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AN EXPERIMENTAL STUDY ON COMBINED EFFECT OF NANO-TITANIUM DIOXIDE AND POLYPROPYLENE FIBERS ON STRENGTH CHARACTERISTICS OF CONCRETE

Bharath reddy B[1], V.C.Chandrashekar[2]

[1]*Student, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru-560078, India*
[2]*Assistant Professor, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru-560078, India*

Abstract: *Cementitious concrete has 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 desired properties of concrete. This paper deals with the effects on concrete property with the addition of nano-materials and Fibers.*

Nano-TiO2 is one of the most commonly used material in paints as pigment because of its various advantages. Nano-TiO2 can be used as filler in concrete. In this work, it is aimed to study the performance of standard strength concrete with the use of nanomaterials by replacing the cement partially with nano-titanium dioxide (TiO2) (ranging from 0.5 to 2%).Finally, the strength characteristics of both the concrete have examined by performing compression and flexural tests. At 1% replacement of cement, compressive strength of the concrete was increased by 11% when compared to the conventional concrete.

Polypropylene is a thermoplastic polymer material utilized as a part of wide assortment of uses including bundling materials. An experimental program was carried out to explore its effects on compressive, tensile, flexural strength under varying Fiber content such as 0%, 0.5%,1%,1.5% & 2% and finding the optimum Polypropylene Fiber content. At 1.5% replacement of cement, compressive strength of the concrete was increased by 18%. The optimum percentage of Polypropylene fiber was obtained to be 1.5 percent of cement by volume. Finally, by combining optimum dosage of titanium dioxide and polypropylene Fibers concrete mix design is made and tested for strength characteristics.

Key words: Nano Titanium Dioxide, Polypropylene Fibers, workability, compressive strength, flexural resistance, split tensile strengths etc.

1. INTRODUCTION: It is well known that concrete is a versatile and porous structure material, having pores of various sizes and shapes. Physical properties of concrete are influenced by its pore structure. Directly or indirectly, several index properties, such as strength and permeability, are related to pore structure of concrete. Pore structure of the concrete highly influences the durability and mechanical properties of concrete.

Titanium Dioxide(Tio2): 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 a possible improvement in mechanical properties of the concrete. Nanoparticles when added in little quantity to the cement paste, due to great surface energy nanoparticles, act as 'nucleus'; by this hydrate product of cement will deposit on them and grow to form conglomeration. Studies made on microstructures of plain cement mortar and cement mortar mixture with the nanoparticles showed that the nanoparticles filled up the pores and reduced Ca(OH)2 by product of hydration. Concrete strength is improved by nanoparticles because they enhance cement paste as well as the interfacial zone between paste and aggregates.

Fig 1: Tio2

Polypropylene Fibers: The Fiber dispersion into concrete is one of the technique to improve the building properties of concrete. Polypropylene Fiber are synthetic Fiber obtained as a by-product from textile industry. These are available in different aspect ratios and are cheap in cost. Polypropylene Fibers are characterized by low specific gravity and low cost. Its use enables reliable and effective utilization of intrinsic tensile and flexural strength of the material along with significant reduction of plastic shrinkage cracking and minimizing of thermal cracking. It provides reinforcement and protects damage of concrete structure and prevents spalling in case of fire. The Fibers are manufactured either by the pulling wire procedure with circular cross section or by extruding the plastic film with rectangular cross-section. They appear either as fibrillated bundles, mono filament.

In this project polypropylene Fibers of blended (12mm) type is used. The project deals with the effects of addition of various proportions of polypropylene Fibers on the properties of concrete in fresh and hardened state. An

experimental program was carried out to explore its effects on workability, compressive, flexural, split tensile strength and modulus of elasticity of concrete.

Fig 2: Polypropylene fibers

2. OBJECTIVE OF THE WORK

1) To carry out experimental investigations on engineering properties of nano concrete and fiber concrete with varying titanium dioxide and polypropylene fibers ratio.

