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Self-Cleaning Surface-Coat of Micro Titanium Dioxide on Hardened Cement Mortar Surfaces Irradiated With Sunlight

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Abstract:

One of the common problem happening is the deterioration of building facades due to increase in urban environmental pollution. Self cleaning cementitious materials have come under spotlight as a intelligent building materials and green materials for sustainable environment. Titanium dioxide is a promising photo catalytic material in degradation of many organic pollutants. This paper illustrates the self cleaning performance of titanium dioxide (size range 130 nm) as a coating applied on hardened cement mortar surfaces. The prepared samples i,e micro TiO_2 coated discs are completely immersed in earlier prepared Rhoda mine B solution(3 mg/l) having a wave length peak at 554.8 nm and exposed to sunlight. In the present study Rhoda mine B dye used as a decolourised indicator under sunlight. The research work done by applying different dosages of TiO_2 on hardened surfaces showed good photocatalytic efficiency as well as its potential application in prevention of building facades due to urban environmental pollution.

Keywords: Micro TiO_2, photo catalysis, Rhoda mine B, Sunlight, Environmental application

1. Introduction

The potential of TiO_2 as a catalyst was discovered by Fujishima and Honda in 1972. TiO_2 is a semiconductor, which has three crystal arrangements anatase, rutile, and brookite, of the three research has shown that titanium dioxide in the anatase exhibits the highest photo activity as a environmental depollutant [1].TiO_2 as a photocatalyst seems to be very promising material due to its several advantages like Strong oxidising power, Anti-bacterial properties, Self-cleansing & De-polluting capabilities, non -toxic, chemical stability, high refractive index [2].When the TiO_2 cement surfaces either hydrophilic or hydrophobic are exposed to the irradiation, the catalyst gets photo excited and then the photocatalytic process begins [3]. TiO_2 is recently found to be an excellent photocatalyst to be used in pavement engineering for reducing vehicle emission pollutants [4]. Pollutants from vehicle exhaust adsorb to the pavement. The TiO_2 coating on the pavement surface activates with the ultraviolet sunlight to break down the pollutants.

Ming Zhi Guo et al.[5] demonstrated an effective way to incorporate nano TiO_2 in photo catalytic cementitious materials by using three TiO_2 sprayed methods .spray A method in which surface layers were sprayed with TiO_2 solution 30 times after mechanical compacting. Spray AB method in which surface layers were sprayed with TiO_2 solution 15 times before compacting and another 15 times after compacting. In spray B method in which surface layers were sprayed with TiO_2 solution 30 times before compacting. The study report that 7 days curing age ,except for the spray A samples ,all other samples experienced a great loss in photo catalytic NO removal activity at 28 days curing age for 5% TiO_2 intermixed samples. The results reveal that spraying method is promising and attractive due to high NO photo catalytic removal efficiency is relatively high, meanwhile sprayed TiO_2 particles on the surface display a satisfactory weathering resistance.

In 2015 A.P. Werle et al.[6] Studied a cool ,self cleaning cement based surface using TiO_2.Commercially available three samples of nano TiO_2 particles namely P25,US NANo -IV and Millennium -TiONA are mixed with white cement and water to get a self cleaning paste. The cement specimens are prepared by replacing 0%, 5% and 30% of the cement by mass by TiO_2.The degradation studies are carried out by using Congo red dye under UV and visible radiation. The loss of colour measured by diffuse reflectance using a UV-visible spectrophotometer.

Marwa M. Hassan.et.al [7] applied three methods of application of ultrafine titanium dioxide coatings to concrete pavement namely the first method consists of applying a cement based 10 mm thin coating to the concrete surface with a titanium dioxide content of 3% and 5%.The second method consists of spraying a water -based TiO_2 (pT)applied to the hardened concrete surface in two parts, firstly the base coat is applied as a primer 2 % by weight of anatase titanium dioxide and again top coat was applied by a spray gun at a rate of 250 g/m^2.The third method consists of sprinkling nano sized titanium dioxide particles to the fresh concrete before hardening .Crystal Millennium PC105 was used for the titanium dioxide nano particles. The study shows the coating with 5% TiO_2 and the PT products were the most efficient in removing nitrogen oxide from the air stream.

The Italian company, Italcementi, developed a type of cement with a titanium dioxide on the surface called TX active ("New kind of cement absorbs pollution", 2006). TX active cement has been used on buildings such as Paris Charles de Gaulle Airport, Rome's Dives in Misericordia church, and Bordeaux's Hotel de Police.

