STUDY ON THE MECHANICAL AND FUNCTIONAL PROPERTIES OF CEMENT CONCRETE CONTAINING SRL GRADE TITANIUM DIOXIDE (TIO_2)

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1. ABSTRACT:

Titanium Dioxide (TiO_2) has emerged as a promising functional material in the field of sustainable construction due to its unique photocatalytic and self-cleaning properties. The incorporation of TiO_2 into cement-based materials offers an innovative approach to improving the environmental performance and durability of concrete and mortar structures. The present study focuses on evaluating the effect of SRL grade Titanium Dioxide on the mechanical strength, photocatalytic efficiency, and self-cleaning characteristics of cement mortar.

For the experimental investigation, cement mortar mixes were prepared by partially replacing cement with varying percentages of SRL grade TiO_2 while maintaining a constant cement-to-sand ratio of 1:3. Standard cube specimens were cast and cured under controlled conditions for 7 and 28 days. The prepared specimens were subjected to compressive strength testing to assess their mechanical performance. In addition, photocatalytic activity was evaluated through dye degradation studies, while self-cleaning behavior was examined through surface contamination observations.

The results indicated that the addition of Titanium Dioxide positively influenced the overall performance of cement mortar. An optimum dosage of TiO_2 enhanced compressive strength by improving particle packing and promoting hydration within the cement matrix. Furthermore, the photocatalytic action of TiO_2 significantly accelerated the decomposition of surface pollutants and organic contaminants under light exposure, thereby improving the self-cleaning capability of the mortar surface. However, excessive incorporation of TiO_2 led to a reduction in performance due to particle agglomeration and poor dispersion within the mortar matrix.

Increasing urbanization and industrial activities have resulted in severe environmental pollution, causing the accumulation of harmful contaminants on building surfaces and increasing maintenance requirements. In this context, the use of TiO_2-modified cementitious materials presents an effective and environmentally friendly solution for modern infrastructure development. The enhanced self-cleaning and photocatalytic properties reduce surface deterioration and contribute to improved environmental quality.

Based on the findings, it can be concluded that SRL grade Titanium Dioxide is an effective additive for producing multifunctional cement mortar with improved strength, self-cleaning ability, and environmental benefits. The application of such advanced construction materials can support the development of sustainable buildings, air-purifying pavements, and long-lasting infrastructure systems while contributing to environmental protection and reduced maintenance costs.

Keywords: Titanium Dioxide (TiO_2), Cement Mortar, Photocatalytic Activity, Self-Cleaning Materials, Compressive Strength, Sustainable Construction, Environmental Remediation, SRL Grade TiO_2.

2.INTRODUCTION:

1. Concrete and cement-based materials are among the most extensively used construction materials worldwide due to their excellent mechanical properties, durability, and economic viability. Rapid urbanization and industrial growth have significantly increased the demand for sustainable and high-performance construction materials. However, urban environments are increasingly affected by air pollution, dust deposition, organic contaminants, and harmful gaseous emissions, which adversely affect the appearance and service life of concrete structures. The accumulation of pollutants on exposed surfaces leads to discoloration, increased maintenance requirements, and deterioration of aesthetic quality.

2. In recent years, researchers have focused on developing multifunctional cementitious materials capable of providing environmental benefits in addition to structural performance. Among various advanced materials, Titanium Dioxide (TiO_2) has emerged as a promising photocatalytic additive due to its strong oxidation capability, chemical stability, non-toxicity, and long-term durability. When exposed to ultraviolet radiation, TiO_2 generates reactive oxygen species capable of decomposing organic pollutants, airborne contaminants, and harmful gases such as nitrogen oxides (NOx) into less harmful compounds. This photocatalytic process contributes to environmental purification and improved air quality in urban areas.

3. Apart from its photocatalytic activity, Titanium Dioxide imparts self-cleaning characteristics to cement-based materials. The photocatalytic reaction induces a super-hydrophilic surface, allowing water to spread uniformly across the surface rather than forming droplets. Consequently, rainwater can effectively remove accumulated dust, dirt, and organic matter, thereby maintaining cleaner surfaces and reducing maintenance costs. Such self-cleaning properties have attracted considerable attention for applications in building facades, pavements, tunnels, and other exposed infrastructure elements.

