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Czy beton może oczyszczać powietrze?

CAN CONCRETE PURIFY THE AIR?

Streszczenie

W wielu polskich i europejskich miastach jakość powietrza jest poważnym problemem. Oprócz pyłu, o którym często się mówi, za silne zanieczyszczenie odpowiadają głównie tlenki azotu (NO_x) i lotne związki organiczne (VOC). NO_2 uszkadza układ oddechowy, co ma wpływ głównie na dzieci.

Cząstki aktywne fotokatalitycznie, zawieszone w górnej warstwie betonu, zmieniają go w powierzchnię zmniejszającą zanieczyszczenie powietrza. Zanieczyszczenia, takie jak tlenki azotu lub gazy organiczne, w kontakcie z tą powierzchnią są rozkładane lub utleniane, co powoduje, że stają się nieszkodliwe. Nowa technika zwana „TX Active®" jest oparta na procesie fotolizy. To zjawisko można znacznie przyspieszyć za pomocą aktywnych fotokatalitycznie cząstek dwutlenku tytanu. TX Active® opracowano w celu zmniejszenia zanieczyszczenia powietrza w ogóle. Zastosowania oparte na TX Active® wprowadziły innowacyjną technologię do świata betonu. Stąd markowy cement TioCem® może skutecznie przyczyniać się do oczyszczania powietrza poprzez wykorzystanie technologii TX Active® w licznych elementach betonowych, takich jak bruk, dachówki, płytki elewacyjne, betonowe nawierzchnie dróg, whitetopping (nakładki betonowe na nawierzchni asfaltowej), zaprawy itd.

Abstract

In many Polish and European cities air quality is a massive problem. Besides the frequently discussed particulate matter, nitrogen oxides (NO_x) and volatile organic compounds (VOC) are mainly responsible for the heavy pollution. NO_2 harms the respiratory system which affects predominantly children.

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Photocatalytic active particles dispersed in the top-layer concrete turn it into an air pollutant reducing surface. Pollutants such as nitrogen oxides or organic gases getting in contact with the surface are decomposed or oxidized and therewith rendered harmless. A brand new technique called "TX Active® is based on the process of photolysis. With the help of photocatalytic active particles of titanium dioxide, this effect can be accelerated extensively. TX Active® was developed to reduce air pollution in general. Applications based on TX Active® have introduced an innovative technology into the concrete world. Hence premium brand cement TioCem® can effectively contribute to the air purification by using TX Active® technology in numerous concrete components such as pavement, roof tiles, facade plates, concrete road surfaces, whitetopping, mortars etc.

1. Concrete surface purifies the air

Can concrete surface purify the air? What seems to be a science fiction story at first sight becomes today's reality by means of nanotechnology.

Photocatalytic active particles dispersed in the top-layer concrete turn the pavement into an air pollutant reducing surface. Pollutants such as e.g. nitrogen oxide or organic gases getting in contact with the surface are decomposed or oxidized and therewith rendered harmless. Hence concrete surface (façade elements, pavement, blocks, toppings) with premium brand cement TioCem® can effectively contribute to air purification.

The requirements on concrete as state-of-the-art[1] building material are becoming more and more complex with regard to its properties. First of all, concrete is used to construct buildings and structures. However, it also shows various additional characteristics such as being highly durable and favourable to the environment and offering huge opportunities to achieve an aesthetically pleasing and functional design. By using a certain titanium dioxide (TiO_2) modification, concrete surface can fulfil even more functions. It is possible to use the energy provided by the sunlight to degrade organic and inorganic pollutants.

1.1. Air quality problem

In whole Europe, mainly in capitals, large city agglomerations and in the vicinity of industrial processes the air quality is a massive problem. The emission of hazardous substances increased in recent years dramatically. Responsible authorities consider the maintenance or improvement of air quality as a growing challenge. Besides the frequently discussed particulate matter - fine dust, sulphur oxide (SO_2), carbon monoxide (CO), ozone (O_3) nitrogen oxides (NO_x) and volatile organic compounds (VOC) are mainly responsible for the heavy pollution. In consequence, especially in cities and thus in direct surrounding of the people, the increasing pollution due to exhaust gases leads to impairment of the lung function and increased risk of respiratory diseases. NO_2 harms the respiratory system and favors amongst others the chronic bronchitis which affects predominantly children.

