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"EXPERIMENTAL INVESTIGATION ON FLY ASH BASED GEO POLYMER SELF CLEANING CONCRETE"- A Literature Review

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Abstract

Concrete is the most comprehensively used material for construction in building technology. However, production of the cement releases huge amounts of carbon dioxide (CO2) to the atmosphere that leads to increasing the global warming worldwide. Thus, for environmental friendly construction an innovative alternative material such as photo catalyst concrete has been established. Photocatalytic concrete replaces the Conventional cement and gives eco-friendly alternative binder. This technology offered Nano particles to improve their mechanical properties by adding the Nano clay into the cement paste. Such type of concrete also has been developed to be performed as self-cleaning construction materials. The self-cleaning properties of the concrete are improvised with the help of photocatalytic materials such as titanium Di-oxide (TiO2). Self-cleaning concrete that contains those photocatalytic will be strengthened by ultraviolet (UV) radiation and hastens the disintegration of organic particulates. Thus, the neatness of the building surfaces can be sustained and pollution developed in air can be reduced. In this article, a brief review about self-cleaning concrete is discussed. The test for determining the self-cleaning property of the photocatalytic concrete is examined by using RhB (Rhoda mine dye) discolouration under U.V. light, which is also considered as a standard test for self-cleaning cementitious materials. The results will give an idea regarding the suitability of alternative material rather than conventional concrete and with the photocatalytic action the concrete will be used as self-cleaning which will be eco-friendly for environment.In this article, a brief review about self-cleaning concrete is also discussed.The main aim of this study was to examine the features of concrete with the accumulation of fly ash and comparing it with the control mix, thus determining the advantages and disadvantages of doing so.

***Keywords**:* Self Cleaning Concrete, Green Concrete, Photocatalytic action, Compressive Strength, Tensile Strength, Flexural Strength.

1. Introduction

The global use of concrete is second only to water. As the demand for concrete as a construction material increases,so also the demand for Portland cement. It is estimatedthat the production of cement will increase. However, it's utilization cause pollution to environment, hence it givesnegative impacts on environment. Air quality is linked withvarious health hazards. Self-cleaning concrete has an abilityto clean their surfaces and removes pollutants from the air.Such concrete is produced by the addition of photo catalyst toconcrete. Self-cleaning concrete uses the energy from ultraviolet raysto oxidize organic compounds. This accelerate the process ofnatural oxidation and faster pollutant decomposition. Self-cleaning concrete has two primary benefits which are keptsurface free of dirt and ensure a cleaner environment.Photocatalytic materials are help to mitigate air pollutiondirectly. These materials absorb ultraviolet radiation fromthe sun, hydroxyl radicals and superoxide anions are createdthat have the ability to react with pollutant molecules suchas NOx to convert them to other, less harmful substances.This could be particularly advantageous in areas with highlevels of air pollution. The properties of photo catalysts include photocatalytic water and air purifiers, photocatalytic self-cleaning, and antibacterial effects. Its application is limited due to chemical engineering limitations such as photo catalyst support or separation of photo catalyst from effluent. On other hand, Geopolymer concretes with self-cleaning behaviour are green alternative to overcome this problem. This is because they offer tremendous environmental benefits such as decreasing the CO_2 emissions, economical, durable and environmentally friendly.Geopolymer cement has their own unique properties which are able to withstand at high temperature and also resistant to salt and acid. Self-cleaning concrete or photocatalytic concrete will keep the concrete surface free of dirt and keeps its colour, even in polluted condition and industrial areas. This concrete also called as green concrete due to its self-cleaning properties

