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Improve Indoor Air Quality by Using Titanium Dioxide as Coating Photocatalyses under UV Irradiation

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Abstract: Air inside buildings can be more polluted than outdoor because there are various sources of pollution in the big cities. This study present the results of a study on the efficiency of contribute air cleaning agents such as Titanium dioxide (TiO_2) into the technique of producing concrete composite panels using local waste materials for solving the problem of Carbon dioxide (CO_2) in indoor air buildings. Factors which would have an effect on the performance of the panel were studied including the porosity of panel, different types of waste materials and types percentage of TiO_2 used within the mix design. The degradation process under laboratory conditions was studied using chemiluminescence analysis method for measuring the performance of photocatalytic active concrete products. The results show that the photo degradation of CO_2 is related to the porosity of the sample when the porosity of sample was increased so the CO_2 was removal ability.

Key words: Sources, pollution, efficiency, technique, degradation, Malaysia

INTRODUCTION

Indoor air quality has received immense attention in the early 1990s. The indoor air quality in any building can be compromised by microbial contaminants (mold, bacteria and gases), chemicals (such as carbon dioxide, formaldehyde), allergens or any mass or energy stressor that can induce health effects (John *et al*., 2000). The concentration of Carbon dioxide (CO_2) in Earth's atmosphere is approximately 390 ppm by volume as of 2010 and rising by about 1.9 ppm year^{-1}. The present level is higher than at any time during the last 800 thousand years and likely higher than in the past 20 million years (Hoffmann *et al*., 1995). Hence a clean indoor air is important for the well-being and health of people because most of people spend 90% of their time indoors especially the young, the elderly and those who are chronically ill.

USEPA (1995) identified indoor air pollution is one of the top environmental risk. Additionally, the construction industry is the major source of air pollution; transportation for a high population density of people and the numerous tall buildings hinder and prevent the dispersion of air pollutants generated by a high concentration of vehicles at the street level (Li *et al*., 2001). Several of studies apparent that there is a need to remove pollutants such as Carbon dioxide (CO_2) and Nitrogen Oxides (NO) from the atmosphere not only do these gases pose a threat to health, they are also causing degradation to many inner city buildings (Jones, 1999). This study attempts to lower these emissions by using cleaner air such as photo catalyst which a way of removing pollutants from the atmosphere to be the most feasible option to improve indoor air quality to develop a local low cost building panel system suited to their tropical climate.

The current study was designed to investigate the efficiency performance of photo catalytic materials such as Titanium dioxide on the technique of producing concrete composite panels using local waste materials for solving the problem of the increasing rates of Carbon dioxide (CO_2) in indoor air buildings.

Over the last 10 years the scientific and engineering interest in the application of semiconductor photo catalysis has grown exponentially. In the areas of water, air and wastewater treatment alone, the rate of publication exceeds 200 papers per year averaged over the last 10 years (Poon *et al*., 2001). The use of nanotechnology to important advanced oxidation effect on materials via photo catalysis is a novel approach.

Oxidation eliminates like (TiO_2) photo catalyst has received significant interest in recent years due to its fascinating properties such as electronic, optical and UV absorption (Kawashima and Masuda, 1994). Recently, photocatalytic oxidation has shown to be a promising

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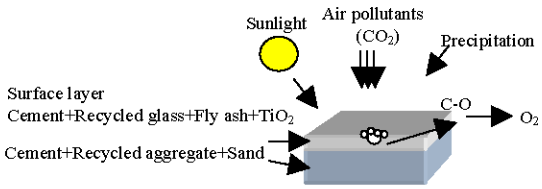

Fig. 1: The design of the photo catalytic paving blocks

and effective technology for pollution control (Yu *et al*., 2002; Fujishima *et al*., 2000; Obuchi *et al*., 1999; Peral *et al*., 1997). However, EPA's (1987), Luo and Ollis (1996) and Kim and Hong (2002) studies showed that the rate of PCO decreased with decreasing pollutant concentration. In addition, at high humidity levels, water vapour competed with TiO_2 for adsorption sites which further decreased the rate of PCO (Ao *et al*., 2003). Scientific studies on photo catalysis started about two and a half decades ago. A chemical material such as Titanium dioxide (TiO_2) which is the one of the most basic materials in the daily life has emerged as an excellent photocatalyst material for environmental purification. Titanium dioxide have already been tested in Japan for concrete paving materials that can facilitate a photocatalytic reaction converting the more toxic forms of air pollutants to less toxic forms e.g., CO_2 and NO (Anpo and Takeuchi, 2003) and (Murata *et al*., 2002). The design of the photocatalytic paving block is shown in the Fig. 1.