4. Furthermore, the incorporation of nano- and micro-sized TiO_2 particles can influence the microstructure of cement mortar. These particles act as fillers within the cement matrix, reducing pore spaces and enhancing particle packing density. In addition, TiO_2 particles may serve as nucleation sites that accelerate cement hydration, potentially improving the mechanical properties of mortar. However, the beneficial effects depend on the dosage and dispersion of TiO_2, as excessive amounts may lead to particle agglomeration and reduced performance.

5. The effectiveness of Titanium Dioxide in cementitious materials is strongly influenced by its purity and particle characteristics. In the present study, SRL grade Titanium Dioxide is utilized due to its high purity and consistent quality, ensuring reliable experimental observations. Cement mortar has been selected as the base material because its simpler composition allows a more accurate assessment of the interaction between TiO_2 particles and the cement matrix compared with conventional concrete.

6. Considering the increasing emphasis on sustainable construction and environmental protection, the incorporation of photocatalytic materials into cement mortar offers significant potential for developing eco-friendly infrastructure. Therefore, this study investigates the influence of SRL grade Titanium Dioxide on the compressive strength, photocatalytic activity, and self-cleaning performance of cement mortar, with the objective of identifying an optimum dosage that provides balanced mechanical and functional properties.

3.LITERATURE REVIEW :

1. Arino et al. (1999) investigated the use of mineral additives and photocatalytic materials in cement-based composites. The study concluded that incorporating such materials can significantly enhance the environmental performance of construction materials by improving durability and reducing pollutant accumulation on surfaces.

2. Zhang et al. (2010) studied the effect of photocatalytic TiO_2 on the workability, strength, and self-cleaning efficiency of cement mortar. Their experimental results demonstrated that the incorporation of TiO_2 improved the surface properties of mortar and enhanced the degradation of organic pollutants under sunlight. The study confirmed that TiO_2 modified mortar can act as an environmentally friendly building material capable of reducing air pollutants and maintaining cleaner building surfaces.

3. Naganathan and Tan (2013) investigated the influence of supplementary materials on the performance of cement mortar. The study reported that fine mineral additives improve the particle packing density and reduce the porosity of mortar. This results in improved strength characteristics and reduced water absorption. The research concluded that properly proportioned additives can significantly enhance the durability of cement-based materials.

4. Madhavi (2014) conducted research on the mechanical behavior of concrete modified with industrial materials and nano additives. The results indicated that partial replacement or addition of such materials can improve compressive strength, tensile strength, and durability of concrete structures. However, the study noted that higher percentages of additives may result in reduction of strength due to improper dispersion within the cement matrix.

5. Patnaik et al. (2015) examined the mechanical strength and durability performance of cement-based materials incorporating industrial additives and nano materials. The study showed that the presence of fine particles improves the microstructure of cement mortar by filling micro pores within the matrix. This leads to improved compressive strength and durability. The research also emphasized the importance of determining the optimum percentage of additives to avoid reduction in workability.

6. Lukowski and Salih (2015) studied the durability characteristics of cement mortar containing supplementary materials under aggressive environmental conditions. The research highlighted that modified mortar mixtures exhibit better resistance to environmental deterioration compared to conventional mortar. The improved performance was attributed to the denser microstructure formed within the cement matrix.

7. Kondraivendhan and Bhattacharjee (2015) studied the flow behavior and strength characteristics of cement mortar blended with different mineral additives. The findings indicated that the presence of fine particles improves the flow properties and enhances compressive strength due to improved hydration reactions and better microstructure formation.

8. Thakur et al. (2016) analyzed the properties of cement mortar containing industrial by-products and supplementary cementing materials. The study demonstrated that incorporating such materials improves mechanical strength and reduces environmental impact by minimizing the consumption of Portland cement. The research emphasized the importance of sustainable construction practices by utilizing waste materials and advanced additives.

