Experimental Study of Self-cleaning Concrete by Using Various Photocatalysts

Geethu Benny and Gayathri Krishna Kumar

Abstract A construction material that removes pollutants from the air as it keeps its surface clean. This new astonishing concrete that not only keeps itself clean but also removes pollutants from the air is called Self-Cleaning Concrete. 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. In this paper a study has been carried out on the compressive strength of self-cleaning concrete by introducing the photocatalytic materials such as titania (TiO_2), zinc oxide (ZnO), aluminium oxide (Al_2O_3). Self-cleaning property of the photocatalytic concrete is studied by using RhB (Rhodamine dye) discolouration under UV light, a standard test for self-cleaning cementitious materials. The properties of self-cleaning concrete is then compared with the that of M25 grade normal concrete and the results are studied.

Keywords Self-cleaning concrete · TiO_2 · ZnO · Al_2O_3 · Rhodamine dye · Compressive strength

1 Introduction

Buildings are exposed to many organic contaminants. From bird residue to diesel fumes, all urban buildings are constantly exposed to organic material that makes their surfaces appear dirty. Yet there's another kind of organic material constantly bombarding buildings that is harder to see: NO_x (nitrogen oxides). NO_x is the primary component of smog which not only makes buildings dirty, but also threatens the quality of the air we breathe. To overcome this, Photocatalytic materials such as

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titania (TiO_2), zinc oxide (ZnO), Alumina (Al_2O_3) is added to the concrete thus self-cleaning properties can be determined. A construction material removes pollutants from the air as it keeps its surface clean. This new astonishing concrete that not only keeps itself clean but also removes pollutants from the air is called Self Cleaning Concrete. The key to such properties are photocatalytic components that use the energy from ultraviolet rays to oxidize most organic and some inorganic compounds [1]. This accelerates the process of natural oxidation and faster pollutant decomposition. Air pollutants that would normally result in discoloration of exposed surfaces are removed from the atmosphere by the components, and their residues are washed off by rain [1, 2].

2 Objectives of the Study

The objectives of the experimental research work include;

- To access the cleaning capacity of concrete using TiO_2, ZnO, Al_2O_3.
- To study compressive strength, decolourization using RhB dye.
- To compare the compressive strength and decolourization of concrete cubes made from TiO_2, ZnO, Al_2O_3.
- To compare the properties of self-cleaning concrete with that of normal M25 grade concrete.

3 Scope

- Concrete faces the problem of tending to become dirty when exposed to polluted area. This can be reduced by using self-cleaning capability of concrete by using TiO_2, ZnO, Al_2O_3.

4 Experimental Work

4.1 Materials Used

4.1.1 Cement

Ordinary Portland cement (OPC)-53 grades confirming to IS: 12269–1987 was used. The properties are given in Table 1.

Table 1 Properties of cement

Fineness modulus	Specific gravity	Initial setting time
6%	3.17	42 min

Table 2 Properties of fine aggregate

Specific gravity	Grade
2.75	Zone II

Table 3 Properties of coarse aggregate

Specific gravity	Grade
2.83	Well graded

Table 4 Physical properties of titanium dioxide

Average particle size	Purity	Specific gravity
35 nm	99%	1.4

4.1.2 Fine Aggregate

Fine aggregate used for the experimental study was manufactured sand. The physical properties of fine aggregate are given in Table 2.

4.1.3 Coarse Aggregate

Coarse aggregate used in this experiment are of 20 mm nominal size. The physical properties of coarse aggregate are given in Table 3.

4.1.4 Titanium Dioxide

Titanium dioxide is a chemical compound, also known as titania, is the naturally occurring oxide of titanium, chemical formula TiO_2. Table 4 shows the physical properties of titanium dioxide.

4.1.5 Zinc Oxide

Zinc oxide is an inorganic compound with the formula ZnO. ZnO is a white powder that is insoluble in water. Table 5 shows the properties of zinc oxide.

Table 5 Physical properties of zinc oxide

Average particle size	Purity	Specific gravity
55 nm	99%	5.6

Table 6 Physical properties of aluminium oxide

Average particle size	Purity	Specific gravity
55 nm	99%	3.9

4.1.6 Aluminium Oxide

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. It is commonly called alumina. Table 6 shows the properties of aluminium oxide.