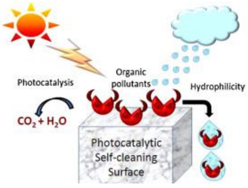

Figure - Photocatalytic reactions on self-cleaning surface

FLY ASH - Use of Fly Ash has become essential for civil engineering because of its economic and environmental benefits (Ravina and Mehta, 1986; Matkovi´c, 1990). The amount of cement that FA can replace is restricted by the amount of free lime in the ash. Aside from its chemical composition, the reactivity of FA is determined by its phase composition, the amount of glassy phase present, the burning temperature of coal or lignite, the specific surface area (SSA), etc. (Matkovi´c, 1990). FA is a pozzolanic material (Tillman et al., 2012). The term pozzolanic refers to materials that, when exposed to lime and water, will form insoluble cementitious compounds, although they have little or no cementing action when they exist alone (Montgomery et al., 1981). FA, or pulverised fuel ash, is a by-product of coal-fired power plants and is used as a mineral additive in cement and concrete. Fig. 1 shows a typical layout of a coal-burning generating station. Pulverized coal is blown into the burning zone of the furnace, where its combustibleconstituents, mainly carbon, hydrogen, and oxygen, ignite at around 1500 ◦C (2700◦F). Quartz, calcite, gypsum, pyrite, feldspar, clay minerals, and other non-combustible minerals are melted at this temperature and form tiny liquid droplets. The droplets carried by the flue gases from the burning zone are cooled rapidly to form small spherical glassy particles. Mechanical and electrical precipitators or baghouses collect solid particles from flue gases. FA refers to the ash particles that "fly" away from the furnace with the flue gases (Thomas, 2013). The features of FA are influenced by various factors, including the type of coal used, the burning conditions, the collection mechanism, etc. (McCarthy and Dyer, 2019). The use of FA as a pozzolanic ingredientand its reaction potentials were first recognized in early 1914; however,a substantial study on the use of FA in concrete was first published in 1937 in the United States (McCarthy and Dyer, 2019; Halstead). In the earlier studies in the 1980 s, it was reported that replacing concrete with FA can significantly improve the mechanical and durability properties of concrete (Montgomery et al., 1981) as FA can improve the microstructure of the paste (Filho et al., 2013). Depending on the application, FA properties, specification limits, geographic location, and climate, FA has traditionally been incorporated in concrete at levels ranging from 15 to 25 % by mass of the cementitious material component (Thomas, 2007). It was reported that, in some rare cases, concrete had been successfully placed incorporating up to 80 % FA (Marceau et al., 2002). The FAs used in concrete are of two types class F and class C according to ASTM. The class F FA is a by-product of bituminous coal combustion. The iron, silica, and alumina content of class F FA is high, but the calcium content is low. It's a glassy substance that requires either cement or lime to activate. FA from sub-bituminous coal and lignite combustion is classified as class C. It contains more calcium than class F FA. Concrete containing class C FA develops strength much more quicklythan concrete containing class F FA (McCarthy and Dyer, 2019; Marceauet al., 2002). The use of FA in concrete is cost-effective, but it alsochanges the concrete properties in its fresh and hardened states, improving workability, strength, and drying shrinkage. Furthermore, the use of FA in concrete solves the storage and disposal problem of FA, an industrial by-product (Atis¸, 2003).

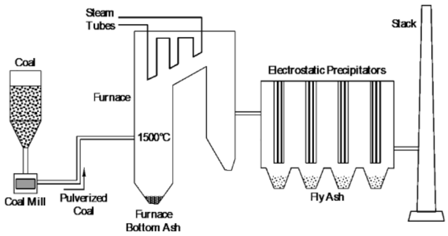

Fig. 1. A schematic diagram of a coal-fired electrical generating station (Thomas, 2013).

Self-Cleaning Concrete - Self-cleaning or photo catalytic concrete, by the name itself it shows its affordability. The name that it looks like revolutionary ideas and some of us may think that it is impossible. But then again it is practical now, many foreign countries are stick to the concrete for its incredible beneficial results. Concrete construction is a expansive field we can innovate into new creation. By using this concrete cleaning technology, we can create a lovely atmosphere and enhance the anti-aging of concrete. However, this type of concrete produces the indoor air purification so we can reduce the health issues. Breathing problems can be reduced slowly. Protecting concrete not ever creates an aware towards users we can take step to achieve this self-purifying/ cleaning technology to purify the concrete using photo catalyst. Photo catalyst is best filters towards the concrete it creates friendly reactivity over the concrete. The response over the cement is neutral it can be washed away by spraying water it will not create any harm to cement and not affect the cement binding properties. Clean buildings provide astonishing environmental benefit is the potential for cleaner air.

