AN EXPERIMENTAL INVESTIGATION ON THE EFFECT OF NANO-TiO_2 PARTICLES ON THE PROPERTIES OF CONCRETE

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Abstract – This paper deals with an experimental investigation conducted on the properties of concrete to know the mechanical properties and durability of concrete on addition of Nano-TiO_2 particles. Cement is replaced by Nano-TiO_2 particles in different percentage, such as 0%, 0.5%, 1.0%, 1.5% & 2.0% respectively. The study is done on M30 grade of concrete. The Nano-TiO_2 particles have been very effective for the replacement of cement at 1.0% for the strength parameter and durability when compared to normal concrete.

***Key Words*: Nano-TiO_2, compressive strength, flexural strength, split tensile strength, shear strength, impact strength, soroptivity.**

1. INTRODUCTION

Concrete is considered as material of the 21st century due to its functional use in the structures, buildings, factories, bridges and airports. The improvement in the concrete strength and durability is needed because of rapid population explosion and technology. To improve concrete properties, different supplementary cementatious material or SCMs are added. Fly ash, blast furnace slag, rice husk, silica fume and even bacteria are some of the supplementary cementatious materials.

Nanotechnology is a rising field of science identified with the comprehension and control of matter at the nano-scale, i.e. at measurements between roughly 1-100 nm. Nanotechnology includes nano-scale science, designing and innovation that included imaging, measuring, displaying and controlling at this length scale. In the serviceability record arrangement of units, the prefix "nano" implies 1-billionth or 10^{-9}. Along these lines 1 nm is 1-billionth of a meter. Nano-powders (grain size, 1-100nm) have high surface area hence it enhance the chemical, optical and mechanical properties. It is anticipated that addition of nano powders into composites will increase strength, reduce voids, and improve self control and cleaning.

Incorporating of nano-particles in order to improve the durability of concrete is rarely reported. Therefore introducing some nano-particles which probably could improve the mechanical and durability properties of cementatious composites is inherent. Due to the new potential uses of nano-particles, there is a global interest in the investigation of the influence of nano particles in construction materials especially cements mortar and concrete. The nano scale size of particles can result in dramatically improved properties from conventional grain-size materials of the same chemical composition. There are several reports on merging nano-particles in concrete which most of them have focused on using SiO2 nano particles.

Nano-TiO2 particles containing concrete acts by triggering photo catalytic degradation of the pollutants, such as NOx, carbon monoxide, VOCs, chlorophenols and aldehydes from vehicle and industrial emissions. Self-cleaning and de-polluting concrete products are already being produced for use in the facades of buildings and in paving materials for roads and have been used in Europe and Japan. In addition to imparting self-cleaning properties, a few studies have shown that nano-TiO2 can accelerate the early-age hydration of Portland cement, improve compressive and flexural strengths, and enhances the abrasion resistance of concrete.

2. EXPERIMENTAL INVESTIGATION

2.1. Material used

2.1.1. Ordinary Portland cement.

Ordinary Portland cement of 43 grade confirming to IS 8112:1989 is used. The chemical composition and cement properties are given in table-1 and table-2.

Table 1: Chemical composition of cement.

Composition	Percentage (%)
CaO	61
SiO_2	23
Al_2O_3	05
$CaSO_4$	04
FeO_3	03
MgO	02
S	01
Alkalis	01

Table 2: Properties of cement.

Properties	Results
Specific gravity	3.15
Normal consistency	33%

Initial setting time	90 min
Final setting time	410 min

2.1.2. Nano-TiO_2

TiO_2 nano-particles with particles size of 30-40 nm were used. The composition of nano–TiO_2 is tabulated in table-3.

Table 3: Properties of Nano-TiO_2.

Particle purity	99.9%
Molecular formula	TiO_2
Average particle size	30-40 nm
Specific surface area	200-20 m^2/g
Bulk density	0.15-0.25 g/cm^3
Color	White
Morphology	Spherical
Atomic weight	79.8658 g/mol

2.1.3. Fine aggregate

Fine aggregate confirming to Zone II as per IS 383 – 1970 and specific gravity 2.72 is used in experiment.

