AN EXPERIMENTAL STUDY ON STRENGTH CHARACTERISTICS BY PARTIAL SUBSTITUTION OF CEMENT WITH NANO TITANIUM DIOXIDE

AKHIL TEJA PERUMALLA[1], SRINIVAS EERA[2]

[1]*M.Tech Student, Department of Civil Engineering, Lingayas Institute of Management and Technology, Andhra Pradesh, India.*

[2]*Assistant Professor, Department of Civil Engineering, Lingayas Institute of Management and Technology, Andhra Pradesh, India.*

---***---

Abstract – *Nano Technology is one of the most active research areas that encompass a number of disciplines, including civil engineering and construction materials. Its applications and advances in concrete materials remain limited. Only a few marketable nano products are commercially available. The main advances have been in the nano science of cementitious materials with an increase in the knowledge and understanding of basic phenomena in cement at the nano scale. In this paper, investigations has been done on the concrete structures by incorporation of Nano titanium dioxide in to the concrete designs in order to study the variations of the strength obtained by partial substitution of cement with percentile replacement of Nano Titanium dioxide in concrete mix proportion. The purpose of this study is to investigate the variations of strength obtained by replacing 0.25%, 0.5%, 1.0%, and 1.25% by weight of cement. The standards of IS 10262:2009 and IS 456:2000 for M30 design is considered in this study. All the possible tests were made on the materials used for the manufacturing of concrete and standard specimens (Cubes) were casted and cured for 7, 14 and 28 days and tested separately and comparisons of test results were done along with normal concrete. The most satisfying results were obtained at the 1.0% percentile replacement of cement.*

Key Words: Nano Technology, Experimental Study, Strength characteristics, Partial substitution, cement, Nano Titanium dioxide.

1. INTRODUCTION

Concrete is a versatile engineering material consisting of cementing substance, Aggregates, water and often controlled amount of entrained air. It is initially a plastic, workable mixture which can be moulded in to a wide variety of shapes when wet. The strength is developed from the hydration due to the reaction between cement and water. The products, mainly calcium silicate, calcium aluminates and calcium hydroxide are relatively insoluble which bind the Aggregate in a hardened matrix. Concrete is considerably stronger in compression than in tension, for structures required to carry only compressive loads such as massive gravity dams and heavy foundations, reinforcement is not required and the concrete is consequently called plain concrete. When the structure is to be subjected to tensile stresses, steel bars are embedded in the concrete. The requisite quantities of material for a given grade of concrete are usually obtained from mix design.

Nanotechnology is a science concerned with the design, construction and utilization of functional structures with at least one characteristic dimension measured in nano-metres. Nano, which comes from the Greek word for dwarf, indicates a billionth. One nano-metre is a billionth of a metre. Definitions of 'nano technology' vary, but it generally refers to understanding and manipulation of matter on the nano-scale, say, from 0.1 run to 100 nm. Nanotechnology initially developed in the fields of physics and chemistry, and most fundamental developments still occur in these fields. Nanotechnology also needs to be applied in areas such as the engineering field. Obviously, the application of nanotechnology to science and engineering has increased in other fields over the years. One area which is one of the most active research areas in the field of nanotechnology is civil engineering.

Nano-materials and nanotechnologies have attracted considerable scientific interest due to the new potential uses of particles in nanometer scale and consequently, large amount of funds and effort have being utilized. Even though construction materials may constitute only a small part of this overall effort, it could pay enormous rewards in the areas of technological breakthroughs and economic benefits. Although today the total market share of nano products for constructions small and deemed to be applied in niche markets, this share is expected to grow in the near future, and nano-particles to play an important role as a basis for the design, development and production of materials construction industry.

