IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

AN EXPERIMENTAL STUDY ON THE STRENGTH PROPERTIES OF CONCRETE WITH TITANIUM DIOXIDE

Vishnusankar C. B.[1, *], Prof. G. Elavarasan, Dr. M. Seethapathi

M.E.Structural Engineer student[1,]Professor,Civil HOD

[1]Department of Civil Engineering, TamilnaduCollege of Engineering, Coimbatore, India.

Abstract: This paper discusses an experimental investigation of the strength properties of concrete with Titanium Dioxide (TiO_2). TiO_2 consists of extremely fine particles that effectively occupy the voids present between coarse and fine aggregates. This approach can reduce voids in concrete while simultaneously increasing the compressive strength of the material. In this study, TiO_2 is utilized as a partial replacement for cement, with varying percentages of 4%, 5%, and 6% by weight. The experiments were conducted by casting the concrete of M45 grade. The selection of these percentages is based on our findings, which indicate that 4%, 5%, and 6% TiO_2 content are optimal for achieving the desired compressive strength in concrete. For the mix design of M45 concrete, established standards such as IS 10262:2009 and IS 456:2000 are employed. The experimental tests are conducted using a Universal Testing Machine (UTM) to evaluate the performance of concrete containing TiO_2 in comparison to conventional concrete. The findings of this study emphasize the positive impact of TiO_2 inclusion on the compressive strength of concrete, indicating that it can be used as an additive in concrete mixtures.

1.INTRODUCTION

Concrete, a fundamental construction material, is composed of hard and chemically inert particulate materials, including coarse aggregate, fine aggregate, cement, and water. Early civilizations like the Egyptians developed substances that resemble modern concrete by utilizing binders such as lime and gypsum. Concrete exhibits excellent compressive strength but is comparatively weaker in tensile strength. The strength of concrete is crucial for its ability to bear loads effectively. Numerous research efforts have been made to enhance concrete's strength (Fava et al. 2003Ma et al. 2015, Sorathiya et al. 2017 Khan, et al. 2018 Mansour, et al. 2021). The strength of concrete primarily depends on the composition and the quality of its ingredients. Typically, admixtures are used to increase the strength of the concrete by reducing the water content (Collepardi, 1998). During the concrete mixing process, a significant number of voids are often present, and these voids can be effectively filled using nano-particles like Titanium Dioxide (TiO2, Kushwaha et al., 2015). Titanium Dioxide (TiO2) fills voids inside the concrete while also increasing its compressive strength. Several studies demonstrated the positive impact of incorporating TiO2 into concrete mixtures alongside Ordinary Portland Cement (Praveenkumar et al. 2019). The incorporation of TiO2 has been shown to elevate both the flexural and compressive strengths of the concrete. In particular, the use of TiO2nano-particles in the concrete mixture results in a notable increase in compressive strength (Shekari et al. 2011). As the proportion of TiO_2nano-particles in the concrete mixture rises, a corresponding increase in compressive strength is observed.

By incorporating TiO2nano-particles with an average particle size ranging from 20µm to 25µm into concrete (Kushwaha et al. 2015), alongside the optimum amount of ground granulated blast furnace slag, the physical and mechanical properties of the concrete specimens were evaluated (Wang et al 2018). TiO2 nanoparticles were found to accelerate the development of Calcium-Silicate-Hydrate (C-S-H) gel when used as a partial replacement for cement by weight (Al-Saffer et al. 2023). The increased crystalline concentration during the early phases of hydration was attributable to this acceleration. As a result of the rapid C-S-H gel formation, the compressive strength of the concrete increased significantly (Khoshakhlagh et al. 2012).

