



(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 6, June 2025

⊕ www.ijirset.com 🖂 ijirset@gmail.com 🖄 +91-9940572462 🕓 +91 63819 07438





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025

|DOI: 10.15680/IJIRSET.2025.1406155|

Enhancing Concrete Strength: The Role of Nano Tio₂ in Mechanical Performance

Sarika S. Warule¹, Prof. P. V. Nimbalkar²

PG Student, Dept. of Civil Engineering, Dr. Vithalrao Vikhe Patil College of Engineering, Ahmednagar, India

Assistant Professor, Dept. of Civil Engineering, Dr. Vithalrao Vikhe Patil College of Engineering, Ahmednagar, India

ABSTRACT: Concrete is the most widely used construction material globally, yet improving its mechanical performance remains a key research focus. This study explores the potential of nano titanium dioxide (Nano TiO₂) as an additive to enhance the strength characteristics of concrete. The research aims to evaluate how different dosages of Nano TiO₂ (ranging from 0.50% to 1.5% by weight of cement) influence the compressive, tensile, and flexural strength of concrete at varying curing periods. By systematically incorporating Nano TiO₂ into concrete mixes, the study investigates its effect on early and long-term mechanical properties, seeking to identify an optimal dosage that maximizes strength without adversely affecting workability or durability. Experimental results demonstrate that Nano TiO₂ can significantly improve concrete's mechanical performance due to its high surface area, filler effect, and ability to accelerate cement hydration. The findings highlight the most effective Nano TiO₂ dosage, offering insights into the development of high-performance, nano-engineered concrete for modern construction needs.

KEYWORDS: Concrete, Titanium Dioxide, Compressive Strength.

I. INTRODUCTION

Concrete, the most ubiquitous material in the world, is a nanostructured, multiphase, composite material that ages over time (Sanchez and Sobolev, 2010). It is composed of an amorphous phase, nanometer- to micrometer-size crystals, and bound water. The properties of concrete exist in, and the degradation mechanisms occur across, multiple length scales (Nano to micro to macro) where the properties of each scale derive from those of the next smaller scale. Nano engineering of concrete can take place in one or more of the three locations such as (a) in the solid phases, (b) in the liquid phases, or (c) at the interfaces between liquid–solid and solid–solid (Garboczi, 2009).

The mechanical behavior of concrete materials depends to a great extent on structural elements and phenomena that are effective on a micro- and Nano scale. The size of the calcium silicate hydrate (C-S-H) phase, the primary component responsible for strength and other properties in cementations systems, lies in the few nanometers range (Taylor, 1997). The structure of C-S-H is much like clay, with thin layers of solids separated by gel pores filled with interlayer and adsorbed water (Mehta, 1986). This has significant impact on the performance of concrete because the structure is sensitive to moisture movement, at times resulting in shrinkage and consequent cracking if accommodations in element sizes are not made (Jennings et al., 2007). Hence, nanotechnology may have the potential to engineer concrete with superior properties through the optimization of material behavior and performance needed to significantly improve mechanical performance, durability, and sustainability. The development of nanotechnology-based concrete materials requires a multidisciplinary approach, consisting of teams of concrete materials experts: civil engineers, chemists, physicists, and materials scientists. Porto et al. (2010) presented an overview of how nanotechnology could be applied to concrete technology, emphasizing the multidisciplinary approach needed for successful breakthroughs leading to ultra-high-performance materials and new multistate models that enable the prediction of bulk material properties from composition and processing parameters. Grove et al. (2010) identified opportunities for nanotechnology leading to new concrete products and materials, and also for improving the sustainability and reducing the environmental footprint of concrete-based materials in the future. Finally, Bergeson et al. (2010) identified the following key breakthroughs in concrete technology that are most likely to result from the use of nanotechnology:

IJIRSET©2025





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025

|DOI: 10.15680/IJIRSET.2025.1406155|

- Development of high-performance cement and concrete materials as measured by their mechanical and durability properties;
- Development of sustainable concrete materials and structures through engineering for different adverse environments, reducing energy consumption during cement production, and enhancing safety;
- Development of intelligent concrete materials through the integration of nanotechnology-based self-sensing and self-powered materials and cyber infrastructure technologies;
- Development of novel concrete materials through nanotechnology-based innovative processing of cement and cement paste; and
- Development of fundamental multistate model(s) for concrete through advanced

Sr. no.	PROPERTIES OF NANO TiO2	
1	Chemical Symbol	TiO2
2	Molar Mass	79.9378g/mol
3	Melting Point	1843 [.] c
4	Boiling Point	2972
5	Density	4.23g/cc

Table 1 Properties of nano Titanium Di-oxide

II. PROBLEM STATEMENT

Concrete is one of the most widely used construction materials due to its versatility and cost-effectiveness. However, its inherent brittleness and limited mechanical strength restrict its application in demanding structural environments. Recent advances in nanotechnology suggest that incorporating nanoparticles such as Titanium Dioxide (Nano TiO₂) into concrete mixtures can potentially enhance its mechanical properties, including compressive strength, tensile strength, and durability. Despite promising preliminary findings, the optimal concentration, dispersion methods, and the underlying mechanisms by which Nano TiO₂ improves concrete strength remain insufficiently understood. This study aims to investigate the role of Nano TiO₂ in enhancing the mechanical performance of concrete, focusing on how different dosages and dispersion techniques influence its microstructure and overall strength.

