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The effect of TiO2 nanoparticles in reduction of environmental pollution in concrete structures

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Abstract. Heterogeneous photocatalysis is developed rapidly in the field of engineering of environmental. It has a good potential to tackle with the enhancing traffic pollution. Adding photocatalyst to usual building materials such as cement and concrete makes friendly environmental materials against the air pollution. TiO2 nanoparticles are a good item for concrete structures for diminishing the air polluting affect by gasses of exhaust. In specific, the transformation of NOx to NO3- is studied and the interaction of TiO2 nanoparticles and concrete is investigated here by experimental test. This paper presents an overview of the principle of photocatalysis and the application in combination with cement, as well as the results of the laboratory research, especially towards air purifying action. In addition, by the analytical models, the influence of TiO2 nanoparticles is studied on the stiffness of the concrete. The Results show that TiO2 nanoparticles have significant effect on the reduction of environmental pollution and increase of stiffness in the concrete structures

Keywords: TiO2 nanoparticles; concrete structures; environmental pollution; stiffness

1. Introduction

In modern civic environments, the quality of life, mobility and comfort are very important issues. In modern countries, the environmental requests are a significant objective in the projects. Applying TiO2 nanoparticles in the concrete is one of the new ideas which can leads to environmental pollution. However, we investigate this subject in this article based on experimental and analytical models.

Nanoparticles have good effects on the mechanical, environmental and chemical properties of structures (Babazadeh *et al*. 2016). The materials with self-cleaning properties based on photocatalyst were presented by some researchers. TiO2 is metal in nature. The oxygen of TiO2 has 3 molecules of anatase, rutile and brookiet. Rutile is in white tint with little photocatalytic reactivity until now. Anatase is superior for photocatalytic. For this purpose, a UV-light with wave length of 387 mm or lower than it is needed. In addition, the light strength is major for optimization the activity of photocatalytic. Researchers focused on the usage of TiO2 nanoparticles in air conditioning, water purification, ceramic tiles, selfcleaning, textile, tunnel lightning and etc. This is since to high surface hydrophilicity activatingTiO2 by UV-light. The layer of water is engrossed between the surface anddirt which wash off of the dirt particles.

(Babazadeh *et al*. 2016, Zhao *et al*. 2017, Zhou *et al*. 2016, Zidi *et al*. 2014, Flores *et al*. 2010). A survey on the application of oxide nanoparticles for improving concrete processing was presented by Khayati *et al*. (2015). Nonlinear vibration of embedded nanocomposite concrete was investigated by Shokravi *et al*. (2017) based on Timoshenko beam model. A mathematical model was introduced by Bakhshandeh Amnieh and Zamzam (2017) for the concrete models reinforced by silicon dioxide (SiO2) nanoparticles subjected to impact load. Zamani Nouri (2016) studied stability analysis of concrete pipes mixed with nanoparticles conveying fluid. Azmi *et al*. (2019) studied dynamic analysis of concrete column reinforced with Sio2 nanoparticles subjected to blast load.

To the best of author knowledge, no work has been presented on reduction of environmental pollution in concrete structures using TiO2 nanoparticles. However, we presented the effect of TiO2 nanoparticles on the mechanical properties and reduction of environmental pollution in concrete structures.

2. Laboratory tests

To obtain the air cleaning activity of TiO2 nanoparticles for building materials, the oxidation of OH and NO into NO2 is obtained. Matter is carried out for pollution induced by taffic and other subjects. The NO oxidation is written using below equations

$$\mathrm{NO} + {}^{\cdot}\mathrm{OH} \xrightarrow{\mathrm{hv,TiO2}} \mathrm{NO_2} + \mathrm{H^+} \tag{1}$$

$$\mathrm{NO_2} + {}^{\cdot}\mathrm{OH} \xrightarrow{\mathrm{hv,TiO2}} \mathrm{NO_3^-} + \mathrm{H^+} \tag{2}$$

Other important items are high temperature and humidity due to water of atmosphere. At higher temperatures, the conversion will be better. The optimum condition is at hot summer daysdue to low humidity and

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high temperature.