1.1.Titanium Dioxide

Rutile, Anatase, and Brookite are the three major phases of titanium dioxide. Rutile is the most stable form of titanium dioxide among these. While stable at normal temperatures, anatase and brookite progressively change into rutile when exposed to high temperatures.(Sivaramalingam et al. 2021).In this study anatase based on TiO_2 was used.Titanium dioxide can be employed in a variety of industries, including a wide range of coloring applications. Concrete containing titanium dioxide has demonstrated self-cleaning properties (Osburn, 2008). This is owing to the presence of hydroxyl radicals and reactive oxygen species, which can not only oxidize contaminants but also compounds that could possibly dirty the surface. For example, organic substances and different sealants.Rhodamine B, a dye recognized for its great colorimetric value, is an example of a particularly persistent pollutant that titanium dioxide can effectively treat.

Many notable constructions, notably Rome's Dives in Misericordia Church, have been built with similar materials. Colorimetric measurements of these buildings were taken over the course of more than two years. The findings imply that photocatalytic cement has a self-cleaning effect, which allows the cement's color to be preserved. Furthermore, photocatalytic surfaces are very hydrophilic, with water contact angles approaching zero. This feature causes water to completely soak the concrete, making it easier to clear debris or chemicals that cannot be destroyed by photocatalysis.

1.2. Objective of the study

The current study aims to evaluate the properties of the concrete experimentally by partially replacing 4%, 5%, and 6% of the cement by weight with titanium dioxide. Retendering with the following test results: compressive strength of cubes on 7, 14, days, and 28 days by the addition of the above.

1.3. Applications of the project

Titanium dioxide is a highly valued substance with numerous applications in the structural and environmental elements of building and civil engineering. Among its many applications, two standouts are roofing tiles and structural concrete, both of which play critical roles in the building industry. This study is focuses on the usage of structural concrete. It aims to fill knowledge gaps and provide significant insights that can improve the use of structural concrete in buildings.

2.Methodology

This study primarily involved the casting of concrete cubes with an M45 grade using a Titanium Dioxide concrete mixture with varying Titanium Dioxide content ranging from 4% to 6%. The compressive strength of these cubes was then assessed at different curing periods, specifically at 3, 7, and 28 days, and compared to that of normal M45 concrete. Compressive and Tensile strength tests are also conducted.

2.1. Materials used

For our experiments, we utilized Ordinary Portland Cement with a grade designation of 53. We employed well-graded, angular-shaped coarse aggregate with a particle size of 20mm and fine aggregate with a particle size of 4.75mm. As for the fine aggregate, we used river sand. Both the coarse and fine aggregates were supplied locally.

2.2.Titanium dioxide

The incorporation of TiO_2 nano particles led to a noticeable increase in compressive strength after a curing period of 28 days. However, it's important to note that this improvement in compressive strength was supplemented by an enhancement in the permeability of the concrete. Furthermore, when the proportion of TiO2 nano particles in the concrete mixture grew, so did the compressive strength.

figure 1.titaniumdioxide (tio$_2$)

Properties of Titanium Dioxide

Chemical formula	=TiO_2
Molar mass	=79.866g/mol
Appearance	=white solid
Odor	=odorless
Density	=4.23g/cm^3
Specific gravity	=3.78
Melting point	=1.843ºC
Magnetic susceptibility	=5.9x10^{-6} cm^3/mol
Refractive index	=2.488(Anatase)
	=2.583(Brooktile)
	=2.609 (Rutile)

3.Mix Design

3.1.ParametersforMix DesignM45

Grade designation= M45

Type of cement= OPC53Grade

Fine aggregate= ZoneII

Specific gravity of titaniumdioxide	=3.78
Minimum cement (as percontract)	=320kg/m^3
Maximum water/cement ratio	=0.42
Degree of quality control	=Good

3.2.WaterCementRatio:

The W/CratiomentionedinTable5ofIS456is 0.45W/Cproposedis0.42.

We should adopt The W/Cratioas0.42.

Cement	=483Kg/m^3
Fine aggregate	=719Kg/m^3
Coarse aggregate	=1104Kg/m^3
Water	=203Kg/m^3
Titanium dioxide	=1.27Kg/m^3

4.Preparation of Specimen

The cube casting mold is 15x15x15cm in size, and the cylinder mold is 152x305mm in size, according to IS: 10086-1982. When constructing the mold for use, the joints between the mold pieces must be thinly coated with oil, and a similar coating of oil must be put between the contact surfaces of the mold's bottom and the base plate to guarantee that no water escapes during filling. To avoid concrete adhesion, the inside surfaces of the assembled mold should be thinly coated with oil. There are four cubes and four cylinders cast.