III. RESULTS AND ANALYSIS



Fig 1 Compression Strength Test

Fig 2 Split tensile strength test

Fig 3 Flexural strength test





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025 |DOI: 10.15680/IJIRSET.2025.1406155|

Compression Strength Test



Graph 1 Compression Strength Test

Results are obtained by giving a gradual loading to the specimens i.e. cubes of 150mmX150mmX150mmX150mm by using universal testing machine. When the 135 specimens are observed and average of them is calculated it is observed that compressive strength of concrete after adding TiO2 increases but only up to a certain percentage limit of TiO2. This particular value is 1%. After 1% it is observed that with increase in the amount of TiO2 compressive strength starts deceasing and future addition will not result into an appreciated value.



Split tensile strength test

Results are obtained by giving a gradual loading to the specimens i.e. beam of 150mmX3000mm by using universal testing machine. When the 45 specimens are observed and average of them is calculated it is observed that split tensile

Graph 2 Split Tensile Strength Test





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025

|DOI: 10.15680/IJIRSET.2025.1406155|

strength of concrete after adding TiO2 increases but only up to a certain percentage limit of TiO2. This particular value is 1%. After 1% it is observed that with increase in the amount of TiO2 split tensile strength starts deceasing and future addition will not result into an appreciated value.

Flexural strength test



Graph 3 Flexural Strength at 28 Day

Results are obtained by giving a gradual loading to the specimens i.e. beam of 150mmX150mmX700mm by using universal testing machine. When the 45 specimens are observed and average of them is calculated it is observed that flexural strength of concrete after adding TiO2 increases but only up to a certain percentage limit of TiO2. This particular value is 1%. After 1% it is observed that with increase in the amount of TiO2 flexural strength starts deceasing and future addition will not result into an appreciated value.

Sulphate Attack Test (Potassium Sulphate (K2So4))

Sr. No.	Type of Concrete	At 7 days (N/mm ²)	At 28 days (N/mm ²)	At 56 days (N/mm ²)
1	Normal Concrete	24.52	29.12	29.36
2	0.50%	25.77	30.97	31.17
3	0.75%	25.91	31.82	33.41
4	1%	27.62	35.59	35.93
5	1.25%	23.56	34.13	34.33
6	1.5%	22.28	32.96	33.27

Table 2 Sulphate attack test

Results are obtained by giving a gradual loading to the specimens i.e. cubes of 150mmX150mmX150mmX150mm by using universal testing machine. When the specimens are observed and average of them is calculated it is observed that compressive strength of concrete after adding TiO2 increases but because of potassium sulphate it again decreases therefore it can be concluded that adding TiO2 thus increases the strength of the concrete but it should be made safe against the potassium sulphate because it does affects the strength of the concrete.





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025

|DOI: 10.15680/IJIRSET.2025.1406155|

Chloride Attack (Sodium Chloride (NACL)

Table 2 Chloride attack test

Sr. No.	Type of Concrete	At 7 days (N/mm2)	At 28 days (N/mm2)	At 56 days (N/mm2)
1	Normal Concrete	25.96	29.89	30.07
2	0.50%	25.11	31.09	31.24
3	0.75%	25.94	32.98	33.84
4	1%	27.39	35.35	35.29
5	1.25%	26.96	33.95	34.57
6	1.5%	26.11	33.09	33.72

Results are obtained by giving a gradual loading to the specimens i.e. Cubes of 150mmx150mmx150mm by using universal testing machine. When the specimens are observed and average of them is calculated it is observed that compressive strength of concrete after adding tio2 increases but because of chloride content it again decreases therefore it can be concluded that adding tio2 thus increases the strength of the concrete but it should be made safe against the chloride content because it does affects the strength of the concrete.

IV. CONCLUSION

Based on the experimental work reported in this study, the following conclusions are drawn:

- Nano materials are the good source of chemicals used for the incrimination of the strength of the ordinary concrete. In this report we had used Titanium di-oxide which is also a Nano material.
- When compressive strength of the concrete added with Nano TiO2 is measured it is found that up to 1% addition of TiO2 b.w.c the compressive strength of the concrete increases by 10.26% at 7 day, 23.23% at 28 day and 22.96% at 56th day.
- When Flexural strength of the concrete added with nano TiO2 is measured it is found that upto 1% addition of TiO2 b.w.c the flexural strength of the concrete increases by 96.14% at 7 day, 66.54% at 28 day and 71.29% at 56 day.
- When split tensile strength of the concrete added with Nano TiO2 is measured it is found that upto 1% addition of TiO2 b.w.c the split tensile strength of the concrete increases by 92.73% at 7 day, 82.57% at 28 day and 87.23% at 56 day.
- When sulphate attack of the concrete added with nano TiO2 is checked it is found that for 1% addition of TiO2 b.w.c the compressive strength due to sulphate attack of the concrete decreases by 4.42% at7 day, 3.45% at 28 day and 2.78% at56 day.
- When chloride attack of the concrete added with Nano TiO2 is checked it is found that for 1% addition of Tio2 b.w.c the compressive strength due to chloride attack of the concrete decreases by 5.22% on 7th day, 4.38% on 28th day and 4.33% on 56th day.
- Hence it can be concluded that use of TiO2 is advisable upto the 1% by weight of the cement for getting good mechanical properties.

