LABORATORY INVESTIGATION OF NANO TITANIUM DIOXIDE (TIO_2) IN CONCRETE FOR PAVEMENT

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Abstract - *Concrete science is a multidisciplinary territory of research where nanotechnology possibly offers the chance to improve the comprehension of Concrete conduct, to design its properties and to bring down generation and natural cost of development materials. In this paper an investigational ponder has been performed by substituting the bond with Nano titanium dioxide in the extents of 0.5 %, 1.0 % and 1.5 % (by weight of cement) to enhance the quality attributes of cement with the expansion of Nano titanium dioxide which not just goes about as a channel to enhance the microstructure yet in addition as an activator to advance pozzolanic response there by bringing about the improvement of the mechanical properties of the Concrete blend. The blend configuration utilized as a part of this examination work was PQC M40 for the unbending asphalt and the blend extent of M40 concrete was landed by utilizing IS 10262: 2009 and IS 456: 2000. The specimens (Concrete shapes and bar) were casted, cured and checked following 28 days to investigate out the compressive quality and flexural quality of cubes and beams. The most extreme compressive and flexural quality is accomplished at 1.0 % of Titanium Dioxide (TiO_2) with replacement by weight of cement.*

Key Words: Compressive Strength, Flexural Strength, M40 Grade Concrete, Nano Titanium Dioxide, Nano Concrete.

1. INTRODUCTION

Nanotechnology is an innovative technology which deals with the materials of size in a range less than 100 nm. Physical and mechanical properties of the specimens were measured after adding Titanium Dioxide (TiO2) nano particles to concrete. TiO_2 nano particle can be used as a replacement of cement (up to 2% weight of cement proportions in concrete) because it could quicken C-S-H gel formation as a result of increased crystalline Ca $(OH)_2$ amount at the early age of hydration and hence increase all the strength of concrete. The nanoparticles benefited in enhancing the porousness and strength of concrete. The three communal stages of titanium dioxide are rutile, anatase and brookite.

Rutile is the steadiest form of titanium dioxide. Anatase and brookite are stable at standard temperatures but on heating gradually converted to rutile. In this research attempt the anatase based TiO_2 was used. Nanotechnology materials while being combined in constructional structures would not only help in extending their lifetime, but would also keep a check on the energy spent by them and at the same time gauging their reactions and reacting to different agents like fire, corrosion, water penetration, fractures, cracks, etc. Nanotechnology has changed our vision, expectations and abilities to control the material world.

Application of titanium dioxide can be used in numerous fields such as it has a wide range of applications from paint, sunscreen to food colorings. It is used for water and air purification has been a subject of extensive research. More recent, the applications have widened to surfaces with self-cleaning, self-sterilizing, bactericidal and anti-fog properties.

The purpose of this study is to investigate compressive quality and flexural quality of cubes and beams with different contents of 0.5 %, 1.0 % and 1.5 % by weight of cement.

2. LITERATURE REVIEW

Jay Sorathiya, Dr. Siddharth Shah, Mr. Smit Kacha, (2017) research includes an attempt to understand the outcome of Anatase Nano Titanium Dioxide (TiO_2) on Conventional Concrete (CC) of M20 grade with various proportions and concluded that the nano-TiO_2 particles added concrete had appreciably higher compressive strength comparable to that of the normal concrete. 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. (Jay Sorathiya, 2017)

Iyappan. A.P, Srikanthan.L, Felix Franklin.S, Bhuvaneswari.J, Preethika.A, 2017, studied the use of Nano Titanium Dioxide (anatase based TiO_2) of size 15 nanometer (nm) to advance the compressive strength and tensile strength of concrete. An experimental study had been carried out by replacing the cement with nano titanium dioxide. The maximum compressive strength and split tensile strength is attained for 1.5% of Titanium Dioxide (TiO_2) with replacement of cement (by weight of cement). (Iyappan. A.P, 2017)

Saloma, Amrinsyah Nasution, Iswandi Imran and Mikrajuddin Abdullah. (2013), in this research Nano Fe_2O_3 & Al_2O_3 (15nm), Nano TiO_2 (15nm) and Nano silica (10-140 nm) were added up to 2.0 % by weight of cement in concrete. It is derived that the Compressive strength, splitting tensile test and Modulus of elasticity of concrete can be considerable. After 3, 7, and 28 days compressive strength and Splitting tensile strength increases considerably. (Saloma, June 2013.)

