WORKABILITY AND STRENGTH CHARACTERISTICS OF M60 GRADE CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH NANO TiO_2

M Suneel[1], K Jagadeep[1], P Venkateswara Rao [1]

1. S R K R Engineering College, Andhra Pradesh, India

ABSTRACT. Nano TiO_2 is the one of the most common materials used in paints as pigment because of its various advantages. Nano TiO_2 can be used as filler material in concrete for filling several intervals in concrete such as flaws, voids, fissures, bleeding channels, etc, by which the strength of the concrete can be improved. In the present work, it is aimed to study the performance of M60 grade high strength concrete with the use of nanomaterials has been carried out by replacing the cement partially with nano titanium dioxide (TiO_2) (ranging from 0.5% to 2%). The workability of M60 grade concrete with and without incorporating Nano TiO_2 has been studied by conducting slump cone test and compaction factor test. Finally, the strength characteristics of both the concrete have examined by performing compression, split tensile and flexural tests. The application of nanotechnology by incorporating nanomaterials in concrete has added a new dimension to improve the mechanical properties of the concrete.Workability is decreased with the increase in replacement and strength is increased up to 1% replacement of cement. Based on the experimental results, it was noticed that at 1% replacement of cement, the compressive strength of the concrete was increased by 6% when compared to the conventional concrete. This concrete is used at the places where high strength and low permeability are required.

Keywords: Nano technology**,** Nano TiO_2, High strength concrete.

M Suneel is an Assistant Professor in the Department of Civil Engineering, S.R.K.R. Engineering College, Andhra Pradesh, India. He has five years experience in construction. His research interest includes workability and strength characteristics of concrete by using different materials.

K Jagadeep, is an Assistant Professor in the Department of Civil Engineering, S.R.K.R. Engineering College, Andhra Pradesh, India. His research interest includes concrete properties and building drawing.

P Venkateswara Rao, is an Assistant Professor in the Department of Civil Engineering, S.R.K.R. Engineering College, Andhra Pradesh, India. He has three years experience in construction. His research interest includes concrete and surveying.

INTRODUCTION

It is well known that concrete is a heterogeneous and porous material, in which there are many pores with different sizes and shapes. Physical properties of concrete are influenced by its pore structure. Directly or indirectly many important properties, such as strength and permeability, are related to the pore structure of concrete [1, 2]. It is generally agreed that the pore structure of concrete is one of its most important characteristics and strongly affects both its durability and mechanical properties [3].

Nanotechnology is one of the most research areas which have wide applications in almost all the fields. These finer size particles would get filled in the voids by which there would be possible improvement of mechanical properties of the concrete. Nano-particles when added in small quantity to the cement paste, during hydration due to nano particle's great surface energy the hydrate products of cement will deposit on them and grow to form conglomeration containing the nano-particles as 'nucleus'. Microstructures between the cement mortar mixed with the nano-particles and the plain cement mortar showed that the nano particles filled up the pores and reduced $Ca(OH)_2$ compound among the hydrates. The strengthening effect of nano-particles would be further enhanced in concrete because the nano-particles improve not only the cement paste, but also the interface between paste and aggregates [4].

The compressive and flexural strengths of concretes containing nano-SiO_2 are lower than that of concretes containing the same amount of nano-TiO_2, which is primarily attributed to the fact that the particle diameter of nano-SiO_2 (10nm) is smaller than that of nano-TiO_2 (15nm), and the specific surface area of nano-SiO_2 ($640m^2/g$) is much larger than that of nano-TiO_2 ($240m^2/g$), so that it is more difficult to uniformly disperse than nano-TiO_2 in cement matrix [5].

There are different types of Nano materials. Some of them used in construction are carbon Nano tubes, Nano clays, mineral oxides such as silica, alumina, metallic oxides such as zinc, iron, titanium, zirconium etc. Recently, the addition of nano-TiO_2 into cement-based material has drawn great attention due to its chemical stability, high catalytic activity and low price [6–8]. One of the shortages of introducing nano-particle into cementitious material is the reduction of the workability due to its high specific surface area [9, 10]. The increase of the amount of water needed when nano-particle is added could be due to its small size and great surface area, which will absorb more water on the surface [11, 12].