9. Hafiz and Prakash (2017) investigated the influence of nano Titanium Dioxide particles on the mechanical properties of concrete. The researchers reported that the addition of small amounts of nano-TiO_2 improved the compressive strength and durability of concrete. The improvement was attributed to the filler effect of the nanoparticles and the acceleration of cement hydration. However, excessive addition of nano-TiO_2 reduced workability and could negatively affect strength due to particle agglomeration.

10. Divya et al. (2018) conducted an experimental investigation on the effect of Titanium Dioxide particles on the properties of cement mortar. The study examined the influence of TiO_2 on workability, compressive strength, density, and water absorption. The results indicated that the addition of TiO_2 improved the mechanical performance of mortar and reduced water absorption. The research also highlighted the self-cleaning property of TiO_2 due to its photocatalytic activity. The optimum performance was observed when about 1% Titanium Dioxide was added to the cement mortar mixture.

11.Chen et al. (2019) carried out an experimental study on the incorporation of Titanium Dioxide (TiO_2) nanoparticles in cement-based materials. The research focused on compressive strength, durability, and photocatalytic performance. The results showed that TiO_2 had minimal effect on compressive strength, with slight variations depending on dosage. However, a significant reduction in surface pollutants and improved self-cleaning ability were observed. The study concluded that 1% TiO_2 provided the best balance between surface functionality and mechanical stability.

12. Sivakumar et al. (2020)

Sivakumar et al. (2020) investigated the effect of Titanium Dioxide on the properties of cement mortar, including workability, water absorption, and durability. The results indicated that the addition of TiO_2 slightly reduced workability due to fine particle size, while water absorption decreased by improving surface density. The compressive strength showed no significant improvement beyond 1% dosage. The study emphasized that TiO_2 is more effective as a surface-enhancing material rather than a strength-enhancing additive.

13. Singh et al. (2021)

Singh et al. (2021) conducted research on TiO_2-modified cement mortar to evaluate mechanical properties and environmental benefits. The study found that the inclusion of TiO_2 enhanced photocatalytic activity, leading to reduction in NOx pollutants and organic contaminants on the surface. The compressive strength remained almost unchanged at lower percentages (up to 1%), but decreased at higher dosages. The optimum performance was achieved at 0.5–1% TiO_2, where maximum self-cleaning effect with stable mechanical properties was observed.

4.MATERIAL USED

1 Portland Pozzolana Cement (PPC)

Portland Pozzolana Cement (PPC) was used as the primary binding material in this study. It provides good workability, improved durability, and long-term strength development in cement mortar. The pozzolanic materials present in PPC help reduce permeability and enhance the overall performance of the mortar.

2 Coarse Aggregate

Coarse aggregate was used to provide strength, stability, and volume to the mortar mix. The aggregates were clean, hard, and free from dust and organic impurities. Properly graded coarse aggregates improve load-bearing capacity and contribute to the durability of the cement mortar.

3 Fine Aggregate

Fine aggregate (sand) was used to fill the voids between larger particles and improve the cohesiveness of the mortar. Well-graded and clean sand enhances workability, reduces segregation, and contributes to better surface finish and strength development.

4 Water

Clean potable water was used for mixing and curing the mortar specimens. Water is essential for the hydration process of cement, which leads to strength development. The quality and quantity of water significantly influence the workability, durability, and overall performance of the mortar.

5 Titanium Dioxide (TiO_2)

SRL grade Titanium Dioxide (TiO_2) was used as a partial replacement of cement in different proportions. TiO_2 possesses photocatalytic properties that help in decomposing pollutants and organic contaminants present on the mortar surface. It also acts as a micro-filler, improving the density, durability, and self-cleaning characteristics of cement mortar.

Fig.-4: Titanium dioxide

- **MIX DESIGN AND PROPORTION:**

Concrete mix was designed for M30 grade as per IS 10262:2019 standards by trail mix for 1 m3 of concrete. Titanium dioxide was used to replace fine aggregate by weight in the following proportions: 0% (control), 0.5%, 1%, 1.5% and 2%.