Abhishek Singh Kushwaha, Rachit Saxena and Shilpa Pal (2015), in this study, M30 grade concrete was cast and cement was partially replaced by titanium dioxide (by weight). The amount of TiO_2 was varied from 1% to 3% by weight of cement. TiO_2 acts as the Nano particles that fill the Nano-voids in concrete that leads to the increment of compressive strength. The 1% of TiO_2 is optimum for compressive strength of concrete. (Abhishek Singh Kushwaha, June 2015.)

Zhen Li, Baoguo Han, Xun Yu, Sufen Dong, Liqing Zhang, Xufeng Dong, Jinping Ou (2017) made an attempt in which Nano TiO_2 was added into RPC to develop high-performance concrete. The study concluded that the adding of Nano TiO_2 can expand the mechanical properties of RPC and decrease the electrical resistivity of Rapid Portland Cement. The composites at curing age of 3 and 28 days had the maximum surges in flexural strength with 52.72% (2.81 MPa) and 47.07% (3.62 MPa) respectively. Further the increases in compressive strength of the composites are also notified. The compactness model demonstrated that Nano TiO_2 can progress the compactness and decline the permeability of RPC. (Zhen Li, 2017)

Ali Nazari (2011) made an attempt to explore the effect of Nano-TiO_2 particles mixed with concrete on a flexural strength with respected to the conventional concrete and concluded that the cement would be effectually replaced with Nano-TiO_2 units up to desire limit of 2.0%. Optimum dose of Nano-TiO_2 particles content was achieved with 1.0% by weight of cement for the samples cured in water for 7, 28 and 90 days. (Nazari, 2011)

3. LABORATORY INVESTIGATION FOR MATERIAL USED

3.1 CEMENT

OPC of Ultra Tech Cement Brand with 53 Grade of cement was used. Cement is a binder, a substance used for road construction that sets, hardens and adheres to other materials, binding them together. It gets its strength from chemical reactions between the cement and water. The process is known as hydration. Checking of materials is an essential part as the life of structure is dependent on the quality of material used. All the laboratory material tests were achieved as per the IS: 4031 – 1988. Tests results and properties of the cement are as shown in Table No. 1.

Table 1: Properties of Cement

Cement		
1	Specific Gravity of Cement	3.15
2	Standard Consistency of cement	30.50%
3	Initial Setting Time	117 mins
4	Final setting Time	230 mins
5	Fineness of Cement	2.48%
6	Soundness of cement	2.3 mm
7	Compressive Strength of Cement (28 Days)	60.09 N/mm²

3.2 COARSE AGGREGATE

Aggregates are generally thought of as inert filler within a concrete mix. But a closer look reveals the major role and influence aggregate plays in the properties of both fresh and hardened concrete. Changes in gradation, maximum size, unit weight, and moisture content can all alter the character and performance of your concrete mix. In this study, Coarse aggregate size of 20 mm and 10 mm, crushed, free from organic impurities conform from IS: 2386 – 1963 were used. All the laboratory tests were performed as per the Indian codal provisions. Results and properties of the coarse aggregate are as shown in Table No. 2 and the gradation curve of the coarse aggregate (Figure 1 and 2).