2.1.4. Coarse aggregate

Locally available 20mm and down size aggregates are used. The properties of coarse aggregate are organized in table-4.

Table 4: Properties of coarse aggregate

Properties	Results
Size of coarse aggregate	20mm down angular
Specific gravity	2.74
Loose density	1449 kg/m^3
Compacted density	1600 kg/m^3

2.2. Experimental procedure

- Moulds are cleaned, lightly oiled and properly fixed.
- Take water, cement, sand, aggregate in the proportion as 0.45:1:1.53:2.62 (M30, mix design as per IS-10262-2009).
- Make the fresh concrete by replacing the cement by different percentage of Nano-TiO_2 (0%, 0.5%, 1.0%, 1.5% and 2.0%).
- After conducting workability tests pour the concrete in to moulds and ensure proper compaction.
- After 24 hours of time, de-mould the specimen and transfer into the curing tank carefully. Take the specimen for testing after 28 days from curing tank.
- Provide 24 hours of drying period for specimen in atmosphere before conducting tests.

3. TEST RESULTS AND DISCUSSIONS

3.1.1. Initial setting time and final setting time

It is observed that initial setting time and final setting time of cement matrix goes on decreasing as the percentage replacement of cement by TiO_2 nano-particles increase. This may be due to the fact that the nano- TiO_2 particles fill all the pores of the cement matrix thereby decreasing the initial and final setting time. The results are tabulated in table-5 and variation of initial setting time and final setting time is shown in figure-1.

Table 5: Initial and final setting time

% replacement of cement by Nano-TiO_2	Initial setting time (min)	Final setting time (min)
0%	90	410
0.5%	80	380
1.0%	70	350
1.5%	65	300
2.0%	60	280

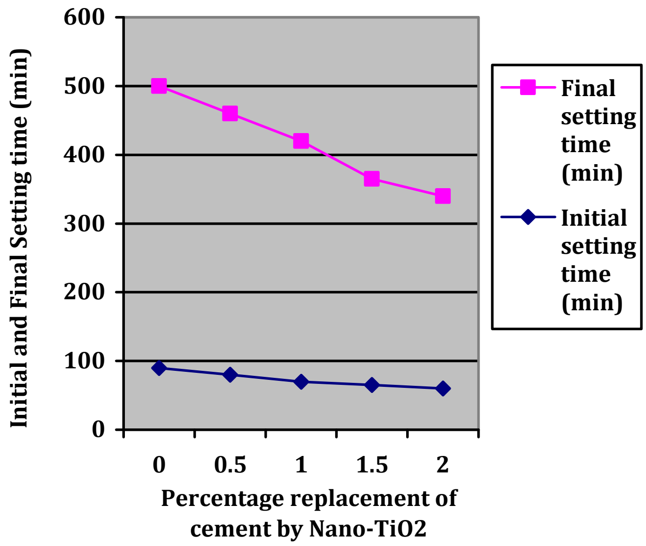

Figure 1: Variation of initial and final setting time.

3.1.2. Workability tests

It is observed that the workability of concrete produced by replacing cement by Nano-TiO_2 particles as measured from slump, compaction factor, percentage flow and Vee-Bee degrees goes on decreasing as the Nano-TiO_2 percentage increase. This may be due to the fact that the Nano-TiO_2 particles make the concrete stiff and sticky thereby reducing the flow. The results are tabulated in table-6.

Table 6: Workability test results.

Percentage replacement of cement by Nano-TiO_2	Slump (mm)	Compaction factor	Vee-Bee (seconds)	Flow percentage
0%	25	0.96	10	34
0.5%	15	0.92	13	32
1.0%	0	0.87	16	30.5
1.5%	0	0.81	21	25.5
2.0%	0	0.78	24	25

3.1.3. Near surface characteristics

It is observed that the water absorption and soroptivity of concrete produced by replacing cement by Nano-TiO_2 particles show minimum value at 1% replacement. After 1% replacement the water absorption and soroptivity values increase. This may be due to the fact that at 1% replacement of cement by TiO_2 nano-particles all the pores of concrete will be filled by giving a compact micro structure to concrete. The results are tabulated in table-7 and variation of water absorption and soroptivity is shown in figure-2 and figure-3 respectively.

