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TITANIUM DIOXIDE - AN EXPERIMENTAL STUDY OF SELF-CLEANING CONCRETE (M25 GRADE)

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Abstract: This research paper presents a comprehensive analysis of the influence of titanium dioxide (TiO_2) on enhancing the cleanliness of concrete structures. The objective of this study is to investigate the effectiveness of TiO_2 in promoting self-cleaning properties and reducing maintenance requirements in concrete. Traditional cleaning methods for concrete surfaces are often labor-intensive, costly, and environmentally unfriendly. In response to these challenges, the integration of photocatalytic materials, such as TiO_2, into concrete formulations has emerged as a promising solution. TiO_2 exhibits photocatalytic properties, allowing it to interact with ultraviolet (UV) light and generate reactive oxygen species (ROS), which can break down organic substances and pollutants. This study conducts a rigorous experimental methodology, including laboratory experiments and field observations, to evaluate the impact of TiO_2 on concrete's self-cleaning capabilities. The analysis encompasses surface cleanliness, degradation of organic substances, reduction of pollutants, and long-term durability under real-world conditions. The results highlight the effectiveness of TiO_2 in degrading organic substances, reducing pollutants, and maintaining cleaner concrete surfaces. Furthermore, the research investigates the implications of TiO_2 incorporation on maintenance requirements and lifecycle costs, emphasizing the potential for sustainable and maintenance-friendly concrete solutions. The findings from this study contribute to advancing the understanding of TiO_2's influence on enhancing concrete cleanliness, paving the way for the development of cleaner and more sustainable concrete structures.

***Index Terms* - Titanium Dioxide (TiO_2), Rhodamine B dye, TiO_2, Self-Cleaning Concrete, Photocatalyst, Compressive Strength.**

I. INTRODUCTION

Concrete structures are widely utilized in the construction industry due to their durability, strength, and versatility. However, the accumulation of dirt, pollutants, and organic matter on concrete surfaces presents challenges in maintaining cleanliness, aesthetics, and long-term durability. Conventional cleaning methods often involve labour-intensive procedures, the use of chemical cleaners, and substantial costs, leading to environmental concerns. Consequently, there is a growing need to explore innovative approaches to enhance the cleanliness of concrete and reduce maintenance efforts.

To address the limitations of traditional cleaning methods, researchers have been investigating the integration of photocatalytic materials, specifically titanium dioxide (TiO_2), into concrete formulations. TiO_2 possesses photocatalytic properties, enabling it to interact with ultraviolet (UV) light and generate reactive oxygen species (ROS), which have the ability to break down organic substances and pollutants. This concept of self-cleaning concrete, wherein contaminants are naturally degraded through a photocatalytic process, has garnered significant interest. However, despite the potential benefits of TiO_2-incorporated concrete, there is a need for a comprehensive analysis to evaluate its efficacy, limitations, and practical applicability. The current literature lacks a thorough examination of TiO_2's influence on enhancing concrete cleanliness, including its self-cleaning performance, durability, and maintenance aspects under real-world conditions.

Therefore, this research paper aims to fill this research gap by conducting a detailed analysis of the influence of titanium dioxide on enhancing concrete cleanliness. The primary objective is to investigate the effectiveness of TiO_2 in promoting self-cleaning properties in concrete structures. Additionally, this study aims to assess the long-term performance and durability of TiO_2-incorporated concrete and determine its impact on maintenance requirements and lifecycle costs. By conducting a comprehensive experimental methodology, consisting of laboratory experiments and field observations, this research will provide valuable insights into the effectiveness of TiO_2 in degrading organic substances, reducing pollutants, and maintaining cleaner concrete surfaces. The findings will not only contribute to advancing the understanding of TiO_2's influence on enhancing concrete cleanliness but also inform the development of more sustainable and maintenance-friendly concrete structures.

In this research endeavour is significant in addressing the limitations of traditional cleaning methods and exploring the potential of TiO_2 as a viable solution for enhancing concrete cleanliness. The subsequent sections of this paper will delve into the methodology, results, and discussion, presenting a detailed analysis of the impact of titanium dioxide on self-cleaning properties, durability, and maintenance requirements of concrete structures.