Table 2: Properties of Coarse Aggregate

Coarse Aggregate		
1	Specific Gravity of 20 mm Aggregate	2.92
2	Specific Gravity of 10 mm Aggregate	2.96
3	Water Absorption of 20 mm Aggregate	0.98 %
4	Water Absorption of 10 mm Aggregate	1.06 %
5	FI / EI Index of 20 mm Aggregate	12.11 / 12.33 %
6	FI + EI Index of 20 mm Aggregate	24.44 %
7	FI / EI Index of 10 mm Aggregate	13.44 / 12.29 %
8	FI + EI Index of 10 mm Aggregate	25.73 %
9	Aggregate Impact Value	13.47 %
10	Loss Angeles Abrasion Value	18.20 %
11	Aggregate Crushing Value	26.48 %

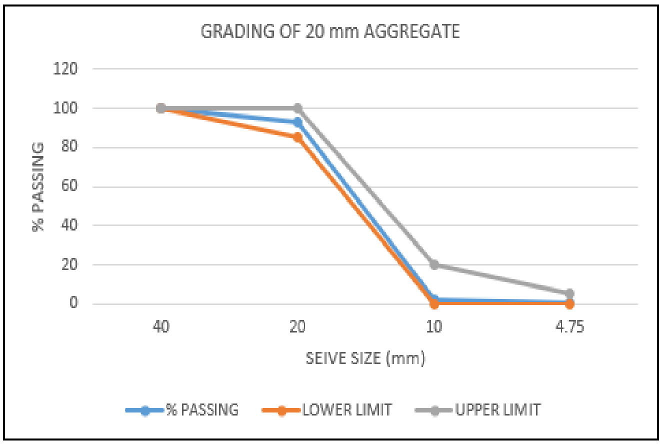

Figure 1: Gradation Curve of 20 mm Aggregate

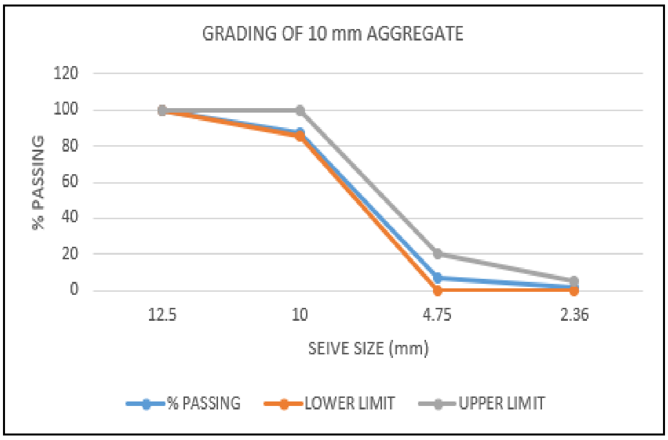

Figure 2: Gradation Curve of 10 mm Aggregate

3.3 FINE AGGREGATE

Sand is a major component of concrete and without the sand, concrete will not function as intended. The properties of a specific concrete mix will be determined by the proportion and type of sand used to formulate the concrete. Sand is usually a larger component of the mix than cement. Fine aggregate found from river, free from organic impurities conform from IS: 2386 – 1963 and IS: 383 - 1970 were used. All the laboratory tests were performed as per the Indian codal provisions. Results and properties of the coarse aggregate are as shown in Table No. 3 and the gradation curve of the fine aggregate (Figure 3 and 4).

Table 3: Properties of Fine Aggregate

Fine Aggregate		
1	Specific Gravity of Fine Aggregate	2.61
2	Water Absorption of Fine Aggregate	1.55%
3	Fineness Modulus of Fine Aggregate	2.61