Photo catalyst -There are a lot of materials that act as photo catalyst. It can be seen through a few researches that have been carried out in order to investigate the influence of photo catalyst in cementitious materials. Nanoparticles are used as photo catalyst in order to improve the performance of the cement properties. Nanoparticles that being added to cement can function as either an admixture in cement paste or to replace part of cement. These nanoparticles act as fillers in the empty space, well distributed, increasing rate of hydration and tendency to agglomerate during mixing. Nanoparticles that most common used in cement products are silicon oxide (SiO_2), zinc oxide (ZnO), titania or titanium dioxide (TiO_2), aluminium oxide (Al_2O_3) and carbon nanotubes. Research reported that the addition of nano-silica into the cement paste influenced the mechanical properties of the products. A few studies showed that by adding nanoparticles of TiO_2 are mostly performed with photocatalytic activity due to its chemical stability and high catalytic activity. In concretes that contain nano-TiO_2, the resistance to penetration of chloride is higher than concretes that contain the same amounts of nano-SiO_2. This is due to the refinement of pore structure increases while the chloride penetration decreases with the content of nano-particles. The addition of nano-TiO_2 shows a positive result with fewer cracks in compact microstructure and enhances the formation of geopolymer. The compressive strength can be improved by increasing the amount of nano-TiO_2 in the modified cement. Several researches have been conducted on the incorporation of TiO_2 into concrete specimens. The photo catalyst, 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.

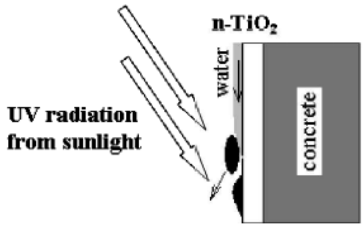

Figure - Self-cleaning effect of n- TiO_2 at concrete surface

Geo Polymer Concrete **-**Geo-polymer is an inorganic polymer. Joseph Davidovits (1978) proposed that an alkaline liquid could be used to react with silicon (Si) and aluminium (Al) as source material of geological origin or with by-product materials such as fly ash and rice husk ash to produce binders. Since the chemical reaction that is taking place in this case is a polymerization process and the precursors are of geological origin, these binders were named as geo polymer. Geo-polymer Concrete is gaining importance world over as the carbon emission and consequent global warming has become the major concern of the entire countries world over. One tone of cement production results in the emission of one tone of carbon dioxide. Many countries are promoting the use of fly ash as building material by granting carbon credit, which will not only reduce the production of cement and emission of carbon dioxide but also promotes the consumption of the waste material fly ash which poses a major problem for disposal world over. In India almost all the states have thermal power plants and abundant availability of fly ash. The alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geo-polymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. The alkaline solution sodium hydroxide and sodium silicates are cheap and locally available. This paper is devoted to heat-cured low-calcium fly ash-based geo- polymer concrete. Low calcium (ASTM Class F) fly ash is preferred as a source material than high-calcium (ASTM Class C) fly ash.

Geo polymerisation

The geo polymerisation process takes place due to the rapid chemical reaction between Si-Al minerals and alkaline liquids, which in turn produce a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds (Davidovits 1994).

Mn [-(SiO2) z–AlO2] n. wH2O (1.1)

where: M is the alkaline element or cation such as potassium, sodium or calcium; the symbol denotes the existence of a bond, n is the degree of polymerisation or poly condensation; z is1, 2, 3, or even higher, up to 32.

The typical formation of geopolymer material is illustrated by Equations 1.2 and 1.3 (Van Jaarsveld et al. 1999; Davidovits 1994):

The chemical reaction between Si-Al minerals and alkaline liquids consists of the following stages (Glukhovsky 1959; Davidovits 1994; Xu & van Deventer 2000):

- Destruction of Si and Al atoms from the source material through the multifaceted action of hydroxide ions.
- Coagulation and condensation of precursor ions into monomers.
- Poly condensation/polymerisation of monomers into polymeric crystalline structures.

Nevertheless, the above three processes can overlap each other and occur simultaneously. Thus, it is hard to separate and assess one by one individually (Palomo et al. 1999). Subsequently, the following three fundamental forms of geopolymer occurs (Davidovits 1994):

- Poly-sialate, which contains [-Si-O-Al-O-] as the reoccurring element.
- Poly-sialate-siloxo, which contains [-Si-O-Al-O-Si-O-] as the reoccurring element.
- Poly-sialate-disiloxo, which contains [-Si-O-Al-O-Si-O-Si- O-] as the reoccurring element. Sialate is an abbreviation of silicon-oxo-aluminate.