4.1.7 Rhodamine B

It is a chemical compound and a dye. It is often used as a tracer dye within water to determine the rate and direction of flow and transport. Rhoda mine dyes are used extensively in biotechnology applications.

4.2 Mix Proportion

M25 grade mix design was carried out with reference to IS code-10262: 2009 [1]. A ploy-carboxylate ether based superplasticiser is used at a dosage of 0.3% by weight of cement to improve the workability. Trial and error method is adopted to arrive at the suitable normal concrete mix. Hence arrived at a mix proportion which is tabulated in Table 7

Hence the mix proportion adopted is 1:1.77:3.24.

Table 7 Mix proportion

Cement (kg)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Chemical admixture (kg/m^3)	Water (kg/m^3)
390	693.2	1264	1.17	169.5

4.3 Methodology

- The properties of the raw materials such as cement, fine aggregate, coarse aggregate which are used for the investigation is studied. All the experiments that are done to determine the characteristics of the materials are carried out as per Indian Standards.
- All the materials for casting concrete were taken and were mixed using hand mixing under desirable conditions and they are allowed for casting in the prefabricated moulds [3].
- In the mix TiO_2, ZnO, Al_2O_3 were added in varying percentages such as 0.5%, 1%, 1.5% of weight of cement and self-cleaning concrete is made.
- Specimens were demoulded 24 h after casting and are cured in water until the testing age [4].
- The compressive strength of concrete cubes of size 150 × 150 × 150 mm were tested at 7 days and 28 days to obtain optimum of TiO_2, ZnO, Al_2O_3.
- Self-cleaning action of concrete is studied on cubes with the help of RhB solution. 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.

4.4 Results and Discussions

4.4.1 Estimation of Optimum Percentage of Photocatalysts

Concrete cubes were casted with varying percentages of TiO_2, ZnO, Al_2O_3. 3 cubes were prepared for each mix and compressive strength test was conducted after 7 days and 28 days appropriate curing. Based on the results optimum percentage of different photocatalysts were determined.

The results indicated that the compressive strength of concrete produced by adding photocatalytic (TiO_2, ZnO, Al_2O_3) nano-particles show higher value at 1% which is greater than the value for control mix. This may be due to the fact that 1% of these nano-particles will fill all the pores of concrete thus imparts a dense micro structure to concrete [5, 6]. After 1% of TiO_2, ZnO, Al_2O_3 the compressive strength decreases this may be due to excess amount of these photocatalysts covers the cement particles which disrupt the water cement reaction and hence the strength decreases on further increment. Therefore the optimum percentage is found to be 1–1.5%. Figures 1, 2 and 3 depicts the variation of average compressive strength for varying percentages of TiO_2, ZnO, Al_2O_3 respectively.

Figure 4 depicts the graph between average compressive strength v/s optimum dosage of TiO_2, ZnO, Al_2O_3.

