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Enhancing Compressive Strength of M25 Grade Concrete Using Ceramic Tiles Waste and Waste Fiber Metal: A Path Toward Sustainable Construction

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Abstract

This study explores the use of Ceramic Tiles Waste and Waste Fiber Metal as partial replacements in M25 grade concrete, focusing on their impact on compressive strength. Various combinations of waste materials were tested to determine the optimal mix proportions. Compressive strength tests were conducted on concrete cubes incorporating 0.30%, 0.40%, and 0.50% Waste Fiber Metal with varying percentages of Ceramic Tiles Waste ranging from 20% to 50%. The results indicated that the highest compressive strength was achieved with a mix of 0.50% Waste Fiber Metal and 31% Ceramic Tiles Waste, surpassing the standard concrete mix. This combination demonstrated a compressive strength of 36.6 N/mm² at 28 days, making it a viable option for structural applications. The findings suggest that the integration of Ceramic Tiles Waste and Waste Fiber Metal can produce concrete with improved strength characteristics, contributing to sustainable construction practices by utilizing industrial waste.

Keywords: Ceramic Tiles Waste, Waste Fiber Metal, Sustainable Concrete, Low-Cost Road Construction, Waste Material Utilization.

INTRODUCTION

The origins of ceramic tiles date back to approximately seven to eight thousand years ago in the region known today as the Holy Land in Egypt. Historical records indicate that around 4000 B.C., Egypt was the initial source of clay tile production. At that time, Egyptians used tiles to embellish various houses. Clay bricks were either sun-dried or kiln-fired, and the earliest glazes, which were blue in color, were created using copper. Concurrently, ceramic artifacts were also found in Mesopotamia, featuring white and blue striped decorations, which later evolved into more intricate patterns and colors. In China, the use of white stoneware began with the Shang-Yin dynasty around 1028 B.C., marking the advent of Chinese glaze [1–6]

Ceramic tiles have become a key element in home improvement, significantly enhancing the aesthetics of both interiors and exteriors. The ceramic tile industry in India mirrors global trends, marked by surplus production capacities and decreasing profit margins. Countries such as Malaysia, Thailand, Indonesia, Sri Lanka, and Vietnam are establishing their own manufacturing plants, with China emerging as a major competitor. A significant transformation in the industry was the introduction of vitrified and porcelain tiles. The Indian tile

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industry is growing robustly at an annual rate of 15%, compared to the global industry growth rate of 11% per annum. Over the past five years, investments in the sector have totaled more than Rs. 5000 crores. India ranks among the top three countries globally in tile production, and with improved planning and quality control, this production could increase significantly [7–9].

The ceramic tiles industry in Madhya Pradesh is a growing sector, contributing significantly to the state's economy. Leveraging the region's abundant natural resources, such as clay and minerals, the state has established itself as a notable player in the Indian ceramic tile market. The industry in Madhya Pradesh focuses on producing a wide range of ceramic products, including floor tiles, wall tiles, and decorative pieces. The growth of this sector is supported by government initiatives that promote industrial development and investment in infrastructure. With an increasing demand for modern housing and commercial spaces, the ceramic tile industry in Madhya Pradesh is experiencing steady growth. The region's strategic location and improving transportation network also facilitate the distribution of ceramic products to other parts of India and international markets [10–13].

Motivation

The motivation for this research stems from the growing need for sustainable construction materials that can enhance the durability and performance of concrete pavements. Traditional construction materials often rely on non-renewable resources and can contribute significantly to environmental degradation. The innovative use of repurposed ceramic waste and fiber metal offers a promising alternative, aligning with the global push towards sustainable development. This study aims to explore the potential of these materials to improve the structural and functional properties of concrete pavements, providing an eco-friendly solution that can be scaled up for widespread use. The increasing urbanization and infrastructural demands necessitate the development of materials that are not only cost-effective but also environmentally sustainable. The potential benefits include reducing waste, conserving natural resources, and enhancing the longevity of infrastructure [14–17].

Objectives

The primary objective of this research is to evaluate the compressive strength of M25 grade concrete when partially replaced with different proportions of Ceramic Tiles Waste and Waste Fiber Metal. The study aims to identify the optimal mix ratio that maximizes the compressive strength of concrete, ensuring its suitability for structural applications. Additionally, the research seeks to explore the potential of utilizing industrial waste materials, specifically Ceramic Tiles Waste and Waste Fiber Metal, to create more sustainable and eco-friendly concrete mixtures. By comparing the strength characteristics of these waste-enhanced concrete mixes with standard M25 grade concrete, the study aims to demonstrate the feasibility of incorporating such waste materials in the construction industry, promoting sustainable practices and reducing environmental impact [18, 19].