The Equation 1.3 indicates the release of water during the development of geopolymers. The release of water from the geo polymer paste during the curing and drying stages departs discontinuous nano-pores in the paste matrix. This process enhances the performance of geo polymers. Therefore, the water merely contributes to improve workability as it is not involved in chemical reaction (unlike hydration of cement). The type of application of geo polymeric material is determined by the chemical structure in terms of atomic ratio of Si:Al 1,2,3 initiates a 3D- network that is very rigid, while Si:Al ratio is higher than 15 provide a polymeric character to geo polymeric material. Eventually the polymerization process develops fast accelerated chemical reaction under alkaline environment on Si:Al minerals that forms three dimensional polymeric chain and ring structure consisting Si - Al - O bonds (Davidovits 1999).

2. OBJECTIVES OF THE STUDY

Photocatalytic concrete has the ability to realize air depollution, self-cleaning, plus self-disinfecting. It is fabricated bytotalling photo catalyst into traditional concrete, and the best suitable photo catalyst to fabricate photocatalytic concrete is TitaniumDi-oxide (TiO2). The photocatalytic reaction can happen under the light when energy is higher than the photo catalyst band gap. Theformed highly oxidizing hydroxyl radicals can react with contaminants and create carbon dioxide, water, or other harmless substances.The decomposed pollutants can be taken away by wind or rain to attain the purpose of air depollution and self-cleaning. Thephotocatalytic concrete has immense capacity in the field of degradation of pollutants, deodorization, sterilization, and energyconservation. This study helps to investigate the Self-Cleaning Performance of Concrete with Titanium Dioxide (TiO2)

Addition. Also gives an idea about how TiO2 can be used as a long-lasting material. It also evaluates the Effect of Titanium Dioxide (TiO2) Addition on the Compressive Strength of Concrete

3. Literature Review

Concrete is a widely used construction material, but it can accumulate dust, dirt, and other pollutants that lead to deterioration and loss of aesthetic appeal. Self-cleaning concrete is a promising solution that can clean itself through a photocatalytic reaction. One approach to achieve this is by replacing a portion of the cement with photocatalytic materials, such as titanium dioxide (TiO2). In this literature review, we will summarize the findings of several experimental studies that investigated the use of TiO2 in self-cleaning concrete. The amount of TiO2 added to concrete can affect its self-cleaning ability. Generally, higher TiO2 concentrations lead to better photocatalytic performance, but excessive amounts can negatively impact the mechanical properties of the concrete. Several factors can influence the effectiveness of TiO2 in self-cleaning concrete, such as the type of pollutant, the intensity and duration of UV light exposure, the surface texture of the concrete, and the environmental conditions. TiO2-modified concrete has potential applications in various settings, such as highways, bridges, buildings, and public spaces. However, further research is needed to evaluate its long-term durability, cost-effectiveness, and scalability. TiO2 is a photocatalytic material that can break down pollutants on the surface of concrete when activated by UV light. The resulting reaction produces hydroxyl radicals that can oxidize organic compounds and decompose them into harmless products, such as carbon dioxide and water. The use of TiO2 in self-cleaning concrete has several advantages, including the reduction of air pollution, the prevention of microbial growth, and the maintenance of a clean and aesthetically pleasing surface.

Prof. Rakesh Kumar, 2Ms. Gauri Chandgude, 3Mr. Pravin Gond, 4Mr. Aditya Shete, Ms. Siddhika Jadhav, "A REVIEW ON TITANIUM DIOXIDE - A STUDY OF SELF-CLEANING CONCRETE" 2023 IJCRT | Volume 11, Issue 5 May 2023 | ISSN: 2320-2882 -Building technology relies heavily on the use of concrete, which is the most commonly utilized construction material. However, cement production releases large amounts of carbon dioxide (CO2) into the atmosphere, contributing to increased global warming. Therefore, an alternative environmentally friendly building material such as photo catalyst concrete has been developed. Photocatalytic concrete, with a more environmentally friendly alternative binder, is an innovative building material to replace Portland cement. This technology introduces nanoparticles such as nano clay into the cement paste to improve its mechanical properties. Concrete materials have also been developed to function as self-cleaning building materials. The self-cleaning properties of concrete are provided by the incorporation of photocatalytic materials such as titanium (TiO2). Self-cleaning concrete containing these photo catalysts would be powered by ultraviolet (UV) radiation and accelerate the breakdown of organic particles. In this way, the cleanliness of building surfaces can be maintained and air pollution reduced. This article briefly discusses self-cleaning concrete.

