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Effect on Addition of Nano "Titanium Dioxide" (TiO_2) on Compressive Strength of Cementitious Concrete

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Abstract

Cementitious concrete has great practical difficulties in achieving high compressive strength and durability of high performance structures. But it becomes a challenge to increase the compressive strength and durability of particular cementitious composite and also maintaining basic desirable properties of concrete. This paper addresses these problems by the addition of nano-materials. In this study, an attempt is made to understand the effect of Anatase Nano Titanium Dioxide (TiO_2), on Conventional Concrete (CC) of M_{20} grade with various proportions 0.5%, 0.75%, 1.0%, 1.25%, 1.5% in relation with the weight of cement. The Workability, Strength parameters at various proportions of Anatase Nano Titanium Dioxide (TiO_2) are tested at different durations. The results obtained are being discussed in the paper.

Keywords: Nano Material, Nano Titanium dioxide, Workability, Strength, conventional concrete.

Abbreviations:
TiO_2: Titanium Dioxide
CC: Conventional concrete
NS: Nano silica

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1 Introduction

The American physicist Richard Feynman tended to, "There's Plenty of Room at the Bottom," at an American Physical Society meeting at Caltech on December 29, 1959, which is routinely held to have offered inspiration to the field of nanotechnology. Nano, which begins from the Greek word for little individual. Nanotechnology is the re-planning of materials by controlling the matter at the atomic level. The key in nanotechnology is the measure of particles considering the way that the properties of materials are affected under a size of nano meter [10^{-9} meter]. Owing to various noteworthy characteristics of nanotechnology derived things, as of late made nano based things can basically diminish current auxiliary building issues. Basically, improvement oversees imaginative materials and methods that have been use being developed. Nanotechnology is the use of very small pieces of material by themselves or their manipulation to create new large scale materials. Types of nano materials:

a. Titanium dioxide (TiO_2)
b. Carbon nanotubes (CNT's)
c. Nano silica (ns)
d. Polycarboxilates
e. Nano Zro_2, etc.

Alaa M. Rashad [1,3] Cementitious composites characteristically demonstrate extremely brittle failure, low tensile capacity and predisposed to cracking. These characteristics of cement Based materials are serious shortcomings that not only impose constraints in structural design, but also affect the long-term durability of structures. To overcome these disadvantages, nanoparticles have been added to the cementitious composites. The addition of nanoparticles into cement concrete is gaining an attention due to their high surface area and therefore high reactivity. Recent experiments have shown that nanoparticles improved the mechanical properties of CSH, reduced porosity and modified the durability of cement matrix.

Nanotechnology use in design and construction process with unique properties, lighter and composite material, sound absorber, fire resistance, water repellents, air cleaners, self-disinfecting surfaces, low maintenance coating. Titanium Dioxide (TiO_2) is very well known and well researched material. The titanium atomic number is 22 and atomic weight is 47.86. Gianluca L. et al**. [14]** Titanium dioxide exists in three mineral forms Anatase, Rutile and Brookite (Fig.1) G. Meacock et al. [11] Anatase type TiO_2 has a crystalline structure that corresponds to the tetragonal system, Rutile type TiO_2 also has a tetragonal crystal structure, Brookite type TiO_2 has a crystalline structure that corresponds to the orthorhombic crystalline structure. Titanium Dioxide is a versatile material that has applications in various products such as paint pigments, sunscreen lotions, electrochemical electrodes, capacitors, solar cells and even as a food colouring agent and in toothpastes**.** G. Husken et al. [10] The manufactured concrete is named as self-cleaning concrete or photocatalytic concrete. This concrete is also known as Green Concrete due to its self-cleaning properties. The applications of nano photocatalytic concrete also include environmental pollution self-disinfecting and cleansing.

2 Literature Review

The Research work has been carried out towards utilization of nano TiO_2 as a concrete ingredient; following are some of the research work in the field.

Nazari, Ali, et al**. [4]** added N1, N2, N3 and N4 are the series N blended concrete with 0.5%, 1.0%, 1.5% and 2.0% of nano-TiO_2 particles, respectively per weight of cement in the concrete and Fixed w/c ratio of 0.4 was used. It was derived that the workability reduction, increased with the increasing NT