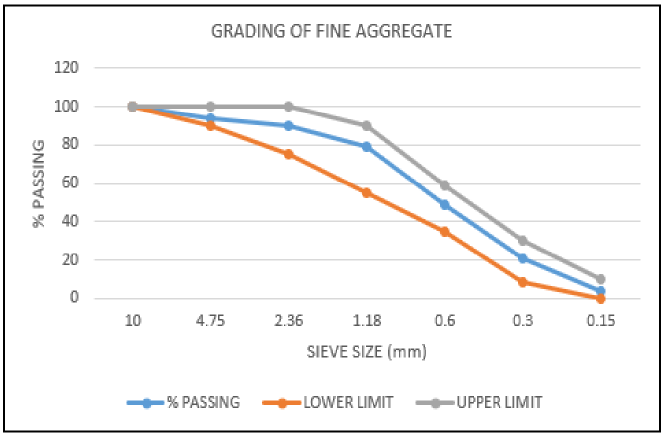

Figure 3: Gradation Curve of Fine Aggregate

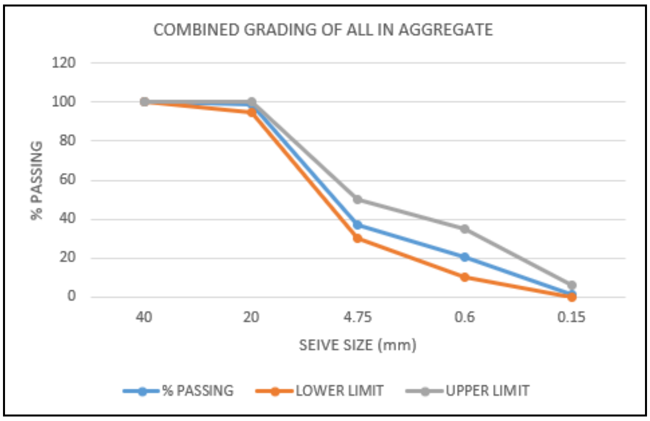

Figure 4: Gradation Curve of All in One Combined Aggregate

3.4 NANO TITANIUM DIOXIDE (NANO TiO2)

Nano Titanium Dioxide (TiO_2) was used as a partial replacement by weight of cement in concrete mixed. Three different dosages, 0.5 %, 1.0 % and 1.5 % by weight of cement was used to determine the properties of the concrete mixed. Physical properties of the Nano Titanium Dioxide (TiO_2) are as shown in Table No. 4.

Table 4: Properties of Nano Titanium Dioxide (TiO_2)

Structure Name	Anatase	Rutile	Brookite
Density (gm/cc)	3.9	4.2	4.18
Refractive Coefficient	2.52	2.71	2.58
Hardness (pascal)	5.5 - 6.0	6.0 - 7.0	5.5 - 6.0
Boiling Point (°C)	Rutile transition	1858 °C	750 °C
Particle size	15 – 30 nm		
In this study Anatase base Nano Titanium Dioxide was use.			

Figure 5: Nano Titanium Dioxide (TiO_2)

3.5 SUPER PLASTICIZER

Superplasticizer is a high range water reducer and retarding admixture. They are soluble macromolecules, which are hundreds of times larger than of water molecule. It increases the workability for reduction in water to cement ratio, initial setting time of concrete and also to be utilized in producing flowing concrete. For study work Rheobuild 821 (EJ) was used as the supper plasticizer. The physical and chemical properties of the Rheobuild 821 (EJ) are as shown in Table No. 5.

Table 5: Properties of Supper Plasticizer

Super Plasticizer		
1	Appearance	Liquid (Yellow)
2	PH	6 (min)
3	Dosage	0.8 % by Volume
4	Specific Gravity	1.22

4. PQC CONCRETE MIXED DESIGN AND EXPERIMENTAL INVESTIGATION

4.1 PQC CONCRETE MIXED DESIGN

There are several methods to design the concrete mixed. Out of that method IRC – 44 method is used to design the concrete mixed. At the end of all consideration and steps mass of the all material (Concrete Mixed Design) is as shown in Table No. 6. PQC design for concrete mixed is as per the IRC 58 – 2015 and MORTH (5th Revision)

Table 6: PQC Concrete Mixed Design

Mass of All Materials For 1 M3 of Concrete				
Material	**Mass (Kg)**			
Percentage by Volume	**0.00 %**	**0.50 %**	**1.00 %**	**1.50 %**
Nano TiO_2	0	8.20	16.40	24.60
Cement	410	401.80	393.60	385.40
Water	139.5	136.61	133.82	131.04
20 Mm Aggregate	850	853.98	857.95	861.91
10 Mm Aggregate	539	541.05	543.56	546.07
Fine Aggregate	667	667.90	671.00	674.11
Admixture (0.8 %)	3.28	3.21	3.15	3.08
Density (Kg/M3)	2608.78	2612.76	2619.48	2626.21
Mixed Proportion	1 : 1.62 : 3.39	1 : 1.66 : 3.47	1 : 1.70 : 3.56	1 : 1.65 : 3.75