Fujushima *et al*. (1999) note that under the illumination of ultraviolet light, photocatalysis shows diverse functions such as the decomposition of air and water contaminants and deodorization as well as self cleaning, antifogging and antibacterial actions. Practical applications of photocatalysts have rapidly expanded in recent years. Photocatalytic materials for indoor purification are in urgent demand because energy and labour saving advantages have been realized when applied to building construction materials in large cities where urban air pollution is very serious (Yoshihiko *et al*., 1999).

MATERIALS AND METHODS

Experimental process

Preparation of materials: Cement material that is used in this study is an Ordinary Portland Cement (OPC) commercially available in Malaysia. Furnace Bottom Ash (FBA) that used is a product of coal fired electricity generation. FBA is the coarser material that falls to the bottom of the furnace during the burning of coal (Kayabal and Bulu, 2000). Only the portion that passed through a 2.36 mm sieve will be use for making the surface layer. The Recycled Aggregate (RA) is also used in this study. It is a crushed C and D waste sourced from a temporary recycling facility. In the plant the C and D waste underwent a process of mechanized sorting; only the smaller fine aggregate proportion will use for making the surface layer of the blocks in this study (BS, 1985). The maximum size of the recycled fine aggregate will use is 2.36 mm. The sand that is used is fine natural river sand commercially available in Malaysia. Chemical material candidate is Titanium dioxide (TiO_2). The best source of titanium dioxide is Anatase sourced commercial available which was used due to its high purity and accurate specifications. It is commonly used in the industry and research community, hence would be useful for comparison with works of other materials (Poon and Cheung, 2007).

Table 1: Mixes prepared with different materials

	Relative proportions (by weight)					
Ratios	Cement	RA	Sand	FBA	Water	TiO_2
R1:2	1	2.0	1.5	0.55	0.06	0.28
R1:2:5	1	2.5	1.5	0.65	0.07	0.30
R1:3	1	3.0	1.5	0.75	0.08	0.32

Sample proportions: The samples were fabricated in steel moulds with internal dimensions of 20×10×5 cm. The wet mixed materials weighed between 400 and 500 g for each sample depending on the different materials. The steel moulds were filled by hand compaction. After 1 day, the samples were removed from their moulds and tested for CO_2 photo degradation at 15, 30 and 60 days with GC gas equipment.

Mix proportions: Mixes prepared with RA, FBA, TiO_2, water and sand. This study focus on useful of recycled materials so a series of mixes are prepares to find out the effects of titanium dioxide and proportions on CO_2 removal efficiency. Mixes with varying cement to aggregate ratios, ranging from 1:2, 1:2:5 and 1:3 is prepared. A large amount of the mixes is prepared by utilizing aggregate sizes from 300-2.36 mm. The varying amount of TiO_2 were studied by preparing samples with the TiO_2 Anatase content ranging from 0.06-0.08% as shown in Table 1.

Equipments: The central part of the experimental setup used is a gas reactor allowing a sample of the size 10-20 cm^2 to be fixed. The reactor is made from materials which are non-absorbing to the applied pollutant and can hold up UV-A light of high irradiance. The reactor is tightly closed with a glass plate made from borosilicate glass allowing the UV-A radiation to pass through with almost no conflict. The surface of the specimen is fixed

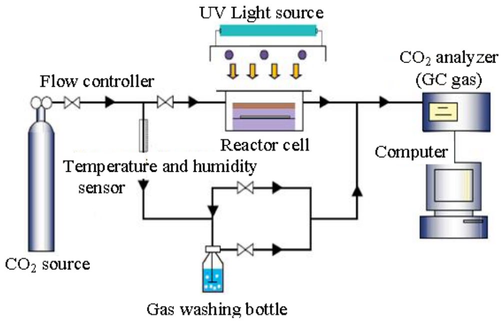

Fig. 2: Schematic diagram of the experiment setup

parallel to the covering glass inside the reactor, leaving a slot of 0.3 cm for the gas to pass through it; the sample gas only passes the reactor through the slot between the sample surface and the glass cover in longitudinal direction.

