BEHAVIOUR OF SELF CLEANING CONCRETE BY USING VARIOUS PHOTOCATALYSTS

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Abstract – *Self cleaning concrete is a technique to reduce the air contaminants such as NO_X, SO_2, CO_2 and VOC'S from vehicular traffic on streets, any industrial activity and the urban environment. Photocatalytic materials are used in conventional concrete for urban buildings and road pavements to reduce air pollution. The photocatalytic material is either titanium dioxide (TiO_2) or zinc oxide (ZnO). Titanium dioxide (TiO_2) or zinc oxide (ZnO) are added to concrete by 0, 0.5, 1, and 1.5% of cement by weight. The compressive strength of concrete cubes cured for 28 days were taken. Durability test of self cleaning concrete was tested by using magnesium sulphate ($MgSO_4$) & sodium chloride (NaCl) solution. Self cleaning property of the photocatalytic concrete is studied by using RhB (Rhodamine dye) discolouration under U.V. light, a standard test for self-cleaning cementitious materials.*

Key Words: self cleaning concrete, TiO_2, ZnO, rhodamine dye, compressive strength, durability

1. INTRODUCTION

The demand of concrete increases as cities grow. However, it's utilization cause pollution to environment, hence it gives negative impacts on environment. Air quality is linked with various health hazards. Self-cleaning concrete has an ability to clean their surfaces and removes pollutants from the air. Such concrete is produced by the addition of photocatalyst to concrete.

Self cleaning concrete uses the energy from ultraviolet rays to oxidize organic compounds. This accelerate the process of natural oxidation and faster pollutant decomposition. Self cleaning concrete has two primary benefits which are kept surface free of dirt and ensure a cleaner environment. Photocatalytic materials are help to mitigate air pollution directly. These materials absorb ultraviolet radiation from the sun, hydroxyl radicals and superoxide anions are created that have the ability to react with pollutant molecules such as NO_x to convert them to other, less harmful substances. This could be particularly advantageous in areas with high levels of air pollution.

Previous research reported about the presence of voids in concrete, that leads to decrement of compressive strength. Thus, nanoparticles photocatalyst would fill the voids between cement particles, thus increase the strength and improve durability, thermal, mechanical, and electrical properties of cementitious materials. Nanoparticles are commonly used as photocatalyst is silicon oxide (SiO_2), zinc oxide (ZnO), aluminium oxide (Al_2O_3) and titanium oxide (TiO_2).

Several researches have been conducted on the incorporation of TiO_2 into concrete specimens. The photocatalyst, Titanium dioxide (TiO_2) is a naturally occurring compound that can decompose gaseous pollutants in the presence of sunlight. Nano titanium (nano-TiO_2) are reported that can improve the mechanical properties and durability properties of concrete. ZnO exhibits a better efficiency in photocatalytic degradation of some reactive dyes in aqueous solution and it can also improve the mechanical properties and durability properties.

2. EXPERIMENTAL WORK

2.1. Material used

2.1.1. Ordinary Portland cement

Ordinary portland cement was used for the present study (grade 53). The tests were conducted according to Indian Standard recommendations. The physical properties of cement are tabulated in Table 1.

Table 1 physical properties of cement

	Properties	Value
1	Specific gravity	3.15
2	Standard consistency (%)	31
3	Initial setting time (in minutes)	44
4	Final setting time (in minutes)	384
5	Fineness	7%

2.1.2 Fine Aggregate

Natural fine aggregate used for the experimental study was manufactured sand. The physical properties of fine aggregate are given in Table2.

Table 2 properties of fine aggregate

Sl No	Properties	Test Results
1	Water absorption (%)	0.6
2	Specific gravity	2.59
3	Bulk density(kg/*l*)	1.31
4	Fineness modulus	3.476
5	Uniformity coefficient (D_{60}/D_{10})	5.677
6	Effective size (D_{10})	0.155
7	Grading zone	Zone II

2.1.3 Coarse Aggregate

Crushed granite angular aggregate from a local source, having a maximum size of 20mm, was used for the present study. The physical properties of natural coarse aggregate are given in Table 3.

Table 3 physical properties of natural coarse aggregate

Sl No	Properties	Test Results
1	Water absorption (%)	1.3
2	Specific gravity	2.69
3	Bulk density	1.5g/cc
4	Fineness modulus	4.309
5	Uniformity coefficient (D_{60}/D_{10})	1.29
6	Effective size (D_{10})	15.523

2.1.4 superplasticizer

Master Glenium Sky 8233 is the high range water reducer used.