4.2 SLUMP TEST

Concrete slump test is performed to evaluate the consistency of concrete mix by prepared the mix at the laboratory or the construction site during the progress of the work. During construction work, the uniform quality control check of concrete was carried out from batch to batch by concrete slump test. Slump test was performed as per the IS: 1199 – 1959. The result of the slump test is given in Table No. 7.

Table 7: Slump of Fresh Concrete (mm)

	Normal Concrete	**NC + 0.5 % Nano TiO_2**	**NC + 1.0 % Nano TiO_2**	**NC + 1.5 % Nano TiO_2**
	Mm	Mm	mm	Mm
Required	25 ± 15	25 ± 15	25 ± 15	25 ± 15
Initial	84	82	82	80
30 min	62	61	59	56
45 min	48	46	45	43
60 min	36	34	33	33

5. RESULTS

5.1 COMPRESSIVE STRENGTH

Concrete cubes, size of 150 mm X 150 mm X 150 mm were casted to get the Compressive Strength of the concrete mixed. Compressive strength was examined after 3, 7 and 28 days of curing. Result of compressive strength is as shown in Table No. 8.

Table 8: Compressive Strength of Concrete Mixed

Compressive strength			
Type of Concrete	**Average Compressive strength (N/mm2)**		
	3 Days	**7 Days**	**28 Days**
NC	35.35	46.79	59.75
NC + 0.5 % Nano TiO_2	38.56	46.90	54.87
NC + 1.0 % Nano TiO_2	**42.80**	**51.91**	**64.65**
NC + 1.5 % Nano TiO_2	40.19	48.53	61.04

5.2 FLEXURAL STRENGTH

Concrete beam of size of 150 mm X 150 mm X 700 mm were casted to get the Flexural Strength of the concrete mixed. Flexural strength was examined after 7 and 28 days of curing. Result of flexural strength is as shown in Table No. 9.

Table 9: Flexural Strength of Concrete Mixed

Flexural strength		
Type of Concrete	Average Flexural strength (N/mm2)	
	7 Days	28 Days
NC	5.10	6.73
NC + 0.5 % Nano TiO_2	5.39	6.40
NC + 1.0 % Nano TiO_2	**5.78**	**7.27**
NC + 1.5 % Nano TiO_2	5.57	6.77

6. CONCLUSION

The study concludes that the addition of Nano TiO_2 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. From the study, the following were concluded

1. Scientifically evaluated test reports on cement, coarse aggregates, fine aggregates for pavement slab shows that engineering properties are fulfilled as per IS Codes. From the plot of all-in combined aggregate gradation chart as shown in figure 4, it shows specifically the obtained gradation line falls within the limit lines which mean that the selected aggregate proportion fulfil the Ministry of Road Transport and Highways (MORTH, 2005) specification.

2. The concrete slump test results of M40 grade concrete with and without Nano Titanium Dioxide (TiO_2) indicates that decreasing rate of the slump is very small. Also, the movements on account of additives are satisfying the properties as set down in codal provisions.

3. The compressive and flexural Strength test results of M40 grade concrete with and without Nano Titanium Dioxide (TiO_2) indicates that compressive and flexural strength increases with increase in dosage of TiO_2 i.e. 0.5 %, 1.0 % and 1.5 % by weight of cement. However, the laboratory investigation shows that compared to M40 concrete mix the maximum compressive and flexural strength of concrete at 1% Nano Titanium Dioxide (TiO_2) i.e. 64.65 N/mm2 (28 days) and 7.27 N/mm2 (28days) respectively.

4. The laboratory investigation reveals that Nano Titanium Dioxide (TiO_2) in concrete proves to be an ideal new approach in road construction.

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