All structural designed parts inside the box are to allow laminar flow of the gas along the sample surface and to put off distribution. Two 10 W UV-A fluorescent lamps (black lights) with wavelengths 366 nm were used to supply photo irradiation to activate the photo catalyst. About two types of sensors are used, temperature and humidity sensor.

The tool was used to analyze the result of CO_2 removal efficiency by computer is GC gas. The schematic illustration of the reactor cell and the test setup is showed in Fig. 2.

RESULTS AND DISCUSSION

Influence of TiO_2 and local material on carbon dioxide photo degradation under UV light: Influence of TiO_2 and local material on Carbon dioxides photo degradation under UV light The results of CO_2 photo degradation as shown in Fig. 3 indicate that the RA mixes achieved a much higher CO_2 removal compared to the sand mixes under UV light after 1 week from the test. This is probably due to the porous nature of RA compared to that of sand. The results also indicate that the CO_2 removal slightly increased when FBA was not included in the mix design. This is able to be due to the higher porosity of FBA particles which was exemplified by its relatively low specific density compared to those of sand and RA.

Effect of particle size of aggregates on carbon dioxide photodegradation: The specimens prepared with different aggregate sizes was believed to affect their ability to remove CO_2 as varying the particle size distribution of aggregates would effectively change the porosity of the specimens. The specimens were divided into to two groups, one was prepared with all aggregate sizes below 2.36 mm included and the other with aggregate

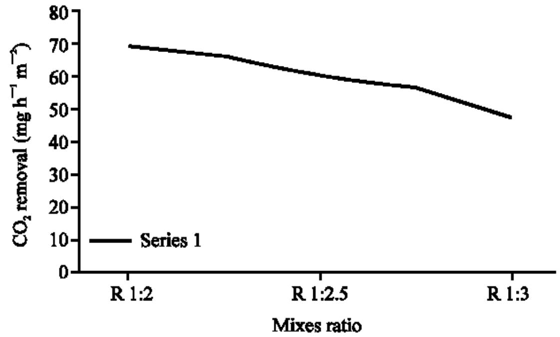

Fig. 3: Influence of TiO_2 and local material on carbon dioxides photo degradation under UV light after 1 week

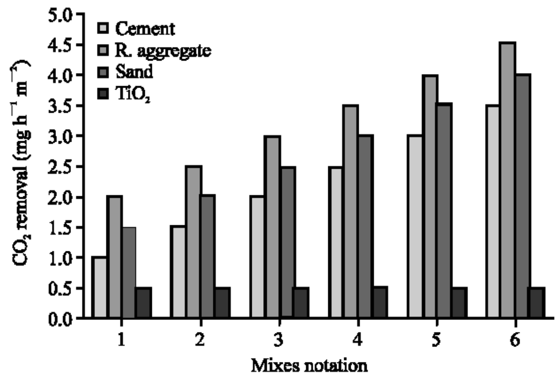

Fig. 4: Influence of TiO_2 and cement/aggregate ratio on carbon dioxides photo degradation under UV light after 2 weeks

sizes only between 300 μm and 2.36 mm included shows the specimens tested at 1 and 2 weeks with cement to aggregate ratio of 1:3. The results indicate that the specimens prepared with aggregate sizes between 300 μm and 2.36 mm (the more absorbent specimens) achieved approximately 6% higher CO_2 removal during the 2 weeks from the test show in Fig. 4.

Lahl and Lambrecht (2008) were found the same result of the applications of different types photo catalytic pavement blocks as is applied in Antwerp, Belgium, in Bergamo, Italy and in Japan. According to (Yoshihiko *et al.*, 1999; Robinson and Nelson, 1995). Vertical applications found in the Netherlands (as part from the IPL project) shows the dependence of the CO_2 removal on the irradiance for low values of irradiance based on own measurements on paving block samples power function describes the relation between the irradiance E and the different concrete mixes of the samples achieved degradation rates for all samples continents aggregate sizes below 3.80 mm.

