Development of a wall covering for indoor air purification : design, characterization and photocatalytic efficiency assessment

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Development of a wall covering for indoor air purification: Design, characterization and photocatalytic efficiency assessment

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Introduction

Air quality topic has been discussed for many years, focusing in most cases on the outdoor air, which is constantly deteriorated by many reasons for example car exhaust gases, factories and many more. A topic which is not that much discussed, but has the same or even deeper direct influence on our lives, is indoor air quality (IAQ). One of the reasons why the IAQ has such an influence is simply because people spend most of the time in indoor environment, e.g. home, car, public transport, office, hospital or public places such as library or museum. Most of things that people collect indoors can emit harmful substances into the environment and affect the comfort, health and productivity of human beings. Moreover, there are many other sources such as smoking, combustion, cleaning agents and outdoor sources /1; 2/.

The current research is focused on the improvement of the IAQ by utilizing photocatalytic oxidation applying a wall covering material. The aim is to incorporate a nano-sized carbon-doped titanium dioxide (C-TiO_2), visible light responsive photocatalyst, into a commercially used waterborne protective top-coating, designed for a wall covering.

Materials & Methods

The photocatalysts were C-TiO_2 in the powder and waterbased slurry (40% of C-TiO_2) form (Kronos International). The protective top-coating was a waterborne acrylic type (BN International). The carrier was a wall covering substrate, consisting of a paper coated with PVC. The glass substrate was used only in case of the C-TiO_2 slurry and only for a pre-conditioning investigation.

The C-TiO_2 powder was firstly pre-dispersed in water by a high-energy mixer and then mixed-in with the top-coating. The C-TiO_2 slurry was mixed in with the top-coating as received. The coatings were then

applied on a wall covering carrier with the size of 100 mm x 200 mm (width x length) by using a drawdown technique. A coating rod with a steel wire producing coatings with a wet thickness of 8 µm was used. The drying under ambient conditions or curing under infrared irradiation was performed. The morphology of the coatings was investigated with the scanning electron microscope. The photocatalytic efficiency was evaluated via a plug-flow experimental set-up (see **Fig. 1**). Nitric oxide was used as a model pollutant. The experimental conditions were fully controlled and in agreement with ISO 22197-1:2007 with the exception of applied visible light source /3/.

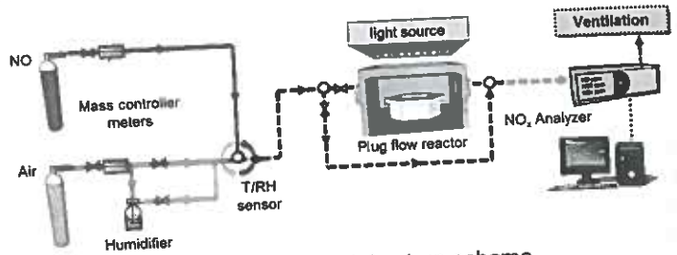

Fig. 1: Experimental set-up scheme

WP coating design

Several coating designs were made with a C-TiO_2 powder and waterborne top-coating (designated **WPXX**). The dosage of the photocatalyst varied from 5 to 20% by weight of the top-coating. Reference samples were made on a wall covering with waterborne acrylic top-coating (designated **WPRX**).

KC coating design

The pre-conditioning of the C-TiO_2 slurry was investigated on a glass carrier. Two sets of coatings were made then using the C-TiO_2 slurry on the wall covering (designated **KCX**). The pure C-TiO_2 slurry and a mixture of C-TiO_2 slurry with the waterborne top-coat were prepared. All designs were made in duplicate in order to evaluate the drying (laboratory) and curing (infrared) effect.

Results

WP coating design

The results showed that the addition of the C-TiO_2 powder into the waterborne coating changes the transparency significantly, due to the micron-sized agglomerates of the photocatalyst. **Fig. 2** shows some selected results of the de-NO_x efficiency (WPR1-refrence; WP21-5% C-TiO_2; WP35-10% C-TiO_2; WP38-20% C-TiO_2). As can be seen, relatively low PCO efficiencies were observed. A dosage of 20% of C-

TiO_2 leads to the NO_x reduction of only 6%. The photocatalyst was after incorporation rather easily removed from the coating by rubbing.

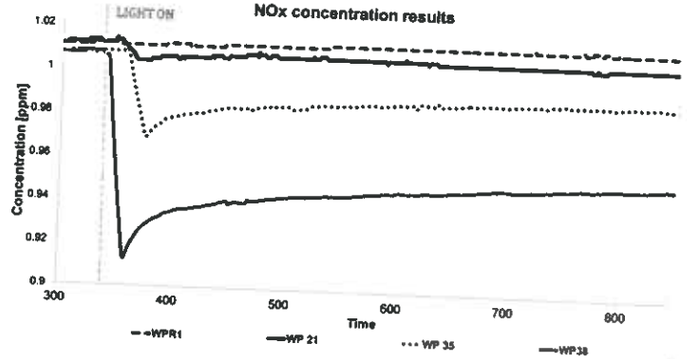

Fig. 2: WPC de-NO_x results

KC coating design

The experiments of the NO_x degradation of the pure C-TiO_2 slurry applied on a glass carrier revealed a necessity for a pre-conditioning phase in order to promote the PCO efficiency of the coating. The pre-conditioning was performed by an ultraviolet irradiation for a period of time.