The seeding effect of nano-TiO_2 promotes the hydration process of cement, which finally leads to a more compact structure of the hardened paste. Nano-TiO_2 increases the compressive strength of cementitious material due to its ability of pore refining and the hydration acceleration effects. The drying shrinkage of nano-TiO_2 added cement-based materials is mitigated by the reduced water loss introduced by its effects on the refining of the pores and the increase of the hydrophilicity of the paste [13]. Concrete properties by incorporation of Nano particles have shown significant results than conventional concrete.

In the present work, an experimental investigation is carried out to study M60 grade high strength concrete with the use of Nano materials by replacing the cement with Nano Titanium Dioxide ranging from 0.5% to 2%. Based on the literature using nano materials will increase density and strength of the concrete, for the present study grade of the concrete is chosen as M60 and it falls in high strength category as per IS 456:2000. Fresh and hardened properties of M60 grade concrete with and without incorporating Nano Titanium Dioxide are studied.

MATERIALS

The materials used in this experimental study for preparing M40 grade concrete by partial replacement of cement with Nano Titanium dioxide are Cement (OPC 53 grade), Nano Titanium Dioxide(TiO_2), fine aggregate, coarse aggregate, water and super plasticizer.

Cement

One of the main ingredients in the concrete is the cement which acts as binding material. In the present study fine ground cement like Ordinary Portland cement (OPC) 53 grade cement is used in order to reduce the pores size in the concrete for the entire work. The cement procured is tested for physical requirements in accordance with IS: 12269-1987. Some physical properties are shown in Table 1.

Table 1 Physical properties of Cement OPC 53

S.NO	PROPERTY		TEST RESULT
1.	Normal Consistency		32%
2.	Setting time	Initial	130 min
		Final	270 min
3.	Specific Gravity		3.15
4.	Compressive strength of cement mortar(1:3)	3(Days)	28.10 MPa
		7(Days)	44.60 MPa
		28(Days)	57.30 MPa

Nano Titanium Dioxide (TiO_2)

Titanium dioxide is one of the most widely used inorganic materials in the world. Nano TiO_2 is naturally occurring oxides of Titanium. Titanium dioxide is also known as 'Titania'. The most common form is pigmentary Titanium dioxide (white solid inorganic substance). It is in white powder form with Nano particles of size ranging from 1-100nm.

Nano TiO_2 particles is second Nano metal oxide particle mostly used for cement-based materials, photo catalytic effect is an important feature needed for Nano engineered building materials. Nano TiO_2 high density about 3.9g/cm^3 and consequently it's higher hardness has a direct impact on cement-based properties and durability.

Fine Aggregate

The river sand, passing through 4.75 mm sieve and retained on 600 µm sieve, confirming to Zone II as per IS 383-1970 was used as fine aggregate in the present study. The sand is free from clay, silt and organic impurities. The physical properties values are tabulated in Table 2.

Coarse Aggregate

Throughout the investigation, crushed coarse aggregates of size 20 mm and 10 mm from the crushing plants are procured and used. The aggregate is tested for its physical requirements are tabulated in Table 3.

Table 2 Properties of Fine Aggregate

S.NO	PROPERTIES	TEST RESULTS
1.	Specific gravity	2.58
2.	Bulk density (kg/m^3)	1620(loose state) 1750(dense state)
3.	Fineness Modulus	2.74
4.	Zone	II

Table 3 Properties of 20mm Coarse Aggregate

S.NO.	PROPERTY	TEST RESULTS
1.	Bulk density(kg/m^3)	1400(loose state)
2.	Specific gravity	2.72
3.	Fineness modulus	7.17

Water

Water is the most important and least expensive ingredient of concrete. Fresh potable water free from organic matter and oil is used in mixing the concrete. Water in required quantities were measured by graduated jar and added to the concrete.

Super Plasticizer (Fosroc Conplast SP430)

Conplast SP430 is a chloride free, super plasticizing admixture is used for concrete making. It is supplied as a brown solution which instantly disperses in water. Conplast SP430 acts as a dispersing agent and reduces water content about 30%. Water logged between cement grains is released when superplasticizer is added to concrete. By using super plasticizers with low water cement ratio workability can be improved and increase in the strength can be seen.