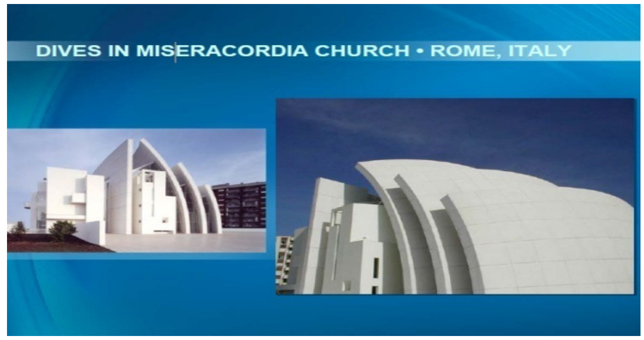

Fig.1. Dives in Miseracordia church- Rome, Italy

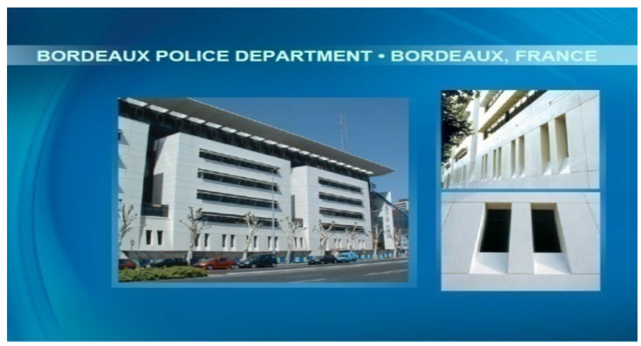

Fig.2. Bordeaux Police Department. Bordeaux, France

2. Experimental section:

2.1 Materials

In present work white cement WHC (J.K. Company) having rapid hardening property was used purchased from locally available dealer. This cement is made from raw materials containing very little iron oxide and manganese oxide and these oxides impart whiteness to the cement. The chemical and physical properties are illustrated in table 1 and 2.The locally available river sand passed through 1 mm sieve which is free from organic matter and silt was used. The physical properties of sand are shown in Table 3. Titanium dioxide(TiO_2) purchased from Molychem company with particle size of 130 nm used . Rhodamine B (RhB) of analytical grade was purchased from M/S S.D. Fine Chemical, Mumbai, India. The water used in the present study is RO treated water used for drinking purpose.

Sl.No	Property	Value
1	Specific gravity	2.67
2	Bulk density (Loose state)	1550 kg/m^3
3	Bulk density (Dense state)	1820 kg/m^3

Table 1 Physical properties of white cement

Sl. No	Physical Properties	Values Obtained	Requirement as per IS 8042:1989
1	Specific Gravity	3.00	----
2	Standard Consistency	32%	----
3	Initial setting time	85 minutes	Should not be less than 30 minutes
4	Final setting time	140 minutes	Should not be more than 600 minutes
5	Soundness(By Le chatelier mould)	3 mm	Should not exceed 10 mm

Table 2 chemical properties of white cement

Chemical Requirements	specifications
Magnesium oxide (% MgO)	3.00
Sulphur trioxide (% SO_3)	3.25
Iron oxide (% Fe_2O_3)	0.30
Insoluble Residue (%)	0.95
Chlorides (%Cl)	0.02

The tests were performed in the laboratory; others are derived from the manufacturer

Table 3 Physical properties of fine aggregate

2.2. Procedure

Hardened specimens of size 70.6 mm x 70.6 mm square discs with a thickness of 10 mm with a cement mortar ratio of 1:3 with 0.45 w/c ratio were prepared and kept in water and cured for 28 days. Later the square discs were oven dried for 30 minutes at a temperature of 100^{0}C.A micro coating of 0 mg/cm^2(control),1 mg/cm^2 (50 mg)2 mg/cm^2 (100 mg),3 mg/cm^2 (150 mg) and 4 mg/cm^2 (200 mg) dosages applied to hardened discs. In the present study a new parameter developed is that the amount of TiO_2 applied on surface to area of square disc in cm^2.After that specimens were dipped in glass beakers containing Rhodamine B dye solution and coated surface are exposed to sunlight for photocatalytic process. Dye helps us to know the degradation of color and to know the performance of photocatalysis. A concentration of 3mg/l of Rh B used for photo catalytic process. A peak wave length of 554.8 nm obtained was used in present study. The absorbance and decolourisation quantification RhB concentration solution was studied by using double beam spectrophotometer 2203 having a wave length range of 200 to 1100 nm with an accuracy of 0.5 nm and a band width of 2 nm. A linear calibration curve is used for determining the unknown concentration of RhB solution by comparing with the known a set of standard samples of known concentration which is done for 10 mg/l concentration dye. For a period of 5 days at a regular interval of time 1 hour the RhB solution was collected from the beakers and its absorbance was measured at 554.8 nm. The photocatalytic efficiency of the micro-TiO_2 coated hardened cement mortars surfaces were studied by

$$\%\ Color\ Removal = \frac{I_0 - I}{I_0} \times 100$$

Where I_0 is the initial dye concentration, I is concentration of dye at any time.

Another set of square discs were prepared ,by keeping one control disc without surface coating and remaining were coated with different dosages of 50mg, 100mg, 150mg and 200mg on hardened cement mortar surfaces. Square disc are allowed to dry in presence of sunlight for 30 minutes. Later the uncoated and coated surfaces are sprayed with Rhodamine B solution and kept in sunlight for a period of time. By visual observation on exposure of discs to sunlight, the surface sprayed with RhB on coated surfaces the colour removal was achieved in 30 minutes. The cycle was repeated for several times in day time in natural sunlight. This experimentation signifies the photocatalytic performance of titanium dioxide in presence of sunlight over RhB.

