20th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2016, Mediterranean Sea Cruising, 24th September - 1st October, 2016

SELF-CLEANING CONCRETE – A CONSTRUCTION MATERIAL FOR BUILDING CLEANER WORLD

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ABSTRACT
The increase of sustainability importance in the world has led to a greater concern of the environmental impact of using concrete in construction. Self-cleaning concrete is attractive not only because of its self-cleaning abilities but also because of its environmentally friendliness. The use of this contemporary cement composite in urban and interurban areas can reduce maintenance cost and ensure a cleaner environment. This paper provides a review on self-cleaning concrete, the main principle behind self-cleaning concrete and its application nowadays.
Keywords: self-cleaning concrete, construction material, photocatalyst

1. INTRODUCTION
Photocatalytic materials represent a technology that could help to mitigate ultraviolet rays and air pollution. These materials use sunlight or other ultraviolet light sources to react with pollutant molecules and convert them to less harmful substances that can be washed away. In this way, photocatalytic materials reduce NO_x, SO_x, VOCs, etc., and also serve as self-cleaning materials [1].
Self-cleaning buildings and pollution-reducing roadways may sound like futuristic ideas, but they are the realities of some of today's concrete [2].
Self-cleaning concrete, also known as smog-eating concrete [3], is one of latest innovations in the field of civil and environmental engineering. Technology based on particles of titanium dioxide, TiO_2, is what makes this concrete special. The technology can be applied by incorporating TiO_2 directly into concrete or by incorporating TiO_2 into photocatalytic coatings for concrete specimens [1,2]. It can be used in all varieties of concrete, and the only difference is that it is capable of breaking down smog or other pollution that has attached itself to the concrete, in a process known as photocatalysis. As sunlight hits the surface, most organic and some inorganic pollutants are neutralized. They would otherwise lead to discoloured concrete surfaces. Rain washes away the pollution from the concrete surface so the buildings stay cleaner, and even more important environmental benefit is the cleaner air [2].

2. HISTORICAL BACKGROUND
It is known since almost 100 years that titanium dioxide, TiO_2, acts as a photo-catalyst that can decompose pollutants under ultraviolet radiation [4]. In 1970s, it was discovered that titanium oxide activated by light illumination decomposes water by electrolysis. Based on this discovery, the products such as titanium oxide coating films, composite material etc. have been developed and applied to water purification, antifouling protection and so on. In the 1980s, organic pollution in water was also decomposed by adding TiO_2 under influence of ultraviolet light. In the 1990s, photocatalysis was firstly applied to building materials to obtain self-cleaning and antibacterial surfaces in Japan. The first official publication on such products was presented by Luigi Cassar et al. in 1997. Since then, the development of photocatalytic concretes has been carried out with increasing innovative solutions, passing from the self-cleaning performance to depolluting effect [1,4,5,6].

3. PHOTOCATALYTIC SELF-CLEANING CONCRETE

3.1. Photocatalysis

The photocatalysis consists of different steps: the photoactive TiO_2 at the surface of the material is activated under the influence of ultraviolet light and, subsequently, the pollutants are oxidized due to the presence of the photocatalyst and precipitated on the surface of the material. Finally, they can be removed from the surface by the rain or cleaning/washing with water, as it is shown in Figure 1 [4]. Photocatalysts can be on or in a concrete structure, and they decompose organic materials that foul the surface. The organic compounds include dirt (soot, grime, oil and particulates) biological organisms (mould, algae, bacteria and allergens), air-borne pollutants (VOCs; tobacco smoke; and the nitrous oxides (NO_x) and sulphuric oxides (SO_x)), and even the chemicals that cause odours. Those compounds break down into oxygen, carbon dioxide, water, sulphate, nitrate and other molecules that are either beneficial to or at have a relatively benign impact on the environment [7,8].

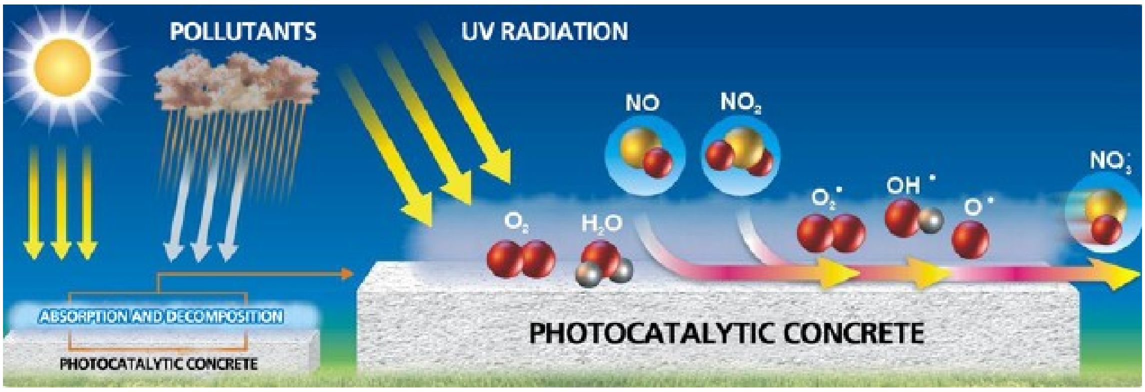

Figure 1. Photocatalysis of the concrete pavement [4]