EXPERIMENTAL PROGRAM

In the present investigation for M60 grade concrete mix proportion is obtained as per IS 10262: 2009 method. Several trial mixes are conducted without adding super plasticizers and it is noticed that mixes are stiff with poor workability. In order to improve workability of the concrete, trial mixes are prepared to fix the dosage of super plasticizer. For all the mixes super plasticizer is added at 0.8% by mass of cement. Mix proportion obtained is shown in Table 4.

Table 4 Mix proportion for M60 Concrete

CEMENT	FINE AGGREGATE	COARSE AGGREGATE	W/C RATIO
1	1.516	2.96	0.35

Totally 5 mixes are prepared with Nano TiO_2 ranging from 0% to 2% as partial replacement of cement to investigate experimentally workability and strength characteristics of M40 grade concrete. As per IS 1199(1959) workability is studied by conducting slump cone test and compaction factor test. As per IS 516(1959) and IS 5816(1999) strengths of the concrete is investigated by conducting tests.

Casting of Specimens

The cast iron moulds are cleaned of dust particles and applied with mineral oil on all the sides, moulds are tightened properly before concrete is poured into moulds. The moulds are placed in the level platform of table vibrating machine. The concrete is filled into the moulds in three layers and vibrated after filling each layer. Excess concrete is removed with a trowel and top surface is finished to mould level and smooth.

Cubical specimens of size 100mm×100mm×100mm are casted for the determination of compressive strength. Cylindrical specimens of size 100mm×200mm are casted for the determination of split tensile strength. Beams of size 500mm×100mm×100mm are casted for the determination of flexural strength.

Curing of Specimens

The specimens are left in the moulds without disturbed at room temperature for about 24 hours after casting. The specimens are removed from the moulds and immediately transferred into the several curing tubs which are filled with fresh water. Water is being changed for every 7 days.

RESULTS AND DISCUSSIONS

Workability results obtained by slump cone test and compaction test are shown in the Table 5. The strength characteristics results of compressive strength, split tensile strength and flexural strength tests are tabulated in 6, 7 and 8 Tables respectively.For each strength test a minimum number of 3 specimens are tested at each period of curing and average value is presented.

Table 5 Workability Test results of concrete

S.NO	% TiO_2	SLUMP (MM)	COMPACTION FACTOR
1	0	37	0.868
2	0.5	33	0.844
3	1.0	27	0.842
4	1.5	24	0.838
5	2.0	18	0.826

From Table 5 it can be observed that values obtained by slump and compaction factor tests, are decreased with the increase in percentage of Nano TiO_2. Nano TiO_2 with high specific surface area acts as a filler material and increase of its content reduces free movement of the particles in concrete mix resulting decrease in workability. For all the percentages of replacements w/c ratio is kept same as 0.35, test results revealed that workability can be improved with increase in w/c ratio for each replacement.

Figure 1 Cube testing

Figure 2 Cylinder testing

Figure 3 Beam testing

Table 6 Compressive strength test results for concrete

S.NO.	% TiO_2	COMPRESSIVE STRENGTH (N/mm^2)		
		3 days	7 days	28 days
1	0	36.50	50.50	70.16
2	0.5	37.83	52.16	71.33
3	1	46.00	62.00	74.66
4	1.5	44.50	54.33	69.16
5	2	40.16	47.83	66.66

From Table 6 it can be seen that at for all the percentages of replacement compressive strength at 7days around 3% to 22 % more than that of 7 days strength 50.50 N/mm^2 of conventional M60, is achieved. And at 28 days around 6% more than that of 28 days 70.16 N/mm^2 of conventional M60 is obtained except M60 with 1.5% and 2% Nano TiO_2 content.Maximum values for all the periods of curing obtained at 1% replacement of cement with Nano TiO_2. Therefore 1% of Nano TiO_2 content can be optimum content in cement concrete of M60 grade. The compressive strength of M60 grade concrete with 1% Nano TiO_2 content is 6% more than M60 conventional concrete. And further increase in replacement of cement with Nano TiO_2 resulted decrease in strength.