The concrete casting process should be done at room temperature, such as 27^{o}C.The cement and titanium dioxide were thoroughly mixed by hand before being combined with fine and coarse aggregate. Following the mixing process, the desired water content is added to the mixture. The concrete mix should then be poured into the mold in three levels with a total of 25 tamping. After 24 hours, the mold should be removed and the curing process should begin for 7 days, 14 days, and 28 days. The cubes and cylinders are removed after 7 days, 14 days, and 28 days for strength testing.

figure 2.mixing titanium dioxide,sand, and cement

figure 3.concrete mixing

figure 4.cube molding

5. Test Result for Hardened Concrete

The results obtained from the compressive strength test and split tensile strength of conventional concrete and titanium dioxide concrete is presented in this section.

5.1.Compressive Strength Test

table5.1.1.conventional concrete

Days	Compressive strength in N/mm^2
7	20
14	34
28	43

table5.1.2.titanium dioxide concrete

Titanium dioxide (TiO2)%	Average compressive strength in N/mm^2		
	7days	14days	28days
4	25.7	33	38.45
5	28.4	37	42
6	33.8	41	49

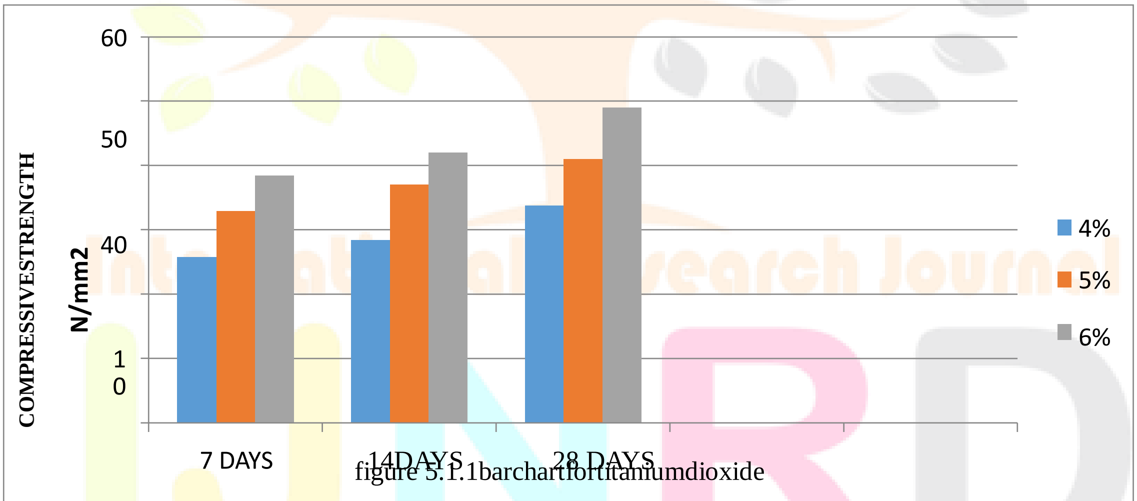

figure 5.1.1barchartfortitaniumdioxide

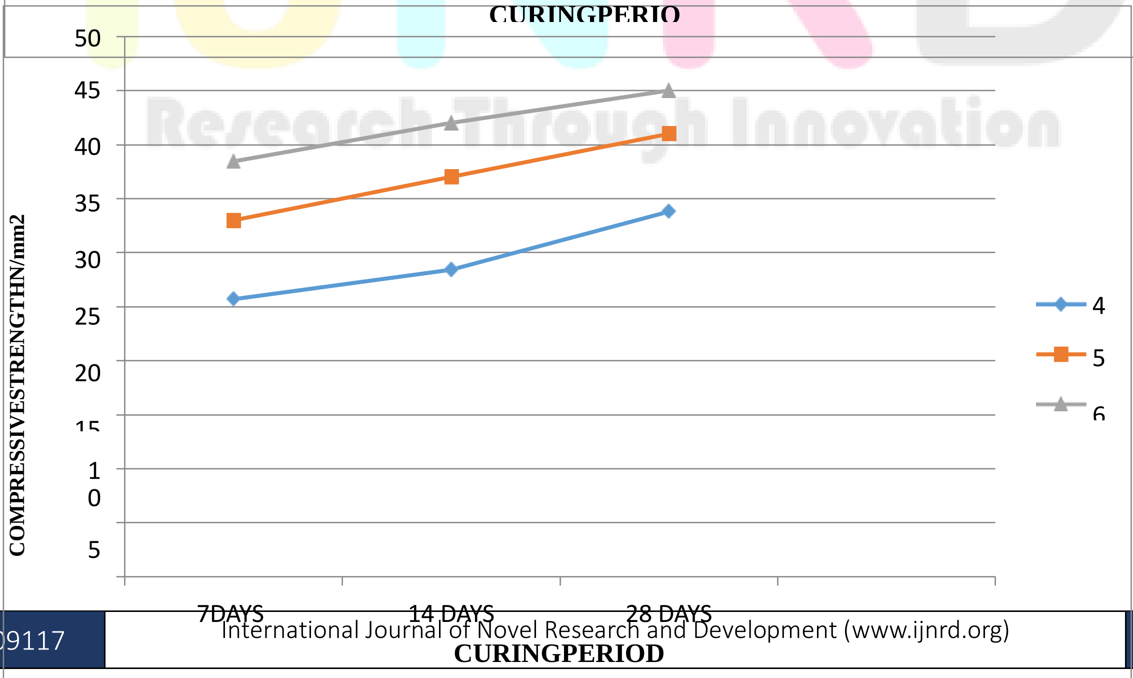

figure 5.1.2linechartfortitaniumdioxide

figure 5.1.3.compressive strength testing of concrete

5.2.Split Tensile Strength

table5.2.1 conventional concrete

Days	**Compressive strength (N/mm^2)**
7	2.78
14	3.25
28	3.92

table5.2.2 titanium dioxide concrete

TitaniumDioxide (TiO2)%	**Average split Tensile strength**		
	7days	**14days**	**28days**
4	3	3.5	4.1
5	3.6	4.2	4.91
6	3.85	4.8	5.9

