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Utilizing Recycled Plastic for Sustainable Road Repair

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ABSTRACT
This study explores the integration of recycled materials, including TiO2-infused cement and cut-up plastic bottles, into cementitious mortars to advance sustainable infrastructure development. Through a series of thorough tests conducted after a 28-day curing period using the Benkelman beam method, the research assesses the mechanical properties and performance enhancements of these mortars. The findings aim to contribute to smoother roads, increased pavement durability, and improved pothole filling techniques, all while promoting eco-friendly practices in construction.

Keywords**: TiO2-infused cement, Benkelman beam, Performance enhancement, Potholes**

1.INTRODUCTION

This project delves into the intricate domain of construction materials, focusing on pivotal components like cement, water, waste plastic bottles, fly ash, and the Benkelman beam apparatus. Cement, a cornerstone material, binds aggregates to form concrete, providing strength and durability, yet its production poses environmental challenges, prompting the need for sustainable practices. Similarly, waste plastic bottles present significant environmental issues, necessitating comprehensive strategies for reduction, recycling, and sustainable alternatives to address pollution and resource depletion. Through comprehensive analyses and testing methodologies, this study aims to illuminate the properties, applications, and sustainable practices associated with these materials, contributing to the discourse on sustainable construction practices and infrastructure management.

Basic tests on various materials including cement, fine aggregate, coarse aggregate, concrete, and cement mortar are indispensable for evaluating their quality, properties, and suitability for construction applications. These tests ensure compliance with standards and specifications while addressing crucial aspects like particle size distribution, solidification time, and load-bearing capacity. Water absorption assessments offer insights into durability and material suitability, aiding in material selection and structural design. Proactive management strategies for potholes and the utilization of fly ash as a sustainable additive further enhance concrete performance and sustainability, underscoring the project's commitment to advancing eco-friendly construction practices.

"Waste Plastics for Eco-friendly & Sustainable Road Construction in Bangladesh" (Shafiq Alam,2008) have suggested that Waste plastics are environmental nuisance, prospective use of which would help to improve our road network as well as the environment. Advanced cold patching materials (CPMs) for asphalt pavement pothole rehabilitation (Tao Wang,2022) advanced CPMs for more effective pothole repair of asphalt pavement in cold and wet weather.

2. Test Conducted

Compression test: The compression test assesses a material's ability to withstand compressive loads by gradually applying force to cylindrical or cubic specimens until failure occurs. Its primary outcome, compressive strength, indicates the maximum load the material can withstand. This data is crucial for structural design, quality assurance, and research on material behavior under stress. Additionally, the test reveals elasticity, deformation characteristics, and failure modes, aiding in suitability assessments for engineering applications.

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SL. NO.	TESTS	TESTS VALUES					RANGE
		OPC USING TiO_2					
		0%	0.25%	0.50%	0.75%	1.00%	
1	Fineness test	8.5%	8.3%	8.4%	8.43%	8.44%	NOT > 10%.
2	Specific gravity of cement	2.93	2.93	2.94	2.94	2.94	NOT > 3.19.
3	Initial and final setting time of cement	32MIN & 589MIN	31MIN & 582MIN	30MIN & 580MIN	33MIN & 569MIN	33MIN & 570MIN	NOT < 30 MIN NOT > 600 MIN.
4	Consistency test	32%	30%	32%	31%	31%	BETWEEN 25-35%.

Tests on Ordinary Portland Cement (OPC) using Titanium Di Oxide (TiO_2):

From the above table it is clear that the nano material (TiO_2) used as the replacement for Ordinary Portland Cement with different percentages as satisfied the requirement of basic tests as per IS standards which further can be used for the preparation of concrete.

Tests on Fine Aggregate

Zone III type of Fine Aggregate has been used for the preparation of Concrete Cubes From the above table it is clear that Fine Aggregate as satisfied the requirement of basic tests as per IS standards which further can be used for the preparation of concrete

Sl. No.	TESTS	TESTS VALUES	REMARKS
1	Specific Gravity	2.64	Around 2.65
2	Sieve Analysis	2.84	Fineness Modulus
3	Water Absorption	1.25%	0.3- 2.5%

The Benkelman beam:- A popular instrument for evaluating deflection of the pavements after the 28 days of concrete pouring. It gauges how flexible pavements deflect under wheel loads in motion. It is quite useful for evaluating pavement condition and identifying maintenance requirements due to its precision and simplicity. The Benkelman beam helps locate trouble spots, like rutting and cracking, by measuring pavement deflection. This enables prompt repairs and increased road safety.