(Nano Titanium Dioxide) content and compressive strength of concrete after 28 days was 13.86%, 17.93%, 15.49% and 6.79% increased with the inclusion of 0.5%, 1%, 1.5%, and 2%NT respectively its original strength. The final result of 1% NT contain is the optimum. L. Bagel et al. [**15, 16**] Concrete is a porous and heterogeneous material, in which there are many pores with different shapes and sizes. It is well known that the pore structure of concrete, strongly influences its physical properties. Many important properties, such as permeability and strength, are directly or indirectly related to the pore structure of concrete. Mao-hua Zhang, Hui Li [**17**] Added 1%, 3% and 5% TiO_2 per cement weight in the concrete and water reducing agents added. It was derived that the reduction in the workability with the inclusion of NT, the reduction in the slump values was 54.54% with the inclusion of 1% or 3%NT, and 72.75% with the inclusion of 5% NT., Concrete after 28 days Increase Compressive strength was 18.03%, 12.76%, and 1.55% respectively its original strength. Ali Nazari [**18**] the author added 0.5%, 1%, 1.5%, and 2% TiO_2 per cement weight in the cement paste. The different pastes were mixed with water or saturated limewater. It was derived that Total heat released decreased with higher content of the NT. The heat of hydration of pastes containing saturated limewater sample was lower than that containing water and concrete after 28 days Increase Compressive strength 13.64%, 20.45%, 15.91% & 11.36%, respectively cured in water and Increase Compressive strength 36.58%, 48.78%, 56.1% & 65.85% respectively cured in saturated limewater its original strength. Abhishek Singh Kushwaha et al. [**13**] Replacement of cement by weight 1%, 2% and 3% TiO_2 in the concrete. Concrete after 28 days decrease Compressive strength was 38.95%, 24.98%, and 16.86% respectively its original strength.

3 Experimental Work

3.1 Material

- Cement

Portland Pozzolana cement conforming to [**7**] IS 1489 (Part 1): 1991 was used to obtain from Ultratech cement. The physical properties of cement are given in Table 1.

- Fine aggregate

Nearby available river sand was used as fine aggregate as per [**9**] IS 383: 1970 their properties are given below. Fine aggregate size must be less than 4.75mm.

- Coarse aggregate

Coarse aggregate size is maximum 20mm used to experiment as meeting the requirements to IS: 383, 1970. Their properties are given in Table no. 3

- Water

Casting and curing in tap water used at available in the college area.

- Nano Titanium Dioxide (TiO_2)

Nano titanium dioxide powder is directly obtained from NANO WINGS PVT. LTD., KHAMMAM-TELANGANA, INDIA. SEM image provided by the above company shown in figure 2. Properties of Nano material listed Table no. 4 provided by Nano Wing Pvt. Ltd.:

Physical Properties of Cement		
Component	Results	Requirements
Fineness (m^2/kg)	363	300 Min.
Standard Consistency (%)	32.5	-
Initial setting time (min.)	170	30 Min.
Final setting time, minutes	270	600 Max.
Soundness Le-Chat Expansion (mm)	0.4	10 Max.
% fly ash addition	28	15 Min.– 35Max.
Compressive Strength, at 28 days (N/mm^2)	60	33 Min.

Table 1: Physical Properties of Cement

Property	Results of Natural Sand
Bulk Density (kg/m^3)	1230
Specific Gravity	2.55
Fineness Modulus	3.20
Water Absorption (%)	1.41

Table 2: Physical properties of fine aggregate

Property	Results of Natural Sand
Bulk Density (kg/m^3)	1342
Specific Gravity	2.74
Fineness Modulus	4.6
Water Absorption (%)	1.5

Table 3: Physical properties of coarse aggregate

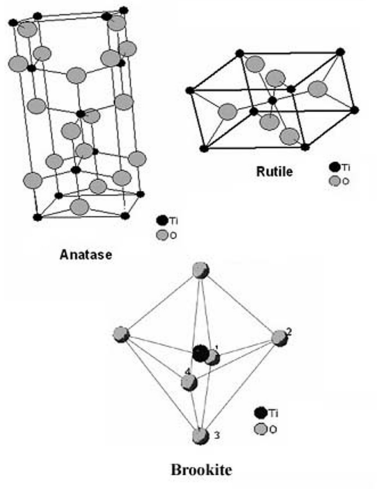

Figure 1: Different forms of TiO_2 (11)

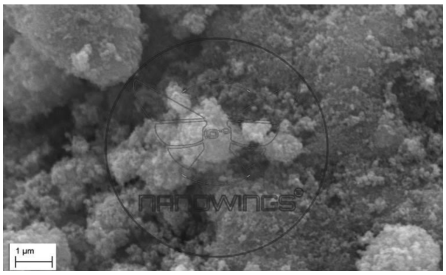

Figure 2: SEM image of TiO_2

Figure 3: nano TiO_2 powder

3.2 Mix Proportions and Mix Design

In this research, M-20 grade of concrete designed as per [6] IS 10262:2009. Concrete mixtures with different proportions of Nano TiO_2 0.5% to 1.5% were cast. Mix design is given in Table no.5

3.3 Tests

- Workability

The property of concrete, which determines the amount of useful internal work necessary to produce full compaction is known as workability. The workability of fresh concrete depends mainly on the material, mix proportion and environmental conditions. The workability of a slump test in the concrete was determined according to [5] IS 1199: 1959.