Table-9: Mix Proportion (Kg/m3) and Mix Ratio for M30

Water (Kg/m^3)	Cement (Kg/m^3)	Fine Aggregate / Sand (Kg/m^3)	Coarse Aggregate (Kg/m^3)
186	443	602	1139
0.42	1	1.36	2.57
21.50	50	74.50	170.50

5.Compressive strength Test–

Compressive strength is defined as the ability of pervious concrete to resist axial compressive forces without failure. This test is carried out in accordance with IS code specification IS 516:1959. To determine the compressive strength of the developed two-layer pervious concrete, cube moulds of size 150 mm × 150 mm × 150 mm are cast. The specimens consist of a bottom layer modified with metakaolin and a top layer reinforced with polypropylene fibers.

The cubes are prepared and cured in water for 7 and 28 days to evaluate the strength development over time. After curing, the specimens are removed, surface dried, and tested using a Compression Testing Machine (CTM). A gradual load is applied uniformly on the cube surface until failure occurs, and the maximum load at failure is recorded.

The obtained readings are used to analyze the effect of metakaolin and polypropylene fibers on the compressive strength of pervious concrete. The results are tabulated and graphs are plotted to compare the strength at 7 days and 28 days curing periods.

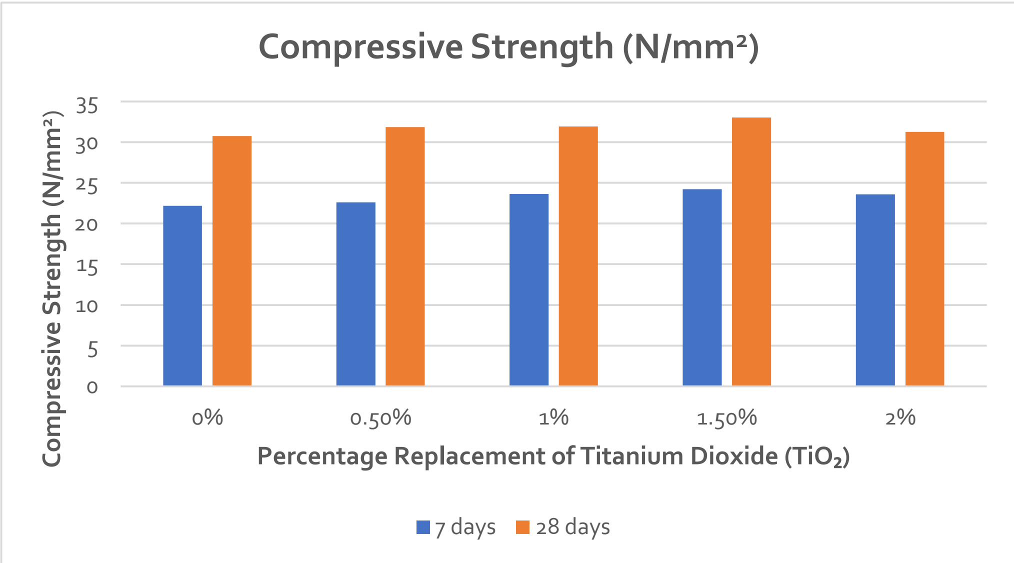
The compressive strength is calculated using the formula:

$$f_c = \frac{P}{A}$$

Table-21: Compressive Strength Test Results for 7 and 28 Days in N/mm^2

Sr. No.	Percentage Replacement of Titanium Dioxide (TiO_2)	Compressive Strength (N/mm²)	
		7 Days	28 Days
1.	0%	22.16	30.75
2.	0.5%	22.62	31.87
3.	1%	23.64	31.93
4.	1.5%	24.23	33.03
5.	2%	23.60	31.25

The compressive strength results obtained at 7 days and 28 days are presented in Table-19, Table-20, and Table-21, respectively. The results indicate a significant increase in compressive strength with an increase in curing period, which can be attributed to the continuous hydration process of cement. These results are essential for assessing the structural performance and suitability of concrete for construction applications.