1.1 NANO TITANIUM DIOXIDE

Titanium dioxide nano particles are ultrafine titanium dioxide particles which exist in nature as the notable minerals rutile, anatase and brookite. Titanium dioxide is fundamentally sourced from ilmenite mineral. Rutile is the steadiest form of Titanium dioxide which is used in this paper. The titanium dioxide nano particles are added to concrete to improve its properties. This white pigment is used as an excellent reflective coating or added to paints, cements and windows for its sterilizing properties. The titanium dioxide breaks down organic pollutants, Volatile organic compounds and bacterial membranes through powerful photo catalytic reactions, reducing air pollutants when it's applied to outdoor surfaces. Being hydrophilic gives self cleaning properties to surfaces to which it is applied, because the rain water is attracted to the surface and forms sheets which collect the pollutants and dirt particles previously broken down and washes them off. The resulting concrete surface has a white color that retains its whiteness very effectively.

1.2 APPLICATION OF NANO-TECHNOLOGY IN CONSTRUCTION

Nanotechnology can be used for design and construction processes in many areas since nanotechnology generated products have many unique characteristics. These characteristics can, again, significantly fix current construction problems, and may change the requirement and organization of construction process.

➢ These include products that are for:

- Lighter and stronger structural composites
- Low maintenance coating
- Improving pipe joining materials and techniques.
- Better properties of cementitious materials
- Reducing the thermal transfer rate of fire retardant and insulation
- Increasing the sound absorption of acoustic absorber
- Increasing the reflectivity of glass

2. OBJECTIVES OF STUDY

The main objectives of this investigation are:

1. Incorporation of nanotechnology into construction technology by substitution in the cementitious materials.
2. The progressive efforts going with nano technology permits cost effective designs and upgraded concrete execution, which can prompt remarkable uses of concrete.
3. Using Nano Titanium an innovative fine material, which assumes indispensible part in filling the pores between crystals of concrete.
4. Studying the strength behaviour of concrete with nano alterations of cement based materials with nano particles.
5. To investigate the strength characteristics of concrete by partial substitution of nano titanium dioxide with 0.25%, 0.5%, 1.0% and 1.25% by weight of cement.
6. Analyzing the strength behaviour of concrete for each percentage substitution of titanium dioxide in concrete.

3. METHODOLOGY

The tree diagrammatic representation for the methodology of this study is as follows:-

Literature Review

Mix design for the selected materials for concrete

Casting the test blocks

Curing on test blocks

Conducting standard tests on concrete blocks

Evaluation and comparison of test results

4. DESIGN PROCEDURE FOR M30

As per IS: 10262-2009, the procedure is as follows:

a) Design Stipulations:
Grade Of concrete: M30
Size of Aggregates: 20mm
Degree of quality control: good
Type of exposure: moderate
Grade of cement: 53 grade OPC

b) Test Data for Materials:
Specific gravity of cement: 3.15
Specific gravity of coarse Aggregate: 2.8
Specific gravity of fine Aggregates: 2.6

c) Sieve Analysis:
Fine Aggregate: Sand zone II according to IS: 383 -1970
Coarse Aggregate: Confirming to IS: 383 -1970

Step-1:- Target mean strength

$F_{min} = f_{min} + t*s$

$= 30 + 1.65*5$

$= 38.25$ N/mm2

Step-2:- water cement ratio

Water cement ratio for 38.25 Mpa is 0.40

Step-3:- Cement content required:

Assume Slump =100mm

Aggregate size =20 mm

From table 2: IS 10262-2009

Water content =186+186*(6/100)

= 197 lts

For addition of super plasticizers water content decreases from 10 to 20%

Water content (final) =197*0.80

= 158 lts
Water/cement = 0.40
Weight of cement = 158/0.4
= 395kg/m³
Step-4:- Volume of coarse Aggregate
From table 3: IS 10262-2009
Volume = 1-10% entrapped air
V = 0.9 m³
Volume of coarse Aggregate = 0.62 * 0.9
= 0.558 m³
Volume of fine Aggregate = 1-coarse Aggregate
= 1-0.558
= 0.442 m³

Mix Calculations:

Volume of concrete = 1m³
Volume of cement = (wt of cement/ specific gravity) * (1/1000)
= (395/3.15) * (1/1000)
= 0.1253m³
Volume of water = (wt of water/ specific gravity) * (1/1000)
= (158/3.15) * (1/1000)
= 0.158m³
Volume of all Aggregates = 1 – (Vol of cement + Vol of water)
= 1 – (0.1253+0.158)
= 0.7167m³
Mass of coarse Aggregate = Vol of all Agg * Vol of coarse Agg * SP Gravity * 1000
= 0.7167 * 0.558 * 2.8 * 1000
= 1120kg/m³
Mass of fine Aggregate = Vol of all Agg * Vol of fine Agg * SP Gravity * 1000
= 0.7167 * 0.442 * 2.6 * 1000
= 824 Kg/m³

Step-5:- Mix proportions
The mix proportion used was 1:2.0:2.9:0.4

- **For 1m³ cube of concrete,**

Cement: 395Kg/M³
Fine Aggregate: 824Kg/M³
Coarse Aggregate: 1120Kg/M³
Water: 158 lit

- QUANTITIES OF MATERIALS REQUIRED FOR NORMAL 9 CUBES

Cement: 11.97Kg
Fine Aggregate: 25.02Kg
Coarse Aggregate: 34.02Kg

- QUANTITY OF MATERIALS REQUIRED FOR NANO TiO_2 12 CUBES

Cement: 15.96Kg
Fine Aggregate: 33.36Kg
Coarse Aggregate: 45.36Kg

5. TESTS ON MATERIALS

5.1. DETERMINATION OF SPECIFIC GRAVITY

The pycnometer is used for Aggregates less than 200mm size.
Let W_1 be the empty weight of pycnometer,
W_2 be the empty weight of pycnometer + dry Aggregates,
W_3 be the empty weight of pycnometer + dry Aggregates+ water and
W_4 be the empty weight of pycnometer + water.
Specific Gravity of Aggregates:

$$G = \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)}$$

RECORD OF OBSERVATIONS

Trail No	Empty Weight of Bottle(W1)	Weight of Bottle + Dry Aggregates (W2)	Weight of bottle + Aggregates + water (W3)	Weight of bottle + water	Specific gravity
1	605	1125	1970	1610	3.0
2	605	1115	1950	1610	2.8
3	605	1115	1950	1610	2.8
				Average	2.8

Table 1: Specific Gravity observations

Reporting of Results
Specific gravity of the given coarse Aggregate is = 2.8
Specific gravity of the given fine Aggregate is = 2.6
Specific gravity of the given cement is = 3.15

5.2. SIEVE ANALYSIS

Proportions of different size fractions to obtain 20mm Aggregate

Sieve sizes (mm)	Weight Retained(gm)	% Weight retained	Cumulative Weight retained	% of passing
80	0	0	0	100
40	0	0	0	100
20	490	9.8	9.8	90.2
10	4411	88.02	98.02	1.98
4.75	99	1.98	100	0

Table 2: Proportions of different size fractions to obtain 20mm Aggregate

Proportions of different size fractions to obtain zone-II sand

Sieve sizes (mm)	Weight Retained (gm)	% Weight Retained	Cumulative Weight retained	% of passing
4.75	25	2.5	2.5	97.5
2.36	52	5.2	7.7	92.3
1.18	161	16.1	23.8	76.2
600µ	355	35.5	59.3	40.7
300µ	364	36.4	95.7	4.3
150µ	36	3.6	99.3	0.7
75µ	5	0.5	99.8	0.2
Pan	2	0.2	100	0

Table 3: Proportions of different size fractions to obtain zone –II sand

Reporting of Results

The results should be calculated and reported as:
i) The cumulative percentage by weight of the total sample.
ii) The percentage by weight of the total sample passing through one sieves and retained on the next smaller sieve, to the nearest 0.1 percent. The results of the sieve analysis may be recorded graphically on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate.

5.3 SHAPE TEST

The **Flakiness Index** is defined as the percentage by weight of Aggregate particles whose least dimension is less than 0.6 times their mean size.