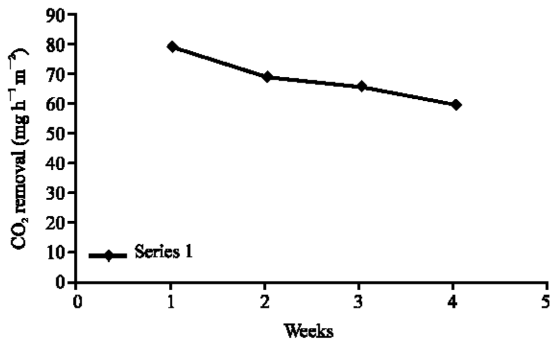

Fig. 5: Influence of porosity on carbon dioxides photo degradation under UV light after 4 weeks

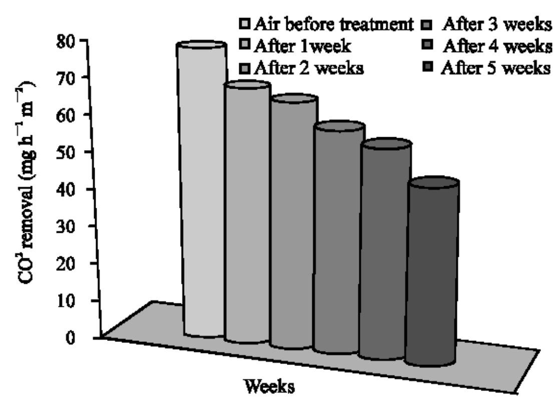

Fig. 6: Influence of porosity on carbon dioxides photo degradation under UV light after 5 weeks

Effect of porosity on carbon dioxides photodegradation: The factors that can influence on the CO_2 removal showed above were all associated with porosity. In Fig. 5 and 6 shows the measured porosity compared with CO_2 removal of some of the selected mixes within the 4 and 5 weeks from the test started. A clear preference can be realized that the CO_2 removal increased with increase in porosity. Okura and Kaneko (2002) shows the influence of the relative porosity depends to a large extent on the type of material used and the effect at the surface prevails over the oxidizing effect when high values of relative humidity are applied.

CONCLUSION

This study shows on the findings on assessing the factors which would affect the ability of the prepared surface layer of the composite panel to remove Carbon dioxides by photo catalytic activities (TiO_2). The primary results show that porosity of the surface layer is important which efficiently increased the area available to reacting with the pollutants. The porosity of the surface layer was affected by the type of materials with which they were prepared. Materials with a lower density led to a higher porosity of the panels. The particle size distributions of the materials used also affected the porosity of the panels. The change in the cement to aggregate ratio of the mixes had an apparent relationship to the carbon dioxides removal ability.

Mixes prepared with lower cement to aggregate ratio were more effective at removing carbon dioxides. Samples that tested at different remedial ages were found to demonstrate different abilities to remove carbon dioxides. The results show that titanium dioxides decreased with age but the decrease stabilized at the age of 90 days. The better performance of the surface layers when fly ash wasn't used. Anatas was used as the better forms sourced from a commercial source hence it be the best photo catalytic ability for improve indoor air quality.

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REFERENCES

Anpo, M. and M. Takeuchi, 2003. The design and development of highly reactive titanium oxide photocatalysts operating under visible light irradiation. J. Catal., 216: 505-516.

Ao, C.H., S.C. Lee, C.L. Mak and L.Y. Chan, 2003. Photo degradation of volatile organic compounds (VOCs) and NO for indoor air purification using TiO_2 promotion versus inhibition effect of NO. Applied Catal. B Environ., 42: 119-129.

BS 812-103.1, 1985. Testing aggregates-methods for determination of particle size distribution. British Standards Institution, http://www.techstreet.com/cgi-bin/detail?doc_no=BS%7C812_103_1_1985&product_id=1107379.