At the same time nitrogen oxides and VOCs are the precursor substances of harmful ozone at ground level and other components of summer smog. Mainly responsible for the nitrogen oxide imissions (more than 85 % of the total production[2]) are traffic as well as combustors (private households and industry). Indeed compulsory catalysts for motor vehicles have substantially reduced the specific emissions. But due to increased traffic density this has little effect on the overall immission situation. This situation is also reflected by the European Commission, thus the EC Directive 199/30/EC and 2001/81/EC was approved. The following guideline 96/62/EG from 27 September, 1996 significantly limits air pollution, prescribing the maximum average NO_2 value within one hour and one calendar year – see Tab. 1. In consequence most big cities will considerably exceed the maximum average value of 40 NO_2/m^3 per year required by an EU regulation from 2010 on.

Table 1. Guideline 96/92/EG – Immission limit values for NO_2

Immission limit values for NO_2	1 hour average value	Average value in on calendar year	
up to 31.12.2009	200 µg/m³	--	maximum 175 exceedings per year
as of 01.01.2010	200 µg/m³	--	maximum 18 exceedings per year
		40 µg/m³	--

Due to the legislative directives, cities are obliged to elaborate air purification plans which in future shall help to observe the critical values. By default of other technical possibilities, those plans foresee in general driving prohibitions for particularly traffic-intense areas. But is this really the only possibility?

1.2. Impact of photocatalytic surface

Many compounds and so also air pollutants are decomposed by sunlight, in particular by energy-rich UV radiation. This natural process of the photolysis takes its time in general. With the help of photo catalysts this effect can be accelerated extensively similar to the catalyst in motor vehicles.

Photo catalysts are semi-conductors with a valence-band and a conduction-band. Activated by UV-light, an electron is transported from the valence-band to the conduction-band. When oxygen gets in contact with such an activated electron, super-oxidion is generated. Gets the valence-band hole in contact with water, the hydroxyl radicals OH• are generated. Both are highly reactive compounds which are able to oxidize most organic compounds and also pollutants such as NO_x, SO_x etc. The principle of reaction is shown in Fig. 1.

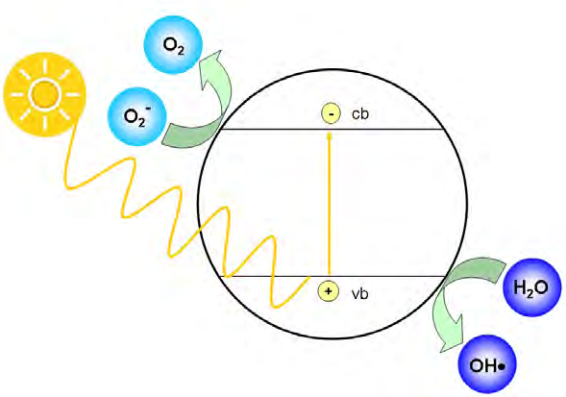

Fig. 1. The principle of formation of hydroxyl radicals OH^-

For several years already the photocatalytic effect has been used in cement-bonded construction materials. Hitherto the attention was turned to an indirect effect, that is the self-cleaning effect[3,4,5] of photocatalytic concrete elements. However, this effect is strongly influenced by the surface structure and porosity. On the concrete surfaces, where photocatalytic active TiO_2 is used, water can react to form highly reactive hydroxyl radicals.

Moreover, there are no standardized test methods which prove the self-cleaning effect. Both aspects encumber significantly a broad acceptance on the market.