2.1.5 Titanium dioxide (TiO_2)

Table 3 Properties of TiO_2

Average particle size (nm)	35
Specific gravity	1.34-1.4
Density (g/cm^3)	0.25
Purity (%)	99%
Colour	white

2.1.6 Zinc oxide

Table 4 Properties of TiO_2

Average particle size (nm)	55
Specific gravity	5.6
Density (g/cm^3)	0.30
Purity (%)	99%
Colour	white

2.2 METHODOLOGY

- Collected raw materials such OPC, coarse aggregate and fine aggregate and finding their physical properties (M30, mix design as per IS-10262 2009).
- Make self cleaning concrete added with nano TiO_2 and self cleaning concrete added with nano ZnO.
- The compressive strength of concrete cubes of size 150x 150x 150 mm were tested at 28 days to obtain optimum of TiO_2 and ZnO.
- Then required number of concrete cubes of size 150x 150x 150 mm was prepared . The cubes were demoulded at 7th day and specimens were immersed in NaCl & $MgSO_4$ solution of 0.5M and 5%. The immersed specimens were removed from the respective solutions at 28days. The compressive strength of the immersed cubes were found after 24 hours. The results were compare with corresponding control mix.
- Self cleaning action of concrete is studied on cubes with the help of RhB solution (500ppm). After one day of curing, the concrete cubes are dipped into RhB solution. Then the cubes are taken out and exposed to direct sunlight to observe the self cleaning action. Photographs are taken at different intervals and the self cleaning action is observed.

2.3 RESULTS AND DISCUSSIONS

2.3.1 Compressive strength

The specimens with varying percentages of titanium dioxide are added on concrete and were tested for compressive strength at 28 day curing and the results are tabulate in table . fig shows the compressive strength of various percentage of titanium dioxide

It is observed that the compressive strength of concrete produced by adding TiO_2 nano-particles show higher value at 1%. After 1% of TiO_2 the compressive strength decreases. The percentage increase in the compressive strength at 1%

replacement is found to be 18.52%. This may be due to the fact that 1% of TiO_2 nano-particles all the pores of concrete will be filled by imparting a dense micro structure to concrete. Excess amount titanium dioxide covers the cement particles which disrupts the water cement reaction and hence the strength decreases on further increment.

Table 6 compressive strength of various percentages of titanium dioxide

Mix	% of titanium dioxide (TiO_2)	Compressive strength at 28 days (MPa)
T_0	0	40.16
$T_{0.5}$	0.5	36
T_1	1	47.6
$T_{1.5}$	1.5	40.19

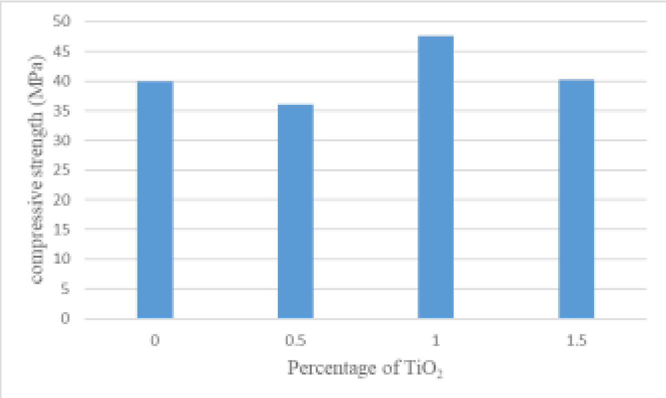


figure 1 compressive strength of titanium dioxide

The specimens with varying percentages of zinc oxide are added on concrete and were tested for compressive strength at 28 day curing and the results are tabulate in table 6 . fig1 shows the compressive strength of various percentage of zinc oxide.

Table 7 compressive strength of various percentages of ZnO

Mix	% of zinc oxide (ZnO)	Compressive strength at 28 days (MPa)
Z_0	0	40.01
$Z_{0.5}$	0.5	32.4
Z_1	1	39.8
$Z_{1.5}$	1.5	35.6

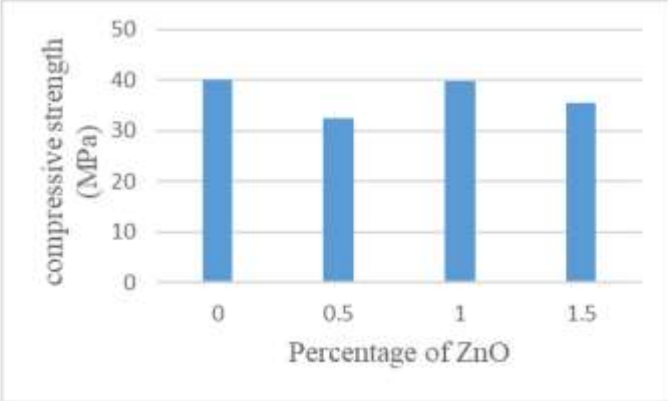


figure 1 compressive strength of ZnO

The compressive strength increases as -19.02%, -0.524% and -11.022% by increasing the ZnO Adding 1% of nanoparticle of ZnO improved the compressive strength as compared to control mix.