EPA's, 1987. Team Study in Los Angeles. Vol. 7, Toxicology and Industrial Health, California, pp: 203-208.

Fujishima, A., T.N. Rao and D.A. Tryk, 2000. Titanium dioxide photocatalysis. J. Photochem. Photobiol. C: Photochem. Rev., 1: 1-21.

Fujushima, A., K. Hashimoto and T. Watanabe, 1999. TiO_2 Photocatalysis Fundamentals and Applications. BKC, Japan, ISBN-13: 978-4939051036.

Hoffmann, M.R., S.T. Martin, W. Choi and D.W. Bahnemann, 1995. Environmental applications of semiconductor photocatalysis. Chem. Rev., 95: 69-96.

John, D., M. Jonathan and F. John, 2000. Indoor Air Quality Handbook. McGraw-Hill, New York.

Jones, A.P., 1999. Indoor air quality and health. Atmos. Env., 33: 4535-4564.

Kawashima, K. and R. Masuda, 1994. Abstracts of papers. Proceedings of the 1st International Conference on Advanced Oxidation Technologies for Water and Air Remediation, June 25-30, London, Canada, pp: 335-336.

Kayabal, K. and G. Bulu, 2000. The usability of bottom ash as an engineering material when amended with different matrices. Eng. Geol., 56: 293-303.

Kim, S.B. and S.C. Hong, 2002. Kinetic study for photocatalytic degradation of volatile organic compounds in air using thin film TiO_2 photocatalyst. Applied Catal. B Environ., 35: 305-315.

Lahl, U. and U. Lambrecht, 2008. High NO_2 levels: Ongoing need for action on diesel emissions. Technical Congress 2008. Verband der Automobilindustrie. http://www.bmu.de/english/air_pollution_control/downloads/doc/41372.php.

Li, W.M., S.C. Lee and L.Y. Chan, 2001. Indoor air quality at nine shopping malls in Hong Kong. Sci. Total Environ., 273: 27-40.

Luo, Y. and D.F. Ollis, 1996. Heterogeneous photo catalytic oxidation of trichloroethylene and toluene mixtures in air: Kinetic promotion and inhibition, time-dependent catalyst activity. J. Catal., 163: 1-11.

Murata, Y., K. Kamitani, H. Tawara and H. Obata, 2002. NOX removing pavement structure. United States Patent Office, Patent No. 6454489. http://www.freepatentsonline.com/6454489.html.

Obuchi, E., T. Sakamoto, K. Nakano and F. Shiraishi, 1999. Photocatalytic decomposition of acetaldehyde over TiO_2/SiO_2 catalyst. Chem. Eng. Sci., 54: 1525-1530.

Okura, I. and M. Kaneko, 2002. Photocatalysis Science and Technology. Springer-Verlag, Berlin, ISBN-13: 978-4062106153.

Peral, J., X. Domenech and D.F. Ollis, 1997. Heterogeneous photocatalysis for purification, decontamination and deodorization of air. J. Chem. Technol. Biotechnol., 70: 117-140.

Poon, C.S. and E. Cheung, 2007. NO removal efficiency of photocatalytic paving blocks prepared with recycled materials. Construction Build. Mater., 21: 1746-1753.

Poon, C.S., A.T.W. Yu and L.H. Ng, 2001. On-site sorting of construction and demolition waste in Hong Kong. Resourc. Conserv. Recycl., 32: 157-172.

Robinson, J. and W.C. Nelson, 1995. National Human Activity Pattern Survey Data Base United States. Environmental Protection Agency, Research Triangle Park, NC.

USEPA, 1995. Characterizing air emissions from indoor sources. EPA Report EPA/600/F-95/005, UnitedStates Environmental Protection Agency, Washingtion DC.

Yoshihiko, M., T. Hideo, O. Hiroshi and T. Koji, 1999. Air purifying pavement: Development of photocatalytic concrete blocks. J. Adv. Oxidat. Technol., 4: 227-230.

Yu, J.C., J. Yu and J. Zhao, 2002. Enhanced photocatalytic activity of mesoporous and ordinary TiO_2 thin films by sulfuric acid treatment. Applied Catal. B Environ., 36: 31-43.