For the last two or three years, research and development has increasingly devoted to pollutant reduction by photocatalytic concrete surfaces. Photocatalytic surfaces of cement-bonded building materials act as an "atmospheric washing machine" by decomposing many air pollutants through their oxidizing effect. Surfaces of building materials modified by TiO_2 can, for example, reduce the amount of gaseous air pollutants occurring as NO_x or formaldehyde, as well on nearly every surface (horizontal or vertical).

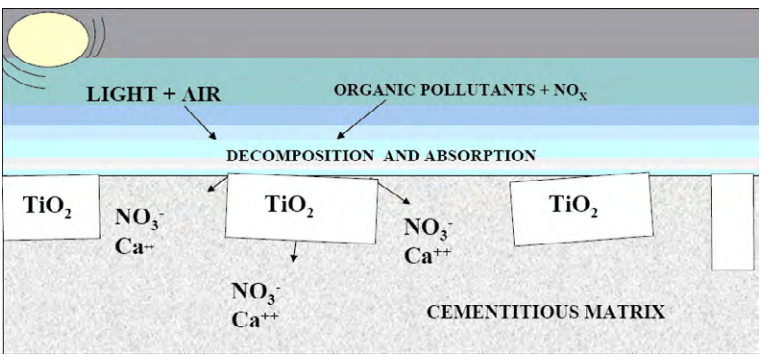

Fig. 2. Pollutants decompositions in air and water[6]

Not least thanks to the PICADA project promoted by the EU, an effective reduction, particularly of nitrogen oxides (NO_x), also under practical conditions can be proven scientifically.

2. TX Active® technology

Recently a brand new technique based on photocatalysis process was introduced into building industry. The technology is called "TX Active®" and represents an advanced feature of cement-bonded building materials mainly of concrete. TX Active® has been developed by the license partner Italcementi S.p.A. TX Active® is a quality mark used to validate the photocatalytic activity of building materials and represents a brand new technique and advanced technology. TX Active® represents patented technology with a secured level of quality and efficiency in terms of utilizing the photocatalytic effect of TiO_2. The logo of TX Active® technology is shown in Fig. 3. To ensure that the finished products meet the high requirements of TX Active®, the photocatalytic activity of finished products is measured to ensure that they will perform as expected.

Fig. 3. TX Active® technology – logo by HeidelbergCement

Moreover, today there are standardized test methods which prove the photocatalytic activity. Some of those methods are:

- ISO 22197-1 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials — Part 1: Removal of nitric oxide
- UNI 11247:2007 Determinazione dell'attivitŕ di degradazione di ossidi di azoto in aria da parte di materiali inorganici fotocatalitici
- UNI 11259:2007 Determinazione dell'attivitŕ fotocatalitica di leganti idraulici - Metodo della rodammina

According to the standardised test method UNI 11247:2007, the properties of TX Active® could be determined and repeatedly controled. Defined conditions of the test method are given below, a scheme of the testing equipment is shown in Fig. 4:

- Concentration of NO_x = 0,55 ppm (0,15 ppm NO_2 + 0,4 ppm NO)
- Moisture of gass 50%; temperature inside chamber 27 °C
- Intensity of UV light inside chamber is 20 W/m^2, wave lenght λ=365nm
- Volume of chamber 3 litres, gas flow 5l/ minute

