An Experimental investigation on self cleaning concrete using nano-titanium dioxide particles

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Abstract - *The growing relevance of sustainability in the world has increased worry about the environmental impact of utilising concrete in construction. Self-cleaning concrete is appealing not just for its self-cleaning qualities, but also for its environmental friendliness. The usage of this modern cement composite in urban and interurban regions can help to minimise maintenance costs while also ensuring a cleaner atmosphere. This paper presents an overview of self-cleaning concrete, the underlying principles of self-cleaning concrete, and its current applications. Titanium dioxide (TiO_2) is added to concrete in amounts ranging from 2% ,3% and 4% by weight of cement. When TiO_2 reacts with light and heat on concrete surfaces, photocatalytic efficiency may be enhanced, and dirt can be broken down into basic oxygen, water, CO_2, nitrate, and sulphate molecules. Photocatalysts assist to transform hazardous air pollutants to less dangerous ones in the presence of UV light. As a result, pollutants and impurities are eliminated from the environment. The compressive strength of concrete cubes that had been cured for 28 days was measured. The self-cleaning ability of photocatalytic concrete is investigated using a typical test for self-cleaning cementitious materials, RhB (Rhodamine dye) discoloration under UV light or sunlight.*

***Key Words*: TiO_2, Self –Cleaning concrete , RhB (Rhodamine dye), Compression Test, Discoloration Test, Nitrogen Dioxide, Photocatalyst, Workability.**

1. INTRODUCTION

As cities grow in size, so does the need for concrete. However, its usage pollutes the environment, and hence has a detrimental influence on the ecosystem. Air quality has been related to a variety of health risks. Self-cleaning concrete can clean its own surfaces while also removing pollutants from the air. The addition of photocatalyst to concrete results in this type of concrete.

One of the most recent inventions in the world of civil and environmental engineering is self-cleaning concrete, often known as smog-eating concrete. This concrete is distinguished by technology based on titanium dioxide (TiO_2) particles. TiO_2 can be included directly into concrete or into photocatalytic coatings on concrete specimens to implement the technique. It may be utilised in any type of concrete, with the exception that it can break down smog or other pollutants that has adhered to the concrete through a process called as photocatalysis. Most organic and some inorganic contaminants are neutralised when sunlight strikes the surface. Otherwise, discoloured concrete surfaces would result. Rain wipes away impurities from the concrete surface, keeping the buildings clean, and the cleaner air is an even more vital environmental advantage.

1.1 Historical information

Titanium dioxide, TiO2, has been recognized for almost a century as a photo-catalyst that may break down contaminants when exposed to UV light. It was found in the 1970s that titanium oxide triggered by light decomposes water via electrolysis. Products such as titanium oxide coating films, composite materials, and other materials have been created based on this finding and used for water purification, antifouling protection, and other applications. Organic contamination in water was degraded in the 1980s by adding TiO2 under the action of UV light. In Japan, photocatalysis was initially used on construction materials in the 1990s to create self-cleaning and antimicrobial surfaces. Luigi Cassar delivered the first formal publication on such items in 1997. Since then, photocatalytic concretes have been developed with a growing number of creative methods, moving from self-cleaning to depolluting effects

1.2 Photocatalysis

The photocatalysis process consists of many steps: the photoactive TiO2 on the material's surface is activated by UV light, and the pollutants are then oxidized and precipitated on the material's surface as a result of the photocatalyst's presence they can be removed from the surface by rain or cleaning/washing with water. Photocatalysts degrade organic molecules that dirty the surface and can be found on or in concrete structures. Dirt (soot, filth, oil, and particulates), biological creatures (mold, algae, bacteria, and allergies), air-borne pollutants (VOCs; cigarette smoke; and the nitrous oxides (NOx) and sulphuric oxides (SOx)), and even odour-causing chemicals are all examples of organic compounds.

2. EXPERIMENTAL WORK

2.1. Material and their characteristics

2.1.1. Cement (Ordinary Portland Cement)

In the presence of water, cement has both cohesive and adhesive capabilities. Hydraulic cement is the name for these types of cement. In concrete, cement is a binding ingredient that holds the other components together to produce a compact mass.For this investigation, ordinary portland cement was employed (grade 53). The testing was carried out in accordance with Indian Standards. Table 1 lists the physical characteristics of cement.

Table -1: Physical characteristics of cement.

