per IS 2386)
7	Grading Zone	Zone II	Zone I, II, III, IV (Zone II ideal)

## 2. Sand:

Sand is an important construction material used mainly for making concrete, mortar, and plastering works. It consists of small particles of rock and minerals and helps provide strength, stability, and proper binding when mixed with cement and water. In construction, different types of sand are used, such as river sand, manufactured sand and plastering sand, depending on the purpose. Good quality sand should be clean, free from clay, silt, and organic impurities to ensure strong and durable construction. Sand plays a crucial role in building houses, roads, and other structures by improving workability and strength.

## 3. GGBS:

GGBS (Ground Granulated Blast Furnace Slag) is a by-product obtained from the iron and steel industry and is widely used in construction as a partial replacement for cement. It produced by rapidly cooling molten blast furnace slag and grinding it into a fine powder. GGBS improves the strength, durability and workability of concrete reduces heat of hydration, and increases resistance to sulphates and chemicals. It is also makes concrete more eco-friendly by reducing cement consumption and carbon emissions, make GGBS a sustainable and cost-effective material for modern construction.



Fig- 3: GGBS

fine particle size and pozzolanic properties, glass powder is increasingly used in concrete, mortar, tiles and other construction applications.



Fig-4: Glass Powder

Table-3: Properties of GGBS

S.NO	Description	Values	Required Value (IS-12089:1987)
1	Specific Gravity	2.89	2.85 – 2.95
2	Fineness (Blaine)	432 m <sup>2</sup> /kg	≥ 275 m <sup>2</sup> /kg (IS: 12089)
3	Bulk Density	1680 kg/m <sup>3</sup>	1450 – 1750 kg/m <sup>3</sup>
4	Initial Setting Time	124 min	≥ 30 minutes (with cement, IS: 4031 Part 5)
5	Final Setting Time	247 min	≤ 600 minutes (with cement)
6	Compressive Strength (28 days)	33.24 MPa	≥ 33 MPa (when used in blended cement)
7	Soundness (Le Chatelier)	8.6 mm	≤ 10 mm (IS: 4031 Part 3)

#### 4. Glass Powder:

Glass powder is a finely ground material produced by crushing waste or recycled glass and is used in construction as a supplementary cementitious material. When added to cement or concrete, glass powder improves strength, durability, and workability and helps reduce permeability. It also contributes to sustainability by recycling waste glass and lowering the use of cement, thereby reducing environmental impact. Due to its

Table-4: Properties of Glass Powder

S.NO	Description	Values	Required Value (IS-Code)
1	Specific Gravity	2.57	2.4 – 2.8 IS 2386 (Part 3)
2	Fineness (Blaine)	384 m <sup>2</sup> /kg	≥ 300 m <sup>2</sup> /kg (for pozzolanic activity) IS 1727:1967
3	Particle Size	70 μm	Should pass 90% through 90 μm sieve IS 1727:1967
4	Initial Setting Time	110 min	≥ 30 minutes (with cement, IS: 4031 Part 5)
5	Final Setting Time	292 min	≤ 600 minutes (with cement) IS 4031 (Part 5)
6	Compressive Strength (28 days)	34.24 MPa	≥ 75% of conventional concrete strength IS 516

#### 5. Fly Ash:

Fly ash is a fine powder by-product produced from the combustion of coal in thermal power plants and is widely used in construction as a supplementary cementitious material. When mixed with cement and concrete, fly ash improves workability, strength, and long-term durability while reducing heat of hydration and cracking. It also enhances resistance to sulphates and chemicals and helps in making concrete more economical and eco-friendly by reducing cement consumption and utilizing industrial waste. Fly ash is commonly used in concrete, bricks, road works and large construction projects.



Fig-5 : Fly Ash

Table-5: Properties of Glass Powder

S.NO	Description	Values	Required Value (IS-Code)
1	Specific Gravity	2.24	1.9 – 2.6 IS 1727:1967
2	Fineness (Blaine)	372 m <sup>2</sup> /kg	≥ 320 m <sup>2</sup> /kg (Blaine fineness) IS 3812 (Part 1):2013
3	Particle Size	38 μm	34% max retained on 45 μm sieve IS 3812 (Part 1):2013
4	Initial Setting Time	142 min	≥ 30 minutes (with cement, IS: 4031 Part 5)
5	Final Setting Time	349 min	≤ 600 minutes (with cement) IS 4031 (Part 5)

6	Compressive Strength (28 days)	38.24 MPa	≥ 75% of conventional concrete strength IS 516
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#### IV. MIXING PROCEDURE:

Dry materials (Cement, Fly Ash, Glass Powder, Sand, GGBS) were gradually added to avoid clustering. Water was then added slowly to achieve the required consistency and workability. The mixing process was continued until a homogeneous mortar was obtained.