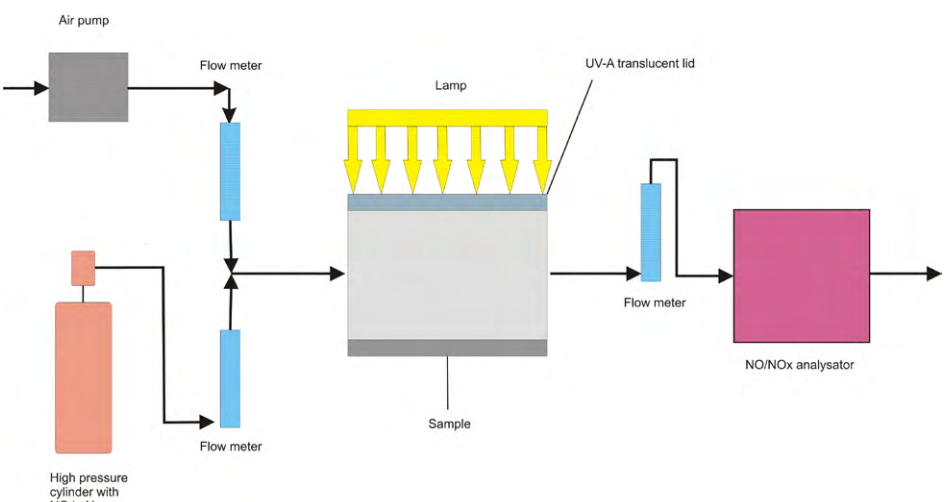

Fig. 4. Scheme of testing equipment for NO_x as in standard 11247:2007

The existence of a standardized testing method enables to compare different properties of various concrete surfaces. The standard provides a strong tool to assess air polution reduction potential based on defined conditions. An example of the testing equipment is shown in Fig. 5a and 5b. Basically it helps to verify the efficiency of TX Active® technology in order to assure the final user about the quality of the concrete products. That is why concrete surfaces with use of TX Active® help to contribute to air pollution reduction in areas of application as in architecture, environment or infrastructure (city centers, parks, calm zones, tunnels, surrounding of traffic structures etc.).

a)

b)

Fig. 5a, 5b. The testing equipment for NO_x reduction – standardized tool

Both aspects support significantly a broad acceptance on the market. Applications based on TX Active® have introduced innovative technology into the concrete word. Hence premium brand cement TioCem® can effectively contribute to air purification by using the TX Active® technology in numerous concrete components such as pavement, roof tiles, facade plates, concrete road surfaces, whitetopping, mortars etc.

By using TX Active® technology and with the application of TioCem®, air pollutants can be abated[6]. Examples of pollutants which can be reduced due to photocatalytic action are:

- Sulphur oxide (SO_2), nitrogen oxides (NO_x),
- Carbon monoxide (CO), ozone (O_3), ammonia (NH_3^+)
- VOC (benzene, toluene etc.), Methyl Mercaptan
- Organic chlorides, aromatic compounds, acetaldehyde, formaldehyde

The benefits of the TX Active® application have been proven by several already accomplished projects and by studies. The results of the PICADA pilot site in Guerville have shown that NO_x mean concentrations inside the canyon were significantly higher than those in the canyon treated with photocatalytic active material. 21,8 to 85,8% higher concentrations were measured in the reference canyon than in the canyon treated with photocatalytic active material (right wall) and 36,3 – 75,4% on the left wall respectively. The applications of concrete photocatalytic surface in Italian towns like Segrate, Calusso and Bergamo show NO_x reduction in practise. The Project "Via Borgo Pallazo" in Bergamo was used as reference photocatalytic surface to measure within authentic conditions. The asphalt surface without photocatalytic properties was used for comparison. It was measured that on a defined day (November 7, 2006) between 9:00 – 17:00 the reduction of NO_x (mean value) was 47%. Several other measurements on other days are presented in Fig. 6.

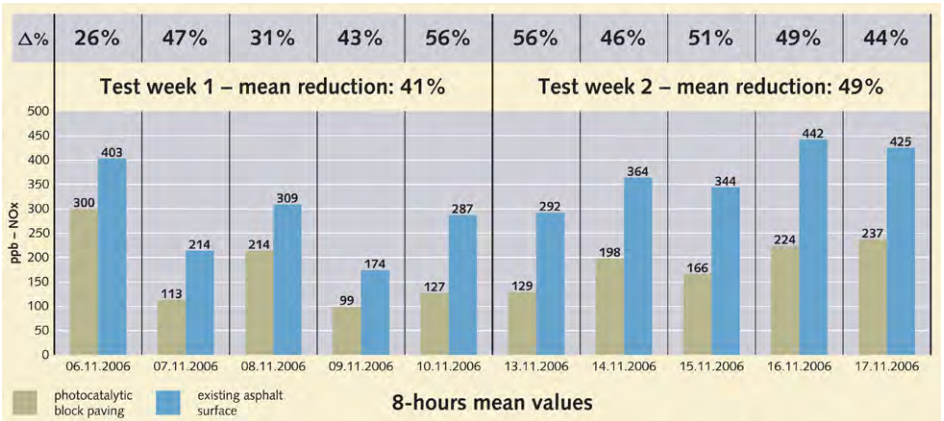

Fig. 6. Via Borgo Palazzo NO_x reduction; mean values measured in the period of 8 hours (9:00 – 17:00)[7]