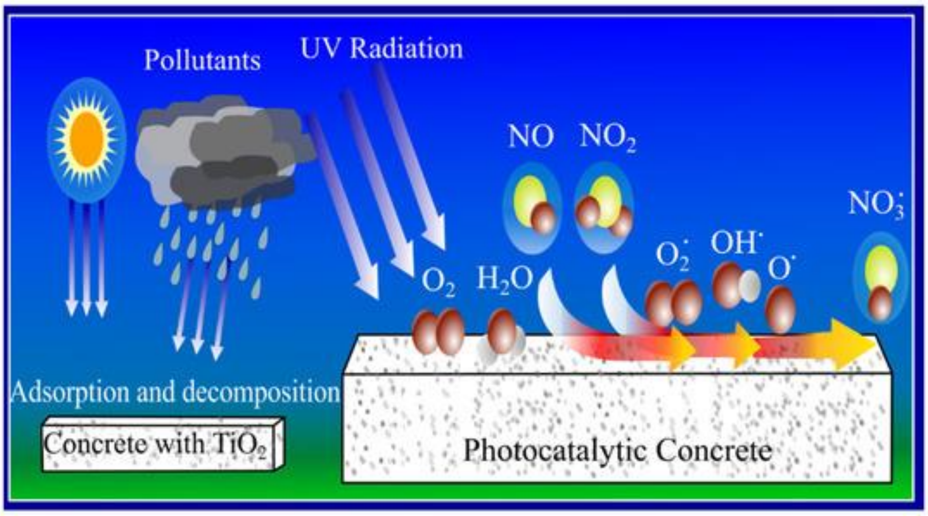

Fig 1: Working Principle
Source: Google

II. Objectives

- To Study the effect on compressive strength of the concrete due to addition of Titanium Dioxide.
- To compare conventional concrete made using Ordinary Portland Cement to concrete containing Photocatalytic cement in context with compressive strength and Photocatalytic properties.
- To investigate how titanium dioxide (TiO2) affects concrete's behavior, as well as how concrete reacts to photocatalysis.

III. LITERATURE REVIEW

The literature review presents an overview of relevant research papers that investigate the application of titanium dioxide (TiO_2) in self-cleaning concrete. The findings and conclusions of the studies conducted by different authors are summarized as follows:

Arafa Awadalla et al. (2011): Explored the use of TiO_2 as a photocatalyst to create self-cleaning concrete and improve indoor air quality. Their study emphasized the potential of TiO_2 in degrading organic pollutants, highlighting its significance in the development of self-cleaning concrete materials.

Adnan Mujkanović (2016): Conducted research on self-cleaning concrete as a construction material for promoting a cleaner environment. The author emphasized the advantages of self-cleaning concrete in reducing maintenance costs and enhancing the sustainability of structures.

Siti Norsaffirah Zailan et al. (2016): Conducted a comprehensive review on self-cleaning geopolymer concrete. Their study explored the properties and applications of geopolymer concrete with self-cleaning capabilities, including the incorporation of TiO_2 as a photocatalyst.

Mark Garger and Evan Marohn (2018): Focused on the utilization of TiO_2 in concrete materials to filter smog pollution from the air. Their study investigated the ability of TiO_2 to react with nitrogen oxide (nox) pollutants, aiming to mitigate their adverse effects on air quality.

Abhijeet Shukla et al. (2018): Conducted an extensive review on the pollution-eating and self-cleaning properties of cementitious materials. The authors discussed the role of TiO_2 and other additives in enhancing the self-cleaning capabilities of concrete, thereby reducing environmental pollution.

T. Arun Kitcha et al. (2018): Carried out an experimental study on photocatalytic concrete using TiO_2. Their research focused on evaluating the efficiency of TiO_2-incorporated concrete in degrading organic pollutants under ultraviolet (UV) light irradiation.

T. Vignesh et al. (2018): Investigated the use of nano-liquid TiO_2 in self-cleaning concrete. Their study explored the influence of nano-sized TiO_2 particles on the self-cleaning performance of concrete and evaluated the effect of TiO_2 concentration on photocatalytic activity.