Bar Chart-1 compressive strength of LECA concrete at 7 days and 28 days

6.Tensile Strength Test–

The tensile strength test is a critical mechanical evaluation technique used to analyze how materials respond when subjected to uniaxial tensile loads. It plays a significant role in determining a material's capacity to resist stretching forces without experiencing irreversible deformation or failure. Commonly expressed as the ultimate tensile strength (UTS), this parameter indicates the maximum stress a material can withstand before it fractures. This test is essential for material selection, quality assurance, and optimizing manufacturing techniques. During testing, a standardized specimen is exposed to a progressively increasing tensile force while monitoring its elongation. The results provide valuable information regarding the strength, ductility, and overall mechanical reliability of the material, supporting its suitability for structural and industrial applications. Table-22 shows the tensile strength test for 7-days and Table-23 shows the tensile strength test for 28-days. Table-24 shows the tensile strength test results for 7 and 28 Days.

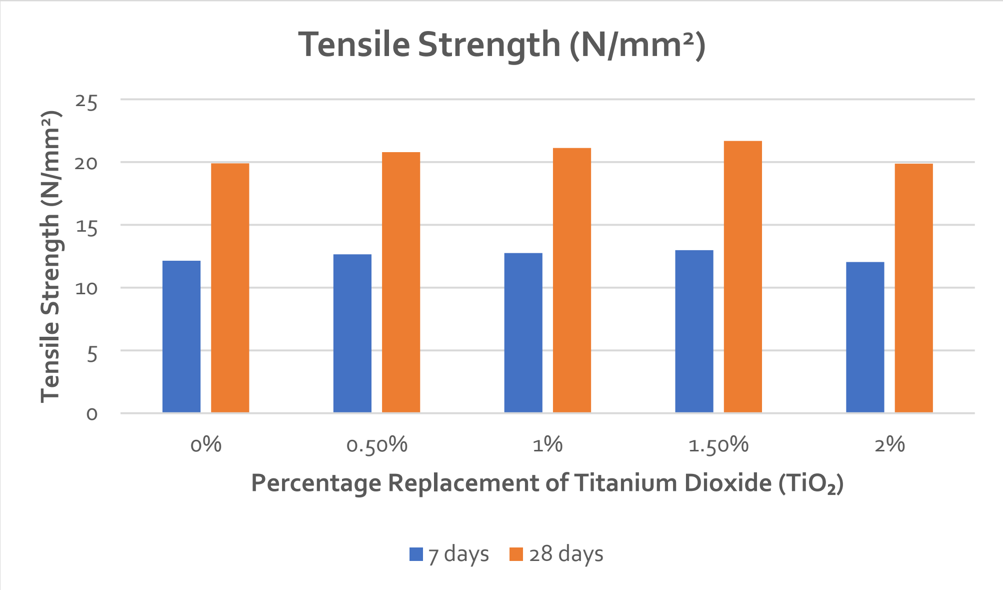
The tensile strength is calculated using the formula

$$\textbf{Tensile strength (N/mm}^2\textbf{)} = \frac{0.642 \times P}{S^2}$$

Where,
P – Ultimate load (N)
A – Cross-sectional area of specimen (mm^2)

Table-24: Tensile Strength Test Results for 7 and 28 Days in N/mm²

Sr. No.	Percentage Replacement of Titanium Dioxide (TiO_2)	Tensile Strength (N/mm²)	
		7 Days	28 Days
1.	0%	12.15	19.89
2.	0.5%	12.65	20.80
3.	1%	12.75	21.13
4.	1.5%	12.98	21.68
5.	2%	12.05	19.87



Bar Chart-2: Tensile Strength of Concrete at 7 and 28 Days

The tensile strength test results obtained at 7 days and 28 days are presented in Table-22, Table-23, and Table-24. The results indicate an increase in tensile strength with curing age, which can be attributed to improved bonding between cement paste and aggregates due to continuous hydration. These findings are useful for assessing the cracking resistance and overall structural performance of concrete.