Table 7 Split tensile strength test results for concrete

S.NO	% TiO_2	SPLIT TENSILE STRENGTH(N/mm^2)		
		3 days	7 days	28 days
1	0	2.737	3.076	3.403
2	0.5	2.928	3.119	3.595
3	1.0	3.225	3.288	3.816
4	1.5	2.928	3.055	3.246
5	2.0	2.609	2.906	3.098

From Table 7 it can be seen that for all the percentages of replacement split tensile strength around 1% to 6% more than that of 7days strength of conventional concrete M60 is achieved. And around 5% to 12% more than that of 28 days strength of conventional concrete M60 is obtained except M60 with 2% Nano TiO_2 content.At 1% replacement of cement with Nano TiO_2concrete resulted maximum values for all the periods of curing. Hence 1% of Nano TiO_2 content can be optimum content in cement concrete of M60 grade. The split tensile strength of M60 grade concrete with 1% Nano TiO_2 content is 12% more than M60 conventional concrete. And further increase in replacement of cement with Nano TiO_2 resulted decrease in strength.

Table 8 Flexural strength test results for concrete

S.NO	% TiO_2	FLEXURAL STRENGTH (N/mm^2)		
		3 days	7 days	28 days
1	0	3.753	4.430	5.170
2	0.5	3.960	4.500	5.280
3	1.0	4.690	4.970	5.460
4	1.5	4.590	4.860	5.200
5	2.0	4.260	4.440	5.070

From Table 8 it is can be observed that for all the percentages of replacement flexural strength around 2% to 12 % more than that of 7 days strength of conventional concrete M60 is achieved. And around 2 % to 5% more than that of 28 days strength of conventional concrete M60 is obtained except M60 with 1.5% and 2% Nano TiO_2 content.The Flexural strength of M60 grade concrete with 1% Nano TiO_2 content is 5% more than M60 conventional concrete. And further increase in replacement of cement with Nano TiO_2 resulted decrease in strength.

For all the percentages of replacements of cement with Nano TiO_2 results obtained are graphically represented for the compressive strength test in figure 1, split tensile strength test in figure 2 and flexural strength test in figure 3. Abscissa represents the percentage of Nano TiO_2 content and Ordinate represents the strength value of that the particular test.