Prathamesh R. Ingole et al. "Self-Cleaning Concrete: The Future" (2022)International Journal of Scientific Research & Engineering Trends Volume 8, Issue 2, Mar-Apr-2022, ISSN (Online): 2395-566X, conducted an experiment to evaluate the effect of adding TiO2 to concrete on its self-cleaning ability. The researchers prepared concrete samples with varying amounts of TiO2 and assessed their self-cleaning properties using a photocatalytic degradation test. The results showed that the addition of TiO2 improved the self-cleaning ability of concrete.

1Hritik S. Behare, 2Aditya N. Bhosale, 3Jeevan C. Kadale, 4Sagar B. Kale 5Dinesh W. Gawatre, "Investigation of Self Cleaning Concrete by Using Titanium Di-Oxide" 2021 JETIR June 2021, Volume 8, Issue 6 www.jetir.org (ISSN-2349-5162) - Concrete is the most extensively used construction materials for building technology. But, cement production releases high amounts of carbon dioxide (CO2) to the atmosphere that leads to increasing the worldwide or global warming. Thus, another,environmental friendly construction material such as photo catalyst concrete has been developed. Photocatalytic concrete appliesgreener alternative binder, which is a modern-day construction material that replaces the Conventional cement. This technologypresented nano particles such as nanoclay into the cement paste in order to improve their mechanical properties. The concretematerials also have been developed to be performed as self-cleaning construction materials. The self-cleaning properties of theconcrete are induced with the help of photocatalytic materials such as titanium Di-oxide (TiO2). Self-cleaning concrete that containsthose photocatalytic will be energized by ultraviolet (UV) radiation and quickens the decomposition of organic particulates. Thus,the spotlessness of the building surfaces can be maintained and the air surrounding air pollution can be reduced. This paper brieflyreviews about self-cleaning concrete.

S.K. Maniarasan, V. Santhosh Kumar, P.Chandrasekaran, Fly Ash Based Self-Cleaning Geopolymer Concrete Using Nanotechnology -A Review, INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 9, ISSUE 02, FEBRUARY 2020 ISSN 2277-8616 - The materials which widely used in construction for building technology is concrete. Anyway, the production ofcement releases high amounts of greenhouse gases (CO2) to the atmosphere that leads to increased global warming. Accordingly, an alternative, sustainable construction material, geopolymer concrete, has been established. Geopolymer concrete seeks a greener alternative binder, which is an innovative construction material that alternates the Portland cement. Introduction of nano-particles in the cement paste to enhance the mechanical properties of geopolymer concrete. The content of concrete has been undertaken to be performed as a self-cleaning material in construction. The self-cleaning concrete properties are encouraging by introducing photocatalytic material of Titania (TiO2). These photo catalysts in Self-cleaning concrete will be motivated by ultraviolet radiation from the source such as the sun and promote the disintegration of organic particles. Hence, the stainlessness. Of the TiO2surfaces can be sustained, and environmental pollution can be reduced. In this review paper, the mechanism, properties, application of both geopolymer and Titania, and health risk hazards are discussed from different author results. In summary, this review paper offers guidance for researchers in the future regarding self-cleaning nanotechnology in geopolymer concrete.

ANJU RAJ, "BEHAVIOUR OF SELF CLEANING CONCRETE BY USING VARIOUS PHOTOCATALYSTS" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072 - Self-cleaning concrete is a technique to reduce the air contaminants such as NOX, SO2, CO2 and VOC'S fromvehicular traffic on streets, any industrial activity and theurban environment. Photocatalytic materials are used inconventional concrete for urban buildings and roadpavements to reduce air pollution. The photocatalytic materialis either titanium dioxide (TiO2) or zinc oxide (ZnO). Titaniumdioxide (TiO2) or zinc oxide (ZnO) are added to concrete by 0,0.5, 1, and 1.5% of cement by weight. The compressivestrength of concrete cubes cured for 28 days were taken.Durability test of self-cleaning concrete was tested by usingmagnesium sulphate (MgSO4) & sodium chloride (NaCl)solution. Self-cleaning property of the photocatalytic concreteis studied by using RhB (Rhodamine dye) discolouration underU.V. light, a standard test for self-cleaning cementitiousmaterials.