Table-6: Percentage of material replacement

Material	Trail-1 (25%) replacement	Trail-2 (15%) replacement
Cement	5%	14%
Sand	70%	71%
Fly Ash	15	7%
GGBS	5%	4%
Glass Powder	5%	4%

#### V. CASTING OF SPECIMENS

The prepared mortar was placed into standard moulds suitable for strength and durability testing. Compaction was carried out manually or using vibration to eliminate entrapped air and ensure uniform density. The surface was levelled and finished properly to maintain dimensional accuracy



Fig-6: Casting Of Tiles

#### VI. CURING OF SPECIMENS

After 24 hours of casting, specimens were demoulded and cured under controlled conditions. Water curing was adopted to facilitate hydration of cement and activation of pozzolanic reactions between

fly ash and lime. Specimens were cured for predetermined durations (such as 7, 14, and 28 days) to study strength development over time.



**Fig-7: Curing of Tiles**

### VII. TESTING OF SPECIMENS

After completion of curing, specimens were subjected to mechanical and durability tests to evaluate performance characteristics.

- Transverse Strength Test
- Resistance to Wear Test

### VIII. TRANSVERSE TEST:

The transverse strength test is conducted to determine the ability of cement tiles to resist bending or breaking under load. This test indicates the flexural strength of the tile and helps evaluate its structural performance when subjected to loads during service. In this test, the tile specimen is supported at two ends, and a load is gradually applied at the center until the tile breaks. The maximum load at which the tile fails is recorded as the breaking load.



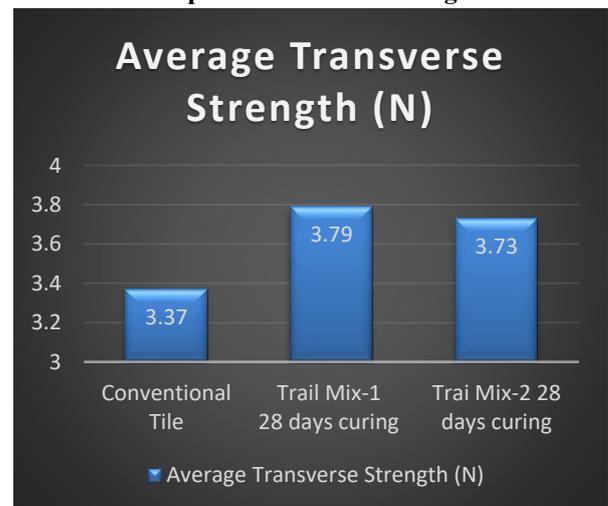
**Fig 3: Transverse Test**

### Test Results:

**Table -4: Test result for Transverse Strength**

Descripti on	Transvers e Strength (N/mm2)	Average Transverse Strength(N/ mm2)	Required Strength As Per IS 13801:2013
Conventio nal Tile	3.40	3.37	≥3 N/mm2
	3.52		
	3.20		
Trail Mix- 1 28 days curing	3.90	3.79	≥3 N/mm2
	3.78		
	3.78		
Trai Mix- 2 28 days curing	3.80	3.73	≥3 N/mm2
	3.72		
	3.68		

**Graph-1 Transverse Strength**

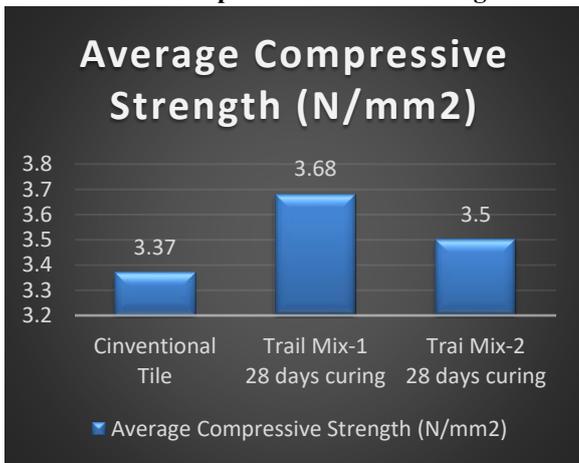


### Compressive Strength Test Results:

Descripti on	Compressive Strength(N/ mm2)	Average Compressive Strength(N/ mm2)	Required Compressive Strength(N/ mm2) As Per IS 1237:2012
Conventi onal Tile	3.20	3.37	≥ 3N/mm2
	3.32		