The **Elongation Index** of an Aggregate is defined as the percentage by weight of particles whose greatest dimension (length) is 1.8 times their mean dimension. This test is applicable to Aggregates larger than 6.3 mm.

5.4 INITIAL & FINAL SETTING TIME OF CEMENT

Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.

Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

5.5 SLUMP TEST

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction.

The test result for M30 grade concrete = 90mm slump

6. SELECTION OF NANO MATERIAL TiO_2 IN%

SELECTION OF 0.25% OF NANO TiO_2:-
The amount of nano TiO_2 with respective to cement in concrete mix for
1 cube = 3.333gm
3 cubes = 10 gm

SELECTION OF 0.5% OF NANO TiO_2:-
The amount of nano TiO_2 with respective to cement in concrete mix for
1 cube = 6.65gm
3 cubes = 20gm

SELECTION OF 1.0% OF NANO TiO_2:-
The amount of nano TiO_2 with respective to cement in concrete mix for
1 cube = 13.33gm
3 cubes = 40gm

SELECTION OF 1.25% OF NANO TiO_2:-
The amount of nano TiO_2 with respective to cement in concrete mix for
1 cube = 16.62gm
3 cubes = 50gm

7. TEST RESULTS

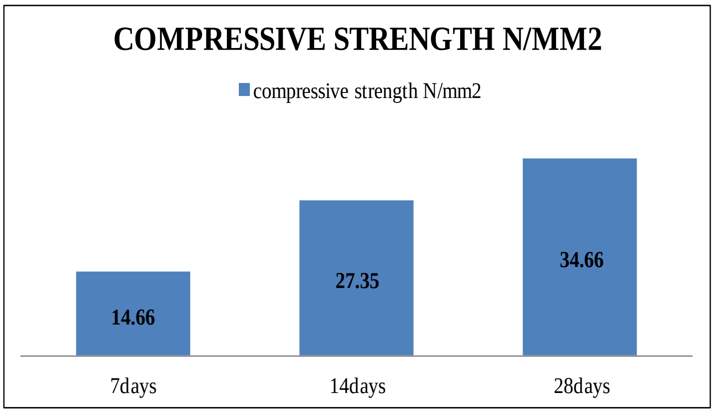
Compressive strength of concrete, out of many tests applied to the concrete, this is utmost important which gives an idea about all the characteristics of concrete. The compressive testing of cubes samples were tested in 3, 7, 28 days.

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 Compressive strength = load applied / area of cube