The experiment set-up is based on the Japanese standard of JIS TR Z 0018 consisting of metal container, pavement block and UV-transparent glass. Air with a NO-doping of 1 ppm over the surface is blown with flow rate of 3 l/min. The height for the free space is about 3 mm. The temperature is 24℃ and the humidity is 51%. The light force is 15 W/m² in the range of 300 and 500 nm.

3. Analytical model

Various methods are used to obtain the average properties of a composite (Mori and Tanaka 1973). Due to its simplicity and accuracy even at high volume fractions of the inclusions, the Mori-Tanaka method (Mori and Tanaka 1973) is employed in this section. The matrix is assumed to be isotropic and elastic, with the Young's modulus E_m and the Poisson's ratio υ_m. The constitutive relations for a layer of the composite with the principal axes parallel to the r, θ and z directions are (Mori and Tanaka 1973, Shi and Feng 2004)

$$\begin{Bmatrix}\sigma_{11}\\ \sigma_{22}\\ \sigma_{33}\\ \sigma_{23}\\ \sigma_{13}\\ \sigma_{12}\end{Bmatrix}=\begin{bmatrix}k+m & l & k-m & 0 & 0 & 0\\ l & n & l & 0 & 0 & 0\\ k-m & l & k+m & 0 & 0 & 0\\ 0 & 0 & 0 & p & 0 & 0\\ 0 & 0 & 0 & 0 & m & 0\\ 0 & 0 & 0 & 0 & 0 & p\end{bmatrix}\begin{Bmatrix}\varepsilon_{11}\\ \varepsilon_{22}\\ \varepsilon_{33}\\ \gamma_{23}\\ \gamma_{13}\\ \gamma_{12}\end{Bmatrix} \quad (1)$$

where σ_{ij}, ε_{ij}, γ_{ij}, k, m, n, l, p are the stress components, the strain components and the stiffness coefficients respectively. Utilizing the Mori-Tanaka method the stiffness coefficients are given by Mori and Tanaka (1973)

$$k=\frac{E_m\{E_m c_m+2k_r(1+\nu_m)[1+c_r(1-2\nu_m)]\}}{2(1+\nu_m)[E_m(1+c_r-2\nu_m)+2c_m k_r(1-\nu_m-2\nu_m^2)]}$$

$$l=\frac{E_m\{c_m\nu_m[E_m+2k_r(1+\nu_m)]+2c_r l_r(1-\nu_m^2)\}}{(1+\nu_m)[E_m(1+c_r-2\nu_m)+2c_m k_r(1-\nu_m-2\nu_m^2)]}$$

$$n=\frac{E_m^2 c_m(1+c_r-c_m\nu_m)+2c_m c_r(k_r n_r-l_r^2)(1+\nu_m)^2(1-2\nu_m)}{(1+\nu_m)[E_m(1+c_r-2\nu_m)+2c_m k_r(1-\nu_m-2\nu_m^2)]}+\frac{E_m[2c_m^2 k_r(1-\nu_m)+c_r n_r(1+c_r-2\nu_m)-4c_m l_r\nu_m]}{E_m(1+c_r-2\nu_m)+2c_m k_r(1-\nu_m-2\nu_m^2)} \quad (2)$$

$$p=\frac{E_m[E_m c_m+2p_r(1+\nu_m)(1+c_r)]}{2(1+\nu_m)[E_m(1+c_r)+2c_m p_r(1+\nu_m)]}$$

$$m=\frac{E_m[E_m c_m+2m_r(1+\nu_m)(3+c_r-4\nu_m)]}{2(1+\nu_m)\{E_m[c_m+4c_r(1-\nu_m)]+2c_m m_r(3-\nu_m-4\nu_m^2)\}}$$

where the subscripts m and r are for matrix and nanoparticles respectively. C_m and C_r are the volume fractions of the concrete and the reinforcer respectively and k_r, l_r, n_r, p_r, m_r are the Hills elastic modulus for the TiO2 nanoparticles (Mori and Tanaka 1973).