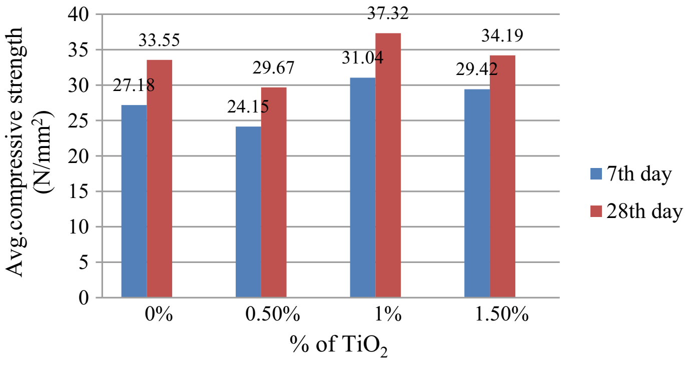

Fig. 1 Average compressive strength versus % of TiO_2

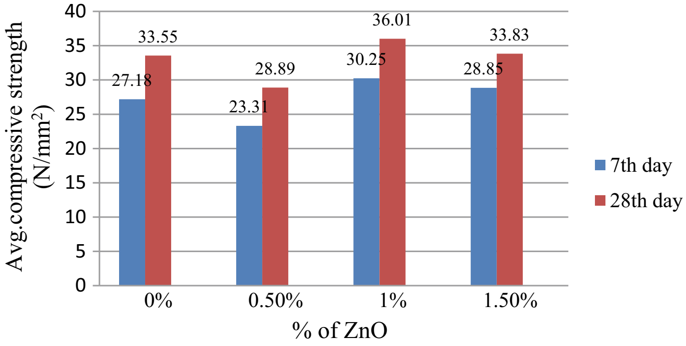

Fig. 2 Average compressive strength versus % of ZnO

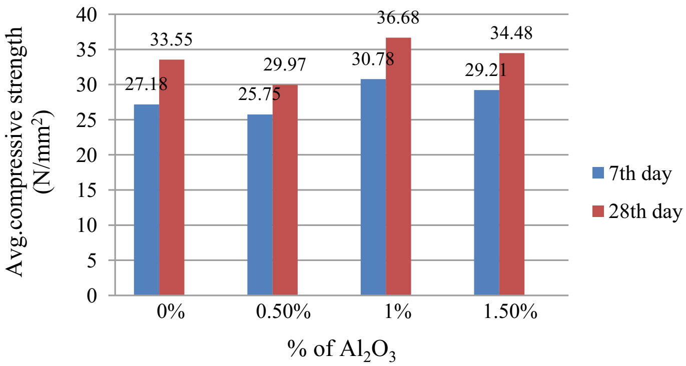

Fig. 3 Average compressive strength versus % of Al_2O_3

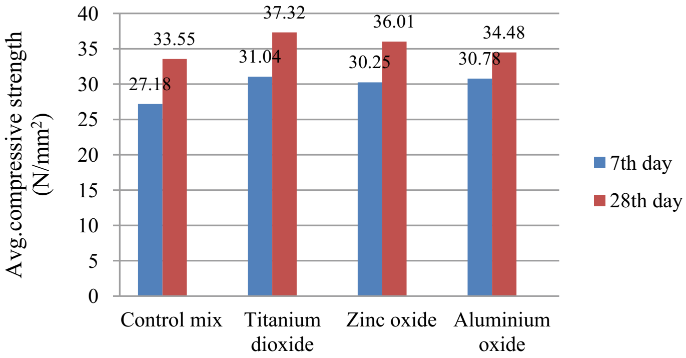

Fig. 4 Average compressive strength versus optimum dosage of TiO_2, ZnO, Al_2O_3

4.4.2 Decolourization Test

Concrete cubes were casted with 1% of TiO_2, ZnO, Al_2O_3. In this test the concrete containing photocatalysts have been evaluated based on decolourization under sun light, (a standard test for self-cleaning cementitious materials). After one day of curing, on the surface of the casted concrete cubes 1 ml of Rhodamine dye is dropped on each cube sample and placed under direct sunlight and the photographs are taken at different intervals and the self-cleaning action is observed [7]. Figure 5, 6, 7 shows the results recorded at different intervals.

The results indicated from the Rhodamine decolourization test is that the cube sample made with 1% TiO_2 shows a better cleaning action compared to that of Al_2O_3, ZnO and control mix (CM). Therefore self-cleaning action of the concrete cubes made with photocatalysts can be compared as; $TiO_2 > Al_2O_3 > ZnO \geq$ CM.