i) Test result for M30 grade normal mix can be observed in below table

GRADE	7 DAYS	14 DAYS	28 DAYS
M30	14.66 N/mm²	27.35 N/mm²	34.66 N/mm²

Table 4: Test result for M30 grade normal mix

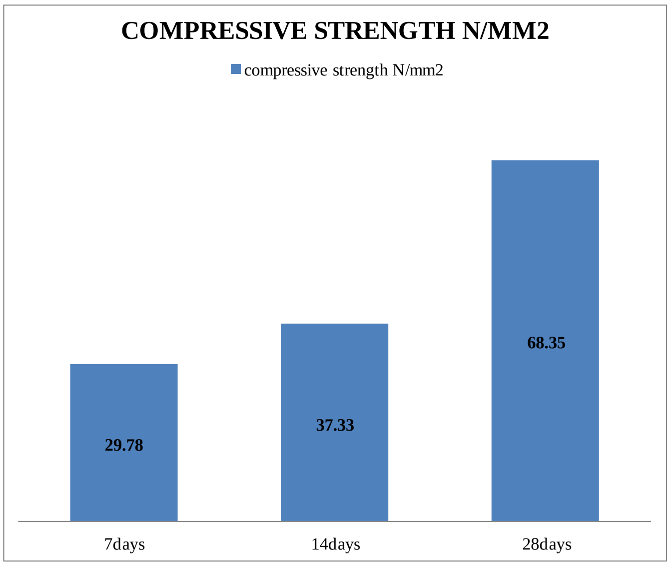


Graph 1: Graph of M30 grade normal concrete mix

ii) Test results for 0.25% addition of TiO_2:-

GRADE	7 DAYS	14 DAYS	28 DAYS
M30	29.78 N/mm²	37.33 N/mm²	68.35 N/mm²

Table 5: Test results for 0.25% addition of TiO_2

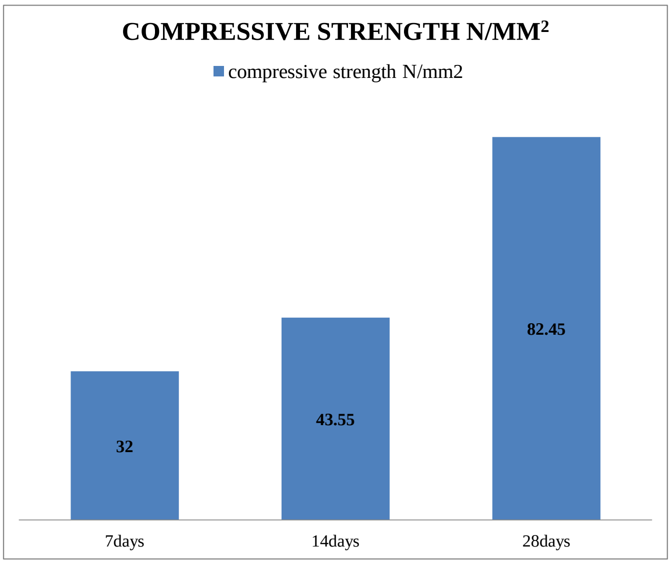


Graph 2: Graph of 0.25% addition of TiO2 concrete cube

iii) Test results for 0.5% addition of TiO_2:-

GRADE	7 DAYS	14 DAYS	28 DAYS
M30	32 N/mm²	43.55 N/mm²	82.45 N/mm²

Table 6: Test results for 0.5% addition of TiO_2

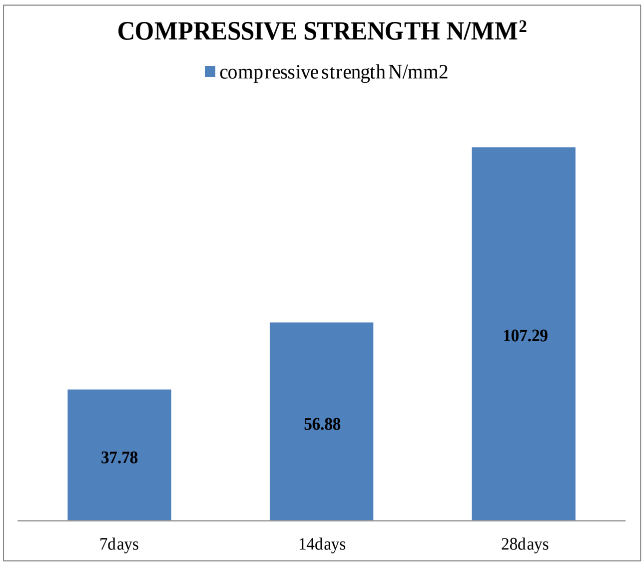


Graph 3: Graph of 0. 5% addition of TiO2 concrete cube

iv) Test results for 1.0% addition of TiO_2:-

GRADE	7 DAYS	14 DAYS	28 DAYS
M30	37.78 N/mm²	56.88 N/mm²	107.29 N/mm²

Table 7: Test results for 1.0% addition of TiO_2

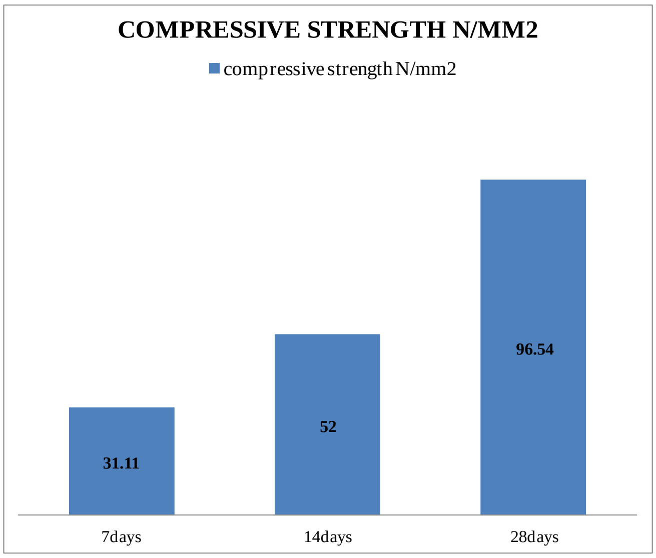


Graph 4: Graph of 1.0% addition of TiO2 concrete cube

v) Test results for 1.25% addition of TiO_2:-

GRADE	7 DAYS	14 DAYS	28 DAYS
M30	31.11 N/mm²	52 N/mm²	96.54 N/mm²

