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Photocatalytic cement-based materials: Comparison of nitrogen oxides and toluene removal potentials and evaluation of self-cleaning performance

Jun Chen, Shi-cong Kou, Chi-sun Poon*

Department of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hong Kong

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ABSTRACT

Using cement-based building materials as a matrix for nano-photocatalysts is an important development for the large scale application of photocatalytic technologies. Air pollution mitigation and self-cleaning surface are two major applications of photocatalytic building materials. In this study, a comparison was made to evaluate the performance of TiO_2 modified concrete surface layers for NO_x and VOC degradation. The self-cleaning performance of TiO_2 modified self-compacting mortars (SCM) developed for decorative applications was also evaluated. The results show that the photocatalytic conversion of toluene by the TiO_2 modified surface layer was not detected, although NO_x could be effectively removed under the same conditions. The presence of toluene did not influence the NO_x removal process. TiO_2 modified SCM were found to be effective in the discoloration of rhodamine B under UV and strong halogen light irradiation. The level of adsorption of the air contaminants onto the active sites of the cement-TiO_2 composite was identified to be the key factor determining the subsequent photocatalytic efficiency.

1. Introduction

The application of photocatalysts has gained considerable interests in the environmental science and technology field in recent years. Photocatalysts can aid and accelerate chemical reactions which convert toxic air pollutants to lesser toxic forms in the presence of UV light and can also be used for other purposes, such as water and odor treatments. The two fundamental surface photochemical properties of photocatalysts, photo-induced redox potential and superhydrophilicity, which are the basis for its environmental application have been extensively studied and described in a number of publications [1–3]. The mechanisms and kinetics of photocatalytic reactions have been mostly investigated using pure photocatalysts, typically titanium dioxide (TiO_2). In real applications, nano-sized photocatalytic materials in the form of powders or film must be immobilized onto support materials/substrates to resist mechanical abrasion and environmental aging, sustaining their performance. Representative supporting materials include glass [4,5], activated carbon fibers [6], paper [7], ceramics [8], and cementitious materials [9,10]. Among these materials, there is a growing interest to use cement-based materials (e.g. cement paste or mortar and concrete) as supports due to their strong binding property and porous structures.

The most appealing properties of photocatalytic building materials is its depollution and self-cleaning surface, which can remove trace levels of air pollutants and maintain their esthetic appearance over time. TiO_2 has been widely utilized to produce concrete pavements by mixing the nano-particles within the pavement surface. This kind of products are already commercially available and have been proved to be one of the promising applications to mitigate urban air pollution, such as reducing nitrogen oxides (NO_x) concentration levels [11,12]. Besides direct mixing of TiO_2 powder with the cementitious materials, other techniques, including sputtering, spray coating and sol-gel dip coating [13–15], have also been used to incorporate the photocatalysts onto the building materials. However, these coatings often have weak adhesion to the substrates, rendering poor durability in aggressive outdoor environments [16].

Pioneering work on using photocatalytic cementitious materials has been focused on the depollution effect, and in which NO_x is often chosen as a target gas pollutant because its concentration can be accurately measured in real time. Regarding the degradation of volatile organic compounds (VOCs), there are only a few studies reporting the degradation performance. Strini et al. [17] designed a stirred flow reactor to measure the photodegradation potential of BTEX at the surface of photocatalytic cementitious materials. They observed that the oxidation rate increased in the order of benzene,

* Corresponding author. Tel.: +852 2766 6024; fax: +852 2334 6389.
E-mail address: cecspoon@polyu.edu.hk (C.-s. Poon).

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