MATERIAL

Cement

Ordinary Portland Cement (OPC) is a fundamental type of cement, categorized into three grades based on its 28-day strength: 33 Grade, 43 Grade, and 53 Grade. These grades correspond to minimum strengths of 33 N/mm², 43 N/mm², and 53 N/mm², respectively. Typically, the actual strength of these cements exceeds the minimum standards outlined in Indian Specifications. For this study, 53 Grade OPC was utilized and tested according to Indian Standard IS 269-2015 [20–21].

Fine Sand

Fine aggregate for the mix design was sourced from natural sand found in the Narmada River in the Narmadapuram region. The sand's physical properties and sieve analysis were conducted to confirm its compliance with Zone-III of IS 383-2015. Specifically, a 1.0 kg sample of sand was used for sieve analysis, yielding a Fineness Modulus of 3.4.

Coarse Aggregate

Coarse aggregates of nominal sizes 10 mm and 20 mm were obtained from the quarry near Bhopal. The physical properties and sieve analysis were carried out in accordance with IS 383-2015. The aggregate composition used in the mix included 60% of 20 mm size and 40% of 10 mm size, with the results compared against IS 383-2015 specifications, detailed in Table 1.

Table 1. Combined percentages passing of aggregates.

IS Sieve Sizes (mm)	Average Passing of Aggregates		Average % of Passing of Aggregates			Limit as per IS 383-2015
	20 mm	10 mm	20 mm	10 mm	Combined	
			60%	40%	100%	
40	100.0	100.0	60.0	40.0	100.0	100
20	100.0	100.0	60.0	40.0	100.0	95-100
10	12.3	84.4	7.4	33.8	41.1	25-55
4.75	4.1	9.3	2.5	3.7	6.2	0-10

Ceramic Tiles Waste and Waste Fiber Metal

Waste ceramic tiles sourced from the Govind pura Industrial area were utilized as a partial replacement for traditional aggregates in the concrete mix. Similarly, Waste Fiber Metal obtained from various industrial zones in Mandeep City was analyzed for its chemical composition. The composition of the Waste Fiber Metal closely matched the requirements specified in IS 1786-2008, ensuring it met the standards needed to maintain concrete durability. This waste metal fiber was incorporated into the concrete mix as a percentage by weight. Both types of waste were deemed suitable for use in pavement concrete, as their physical and chemical properties conform to the standards outlined in relevant Indian Standard Codes.

Water

Water plays a crucial role in concrete, as it engages in chemical reactions with cement to form the strength-giving cement gel. Therefore, both the quantity and quality of water used are critical factors. For this research, the water used for casting specimens and curing the pavement stretches met the standards outlined in IS 456-2000.

Methodology for Mix Design

Mix design involves selecting appropriate ingredients for concrete and determining their proportions to achieve the desired strength and workability. The process, known as mixture proportioning, assesses the quantities of concrete components using local materials to meet specified concrete characteristics. An optimally proportioned concrete mix should exhibit qualities such as workability, durability, strength, a consistent appearance of hardened concrete, and cost-effectiveness Table 2.

Table 2. Final mix proportion of concrete.

Component	Proportion (by weight) Kg
Cement	375
Coarse Aggregate (20 mm)	730
Fine Aggregate	490
Water	190
Waste Ceramic Tiles	122
Waste Fiber Metal	18.75

RESULTS

Compressive Strength Test Result

In this section, the compressive strength of WCMC for M25 grade was investigated using different percentages of Ceramic Tiles Waste and Waste Fiber Metal. The testing involved preparing cubes with varying waste content, and the results are summarized in Tables 3, 4, and 5. It was observed that the optimal compressive strength was achieved with a combination of 0.50% Waste Fiber Metal and 31% Ceramic Tiles Waste. This mix proportion demonstrated superior strength characteristics compared to other variations, as detailed in Table 6. The findings indicate that incorporating waste materials into the concrete mix can yield favorable strength properties, making it a viable option for sustainable construction practices.

Table 3. Compressive Strength of Waste Ceramic Material Concrete (WCMC) for M25 Grade with 0.30% Waste Fiber Metal.