2) The objective is to study the combined effect of Nano Titanium Dioxide and polypropylene Fiber in concrete. To conduct a comparative study on nano-Fiber concrete mix and conventional concrete.

3. MATERIALS AND METHODOLOGY

The materials used in this experimental study for preparing M40 grade concrete by partial replacement of cement with nano-titanium dioxide and Polypropylene Fibers are Cement (OPC 53 grade), Nano-titanium dioxide (TiO2), Polypropylene Fibers, fine aggregate, coarse aggregate, water and superplasticizer.

3.1 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.

Table 1: Propeties of cement

S. No.	Property	Test results
1	Normal consistency	32%
2	Specific gravity	3.15

3.2 Nano-Titanium Dioxide (TiO2)

Titanium dioxide is one of the most widely used inorganic materials in the world. Nano-TiO2 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 nanoparticles of size ranging from 1 to 100 nm. Nano-TiO2 particles are second nano-metal oxide particle mostly used for cement-based materials;. Nano-TiO2 has high density of about 3.9 g/cm3, and consequently, its higher hardness has a direct impact on cement-based properties and durability.

3.3 Polypropylene Fibers

Polypropylene is available in two forms, monofilament Fibers and film Fibers. The Fibers used were fine propylene monofilaments. It is available in 3 different sixes i.e 6mm, 12mm, 24mm. In present investigation 12mm Fiber length is used. Polypropylene has Specific gravity of 0.91 and melting point of 170 degrees C and can withstand temperatures of over 100 degrees C for short periods of time before softening. It is chemically inert and any chemical that can harm these Fibers will probably be much more detrimental to the concrete matrix.

3.4 Fine Aggregate

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

Table *2*: Propeties of Fine aggregates

S. No.	Property	Test results
1	Specific gravity	2.64
2	Bulk density (kg/m3)	1620 (loose) 1750 (dense)
3	Fineness modulus	2.74
4	Zone	II

3.5 Coarse Aggregate

Throughout the present experimental investigation, crushed coarse aggregates of size 20 and 10 mm from the crushing plants are procured and used. Coarse aggregate is tested for its physical requirements.

Table 3: Propeties of coarse aggregates

S. No.	Property	Test results
1	Specific gravity	2.72
2	Bulk density (kg/m3)	1400 (loose)
3	Fineness modulus	7.17

3.6 Water

Water is one of the most important ingredients of concrete, and it is inexpensive. Fresh potable water free from oil and organic is used in the preparation of concrete mix. The required quantity of water for each mix is measured by graduated jar and added.

3.7 Superplasticizer (Fosroc Conplast SP430)

Conplast SP430 is a chloride free, superplasticizing admixture is used for concrete making. It is supplied as a brown solution which instantly disperses in water.

METHODOLOGY

The methodology of the work consist of

1) Identifying the specification of material to be selected.
2) Collection of materials.
3) Identifying the properties of collected materials. Various tests were conducted on cement, fine aggregate, coarse aggregate.
4) Selection of concrete grade.
5) Preparation of mix design of M40 grade concrete.
6) Cubes, cylinder and beams were casted with control mix using natural aggregate.
7) Preparation of test specimen by adding 0.5, 1,1.5 and 2% of polypropylene Fibers in concrete.
8) Workability tests, compressive strength, tensile strength & flexural strength of concrete were conducted.
9) Optimum percentage of Fiber addition in concrete was determined.
10) Preparation of test specimen by adding 0.5, 1,1.5 and 2% of Nano titanium dioxide in concrete.
11) Workability tests, compressive strength, tensile strength & flexural strength of concrete were conducted.
12) Optimum percentage of Tio2 addition in concrete was determined.
13) Finally preparing of test specimen by adding optimum dosage of polypropylene Fibers and nano Tio2 in concrete.
14) Workability tests, compressive strength, tensile strength & flexural strength of concrete Test specimen were conducted.