REFERENCES

- [1] Abdullah, Gamil M. S. et al. (2024) "Effect of titanium dioxide as nanomaterials on mechanical and durability properties of rubberised concrete by applying RSM modelling and optimizations" Original Research article
- [2] Ayad, Achraf & Aly Said (2018) "Using Colloidal Nano Silica to Enhance the Performance of Cementitious Mortars" Open Journal of Civil Engineering
- [3] El-Sayed Salama, Ahmed Hamed et al. (2024) "Mechanical Performance and Microstructure Evolution of Nano-TiO₂ Enhanced Cement – A Comprehensive Experimental Analysis" Advances in Science and Technology – Research Journal
- [4] Dhanapal, Jegatheeswaran et al. (2024) "Eco-Friendly Concrete Solutions: The Role of Titanium Dioxide Nanoparticles in Enhancing Durability and Reducing Environmental Pollutants - A Review" Journal of Environmental Nanotechnology





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025

|DOI: 10.15680/IJIRSET.2025.1406155|

- [5] Döndürena, Mahmud Sami et al. (2022) "A review of the effect and optimization of use of nano-TiO₂ in cementitious composites" Res. Eng. Struct. Mater
- [6] Garg, Rishav et al. (2021) "Experimental Investigation of Electrochemical Corrosion and Chloride Penetration of Concrete Incorporating Colloidal Nanosilica and Silica Fume" J. Electrochem. Sci. Technol
- [7] Hase, B. A., & V. R. Rathi (2015) "Experimental Study On Mechanical Properties Of Concrete By Replacement Of Cement With SCBA And Nano Silica" Journal of Emerging Technologies and Innovative Research
- [8] Hendrix, Douglas et al. (2019) "Behavior of Colloidal Nanosilica in an Ultrahigh Performance Concrete Environment Using Dynamic Light Scattering" MDPI
- [9] IS: 1199-1959. "Indian Standard methods of sampling and analysis of concrete". Bureau of Indian Standards
- [10] IS 10262:2009. "Recommended Guidelines for Concrete Mix Designs". Bureau of Indian Standards
- [11] IS: 1489 (Part 1)-1991. "Specifications for Portland Pozzolana Cement". Bureau of Indian Standards
- [12] IS 516:1959. "Methods of Test for strength of concrete". Bureau of Indian Standards
- [13] IS 383:1970. "Specification For Coarse and Fine Aggregates from Natural Sources for Concrete". Bureau of Indian Standards
- [14] Jenima, J et al. (2024) "A comprehensive review of titanium dioxide nanoparticles in cementitious composites" Heliyon
- [15] Jayakalyani, P et al. (2023) "Study on effects of TiO₂ Nano particles on properties of concrete" IOP Conf. Series: Earth and Environmental Science
- [16] Kim, Taewan et al. (2019) "Characteristics of Ordinary Portland Cement Using the New Colloidal Nano-Silica Mixing Method" applsci, MDPI
- [17] Narender Reddy, Avuthu (2019) "An Experimental Study to Find the Optimum Dosage of Admixtures in Blended Concrete" International Journal of Recent Technology and Engineering
- [18] Pathak, Sudhanshu Sanjeev et al. (2022) "Effect of nano TiO₂ on mechanical properties and microstructure of concrete" Materials Today Proceedings
- [19] Rana, Deepika et al. (2018) "Experimental Study of Strength Property of Concrete Using Nanosilica" International Research Journal of Engineering and Technology (IRJET)
- [20] Rathi, V. R., & C. D. Modhera (2016) "Effect Of Colloidal Nano Silica (CNS) On Properties Of High Strength Concrete At Elevated Temperature" International Journal of Civil Engineering and Technology
- [21] Redaelli, Elena et al. (2016) "Effects of Nanosilica on Early Age Stages of Cement Hydration" Journal of Nanomaterials
- [22] Saloma et al. (2015) "Improvement of concrete durability by nanomaterials" The 5th International Conference of Euro Asia Civil Engineering Forum
- [23] Sorathiya, Jay et al. (2017) "Effect on Addition of Nano Titanium Dioxide (TiO₂) on Compressive Strength of Cementitious Concrete" International Conference on Research and Innovations in Science
- [24] Vandhiyan, R. & E. B. Perumal Pillai (2018) "Influence of Nano Silica Addition on the Behavior of Concrete and Its Impact on Corrosion Resistance" Journal of Computational and Theoretical









INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY





www.ijirset.com