- Compressive Strength

Compressive tests were conducted [8] IS 516-1959 on a 15cmx15cmx15cm cube sample of concrete. For each mixture, three cubes were cast then demoulding after 24 hours. Put the 7 and 28 days curing in water at room temperature. After the 7 and 28 days curing cubes tested under Compression testing machine of 2000 KN capacity.

Component	**Results**
Appearance	White Powder
Bulk Relative Density	3.78 g/cm^3
Crystalline Phase	Anatase
Molecular Weight	79.87 g/mole
Specific Surface area	60 m^2/g
Average Particle Size	50-200 nm
Crystallite Size	10-30nm
Shape	Nearly Spherical
Purity	99%
pH value	6.7

Table 4: Property of nano TiO_2

Volume of Concrete	By Weight (kg/m^3)	By Volume
Cement	290	1
Water	145	0.5
Fine Aggregate	696	2.4
C.A. (20 mm)	1029	3.55
C.A. (10 mm)	400	1.38

Table 5: M-20 mix design proportions

4 Results & Discussion

- Workability

The workability of the concrete mixes with different proportions of used Nano Titanium Dioxide was determined using a slump test having a same w/c ratio for all the mixes and it was observed from the figure 5 that used Nano Titanium dioxide causes orderly decrease in workability as the added of Nano Titanium Dioxide percentage increases.

- Compressive Strength

Added various proportions of titanium dioxide in concrete and increase the compressive strength of concrete. It was observed from the figure 7. The Maximum increase in compressive strength of concrete was observed with 1% used TiO_2, both at 7 and 28 days.

Figure 4: Slump test

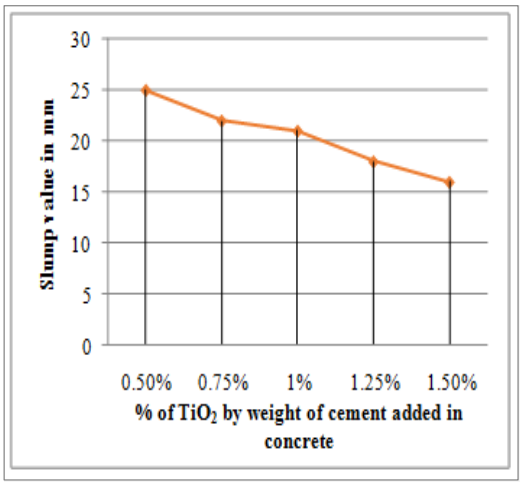

Figure 5: Slump test result

Figure 6: Compression test

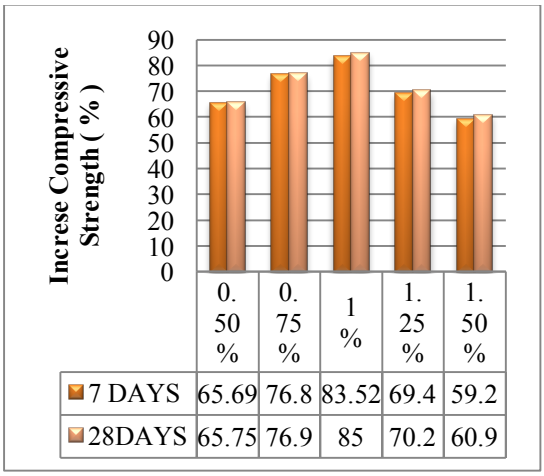

Figure 7: Compressive test result

5 Conclusions

The results show that the nano-TiO_2 particles added concrete had appreciably higher compressive strength comparable to that of the normal concrete. The increase in nano TiO_2 content there is gradual increase in strength as the pores has been filled with TiO_2 because of that strength is increased. It is found that the cement could be gainfully added with nano- TiO_2 particle up to maximum limit of 1.0% with average particle sizes of 15 nm. Although, the optimal level of nano- TiO_2 particle content was achieved with 1.0% added. By increasing percentage of toi2 more than 1%, compressive strength of the concrete is decreased this happen due to the decrease of crystalline $Ca(OH)_2$ content required for C-S-H gel formation and unsuitably dispersed nanoparticles in the concrete matrix. Nano-TiO_2 particles added in concrete by weight of cement decreased workability of fresh concrete with respect to increase the content of titanium dioxide in concrete.

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