	3.61		
Trail Mix-1 28 days curing	3.30	3.68	≥ 3N/mm <sup>2</sup>
	3.78		
	3.98		
Trai Mix-2 28 days curing	3.40	3.50	≥ 3N/mm <sup>2</sup>
	3.42		
	3.68		

Graph-1 Transverse Strength



## IX. CONCLUSION:

The development of sustainable cement tiles using partial replacement of cement and sand with fly ash, GGBS, and glass powder demonstrates strong technical, environmental, and economic potential. The experimental results indicate that incorporating these industrial by-products and waste materials can significantly reduce the consumption of ordinary Portland cement and natural sand without compromising the essential performance requirements of cement tiles. Fly ash and GGBS effectively enhanced the pozzolanic and latent hydraulic reactions, contributing to improved long-term strength, durability, and reduced permeability of the tiles. Glass powder, when finely ground and used as a partial sand replacement, showed good filler effects and supplementary cementitious behavior, leading to better particle packing and surface finish. Optimal replacement levels resulted in comparable or improved compressive strength, water absorption, and abrasion resistance when compared to conventional cement tiles. From an environmental perspective, the use of fly ash, GGBS, and glass powder reduces carbon dioxide emissions associated with cement production, diverts industrial and glass waste from landfills, and conserves natural resources. Economically, these materials can lower production costs due to reduced cement and

sand demand, making the tiles more cost-effective and suitable for large-scale adoption.

Overall, the study confirms that sustainable cement tiles incorporating fly ash, GGBS, and glass powder are viable alternatives to traditional tiles. With proper mix design and quality control, such tiles can meet structural and durability standards while promoting sustainable construction practices. Future research may focus on long-term durability, field performance, and optimization of replacement percentages for different applications.

## REFERENCES

- [1] Abdul & Siddique, *Properties of sustainable concrete containing fly ash, slag and recycled aggregate*, Construction and Building Materials (2009). (from literature review)
- [2] Ali, T., Qureshi, M. Z., Onyelowe, K. C., et al. *Optimizing recycled aggregate concrete performance with fly ash and coconut fiber*. Scientific Reports (2025).
- [3] Anitha Bhatia et al. (2016): Highlighted green concrete technology as a means to conserve natural resources, reduce costs, and promote sustainability
- [4] Ali, T., Qureshi, M. Z., Onyelowe, K. C., et al. *Optimizing recycled aggregate concrete performance with fly ash and coconut fiber*. Scientific Reports (2025).
- [5] Anitha Bhatia et al. (2016): Highlighted green concrete technology as a means to conserve natural resources, reduce costs, and promote sustainability
- [6] Ali, T., Qureshi, M. Z., Onyelowe, K. C., et al. *Optimizing recycled aggregate concrete performance with fly ash and coconut fiber*. Scientific Reports (2025).
- [7] Anitha Bhatia et al. (2016): Highlighted green concrete technology as a means to conserve natural resources, reduce costs, and promote sustainability.
- [8] Anitha Bhatia et al. (2016): Highlighted green concrete technology as a means to conserve natural resources, reduce costs, and promote sustainability.

## IS CODES

1. IS:456-2000 Code of practice for plain and reinforced concrete
2. IS:12269-1987 Specification for 53 Grade OPC.
3. IS:269-2015 specifications for 33, 43 and 53 grade OPC.
4. IS:13801-2013 Tolerances for Ceramic Tiles.
5. IS 1237 Cement Concrete Flooring Tiles – Specification
6. IS 3812 Part 1 Pulverized Fuel Ash for Use as Pozzolana in Cement and Concrete
7. IS 712 Specification for Building Limes
6. IS 3812 Part 1 Pulverized Fuel Ash for Use as Pozzolana in Cement and Concrete
7. IS 712 Specification for Building Limes