	Characteristics	
1.	Standard consistency (%)	30%
2.	Specific Gravity	3.15
3.	Initial setting time (in min)	30
4.	Final setting time (in min)	600
5.	Fineness	7%

2.1.2.Titanium Dioxide

Titanium dioxide, often known as pigment or titania, is a naturally occurring titanium oxide having the formula TiO2. Increased photocatalytic activity is another feature of TiO2, which is aided by the nanoparticles' high surface-to-volume ratio as compared to microparticles.

About two and a half decades ago, scientists began researching light catalysis. Among the most fundamental elements in our everyday liv, titanium dioxide (TiO2), has evolved as a good photo catalyst material for environmental cleaning. The present state of TiO2 photo catalysis, particularly photo catalytic air filtration, is examined in this study. Only when the surface is exposed to UV or sunlight can photo catalysis occur. It is a powder with the chemical formula TiO2 and a molar mass of 79.87. The colour of titanium dioxide is white.

IS 13463-67-7 tio2 is a soft substance that melts at 1800 degrees Celsius. It has unique properties, such as insulation, corrosion resistance, flags, and so forth. It's polymorphous, with three different crystal formations. rutile, anatase, and brookite are the three types of minerals.

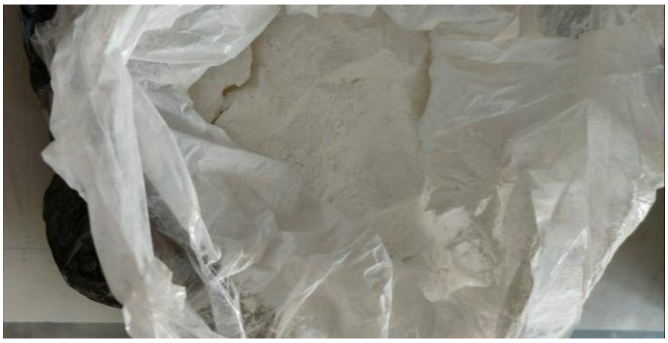

Fig -1 Nano Titanium Dioxide Particles

A.Titanium Dioxide Structure

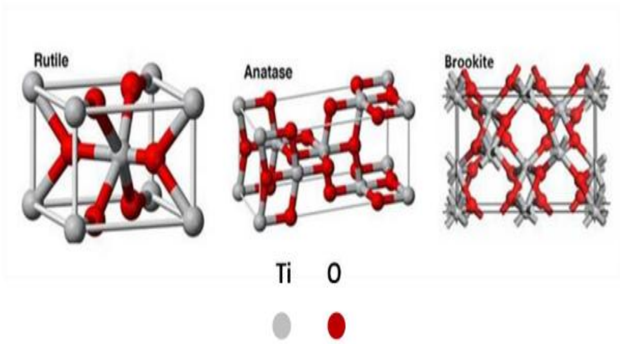

Fig -2 TiO_2 Structure

B.Physical property of Titanium Dioxide

Molar Mass	233.40g/mol
Refractive index	2.77-2.55
Density	4.5g/cm^3
Boiling point	1600 ^oC
Melting point	1580 ^oC

C.Chemical property of Titanium Dioxide

Titanium dioxide is non-toxic and also has stable chemical characteristics. Under normal temperatures, it practically has no reactivity with other materials. It's a somewhat acidic substance. Apart from alkali and warm nitric acid, it has no interaction with oxygen, hydrogen sulphide, sulphur dioxide, carbon dioxide, or ammonia, and is insoluble in water, fatty acids, other organic acids, and mild inorganic acids.

2.1.3 Fine Aggregate

Sand with rounder grains instead of angular grains can be used to make higher-quality concrete. Sea sand, which includes salt and other pollutants, must be replaced with river or artificial sand. Manufactured sand is employed as fine aggregate in this project. The zone is discovered using sieve analysis.

Table-2: Properties Of fine aggregate

	Properties	
1	Water absorption	0.6%
2	Specific gravity	2.60
3	Bulk Density	1.31(kg/l)
4	Fineness Modulus	3.47

2.1.4 Coarse Aggregate

Because coarse aggregate is extracted from rock mines or scraped from river beds, its size, shape, toughness, texture, and other characteristics vary widely depending on where it is mined. Coarse aggregate is classified as either smoother or rounded (such as river gravel) or angular (such as sand) (such as crushed stone). Because of this diversity, test techniques have been developed to identify the most important traits, as precise identification is unattainable. Relative density (or specific gravity), bulk density, and absorption are three essential properties that are widely employed to explain the behaviour of coarse aggregates. In our research, we utilized a 20mm aggregate.