3.2. Nanotechnology

The use of nanotechnology to important advanced oxidation effect on materials via photocatalysis is a novel approach. Titanium dioxide or titania, TiO_2, is the one of the most basic materials in our daily life, and it has emerged as an excellent photocatalyst material for environmental purification [9]. It is widely used as a white pigment in paint, plastics, cosmetics, and a many other products. To make it photocatalytic it is necessary to manipulate the material to create extremely fine nanotechnology-sized particles with a different atomic structure. This new type of titanium, at the nano-scale, undergoes a quantum transformation and becomes a semiconductor. Activated by the ultraviolet light, titanium dioxide creates a charge separation of electron and electron holes, and those electrons disperse on the surface of the photocatalyst. They react with external substances causing chemical reductions and oxidations and forming hydroxyl radicals that act as powerful oxidants to decompose those compounds [7,8]. Figure 2 shows a nitrogen oxide being converted into a nitrate.

Thus, TiO_2 in combination with cement leads to a transformation of the NO_x into NO_3, which is adsorbed at the surface due to the alkalinity of the concrete. A synergetic effect is created in the presence of the cement matrix, which helps to effectively trap the reactant gases (NO and NO_2) together with the nitrate salt formed and the deposited nitrate can be washed away [4,8].

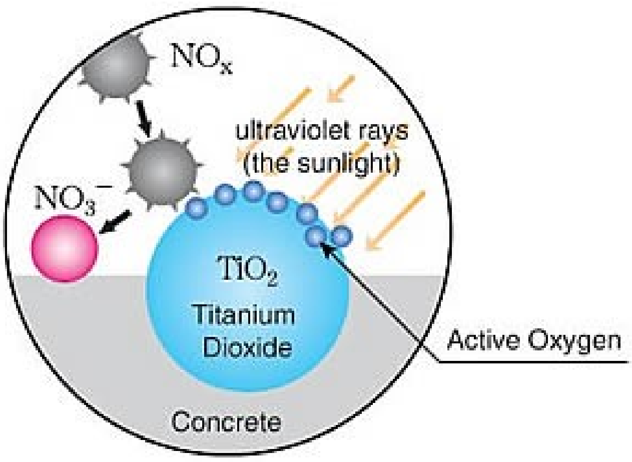

Figure 2. Photocatalytic TiO_2 accelerates the decomposition of pollutants such as NOx [8]

4. APPLICATION OF SELF-CLEANING CONCRETE

Beyond the visual benefits, self-cleaning concrete is being used to purify water, fight disease by reducing the spread of germs, and to increase the shelf life of fruit by reducing the concentration of ethylene gas (associated with the ripening of fruit) in distribution facilities [8].

Photocatalytic self-cleaning concrete is already used for:

- concrete paver blocks, sound barriers and facade elements,
- precast architectural concrete panels, pavements, sidewalks,
- finish coat applications, roof tiles, cement-based tiles and
- cement-based restoration products [10].

Figure 3 shows the difference between ordinary concrete building and self-cleaning concrete building [11].

a) *b)*

Figure 3. Ordinary concrete building (a) and self-cleaning concrete building (b) [11]

New applications are being found for photocatalysts in fabrics and clothing, personal care products, and other everyday products: for example, there are already photocatalytic antibacterial deodorant pantyhose in Japan [8].

Self-cleaning concrete technology is considerably used in Japan and Europe. Since Europe is the home of the reigning showplace of photocatalytic technology, the Jubilee Church (also known as the Dives in Misericordia) in Rome, was completed in 2003. The Jubilee Church was designed by the award-winning international architectural firm of Richard Meier & Partners Architects LLP. The Church of Dio Padre Misericordioso, built as part of the Vicarage project "50 Churches for Rome

2000", was designed as a mark and symbol of the Grand Jubilee of 2000 it takes on the idea of a ship, a ship which ploughs the seas of the Third millennium. The three shells discretely imply the Holy Trinity. This is the Church of the Year 2000 [8,12,19].
Self-cleaning concrete is convenient even for buildings in highly polluted locations—one noted application is the Air France headquarters at Roissy-Charles de Gaulle International Airport near Paris where a white concrete building has remained extremely white [2,8,13].
Self-cleaning concrete is to be used in renovation of The Sarajevo Bridge which passes over Avinguda Meridiana, one of the northern approaches to Barcelona. This bridge already got a nickname Smog-eating Bridge [14,15].
The first case of use self-cleaning concrete in USA was to built two scupltures to the St. Anthony Falls Bridge in Minneapolis. The sculptures of 9 m high are designed to look like an international cartographic symbol for water [16,17].

5. CONCLUSION

Self-cleaning concrete is one of latest innovations in the field of civil and environmental engineering. Application of TiO_2 photocatalysis is what makes this concrete special. The technology can be applied by incorporating TiO_2 directly into concrete or by incorporating TiO_2 into photocatalytic coatings for concrete specimens. In this process, the synergy of sun-light, atmospheric oxygen and water allows to obtain self -cleaning surface. The photocatalysis begins with activation of the photoactive TiO_2 at the surface of the material under the influence of ultraviolet light. In the next step of process the pollutants are oxidized due to the presence of the photocatalyst and precipitated on the surface of the material. At the end, they are removed from the surface by the rain or cleaning/washing with water. In this way constructions stay cleaner and maintenance costs are reduced.

6. REFERENCES

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