Fig 3: wet mix of Tio2 and fiber in concrete

Casting of Specimens: For the determination of compressive strength of concrete, cubical specimens of size 150 mm * 150 mm * 150 mm are cast. For the determination of split tensile strength and flexural strength of concrete, cylindrical specimens of size 100 mm * 200 mm , beams of size 500 mm * 100 mm * 100 mm and cylinders of size 150*300mm are cast respectively.

Curing of Specimens: The casted specimens along with the moulds are left at room temperature without disturbing for about 24 h after casting. The concrete specimens are taken out by loosening the moulds and immediately transferred them into the curing tank which is filled with freshwater. Water is being changed for every 7 days.

Fig 4: curing of cubes

cement	Fine aggregate	coarse aggregate
1	1.825	3.420

Table 4: Mix proportion for M40 concrete with w/c ratio 0.4

Fig 5: Compression test

Fig 6: Universal testing machine (UTM)

4. RESULT AND DISCUSSIONS

i) Polypropylene Fiber as additive

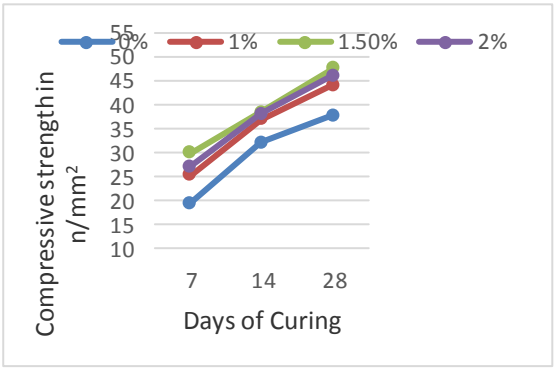

Fig 1: Graph showing Compressive strength for various fiber proportion

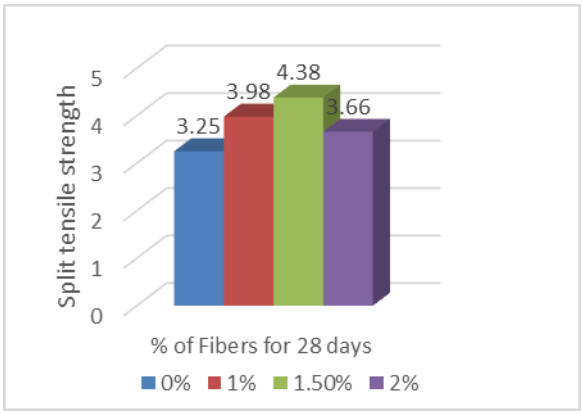

Fig 2: bar graph showing split tensile strength

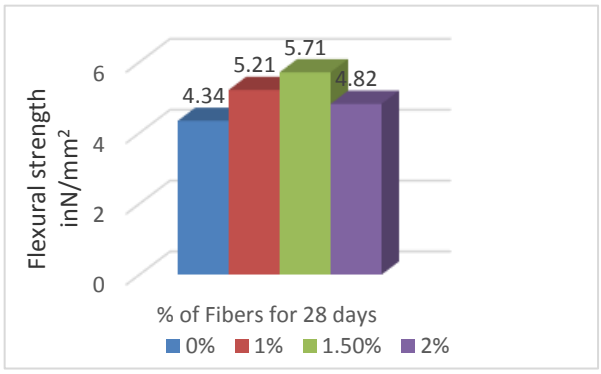

Fig 3: bar graph showing Flexural strength

Case-1: Test result for M40 control mix can be observed in the Graphs, optimum strength of concrete is obtained for 1.5% replacement of cement by polypropylene Fibers and any further addition lead to decrease in concrete strength. The compression testing of cubes samples were tested in 3, 7 and 28 days. The strength characteristics results of compressive strength, split tensile strength and flexural strength tests are shown.

ii) Titanium dioxide as additive:

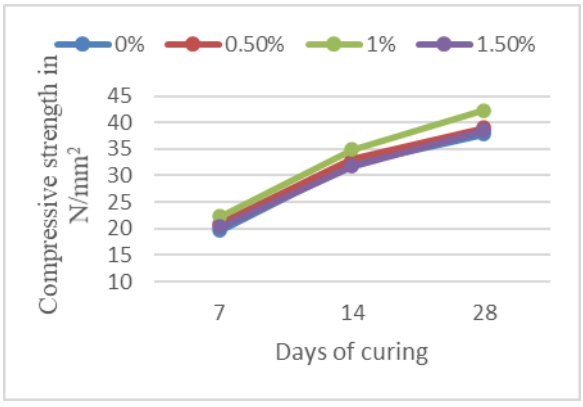

Fig 4: graph showing compressive strength for various Tio2 proportion

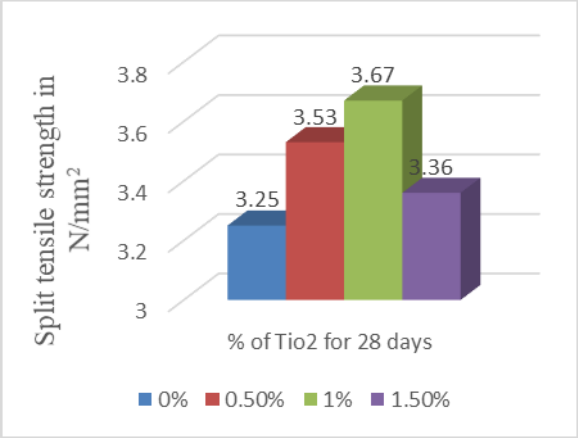

Fig 5: bar graph of split tensile strength

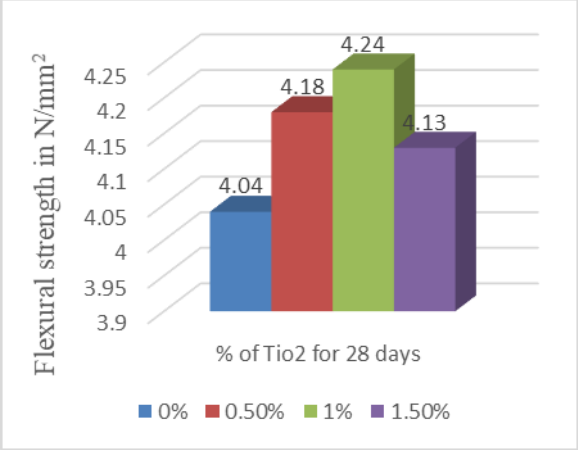

Fig 6: bar graph showing flexural strength

Case-2: Test result for M40 control mix can be observed in the table. Similarly refer table 2, optimum strength of concrete is obtained for 1% replacement of cement by titanium dioxide and any further addition lead to decrease in concrete strength. The compression testing of cubes samples were tested in 3, 7 and 28 days. The compressive strength of concrete can be calculated by the ratio of load applied on one cube to the area of one face of cube i.e. (150mm x 150mm). Due to small size titanium dioxide it fill the voids of mortar of concrete which leads in increase of strength, excess amount titanium dioxide covers the cement particles which disrupts the water cement reaction and hence the strength decreases on further increment.

iii) Optimum dosage of Fiber-Tio2 as additives:

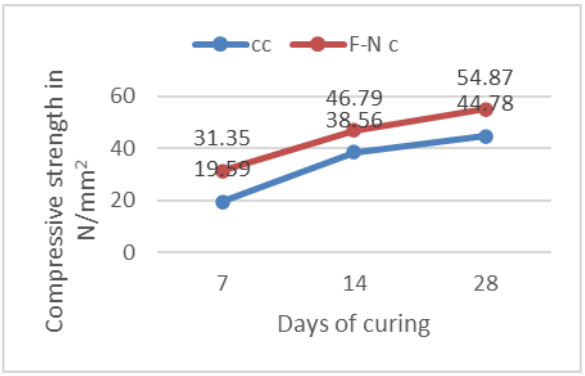

Fig 7: graph showing compressive strength

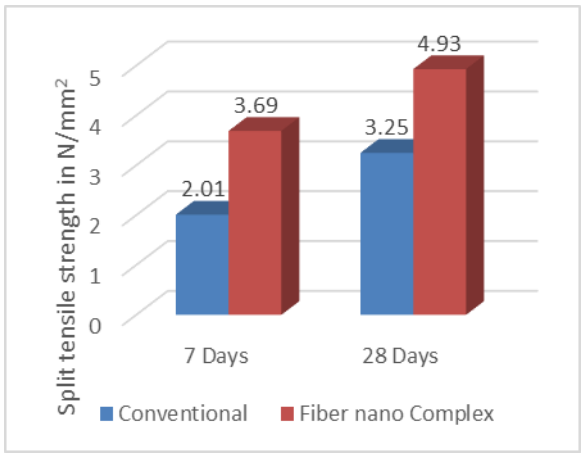

Fig 8: bar graph showing Split tensile strength

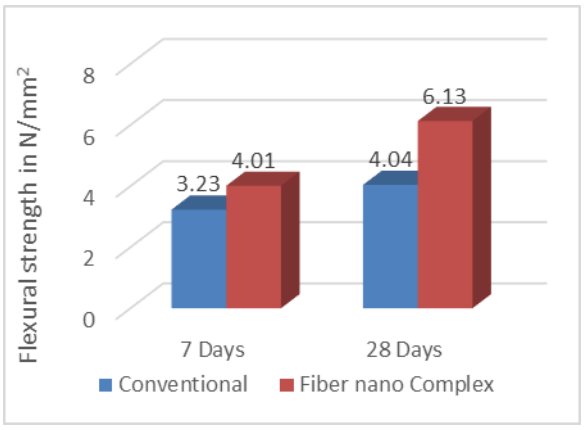

Fig 9: bar graph showing Flexural strength

Finally by adding optimum dosage of Tio2 and Fibers to concrete mix and tests were conducted to study combined effect of both Fibers and Tio2 on strength characteristics of concrete.

5. COST ANALYSIS:

As shown in the table cost of conventional concrete is about 5800Rs per cubic meter and the cost of concrete with addition of PP fibers and Tio2 is about 7300Rs.we can observe that there is 20% increase in the cost due to additives by which we got about 22% increase in compressive strength which we got about 22% increase in compressive strength, 27% increase in the Split tensile strength and 33% in the Flexural strength was observed. Hence by considering the increment in the strength properties the cost was adoptable and economical.

Table 6: Cost of producing 1m³ of Additive based concrete

Material	Quantity in kg/m³	Rs/unit	Cost (Rs)
Water	140	0.5/litre	70
Cement	341.25	7/kg	2365
Fine aggregates	886	1.75/kg	1550
Coarse aggregates	1145	1.33/kg	1522
Superplasticizer	7	150/unit	200
Tio2	3.5	300/kg	1050
PP Fibers	5.25	100/kg	525

Total cost for 1m³ concrete **= 7300 Rs**

6. CONCLUSIONS

The compressive strength has been increased by the 1% replacement of cement by titanium dioxide about 11% and further strength decreases on increment of titanium dioxide. Titanium dioxide used in this experimental work is anatase base having particles size 20-25µm.Further study can be extended on various properties of concrete by changing the particles size of titanium dioxide and various grade of concrete. Compressive strength of 1.5% of blended length polypropylene fiber reinforced concrete has found to be 17% increase in strength, when compared to that of Conventional concrete. Strength enhancement in split tensile strength is 22%, flexural strength is 24% compared to that of Conventional concrete. The experimental studies proved to be the best method or way in providing strong and durable concrete. It is observed 1.5% fiber in concrete yields max. strength.

By combining Fibers and Tio2 of optimum dosage and adding it to concrete mix increases compressive strength about 24% which is more economical in the field of construction.

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