Dr. S.U. Kannan et al. (2018): Examined the properties of self-cleaning concrete using TiO_2. Their research investigated the impact of varying TiO_2 dosages on the mechanical, durability, and self-cleaning properties of concrete.

Anju Raj (2019): Studied the behavior of self-cleaning concrete using different photocatalysts, including TiO_2. The research focused on evaluating the effect of various photocatalysts on the self-cleaning efficiency and durability of concrete.

Ilker Bekir Topçu et al. (2020): Provided an overview of self-cleaning concretes, highlighting different approaches and materials employed to achieve self-cleaning properties. The authors emphasized the widespread use of TiO_2 as a photocatalyst in self-cleaning concrete.

Hansaraj Dikkara et al. (2020): Investigated the utilization of TiO_2 as a photocatalyst for creating self-cleaning concrete. Their study focused on the photocatalytic degradation of organic pollutants and the optimization of TiO_2 dosage to enhance self-cleaning performance.

Hritik S. Behare et al. (2021): Examined self-cleaning concrete incorporating TiO_2 and analyzed its effectiveness in degrading organic substances. The authors evaluated the self-cleaning efficiency and durability of TiO_2 -incorporated concrete under various environmental conditions.

IV. METHODOLOGY

This research employs a attentive and systematic methodology to evaluate the influence of titanium dioxide (TiO_2) on enhancing the cleanliness of concrete structures. The methodology encompasses laboratory experiments and field observations to comprehensively assess the self-cleaning properties, durability, and maintenance aspects of TiO_2-incorporated concrete under real-world conditions.

1. Materials and Sample Preparation:

Concrete specimens are prepared using standard procedures, incorporating varying concentrations of TiO_2 as the photocatalytic additive. The concrete mix design follows industry standards to ensure consistency and reliability. Special attention is given to accurately measuring and proportioning the materials, including cement, aggregates, water, and TiO_2 nanoparticles.

2. Experimental Setup:

The prepared concrete specimens are subjected to controlled exposure to ultraviolet (UV) light and environmental conditions in the laboratory. The exposure duration is determined based on representative real-world scenarios and anticipated weathering conditions. Multiple samples are used for each TiO_2 concentration to ensure statistical validity and reliability of the results.

3. Self-Cleaning Performance Analysis:

The self-cleaning performance of TiO_2 -incorporated concrete is evaluated through comprehensive analyses of surface cleanliness. Digital imaging is employed to assess the level of contaminants, dirt, and organic substances on the concrete surface before and after exposure to UV light.

Fig 2: Sample cubes placed under sunlight

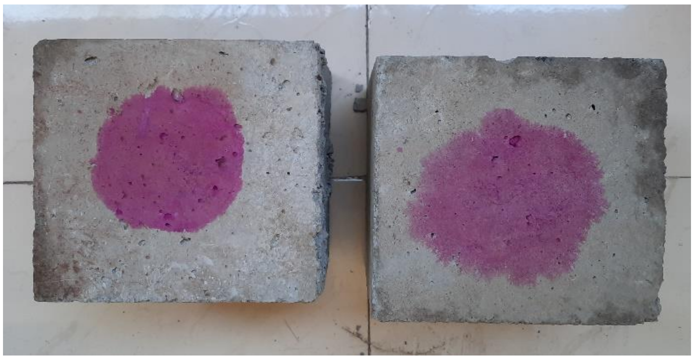

Fig 3: After 4 hours under sunlight

Fig 4: After 8 hours under sunlight

Fig 5: After 16 hours under sunlight

4. Reduction of Pollutants:

The reduction of pollutants, including nitrogen oxides (NO_x) and volatile organic compounds (VOCs), is assessed through gas phase analysis. The concrete specimens are exposed to a controlled environment containing known concentrations of pollutants. The reduction in pollutant levels indicates the efficacy of TiO_2 in purifying the surrounding air.

5. Durability Testing:

Long-term durability tests are conducted to assess the performance of TiO_2-incorporated concrete under realistic environmental conditions. These tests include exposure to simulated weathering conditions. The specimens are monitored for changes in surface morphology, color stability, and mechanical properties, such as compressive strength test.