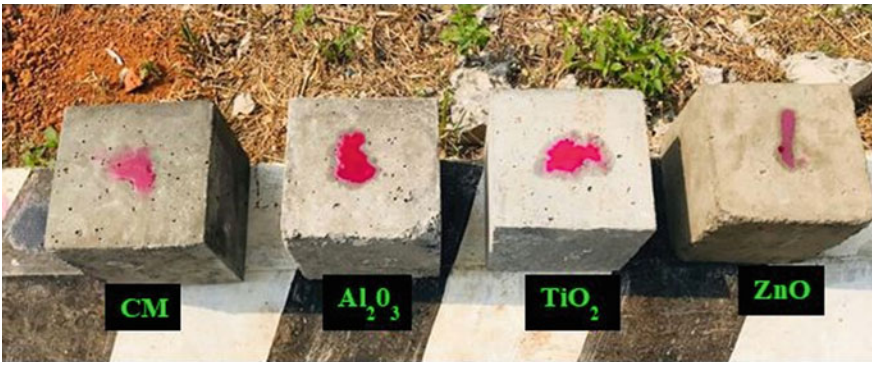

Fig. 5 Sample cubes placed under sunlight

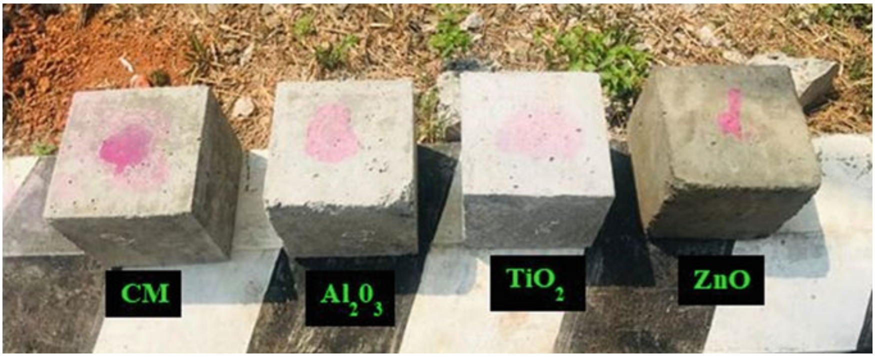

Fig. 6 After 2 h under sunlight

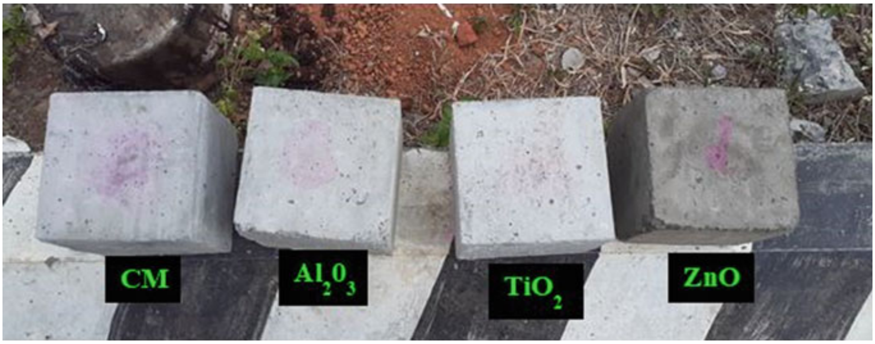

Fig. 7 After 5 h under sunlight

5 Conclusions

- Adding 0.5%, 1%, 1.5% of TiO_2, ZnO, Al_2O_3, it is observed that 1% of addition gives higher compressive strength than the control mix.
- The increase in strength is may be due to nanoparticles act as a protective material to improve the density of concrete that decreases the porosity of concrete significantly.
- The results indicated from the Rhodamine decolourization test is that the cube sample made with 1% TiO_2 shows a better cleaning action compared to that of Al_2O_3, ZnO and control mix (CM).

References

1. Antony J, Kannan SU (2018) Study on the properties of self cleaning concrete using titanium dioxide. J Trend Sci Res Dev 2:248–253
2. Dhanabal M, Sakthivel R, Arun T (2018) Experimental study of photocatalytic concrete using titanium dioxide. J Innov Res Sci Technol 4(11)
3. Feng D, Xie N, Gong C, Leng Z, Xiao H, Lui H, Shi X (2013) Study on the properties of self-cleaning concrete using titanium dioxide. Indus Eng Chem Res 52:11575–11582
4. Abdul Hafiz SB, Prakash KB (2017) An experimental investigation on the effect of nano-TiO_2 particles on the properties of concrete. J Eng Technol 4:2621–2626
5. Raj A (2019) Behaviour of self-cleaning concrete by using various photocatalysts. Int Res J Eng Technol 06(05)
6. Pathak A, Tiwari A (2017) Effect of zinc oxide nanoparticle on compressive strength and durability of concrete. J Res Appl Sci Eng Technol 5:445–500
7. Vignesh T, Sumathi A, Saravana Raja Mohan K (2018) Study on self-cleaning concrete using nano-liquid TiO_2. Int J Eng Technol 7(3.12):860–863