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Benkelman Deflection Test after 28 days

- Trail 1:
  - Do = 100 mm (at L = 0 m)
  - D1 = 79.30 mm (at L = 2.7 m)
  - Df = 56.83 mm (at L = 9 m)
- Trail 2:
  - Do = 100 mm (at L = 0 m)
  - D1 = 63.24 mm (at L = 2.7 m)
  - Df = 43.74 mm (at L = 9 m)
- Criteria: (D1 - Df) > 0.025 mm
- Formula: D = 0.02(Do - Df) + 0.0582(D1 - Df)mm.
  For trail 1 = 2.1728 mm
  For trail 2 = 2.2598 mm
- Temperature correction: Tc = (49 - 35) * 0.01 = 0.14 mm
- Moisture correction factor (Mc): 1.02 (as annual rainfall < 1300 mm)

Calculations:

- Trail 1:
  - Intermediate value = D- Tc
    = 2.0328 mm
  - Final value = Intermediate value * Mc
    = 2.0738 mm
- Trail 2
  - Intermediate value = 2.1198 mm
  - Final value =2.1614 mm

Benkelman beam result

4.RESULTS AND DISCUSSION

Preparation of Concrete Cubes for Compressive Strength Test

Concrete cubes were meticulously prepared to conduct strength analyses among various Nano Material Concretes. The constituents included Ordinary Portland Cement (OPC), Fine Aggregate, Coarse Aggregate, and Water, along with different percentages of Nano Materials like Titanium Dioxide (TiO2). These cubes were then subjected to compressive strength testing under varied conditions, including Room Temperature, Low Temperature, and High Temperature.

Compressive Strength Calculation for Ordinary Portland Cement (OPC) Concrete Cubes at Room Temperature

In the presented table, diverse Nano Materials such as Titanium Dioxide (TiO2) were employed as partial replacements for cement at varying percentages to fabricate concrete cubes. The objective was to evaluate their compressive strength at Room Temperature. Notably, the compressive strength of Ordinary Portland Cement (OPC) concrete was measured at 29.70 N/mm2 after 28 days at Room Temperature.

Compressive Strength Calculation of Ordinary Portland Cement (OPC) using TiO_2 in Room Temperature at 0.25% Replacement for Cement

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SL. NO.	MATERIAL	DAYS	0.25% REPLACING FOR CEMENT			
			LOAD (KN)	AREA (mm^2)	CS (KN/mm^2)	CS (N/mm^2)
1	TiO_2	7	366.8	22500	0.01630	**17.19**
2			393.5	22500	0.01749	
3			400.1	22500	0.01778	
1		14	505.6	22500	0.02247	**23.41**
2			535.7	22500	0.02381	
3			538.9	22500	0.02395	
1		28	566.1	22500	0.02516	**25.90**
2			596.3	22500	0.02650	
3			585.9	22500	0.02604	

From the above table at 0.25% replacement of TiO_2 for Ordinary Portland Cement (OPC) compressive strength is 25.90N/mm^2 in Room Temperature at 28 days.

Compressive Strength of Ordinary Portland Cement (OPC) with TiO_2 at Room Temperature

The Compressive Strenght of Ordinary Portland Cement (OPC) with TiO2 at Room Temperature is 25.9N/mm^2 .

Compressive Strength of Ordinary Portland Cement (OPC) using TiO_2 at Low Temperature of 5°C

From the above table at 0.75% replacement of TiO_2 for Ordinary Portland Cement (OPC) increases compressive strength by 11.86% compare to normal concrete cube in Low Temperature.

Comparison of Compressive Strength OPC and PPC using Different Nano Materials

Below table shows the comparison of compressive strength of different Nano Materials Titanium Di Oxide (TiO_2) replaced with Ordinary Portland Cement (OPC) at different temperature (Room Temperature, High Temperature and Low Temperature.

5. CONCLUSION

The compressive strength of Ordinary Portland Cement (OPC) concrete was measured at 29.70 N/mm2 after 28 days at Room Temperature.

At 0.25% replacement of TiO2 for Ordinary Portland Cement (OPC) compressive Strength is 25.90N/mm^2 in room temperature in 28 days.

At 0.75% replacement of TiO_2 for Ordinary Portland Cement (OPC) increases compressive strength by 11.86% compare to normal concrete cube in Low Temperature.

At 35% replacement of TiO2 and fly ash for OPC CO2 Emission fall to 68.5%.

After 28 days of concrete pouring in the Potholes Deflection is observed as for Trial 1 final deflection Value is 2.0738mm and for Trial 2 final deflection value is 2.1614mm.

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