Fig 6: Compressive Strength Test

V. Results Analysis

1. For 1% of TiO_2

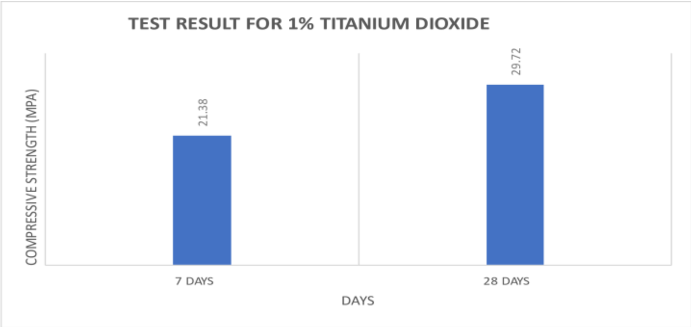

Fig 7: Graphical Representation of Results for 1% of TiO_2

2. For 2% of TiO_2

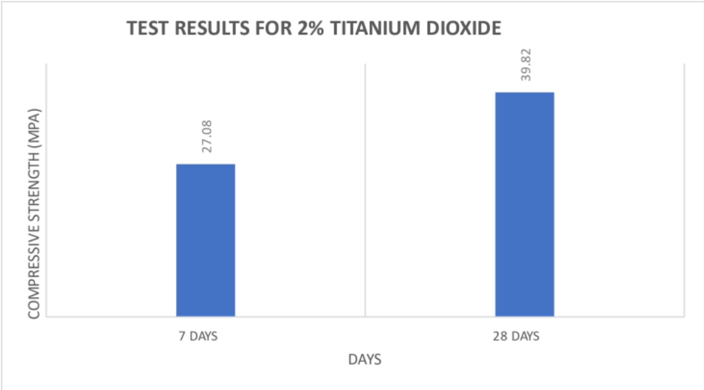

Fig 8: Graphical Representation of Results for 2% of TiO_2

3. For 3% of TiO_2

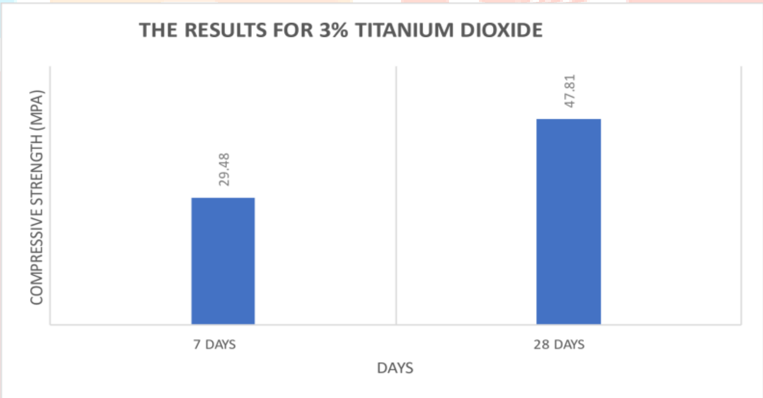

Fig 9: Graphical Representation of Results for 3% of TiO_2

4. For 4% of TiO_2

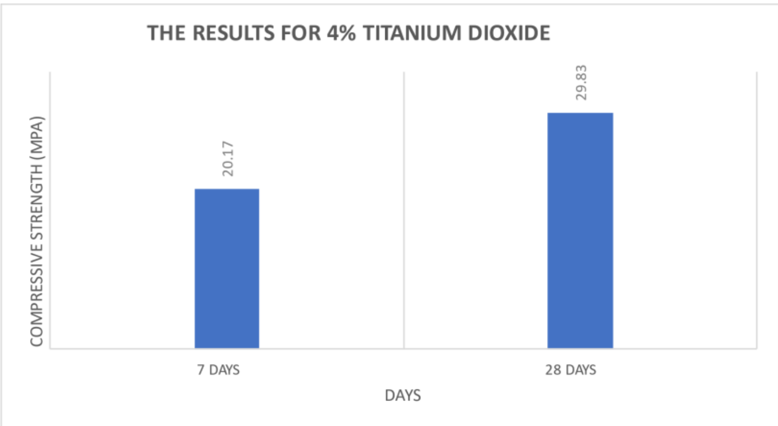

Fig 10: Graphical Representation of Results for 4% of TiO_2

5. For 5% of TiO_2

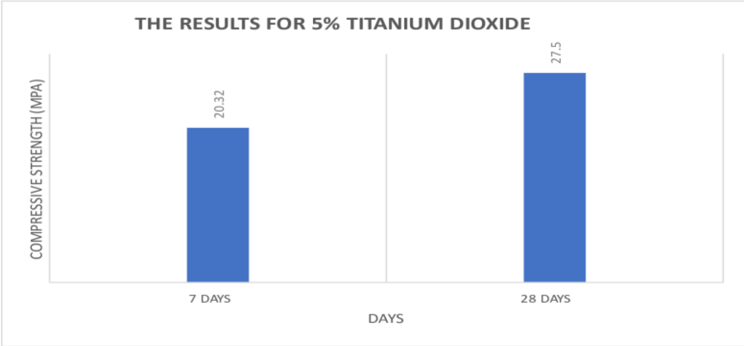

Fig 11: Graphical Representation of Results for 5% of TiO_2

6. Comparison of Compressive Strength

Table 1: Comparison of Compressive Strength

TiO_2 Percentage	For 7 Days	For 28 days
1% TiO_2	21.38	29.72
2% TiO_2	27.08	39.82
3% TiO_2	29.48	47.81
4% TiO_2	20.17	29.83
5% TiO_2	20.32	27.05

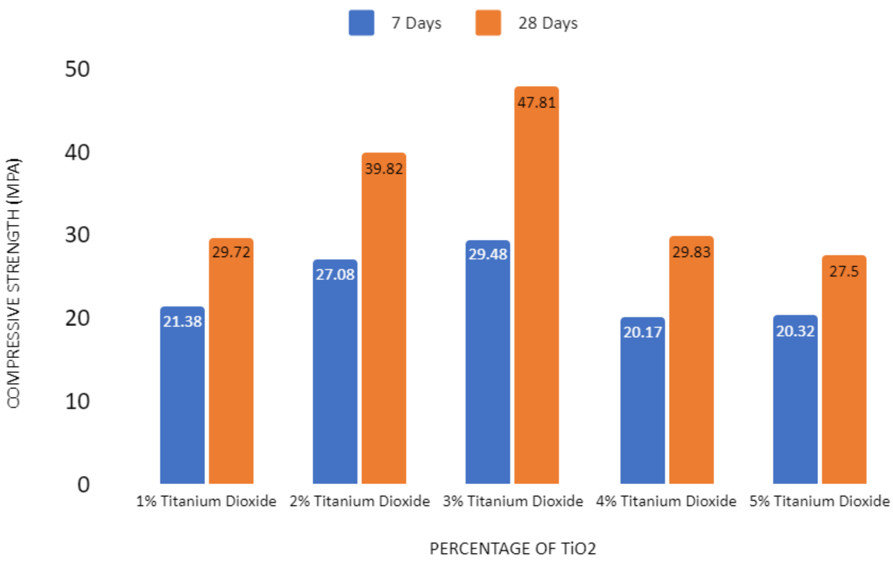

Fig 12: Graphical Representation Comparison of Compressive Strength

VI. CONCLUSION

The compressive strength was determined for the M25 grade of concrete at different curing periods and different percentages of titanium dioxide (TiO_2) dosage in concrete, as listed in Table 1. Three cubes were cast for every different percentage for different curing periods (7 days and 28 days), and average compressive strength were calculated.

The result shows that the titanium dioxide (TiO_2) added in concrete has an appreciably higher compressive strength compared to normal concrete. The increase in TiO_2 cause a gradual increase in the compressive strength of concrete, but at the same time, the study shows that the increase in compressive strength is limited to a particular percentage.

In this study, we conclude that the maximum compressive strength is obtained at 3% of TiO_2. After that it failed to gain compressive strength as it has a high amount of titanium dioxide in the concrete and a low amount of cement.

The decolorization test results show that when the TiO_2 content is high, the decolorization is also high. As the dosage of TiO_2 increases, the time of decolorization decreases. From this study, we conclude that it is advantageous to use 3% of titanium dioxide content for better compressive strength and decoloriztion.

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