S.N.	Set No.	Ceramic Tiles Waste	Dial Reading (Tonnes)	Cube Area (cm²)	Compressive Strength at 28 Days (N/mm²)	Average Strength (N/mm²)
1	1	Normal Case	86.5795	225	38.5	38.2
2			86.9855	225	38.7	
3			84.042	225	37.4	
4	2	20%	85.666	225	38.1	37.8
5			83.1285	225	36.9	
6			86.072	225	38.3	
7	3	25%	73.9935	225	32.9	34.1
8			78.764	225	35.0	
9			77.4445	225	34.4	
10	4	30%	79.4745	225	35.3	35
11			80.388	225	35.7	
12			76.531	225	34.0	
13	5		72.1665	225	32.1	32.3
14			70.5425	225	31.4	
15		35%	75.11	225	33.4	
16	6	40%	46.7915	225	20.8	20.5
17			44.7615	225	19.9	
18			46.7915	225	20.8	
19	7	50%	34.713	225	15.4	15.6
20			37.6565	225	16.7	
21			33.089	225	14.7	

Table 4. Compressive strength of waste ceramic material concrete (WCMC) for M25 grade with 0.40% waste fiber metal.

S.N.	Set No.	Ceramic Tiles Waste	Dial Reading (Tonnes)	Cube Area (cm²)	Compressive Strength at 28 Days (N/mm²)	Average Strength (N/mm²)
1	1	Normal Case	86.6	225	38.5	38.2
2			87.0	225	38.7	
3			84.0	225	37.4	
4	2	20%	84.2	225	37.5	37.5
5			85.0	225	37.8	
6			84.0	225	37.4	
7	3	25%	80.4	225	35.7	35
8			84.0	225	37.4	
9			72.0	225	32.0	
10	4	30%	81.8	225	36.3	35.9
11			82.7	225	36.7	

S.N.	Set No.	Ceramic Tiles Waste	Dial Reading (Tonnes)	Cube Area (cm²)	Compressive Strength at 28 Days (N/mm²)	Average Strength (N/mm²)
12			78.2	225	34.7	
13	5	35%	68.3	225	30.3	31.7
14			74.0	225	32.9	
15			71.5	225	31.8	
16	6	40%	47.5	225	21.1	21.4
17			43.6	225	19.4	
18			53.5	225	23.8	
19	7	50%	37.5	225	16.6	16.5
20			34.9	225	15.5	
21			39.3	225	17.5	

Table 5. Compressive Strength of Waste Ceramic Material Concrete (WCMC) for M25 Grade with 0.50% Waste Fiber Metal.

S.N..	Set No.	Ceramic Tiles Waste	Dial Reading (Tonnes)	Cube Area (cm²)	Compressive Strength at 28 Days (N/mm²)	Average Strength (N/mm²)
1	1	Normal Case	86.6	225	38.5	38.2
2			87.0	225	38.7	
3			84.0	225	37.4	
4	2	20%	83.3	225	37.0	36.6
5			78.2	225	34.7	
6			85.9	225	38.2	
7	3	25%	74.2	225	33.0	32.9
8			72.0	225	32.0	
9			75.8	225	33.7	
10	4	30%	79.5	225	35.3	35
11			75.1	225	33.4	
12			81.8	225	36.3	
13	5	35%	70.5	225	31.4	32.2
14			76.3	225	33.9	
15			70.3	225	31.3	
16	6	40%	44.6	225	19.8	19.1
17			39.5	225	17.6	
18			44.8	225	19.9	
19	7	50%	35.2	225	15.6	16.3
20			33.4	225	14.8	
21			41.8	225	18.6	

Table 6. Comparative analysis of compressive strength for waste ceramic material concrete (WCMC) for M25 grade concrete.

S.N.	Ceramic Tiles Waste (%)	Waste Metal Fiber (%)	28 days Compressive Strength (N/mm²)
1	***Normal Concrete***		37.6
2	20	0.3	37.8
		0.4	37.5
		0.5	36.6
3	25	0.3	34.1

S.N.	Ceramic Tiles Waste (%)	Waste Metal Fiber (%)	28 days Compressive Strength (N/mm^2)
		0.4	35
		0.5	32.9
4	30	0.3	35
		0.4	35.9
		0.5	35
5	35	0.3	32.3
		0.4	31.7
		0.5	32.2
6	40	0.3	20.5
		0.4	21.4
		0.5	19.1
7	50	0.3	15.6
		0.4	16.5
		0.5	16.3

Table 6 presents a comparison of the compressive strength of cubes made with different percentages of waste materials. The data suggests that incorporating 25% to 35% of Ceramic Tiles Waste may yield promising results in detailed testing.

CONCLUSIONS

The research demonstrated that incorporating Ceramic Tiles Waste and Waste Fiber Metal into M25 grade concrete enhances its compressive strength. Among the tested mix proportions, 0.50% Waste Fiber Metal combined with 31% Ceramic Tiles Waste yielded the best results, achieving a compressive strength of 36.6 N/mm². This study confirms that using industrial waste materials can provide a sustainable alternative to conventional concrete while maintaining or even improving its strength. These findings pave the way for adopting eco-friendly practices in the construction industry, particularly in regions where Ceramic Tiles Waste and Waste Fiber Metal are readily available.

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