4. Numerical results

The result of the experimental is presented in Figs. 1-3, respectively for No, NO2 and NOx. The input concentration is 1 ppm. When the light is applied, the drop of concentration is 42%. After 5 hours, the NO is cut off for 30 minutes. Hence, the light is applied again and the NO concentration is calculated. The results show a little enhance in NO2 leads to reduction in NO (NO+NO2). The final reduction is depended to the surface exposed size, material, light intensity, NO concentration, ambient temperature and flow rate.

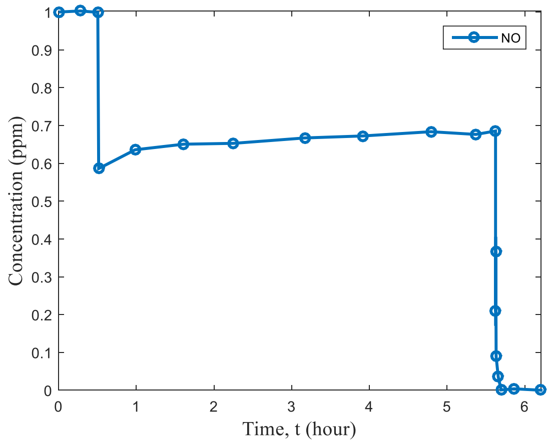

Fig. 1 Concentration of No versus time

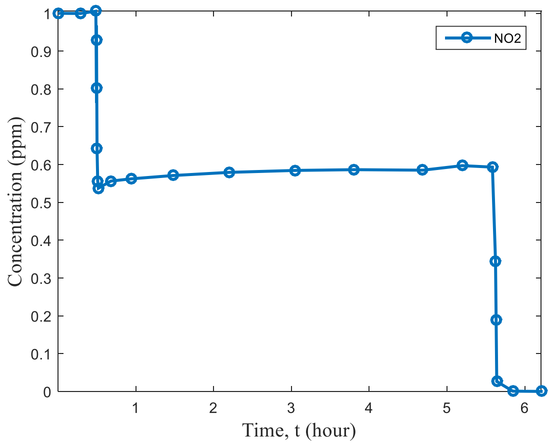

Fig. 2 Concentration of No2 versus time

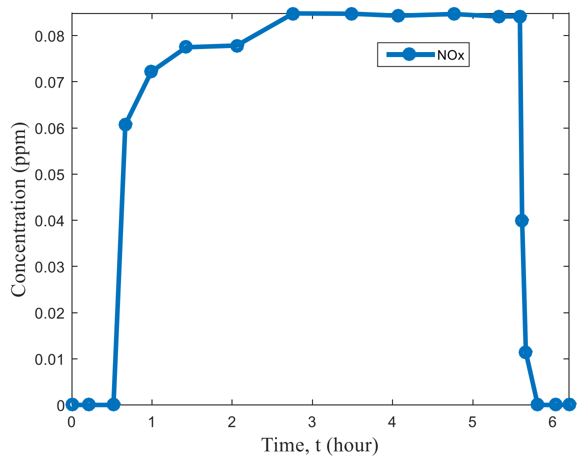

Fig. 3 Concentration of Nox versus time

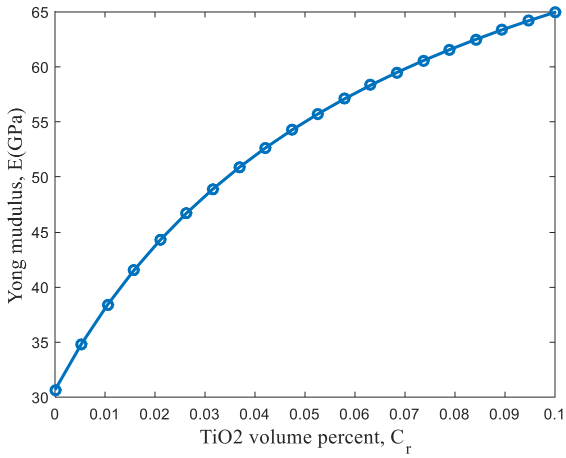

Fig. 4 The effect of TiO2 nanoparticles on the elastic modulus of the concrete

Based on Mori-Tanaka model, the elastic modulus of the concrete with respect to the volume percent of TiO2 nanoparticles is shown in Fig. 4. As can be seen, with enhancing the volume percent of TiO2 nanoparticles, the elastic modulus is increased significantly. In other words, reinforcing the concrete with 10% TiO2 nanoparticles leads to 65% increase in the elastic modulus. This is due to this fact that with enhancing the volume percent of TiO2 nanoparticles, the stiffness of the structure improves.

5. Conclusions

The reduction of environmental pollution by applying TiO2 nanoparticles for construction of concrete structure was studied in this paper based on experimental and Mori-Tanaka model. The effect of using these nanoparticles on the modulus of elasticity was investigated. Results show that after 5 hours, the NO was cut off for 30 minutes. Reinforcing the concrete with 10% silica nanoparticles leads to 65% increase in the elastic modulus. The final reduction is depended to the surface exposed size, material, light intensity, NO concentration, ambient temperature and flow rate. The results shows a little enhance in NO2 leads to reduction in NO (NO+NO2).

References

Azmi, M., Kolahchi, R. and Rabani Bidgoli, M. (2019), "Dynamic analysis of concrete column reinforced with Sio2 nanoparticles subjected to blast load", *Adv. Concrete Constr.*, **7**, 51-63.