Table 7: Near surface characteristics

Percentage replacement of cement by Nano-TiO_2	Water absorption (%)	Percentage variation	Soroptivity ($mm/min^{0.5}$)	Percentage variation
0% (Reference)	0.58	0	20.12	0
0.5%	0.49	-15.51	18	-10.53
1.0%	0.39	-32.75	15	-25.44
1.5%	0.73	25.86	20.12	0
2.0%	0.6	3.44	15.21	24.40

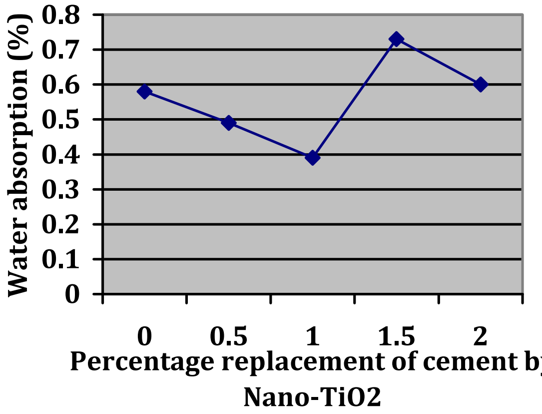

Figure 2: Variation of water absorption

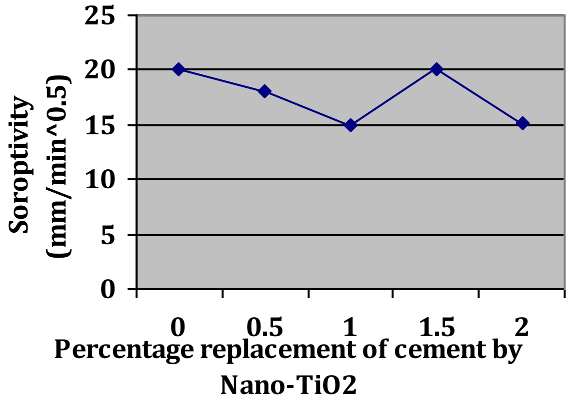

Figure 3: Variation of soroptivity

3.1.4. Hardened tests on concrete

3.1.4.1. Compressive strength

It is observed that the compressive strength of concrete produced by replacing cement by TiO2 nano-particles show higher value at 1% replacement. After 1% replacement the compressive strength decreases. The percentage increase in the compressive strength at 1% replacement is found to be 2.05%. This may be due to the fact that at 1% replacement of cement by TiO_2 nano-particles all the pores of concrete will be filled by imparting a dense micro structure to concrete. Also it may be due to the fact that the Nano-TiO_2 particles act as pozzolona and the pozzolanic reaction enhances the compressive strength of concrete. The results are tabulated in table-8 and variation of compressive strength is shown in figure-4.

Table 8: Results of compressive strength

Percentage replacement of cement by Nano-TiO_2	Compressive strength (MPa)	Percentage variation of compression strength with respect to reference concrete
0% (Reference)	36.43	0%
0.5%	35.26	-3.21%
1.0%	37.18	2.05%
1.5%	33.77	-7.03%
2.0%	31.55	-13.39%