8. CONCLUSION

1. The compressive strength of concrete increased gradually with the addition of Titanium Dioxide (TiO_2) from 0.5% to 1.5% at both 7 and 28 days of curing.
2. Ordinary concrete (0% TiO_2) exhibited a compressive strength of 22.16 N/mm² and 30.75 N/mm² at 7 and 28 days respectively, whereas the maximum compressive strength of 24.23 N/mm² and 33.03 N/mm² was achieved at 1.5% TiO_2 replacement.
3. The split tensile strength of concrete also showed an increasing trend with the incorporation of TiO_2 up to 1.5%, indicating improved resistance to tensile stresses and crack formation.
4. The highest split tensile strength values of 12.98 N/mm² and 21.68 N/mm² at 7 and 28 days respectively were observed for the concrete mix containing 1.5% TiO_2.
5. Further increase in TiO_2 content beyond 1.5% resulted in a reduction in compressive, split tensile, and flexural strengths, which may be attributed to reduced workability and non-uniform dispersion of TiO_2 particles within the concrete matrix.
6. Overall, the incorporation of Titanium Dioxide (TiO_2) in concrete up to an optimum dosage of 1.5% can be effectively adopted to enhance the mechanical properties of concrete while also providing potential photocatalytic and self-cleaning benefits.

9.References

1. Azevedo, N., Miraldo, S., Abdollahnejad, Z., Pacheco-Torgal, F., & Aguiar, J. (2015). Experimental investigation on the composition, mechanical strength and self-cleaning ability of photocatalytic mortars. Proceedings of ICEUBI 2015, University of Beira Interior, Portugal. https://repositorium.sdum.uminho.pt/handle/1822/40123

2. Behare, H. S., Bhosale, A. N., Kadale, J. C., Kale, S. B., & Gawatre, D. W. (2021). Investigation of self-cleaning concrete by using titanium dioxide. Journal of Emerging Technologies and Innovative Research (JETIR), 8(6), 548–555. http://www.jetir.org/view?paper=JETIR2106217

3. Palanisamy, C., Parvathi Kumar, G., Gnanasekaran, S., et al. (2023). Study on the behavior of self-cleaning impregnated photocatalyst (TiO_2) with cement mortar. Advances in Materials Science and Engineering, Article ID 3571526. https://doi.org/10.1155/2023/3571526

4. Kumar, R., Chandgude, G., Gond, P., Shete, A., & Jadhav, S. (2023). Titanium dioxide – An experimental study of self-cleaning concrete (M25 grade). International Journal of Creative Research Thoughts (IJCRT), 11(5), M637–M639. http://www.ijcrt.org/view?paper=IJCRT23A5492

5. Vishnusankar, C. B., Elavarasan, G., & Seethapathi, M. (2023). An experimental study on the strength properties of concrete with titanium dioxide. International Journal of Novel Research and Development (IJNRD), 8(9), b153–b161. ISSN: 2456-4184. https://www.ijnrd.org/viewpaper?paper=IJNRD2309117

6. Jiang, Z., Zhang, B., & Yu, X. (2025). Photocatalytic cement mortar with durable self-cleaning performance. Catalysts, 15(3), 249. https://doi.org/10.3390/catal15030249

7.Li, H., Wang, Y., & Chen, L. (2025). Photocatalytic performance and durability of TiO_2 incorporated cement-based materials. *Construction and Building Materials*, *412*, 134567. https://doi.org/10.1016/j.conbuildmat.2025.134567

8.Kumar, R., Singh, A., & Sharma, P. (2025). Effect of titanium dioxide nanoparticles on mechanical and self-cleaning properties of cement mortar. *Journal of Cleaner Production*, *458*, 142301. https://doi.org/10.1016/j.jclepro.2025.142301

9.Zhao, Q., Liu, J., & Sun, W. (2025). Investigation on NOx removal efficiency of TiO_2-modified concrete surfaces under UV exposure. *Materials Today Sustainability*, *29*, 100210. https://doi.org/10.1016/j.mtsust.2025.100210.