2.1. TioCem® – the photocatalytic cement

After years of scientific research and first pilot applications, e.g. in an office building in Belgium, the application of photocatalytic binder has meanwhile surpassed laboratory status. By means of continuous refinement and optimization, a range of white and grey cements has been developed by HeidelbergCement under the trade name of TioCem® which shows a strong photocatalytic effect. This can particularly be proven by the NO_x reduction which occurs above concrete surfaces containing TioCem® as soon as sun shines on it [Fig. 7]. Pavers fabricated with this technology reduce demonstrably the NO_x concentrations and that of other pollutants in the air above.

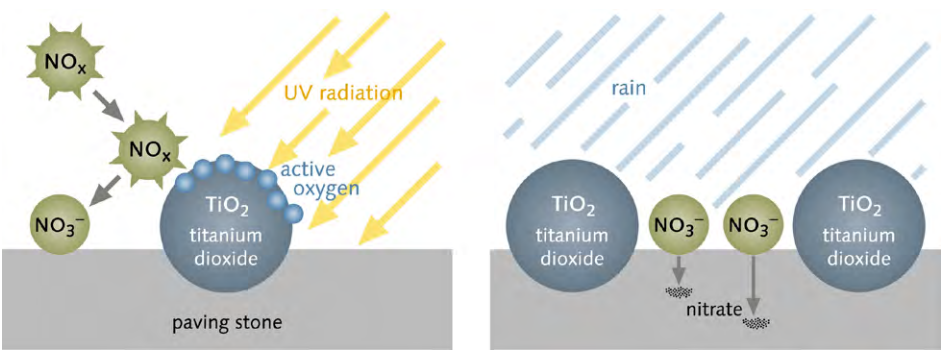

Fig. 7. Reaction process – How TioCem reduces NO_x

In order to use TioCem® to provide the building material's surface with "smart" characteristics, there is either the possibility to use TioCem® directly into the concrete or to use double-layer technology of concrete elements with the application of TioCem® in the top layer.

A first application of TioCem® in Germany was the creation of a paving stone surface in a kindergarten in Bietigheim, with the pavers from Lithonplus (Pasand, Aqua POR). This kindergarten is situated next to a heavily frequented road with accordingly high

pollutant emissions. The application of the TioCem® pavement will result in an amelioration of the air quality so that the children can play untroubled in the yard despite the unfavourable traffic situation.

TioCem® is at the forefront to provide cementitious solutions for the protection of the environment. It is a brand new family of cements decomposing air pollutants. Using photocatalytic reaction, TioCem® helps to improve air quality in our cities and in our daily life. This reality is reflected both by producers and end users of concrete elements in many applications. Up to now there are several products available on the market using TioCem® (TX Active® technology respectively):

- Concrete pavement (Germany)
- Roof tile with mineral coating (Germany)
- Upscale façade elements (Belgium)

Rising awareness inside the community trigger the development of more and more TioCem-based solutions. Ongoing activities linked to the application of photocatalytic concrete surfaces have been recorded in Germany, Great Britain, Czech Republic and Poland.

Many applications of TX Active® technology (TioCem® respectively) Europe-wide confirms that the time has come for a commercial introduction of this innovative technology. The positive effect of TioCem® can be used in numerous concrete applications. The positive trend is evident as more that 1.000.000 m^2 of photocatalytic cement-based material surfaces is applied in Europe by the end of 2007. The future application of TX Active® technology is very promising and will considerably contribute to an improved quality of living.

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