Fig. 3.Visual observation of coated and uncoated surface of TiO2 sprayed with RhB solution

Fig.4.View of WHC discs dipped in Rh B solution exposed to sunlight (Before and after decolourisation)

3. Results and Discussions

A TSA value of 0 mg /cm^2 (without micro TiO_2) coating) represents the photolysis of RhB under sunlight. But in case of coated surfaces with different doses of TiO_2 i.e 1, 2, 3 and 4 mg /cm^2 signifies certain amount of colour decrement of RhB concentration solution under natural sunlight was observed. In photolysis the color removal or reduction of RhB was 32%,but the color reduction efficiency was increased by incremental of doses coating on cement mortar hardened surfaces.For TSA 1, 2, 3 and 4 mg /cm^2 dosages photocatalytic color removal of 54%,65%,78% & 80% was achieved. On visual observation of results the maximum efficiency was obtained for 4 mg /cm^2, but 3 mg /cm^2 efficiency was almost very near. An interesting point is that for 50 mg lesser quantification itself it was almost reached to the maximum efficiency .We can conclude that 3 mg /cm^2 is best achieving maximum efficiency for the taken surface area.

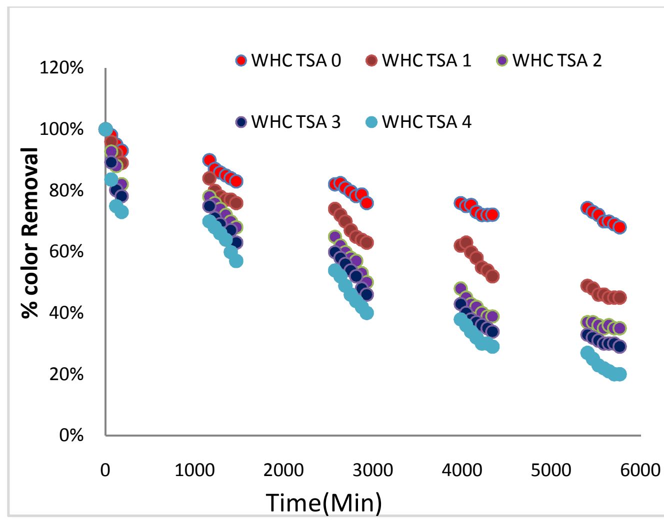

Fig.5. Photo catalytic % color removal of WHC with different TiO_2 Loading

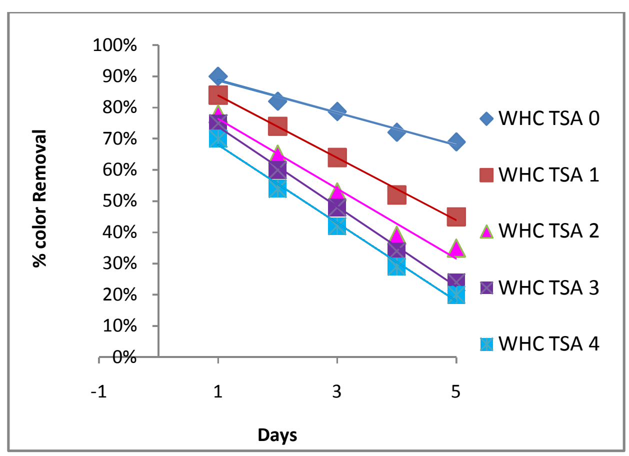

Fig.6. Linear comparison of photocatalytic performance of WHC with different TiO_2 loading

4. Conclusions

The present research work illustrates that the maximum photocatalytic efficiency was obtained with only a minimal coat of titanium dioxide under natural sunlight on cement mortar hardened surfaces .In the present work both photocatalyst and sunlight were combindely used to provide a solution to the environmental urban pollution.The experimental results of the present work shows an easy and convenient way of application of photocatalyst with good photocatalytic efficiency as well as its potential application in prevention of building facades from pollution. Application of TiO_2 photo catalysis to cement and concrete provides an efficient strategy to simultaneously obtain: self-cleaning of building facades, retardation of natural surface ageing as well as air pollution mitigation, simply with the support of sunlight, atmospheric oxygen and water present as humidity and/or rain water.

The research should be carried out on historical monuments and sculptures to preserve by use of photo catalytic surface phenomena.

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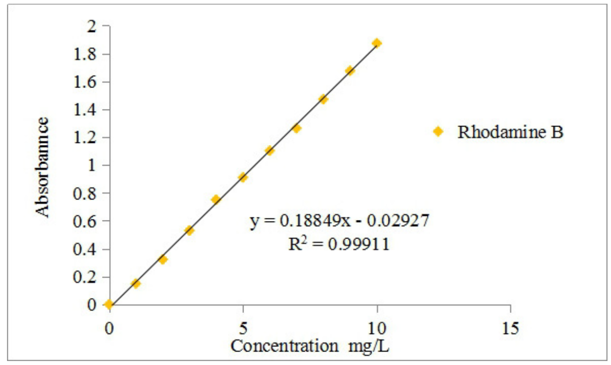

Fig.7. RhB calibration Graph