Table-3: Properties Of coarse aggregate

	Properties	
1	Water absorption	1.3%
2	Specific gravity	2.69
3	Bulk Density	1.5(g/cc)
4	Fineness Modulus	4.30

2.1.5 Rhodamine B Dye

It is a pigment and a chemical substance. It's frequently used as a tracing dye in the water to assess flow and transport rates and directions. Because dyes glow, they may be identified readily and cheaply using equipment.

Fig-3 Rhodamine B Dye

A.Properties Of Rhodamine B Dye

Table-4: Rhodamine B dye properties

Chemical formula	$C_{28}H_{31}ClN_2O_3$
Molar mass	479.02
Appearance	red powder
Melting point	210 to 211 °C

2.1.6.Nitrogen Dioxide

The inorganic molecule NO2 stands for nitrogen dioxide. It's one of a group of nitrogen oxides. NO2 is a byproduct of the factory output of nitric acid, which is generated in millions of tonnes each year. It is a red-brown gas with a uniquely strong, bitter scent that is a major air contaminant at hotter altitudes.

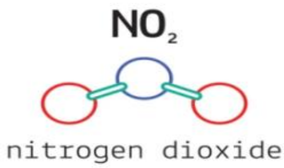

Fig-4 Nitrogen Dioxide

3. METHODOLOGY

- Obtaining physical qualities of raw materials such as OPC, coarse aggregate, and fine aggregate (M25, mix design as per IS-10262 2009).
- The requisite quantity of 150x 150x 150 mm concrete cubes were then made.
- In this experiment, titanium oxide was used to substitute cement in 2%, 3%, and 4% by weight of cement.
- 60% course Aggregate and 40% Fine Aggregate were used in making of 150x 150x 150 mm concrete cubes.
- Hand-mixed concrete was used, and steel moulds were used to cast the specimens. 24 hours after casting, the specimens were demoulded.
- The concrete is poured into molds in 50mm layer upon layer. The compression tests are carried out using a compression-testing equipment that is hydraulically.
- The concrete strength cubes measuring 150x 150x 150 mm was evaluated for 28 days to determine the best TiO2 concentration.
- With the assistance of RhB solution, the self-cleaning activity of concrete is investigated on cubes (500ppm).

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3.1 Curing

The hydration of cement particles gives concrete its strength. The hydration of cement is not a one-time event, but rather a long-term process. Of course, the rate of hydration is rapid at first, but it gradually decreases with time. The amount of hydration product generated, and hence the amount of get created, is determined by the degree of hydration. Cement requires a w/c ratio of roughly 0.23 for hydration and a w/e ratio of 0.15 for filling the voids in gel pores, as previously stated.

Fig-5 Curing Concrete cubes

4. CONCRETE TESTS

The purpose of the experiment was to investigate the qualities of M25 grade concrete using titanium dioxide as a substitute for cement. After 28 days, the compressive strength of the cubes is measured after 2%, 3%, and 4% of the cement has been replaced. Ordinary Portland cement produced sand, and coarse aggregate, as well as titanium dioxide, are used to make the test specimens. The gravel was limited to a maximum size of 20mm. M25 fresh concrete proportions were employed, with a water-cement ratio of 0.4.

In the instance of cubes, the concrete mix design was recommended to attain a strength properties of 25MPa after 28 days of curing. Concrete cubes (150mm x 150mm x 150mm) were manufactured for both standard and non-traditional mixtures. Each layer was compressed using a 16mm diameter rod and 25 blows.

4.1 Workability

Workability is a characteristic of concrete that defines how much beneficial internal labour is required to achieve complete compaction. The material, mix percentage, and ambient variables all influence the workability of fresh concrete.

The workability of concrete containing various quantities of Nano Titanium Dioxide was measured using a slump test with the same w/c ratio for all of the mixes, as shown in chart 1. As the percentage of Nano Titanium Dioxide applied increases, workability decreases in a predictable manner.