The de-NO_x experiments performed on a wall covering coated with the pure C-TiO_2 slurry and with the C-TiO_2 slurry mixed with a waterborne top-coating showed positive results.

A NO_x degradation efficiency of 12 and 16% was observed for samples coated by C-TiO_2 slurry and dried under laboratory conditions (lab) or cured by infrared irradiation (IR), respectively.

Table 1: KC de-NO_x results

	C	NO	NO_2	NO_x		C	NO	NO_2	NO_x
KC1 (lab)	$C_{initial}$ [ppm]	1.01	0.01	1.01	KC2 (IR)	$C_{initial}$ [ppm]	1.01	0.00	1.01
	C_{final} [ppm]	0.73	0.16	0.89		C_{final} [ppm]	0.68	0.16	0.85
%degradation		27.72	-	**11.88**	%degradation		32.67	-	**15.84**
KC3 (lab)	$C_{initial}$ [ppm]	1.01	0.00	1.01	KC4 (IR)	$C_{initial}$ [ppm]	1.01	0.00	1.01
	C_{final} [ppm]	0.99	0.01	1.01		C_{final} [ppm]	0.82	0.06	0.88
%degradation		1.98	-	-	%degradation		18.81	-	**12.87**

A NO_x degradation efficiency of 0 or 13% was observed for samples coated by mixture of C-TiO_2 slurry and waterborne top-coating and dried under laboratory conditions (lab) or cured by infrared irradiation (IR), respectively. The irradiation treatment had more profound effect on the PCO efficiency of the coating than in the case of applied pure C-TiO_2 slurry.
The as-prepared coatings were transparent (due to the nano-scale of the particles) with a pale brownish colour. The morphology analysis revealed a formation of micro-cracks, possibly due to the heat treatment or an uneven thickness of the coating which was observed in case of applied pure C-TiO_2 slurry. This will be a subject for the further investigation. In the terms of durability, the coating seems to be enhanced comparing to the ones prepared with C-TiO_2 powder.

Conclusion

This article presents the preparation, treatment, morphology and assessment of a photocatalytic coating.
The experimental results showed that the addition of the powder C-TiO_2 strongly affects the transparency of the coating. On the other hand, the PCO efficiency and durability is low, considering the photocatalyst dosage. This could be avoided by breaking-up the agglomerates into nano-scale fractions prior to the application.
The application of C-TiO_2 slurry proved to be efficient only after a pre-conditioning phase which is necessary for exposing the photocatalyst to the environment. The infrared curing treatment of the samples prepared with a mixture of C-TiO_2 slurry and waterborne top-coating seems to be beneficial for the promotion of the PCO activity.

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Stability of Ca_2Al-PCE-LDH Organo-Mineral Phases against Anions Occurring in Cement Pore Solution

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Introduction

Polycarboxylate-based superplasticizers (PCEs) are the most important admixtures for use in modern concrete technology /1/. They improve its flow properties and/or reduce the water-to-cement ratio (w/c) in order to reach high strength and durability. Therefore, it is necessary to understand all potential interactions between PCEs and the mineral compounds formed during cement hydration. When PCEs are admixed to concrete, they adsorb onto the surface of cement hydrates (especially ettringite), thus producing high fluidity /2/. The adsorbed layer of PCEs exerts a combination of electrostatic repulsion and steric effect between the cement particles which causes the dispersing effect /3/.
During the hydration process of cement, the clinker phases tricalcium aluminate (C_3A) and tetracalcium alumoferrite (C_4AF) produce hydrocalumite-type layered double hydroxides (LDHs) which can intercalate various anions between their cationic main layers.
Normally, Portland cement (OPC) clinker contains approx. 5–10 wt-% of C_3A. During its hydration, the layered phases C_2AH_8 and C_4AH_{13} are formed initially as metastable compounds. These two phases belong to the family of calcium aluminum layered double hydroxides (Ca_2Al–LDHs) which contain hydroxide as interlayer anion /4/. Within minutes or hours (depending on temperature) they convert to cubic katoite, C_3AH_6 which constitutes thermodynamically the most stable calciumaluminate hydrate at room temperature.
Sulfate which is commonly added to OPC to control its setting behavior can also intercalate into the layered calcium aluminate hydrates, resulting in $[Ca_4Al_2(OH)_{12}](SO_4)\cdot 6H_2O$, or monosulfo aluminate (AF_m phase) /5/. Additionally, carbonate ions formed from atmospheric carbon dioxide in the highly alkaline pore solution can also intercalate into the layered calcium aluminate hydrates forming monocarbo aluminate (MC).
In this paper, the potential for anion exchange between Ca_2Al-PCE intercalates and the ions OH^-, SO_4^{2-} and CO_3^{2-}, resp., was investigated. Also, the anion exchange between monosulfo aluminate or C_4AH_{13} and PCE polymers was looked at.