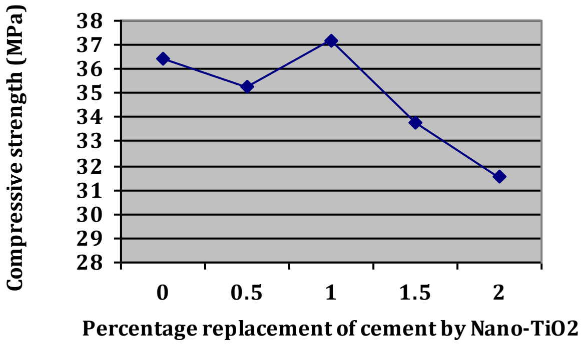

Figure 4: Variation of compressive strength

3.1.4.2. Split tensile strength

It is observed that the split tensile strength of concrete produced by replacing cement by TiO_2 nano-particles show higher value at 1% replacement. After 1% replacement the split tensile strength decreases. The percentage increase in the split tensile strength at 1% replacement is found to be 14.67%. This may be due to the fact that at 1% replacement of cement by TiO_2 nano-particles all the pores of concrete will be filled by imparting a dense micro structure to concrete. Also it may be due to the fact that the Nano-TiO_2 particles act as pozzolona and the pozzolanic reaction enhances the split tensile strength of concrete. The results are tabulated in table-9 and variation of split tensile strength is shown in figure-5.

Table 9: Results of split tensile strength

Percentage replacement of cement by Nano-TiO_2	Split tensile strength (MPa)	Percentage variation of split tensile strength with respect to reference concrete
0% (Reference)	3.34	0%
0.5%	2.54	-23.95%
1.0%	2.87	-14.67%
1.5%	2.54	-23.95%
2.0%	2.51	-24.85%

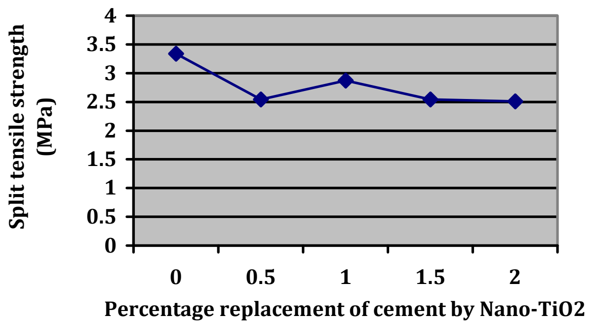

Figure 5: Variations of split tensile strength

3.1.4.3. Flexural strength

It is observed that the flexural strength of concrete produced by replacing cement by TiO_2 nano-particles show higher value at 1% replacement. After 1% replacement the flexural strength decreases. The percentage increase in the flexural strength at 1% replacement is found to be 16.36%. This may be due to the fact that at 1% replacement of cement by TiO_2 nano-particles all the pores of concrete will be filled by imparting a dense micro structure to concrete. Also it may be due to the fact that the Nano-TiO_2 particles act as pozzolona and the pozzolanic reaction enhances the flexural strength of concrete. The results are tabulated in table-10 and variation of flexural strength is shown in figure-6.

Table 10: Results of flexural strength

Percentage replacement of cement by Nano-TiO_2	Flexural strength (MPa)	Percentage variation of flexural strength with respect to reference concrete
0% (Reference)	5.5	0%
0.5%	4.6	-18.90%
1.0%	6.4	16.36%
1.5%	4.86	-11.63%
2.0%	4.2	-23.63%

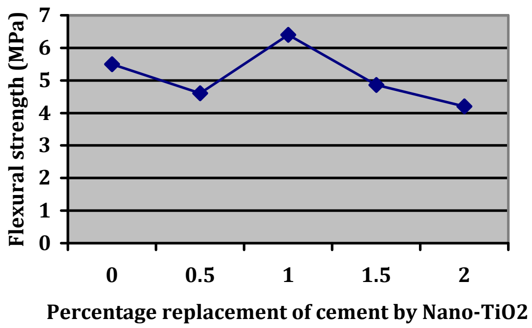

Figure 6: Variation of flexural strength

3.1.4.4. Shear strength

It is observed that the shear strength of concrete produced by replacing cement by TiO_2 nano-particles show higher value at 1% replacement. After 1% replacement the shear strength decreases. The percentage increase in the shear strength at 1% replacement is found to be 12.97%. This may be due to the fact that at 1% replacement of cement by TiO_2 nano-particles all the pores of concrete will be filled by imparting a dense micro structure to concrete. Also it may be due to the fact that the Nano-TiO_2 particles act as pozzolona and the pozzolanic reaction enhances the shear strength of concrete. The results are tabulated in table-11 and variation of shear strength is shown in figure-7.