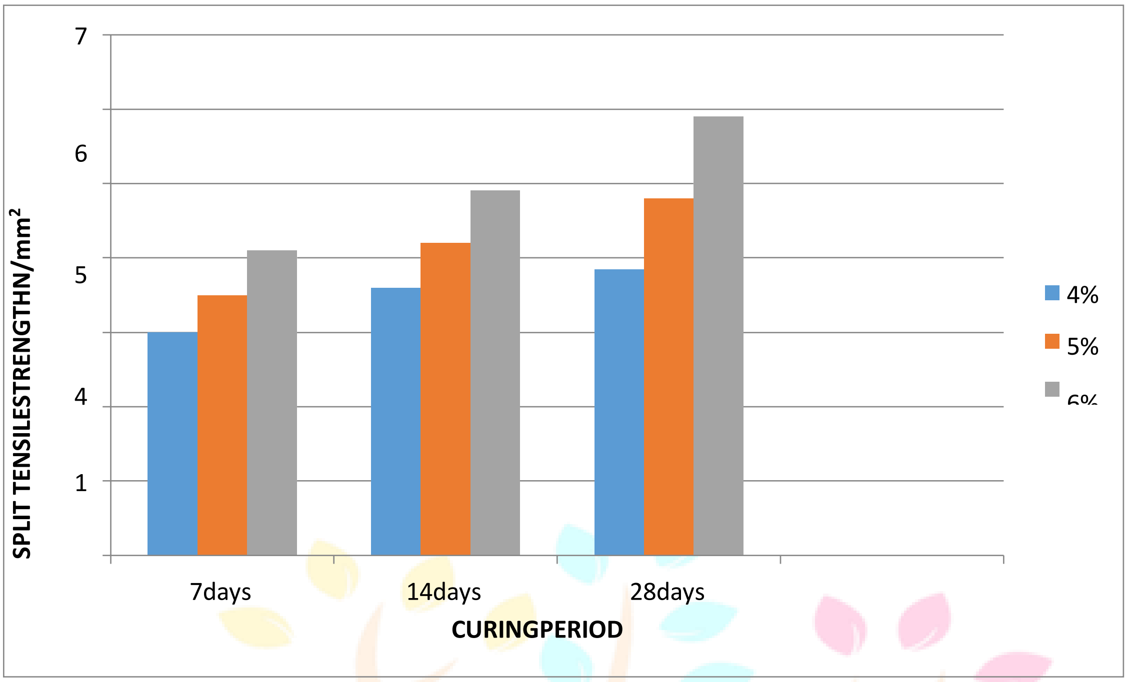

figure 5.2.1barchart for titanium dioxide

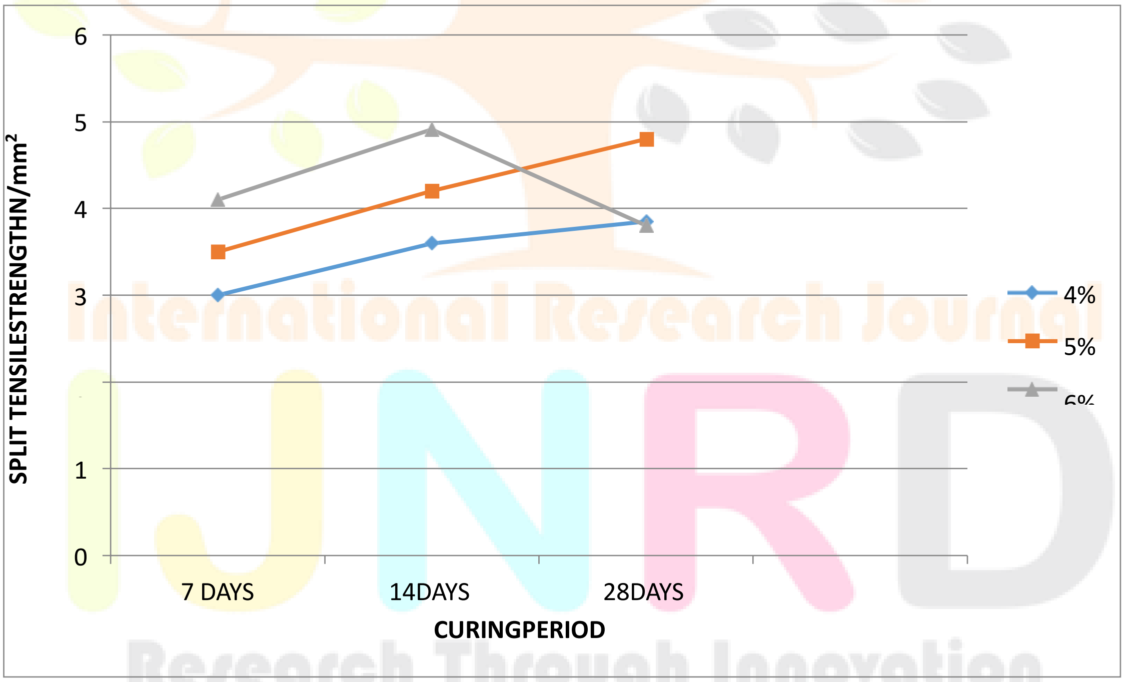

figure 5.2.2linechart for titanium dioxide

figure 5.1.1 tensile strength testing of concrete

The tables and bar charts above shows the titanium dioxide mix concrete is more strengther than conventional concrete.