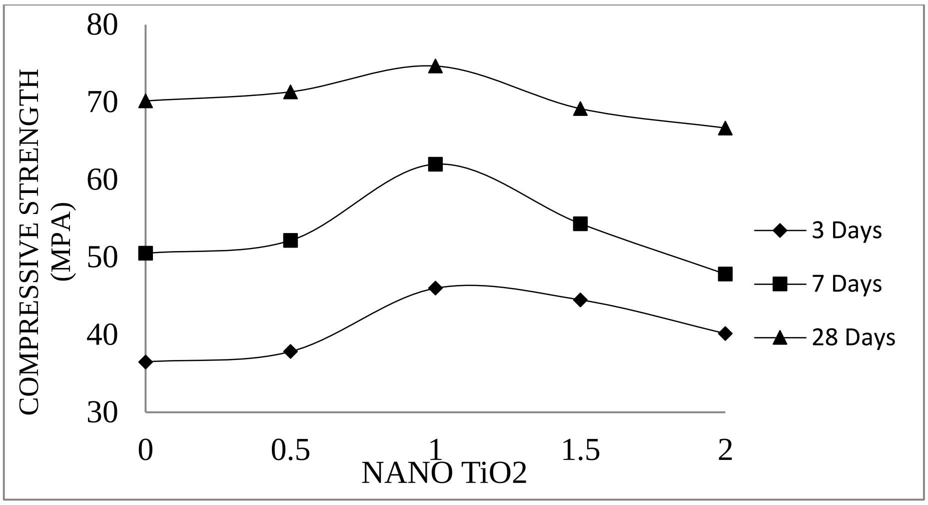

Figure 4 Effect of Nano TiO_2 content on compressive strength of concrete

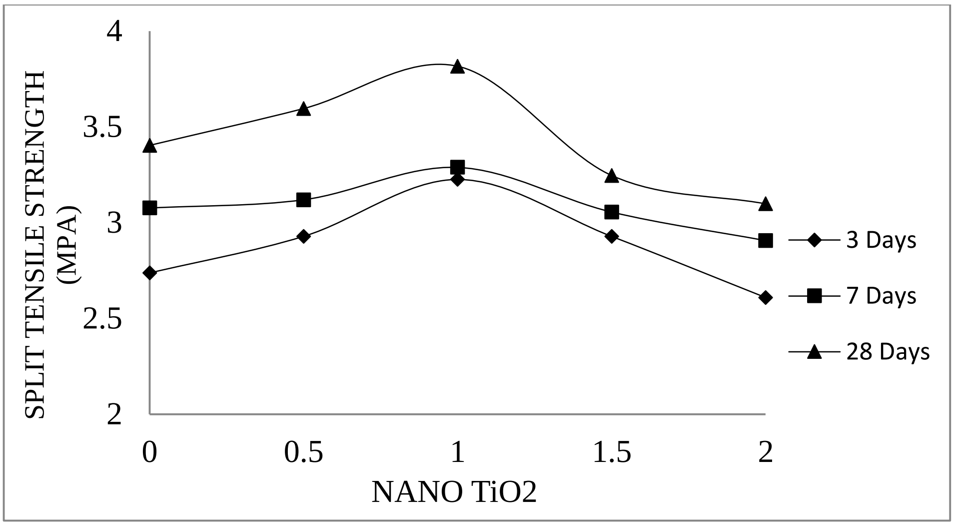

Figure 5 Effect of Nano TiO_2 content on split tensile strength of concrete

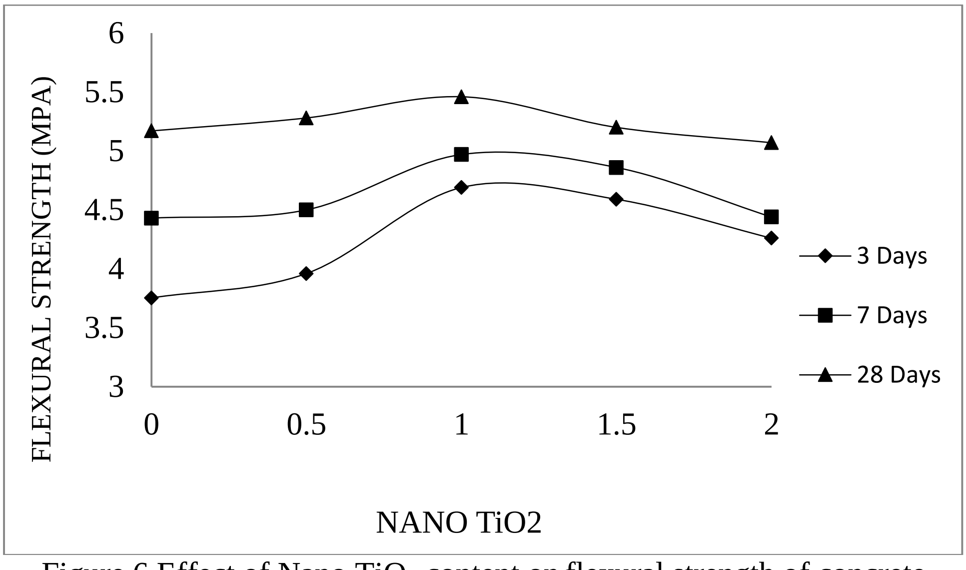

Figure 6 Effect of Nano TiO_2 content on flexural strength of concrete

CONCLUSIONS

The workability of concrete is decreased with the increase in the percentage of Nano Titanium Dioxide (TiO_2). It is observed that increase of Nano TiO_2 content, resulted stiff concrete mixes leading to decrease in slump value and compaction factor. The increase in percentage of Nano TiO_2 increases the powder content in concrete, which reduced free movement of particles with same water-cement ratio 0.35 and superplasticizer 0.8% by mass of cement.

From the three tests compressive strength, split tensile strength and flexural strength maximum values obtained for 1% replacement of cement with Nano TiO_2 are 74.66 N/mm^2, 3.816 N/mm^2 and 5.46 N/mm^2 respectively at 28 days age of M60 grade concrete. Further increase in percentage of Nano TiO_2 all three types of strength tests shown decrease in values. It might be because of less space available for the growth of CSH gel compared to 0.5% and 1% of Nano TiO_2. From the result it can be concluded that 1% of Nano TiO_2 could be the optimum content and replacement of cement in concrete which results better compared to the conventional concrete.

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