Nanoparticles fill the cement pores, thus improvement of strength will be expected. Since the content of NZ is too large, this particle cannot be well dispersed and consequently by combining nanoparticles, weak zones are formed.

2.3.2 Chloride attack

The concrete specimens which were dipped into the sodium chloride solutions (0.5M)was evaluated. The compressive strength of three samples was calculated and the average value was noted.

Table 9 chloride attack

Concrete type	Compressive strength at 28 day(MPa)
Control mix	31.4
TiO_2	38.8
ZnO	35.6

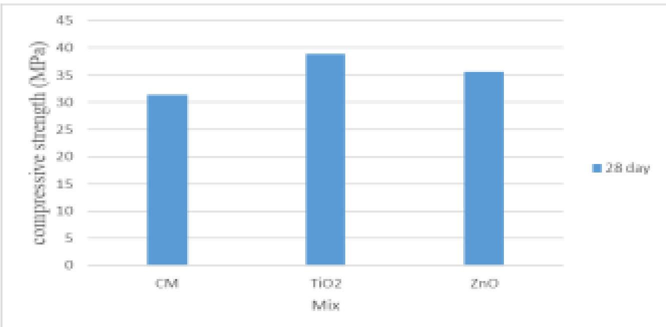


Figure 2 results of chloride attack

2.3.3 sulphate attack

The concrete specimens which were dipped into the magnesium sulphate solutions(5%) was evaluated. The compressive strength of three samples was calculated and the average value was noted.

Table 10 sulphate attack

Concrete type	Compressive strength at 28 day(MPa)
Control mix	30.6
TiO_2	36
ZnO	33.2

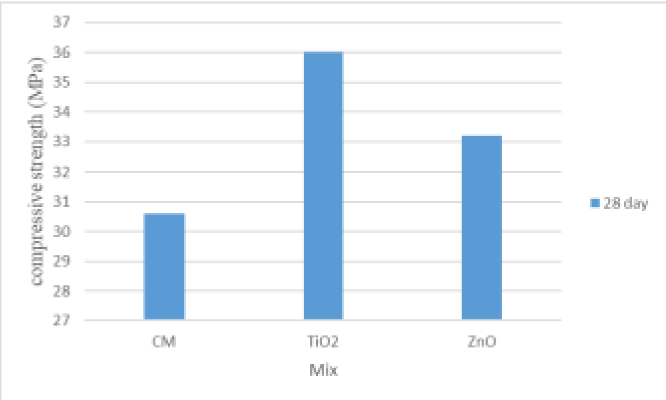


Figure 3 results of sulphate attack

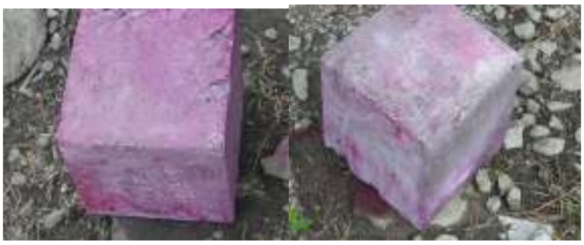
2.3.3 RHODAMINE B DYE DECOLOURIZATION TEST

In this test the concrete photo catalysts have been evaluated based on decolourization under sun light, a standard test for self cleaning cementious materials). After one day of curing, the concrete cubes are dipped into RhB solution. Then the cubes are taken out and exposed to direct sunlight to observe the self cleaning action. Photographs are taken at different intervals and the self cleaning action is observed.

CM TiO$_2$

ZnO

Figure 4 sample cubes placed under sunlight



CM TiO$_2$

ZnO

Fig 5 after 2 hours under sunlight

CM TiO$_2$

ZnO

Fig 6 after 4 hours under sunlight

3. CONCLUSIONS

- Optimum value of self cleaning concrete added with TiO_2 is 1%.
- Maximum compressive strength is obtaind at 1% for self cleaning concrete added with 1%.
- The durability of self-cleaning concrete containing 1% of TiO_2 exhibits better resistance against sulphate attack and chloride attack.
- The methylene rhodaminee decolorization test showed that ZnO was more efficient than TiO_2.

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