6. Conclusions

Based on this experimental investigation, it is found that titaniumdioxide can be used as an additive to cement. Moreover, after 28 days of curing, the concrete with 4% titanium dioxide achieves its maximum compressive strength when compared to normal concrete. Furthermore, the maximum split tensile strength is recorded in concrete containing 4% titanium dioxide. In the context of high-strength concrete usage, a high-rise structure is typically considered to be around 30 stories tall. This allows for the potential reduction of column and beam dimensions due to the enhanced strength properties of the concrete. Furthermore, there is an economic benefit associated with the use of high-strength concrete. This benefit is derived from the increase in the amount of rentable floor space, particularly on the lower floors, as the space occupied by columns decreases.

Acknowledgments

The authors would like to thank the Department of Civil Engineering at Tamilnadu College of Engineering in Coimbatore for their continuous support.

REFERENCE

- Al-Saffar, F. Y., Wong, L. S., & Paul, S. C. (2023). An Elucidative Review of the Nanomaterial Effect on the Durability and Calcium-Silicate-Hydrate (CSH) Gel Development of Concrete. Gels, 9(8), 613.
- Collepardi, M. (1998). Admixtures used to enhance placing characteristics of concrete. Cement and concrete composites, 20(2-3), 103-112.
- Fava C, Bergol L, Fornasier G (2003).Wallevik O, Nielsson I Fracture behaviour of self -compacting concrete. Proceedings of 3rd International Rilem Symposium on Self-compacting Concrete. Rilem Publications Sarl, Reykjavik, Iceland. 628–636.
- Khan, U. A., Jahanzaib, H. M., Khan, M., & Ali, M. (2018). Improving the tensile energy absorption of high strength natural fiber reinforced concrete with fly-ash for bridge girders. Key engineering materials, 765, 335-342.
- Khoshakhlagh, A., Nazari, A., &Khalaj, G. (2012). Effects of Fe2O3 nanoparticles on water permeability and strength assessments of high strength self-compacting concrete. Journal of Materials Science & Technology, 28(1), 73-82.

- Ma, B., Li, H., Mei, J., Li, X., & Chen, F. (2015). Effects of nano-TiO 2 on the toughness and durability of cement-based material. Advances in Materials Science and Engineering.
- Mansour, W., Sakr, M., Seleemah, A., Tayeh, B. A., & Khalifa, T. (2021). Development of shear capacity equations for RC beams strengthened with UHPFRC. Computers and Concrete, 27(5), 473.
- Osburn, L. (2008). Literature review on the application of titanium dioxide reactive surfaces on urban infrastructure for depolluting and self-cleaning applications. 5th Post Graduate Conference on Construction Industry Development, Bloemfontein, South Africa, 16-18 March 2008, pp 11.
- Praveenkumar, T. R., Vijayalakshmi, M. M., &Meddah, M. S. (2019). Strengths and durability performances of blended cement concrete with TiO2 nanoparticles and rice husk ash. Construction and Building Materials, 217, 343-351.
- Shekari, A. H., &Razzaghi, M. S. (2011). Influence of nano particles on durability and mechanical properties of high performance concrete. Procedia Engineering, 14, 3036-3041.
- Sivaramalingam, A., ThankarajSalammal, S., Soosaimanickam, A., Sakthivel, T., Paul David, S., &Sambandam, B. (2021). Role of TiO2 in Highly Efficient Solar Cells. In Metal, Metal-Oxides and Metal Sulfides for Batteries, Fuel Cells, Solar Cells, Photocatalysis and Health Sensors (pp. 147-168). Cham: Springer International Publishing.
- Sorathiya, J., Shah, S., &Kacha, S. (2017). Effect on addition of nano “titanium dioxide”(TiO2) on compressive strength of cementitious concrete. Kalpa Publications in Civil Engineering, 1, 219-225.
- Wang, L., Zhang, H., & Gao, Y. (2018). Effect of TiO2 nanoparticles on physical and mechanical properties of cement at low temperatures. Advances in materials science and engineering, 2018.