Table 7: Test results for 1.25% addition of TiO_2



Graph 5: Graph of 1.25% addition of TiO2 concrete cube

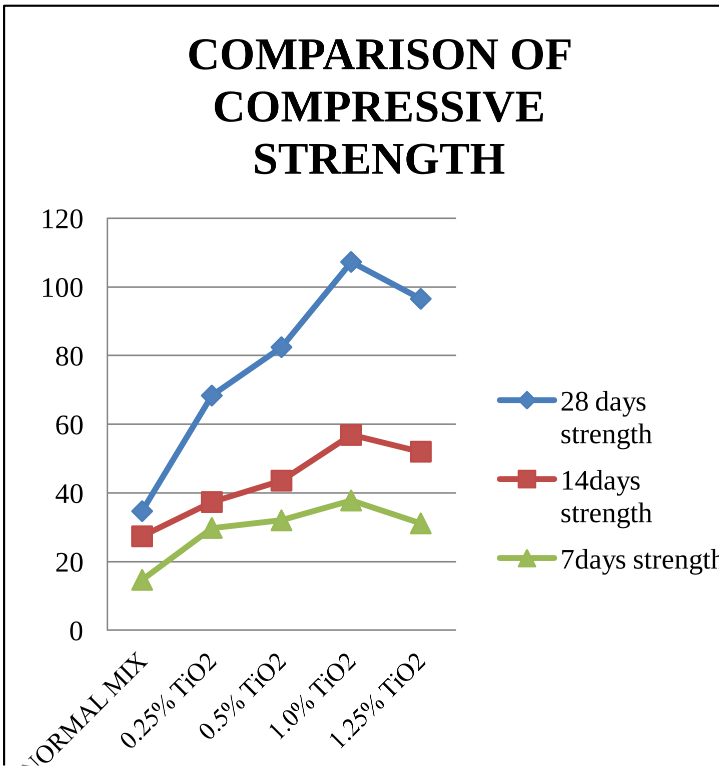
International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 07 | July 2020 www.irjet.net p-ISSN: 2395-0072

COMPARISION OF COMPRESSIVE STRENGTH

The comparison of 7days and 28 days compressive strength of normal concrete with the replacement of TiO_2 mixed concrete of 0.25%, 0.5%, 1.0%, 1.25% are observed in the below graph.

S No	Compressive strength N/mm^2	Normal Concrete	Percentage of TiO_2			
			0.25 %	0.5%	1.0%	1.25 %
1	7 days	14.66	29.78	32	37.78	31.11
2	14 days	27.35	37.33	43.55	56.88	52
3	28 days	34.66	68.35	82.45	107.29	96.54

Table 8: Comparison of Compressive Strength



Graph 6: Comparison of Compressive Strength

8. CONCLUSIONS

The study concludes that the addition of Nano TiO2 in the concrete mixture behaves not only as a filler to improve the microstructure, but also as an activator to promote pozzolanic reaction thereby resulting in the enhancement of the durability and mechanical properties of the mix. Titanium dioxide used in this experimental work is **Rutile** base having particle size 20 nm. From the study, the following were concluded;