Table 11: Results of shear strength

Percentage replacement of cement by Nano-TiO_2	Shear strength (MPa)	Percentage variation of shear strength with respect to reference concrete
0% (Reference)	7.86	0
0.5%	7.12	-9.14
1.0%	8.88	12.97
1.5%	5.36	-31.80
2.0%	5.00	-36.38

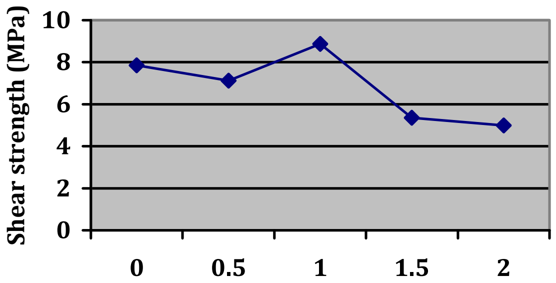

Figure 7: Variation of shear strength

3.1.4.5. Impact strength

It is observed that the impact strength of concrete produced by replacing cement by TiO_2 nano-particles show higher value at 1% replacement. After 1% replacement the impact strength decreases. The percentage increase in the impact strength for initial crack and final failure at 1% replacement is found to be 1.19% & 22.88%. This may be due to the fact that at 1% replacement of cement by TiO_2 nano-particles all the pores of concrete will be filled by imparting a dense micro structure to concrete. Also it may be due to the fact that the Nano-TiO_2 particles act as pozzolona and the pozzolanic reaction enhances the impact strength of concrete. The results are tabulated in table-12 and variation of impact strength is shown in figure-8.

Table 12: Results of impact strength

Percentage replacement of cement by Nano-TiO_2	Impact strength for initial crack (N-m)	Percentage variation of impact strength for initial crack with respect to reference concrete	Impact strength for final failure (N-m)	Percentage variation of impact strength for final failure with respect to reference concrete
0% (Reference)	4884.1	0%	5956.03	0%
0.5%	3592.0	-26.45%	3701.7	-37.84%
1.0%	4825.92	-1.19%	4592.85	-22.88%
1.5%	2248.45	-53.96%	2296.40	-61.44%
2.0%	1987.96	-59.29%	2035.94	-65.81%

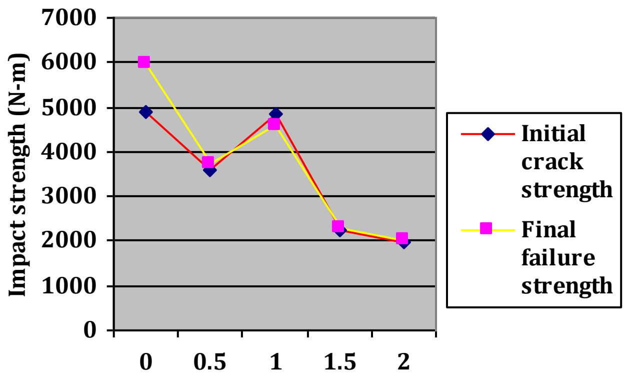

Figure 8: Variation of impact strength

4. Conclusions

Following conclusion may be drawn based on the test results:

- The initial and final setting time of cement matrix goes on decreasing as the percentage replacement of cement by Nano-TiO_2 particles increase.
- The workability of concrete produced by replacing cement by Nano-TiO_2 particles goes on decreasing as the percentage replacement increase.
- The least value of water absorption for concrete is obtained by replacing 1% cement by TiO_2 nano-particles.
- The least value of soroptivity for concrete is obtained by replacing 1% cement by TiO_2 nano-particles.
- The higher value of compressive strength for concrete is obtained by replacing 1% of cement by Nano-TiO_2 particles.
- The higher value of split tensile strength for concrete is obtained by replacing 1% of cement by Nano-TiO_2 particles.
- The higher value of flexural strength for concrete is obtained by replacing 1% of cement by Nano-TiO_2 particles.
- The higher value of impact strength for concrete is obtained by replacing 1% of cement by Nano-TiO_2 particles.
- The higher value of shear strength for concrete is obtained by replacing 1% of cement by Nano-TiO_2 particles.

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