Babazadeh, A., Burgueño, R. and Silva, P.F. (2016), "Evaluation of the critical plastic region length in slender reinforced concrete bridge columns", *Eng. Struct.*, **125**, 280-293.

Bakhshandeh Amnieh, H. and Zamzam, M.S. (2017), "Theoretical and experimental analysis of wave propagation in concrete blocks subjected to impact load considering the effect of nanoparticles", *Comput. Concrete*, **20**, 711-718.

Flores, I., Sobolev, K., Torres, L.M., Valdez, P.L., Zarazua, E. and Cuellar, E.L. (2010), "Performance of cement systems with Nano-SiO_2 particles produced using Sol-gel method", *TRB First International Conference in North America on Nanotechnology in Cement and Concrete*, Irvine, California, USA, May.

Khayati, G.R., Ghasabe, H.M. and Karfarma, M. (2015), "A survey on the application of oxide nanoparticles for improving concrete processing", *Adv. Concrete Constr.*, **3**, 145-159.

Mori, T. and Tanaka, K. (1973), "Average stress in matrix and average elastic energy of materials with misfitting inclusions", *Acta Metallurgica*, **21**, 571- 574.

Shi, D.L. and Feng, X.Q. (2004), "The effect of nanotube waviness and agglomeration on the elastic property of carbon nanotube-reinforced composties", *J. Eng. Mater. Tech.*, **126**, 250-270.

Shokravi, M. (2017), "Vibration analysis of silica nanoparticles-reinforced concrete beams considering agglomeration effects", *Comput. Concrete*, **19**, 333-338.

Zamani Nouri, A. (2018), "The effect of Fe_2O_3 nanoparticles instead cement on the stability of fluid-conveying concrete pipes based on exact solution", *Comput. Concrete*, **21**, 31-37.

Zhao, B., Gao, L., Liao, W. and Zhang, B. (2017), "A new kernel method for hyperspectral image feature extraction", *Geo-spatial Inform. Sci.*, **20**, 309-318.

Zhou, X., Liu, J., Wang, X. and Frank Chen, Y. (2016), "Behavior and design of slender circular tubed-reinforced-concrete columns subjected to eccentric compression", *Eng. Struct.*, **124**, 17-28.

Zidi, M., Tounsi, A. and Bég, O.A. (2014), "Bending analysis of FGM plates under hygro-thermo-mechanical loading using a four variable refined plate theory", *Aerosp. Sci. Tech.*, **34**, 24-34.

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