Fig-6 Slump test

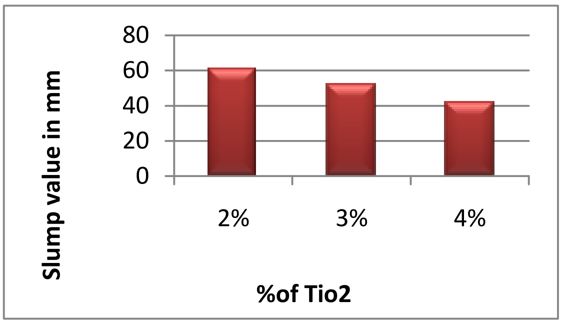

Chart-1 Slump test result

4.2. Compressive Strength Test

The most popular test on the concrete structure is the compressive test, partly because it is simple to execute and partly because most of the desirable properties are found in it. Concrete's distinguishing characteristics are characterized by a high degree of quality. The compressive strength of the material is connected to it.

Fig-7 Compression test

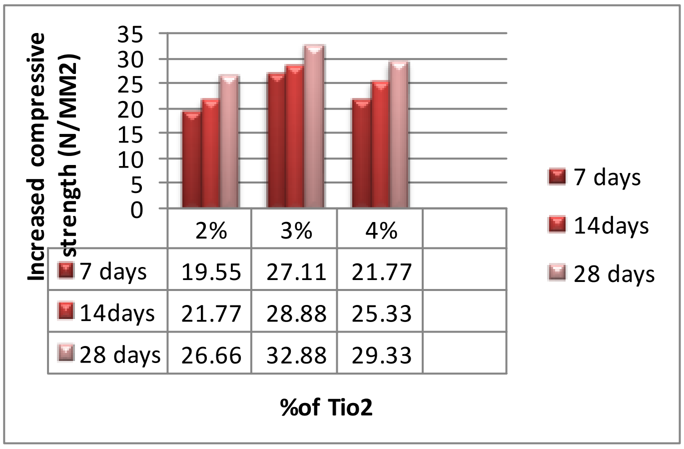

Chart-2 Compressive test Result

4.3. Rhodamine B dye test

The decolorization under sunlight, a common test for self-cleaning cementitious materials, was used to evaluate concrete containing TiO2 photocatalyst in this study. Experiments on dye decolorization of 2%, 3%, and 4% TiO2 replacement concrete in the presence of sunshine are presented.

1ml of Rhodamine dye is put on the top of each molded hardened concrete sample, which is then placed in direct sunshine and the results are recorded

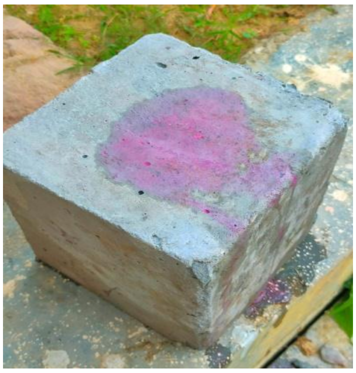

Fig-8 Cubes under sunlight

Fig-9 After 5 hours

Fig-10 11 hours in sunlight

After a few hours, the Rhoda mine dye decolorizes on the top of the cubes, as shown in the examples above. The value of decolorization increases as the amount of TiO2 rises, according to the findings.

4. CONCLUSIONS

One of the most recent breakthroughs in the world of civil and environmental engineering is self-cleaning concrete.

This concrete is unique due to the use of TiO2 photocatalysis. TiO2 can be included directly into concrete or into photocatalytic coverings on concrete samples to implement the technique. The interaction of sunlight, air oxygen, and water in this process results in a self-cleaning surface. Under the effect of UV light, the photoactive TiO2 at the material's surface is activated, which starts the photocatalysis process. The contaminants are oxidized and deposited on the surface of a material in the following phase of the process, thanks to the presence of the photocatalyst. They are eventually washed away from the surface by rain or water cleansing. Constructions remain cleaner as a result, and maintenance expenses are decreased.

- The compressive strength of concrete that contains 3% titanium dioxide as a partial replacement for cement increases with time.
- After curing for 28 days, the compressive strength of concrete samples containing 2%, 3%, and 4% titanium dioxide is higher than the intended mean strength.
- The findings of the decolorization tests reveal that as the amount of Titatinium dioxide grows, so does the amount of decolorization.
- According to the results of the study, using 3% titanium dioxide in concrete samples delivers the best results in terms of strength, decolorization, and oxidation.

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