T Vignesh et al. "Study on Self-Cleaning Concrete Using Nano-liquid TiO2" (2018)Int. J. Eng. Technol., vol. 7, no. 3.12, p. 860, 2018, doi: 10.14419/ijet.v7i3.12.16551prepared self-cleaning concrete by replacing cement with TiO2 nanoparticles and evaluated its self-cleaning ability. The results showed that the TiO2-modified concrete had a higher self-cleaning efficiency than regular concrete, indicating that TiO2 can enhance the self-cleaning ability of concrete.

Siti Norsaffirah Zailan[1], Norsuria Mahmed[1], Mohd Mustafa Al Bakri Abdullah[1,2], Andrei Victor Sandu[3] "Self-cleaning geopolymer concrete - A review" International Conference on Innovative Research 2016 - ICIR Euroinvent 2016 IOP Publishing IOP Conf. Series: Materials Science and Engineering 133 (2016) 012026 doi:10.1088/1757-899X/133/1/012026 - Concrete is the most widely used construction materials for building technology. However, cement production releases high amounts of carbon dioxide (CO_2) to the atmosphere that leads to increasing the global warming. Thus, an alternative, environmental friendly construction material such as geopolymer concrete has been developed. Geopolymer concrete applies greener alternative binder, which is an innovative construction material that replaces the Portland cement. This technology introduced nano-particles such as Nano clay into the cement paste in order to improve their mechanical properties. The concrete materials also have been developed to be functioned as self-cleaning construction materials. The self-cleaning properties of the concrete are induced by introducing the photocatalytic materials such as titania (TiO_2) and zinc oxide (ZnO). Self-cleaning concrete that contains those photo catalysts will be energized by ultraviolet (UV) radiation and accelerates the decomposition of organic particulates. Thus, the cleanliness of the building surfaces can be maintained and the air surrounding air pollution can be reduced. This paper briefly reviews about self-cleaning concrete.

B. Vijaya Rangan "Fly Ash-Based Geo Polymer Concrete" Australian Journal of Structural Engineering · January 2005 DOI: 10.1080/13287982.2005.11464946 - Extensive studies conducted on fly ash-based geopolymer concrete are presented. Salient factors that influence the properties of the geopolymer concrete in the fresh and hardened states are identified. Test data of various short-termand long-term properties of the geopolymer concrete are then presented. The paper describes the results of the testsconducted on large-scale reinforced geopolymer concrete members and illustrates the application of the geopolymerconcrete in the construction industry. Some recent applications of geopolymer concrete in the precast construction andthe economic merits of the geopolymer concrete are also included.

3. Conclusion

This study helps to examine high pollution regions in India and assess the interplay between pollutant concentrations. Also it detects regions where photocatalytic concrete infrastructure has the capacity to be most effective based on the experimental outcomes. To reveal the influence of environmental conditions, particularly temperature, on the photocatalytic pollution degradation mechanism in order to develop a correlation between photocatalytic effectiveness and seasonal climate. The previous studies also reveal that the use of titanium dioxide in self-cleaning concrete has the potential for reducing maintenance costs and extending the lifespan of infrastructure. The self-cleaning properties of the concrete can avert the build-up of dirt, grime, and other pollutants, which can be the source of discoloration and degradation of the surface. The addition of titanium dioxide to concrete has demonstrated the ability to break down pollutants, such as nitrogen oxides when exposed to sunlight. This photocatalytic process is effective in removing surface contaminants from the concrete, leading to a cleaner and more sustainable environment.

In General, the verdicts of this study suggest that the use of titanium dioxide in concrete can subsidize to a cleaner and more maintainable environment while also providing cost-saving benefits. Further research and development in this extent can lead to the prevalentacceptance of self-cleaning concrete as a solution for improving the durability and maintenance of infrastructure.

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