- The optimum quantity of TiO2 can be used in the concrete to gain augmented strength parameters by utilizing as filler or replacing part of cement and also in order to improve the performances of concrete properties.
- The increase of compressive strength is up to 50% when compared with the conventional concrete with just 0.25% replacement of titanium dioxide for 7 and 28 days curing of concrete.
- On further increase in % of titanium dioxide in concrete shows increasing values of strength up to 1%.
- The peak values of strength were observed when the replacement was 1% and 28 days compressive strength value was recorded as **107.29 N/mm^2**.
- Further increase in titanium dioxide gives the decreasing values of strength but still they are far more superior to normal concrete.

On a simple note, the compressive strength has been increased with the addition of 0.25% titanium dioxide and further strength increases on increase of titanium dioxide of 0.5%, 1.0%. Further increase of titanium dioxide will decrease the compressive strength of concrete.

From investigations of this paper it reveals that incorporation of Nano Titanium dioxide is a new ideal approach in concrete construction. Further study can be extended on various properties by changing particle size of titanium dioxide, usage of different admixtures and various grades of concrete.

REFERENCES

[1] IS CODAL PROVISIONS
IS 10262-2009
IS 456-2000
[2] Concrete technology by M.S. Shetty, S. Chand publications.
[3] Sobolev, K., and Gutierrez, M. F. (2005). "How nanotechnology can change the concrete word." American Ceramic Society Bulletin, Vol.84, No.10, pp.14-18.
[4] Wang, K., Shah, S. P., and Voigt, T. (2007). "A novel self-consolidating concrete for slip-form application." TRB 2007 Annual Meeting.
[5] Deb, B-Woods. (2008). "Nanotechnology: Ethics and Society." Taylor and Francis Group, N.Y.
[6] Balaguru, P., and Chong, K. "Nanotechnology and concrete: Research opportunities." Proceedings of ACI Session on "Nanotechnology of Concrete: Recent Developments and Future Perspectives" November 7, 2006, Denver, USA, 16-27.
[7] Boresi, Arthur P.; Chong, Ken P.; Saigal, Sunil. Approximate Solution Methods in Engineering Mechanics, John Wiley, New York, 2002, 280 pp.
[8] Baoguo Ma, Hainan Li, JunpengMei, Xiangguo Li, and Fangjie Chen "Effects of Nano-TiO2 on the Toughness and

Durability of Cement-Based Material". Hindawi Publishing Corporation Advances in Materials Science and Engineering Volume 2015.

[9] Jay Sorathiya, Dr. Siddharth Shah and Mr. Smit Kacha "Effect on Addition of Nano Titanium Dioxide (TiO2) on Compressive Strength of Cementitious Concrete". Kalpa Publications in Civil Engineering Volume 1, 2017.

[10] Aravind R, Devasena M, Sreevidya V and M Vadivel "Dispersion Characteristics and Flexural Behavior of Concrete Using Nano Titanium Dioxide". International Journals of Earth Science and Engineering Vol 9 2016.

[11] Shaaqib. A. Mansuri, Chandni. M. Patel, Yash. U. Shah, Renuka. K. Goswami, C. B. Mishra "Recapitulating Comprisal of TiO_2 in Concrete Mix Design for Pavement". International Research Journal of Engineering and Technology Volume: 05 Issue: 09 | Sep 2018.

[12] Nikunj patel, C. B. Mishra "Laboratory Investigation of Nano Titanium Dioxide (TiO_2) in Concrete for Pavement". International Research Journal of Engineering and Technology Volume: 05 Issue: 05 | May 2018.

BIOGRAPHIES

PERUMALLA0 AKHIL TEJA
P.G Student,
Department of Civil Engineering,
Lingayas Institute of Management and Technology, Andhra Pradesh.

EERA SRINIVAS
Assistant Professor,
Department of Civil Engineering,
Lingayas Institute of Management and Technology, Andhra Pradesh.