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Properties of cement matrix using ZrO_2 photocatalyst for fine dust adsorption

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Abstract

Due to the increase in fine dust caused by deepening air pollution, interest in the adverse effects of fine dust has increased. In this study, experiments were carried out to evaluate the properties of the fine dust adsorption-type matrix by applying the photocatalyst adsorption mechanism to the matrix. ZrO_2 was used as the photocatalyst. As a test item for evaluating the properties of ZrO_2 fine dust adsorption cured product, unit weight, water absorption, flowability, thermal conductivity, strength, and fine dust (PM10, PM2.5) adsorption experiments were conducted. In this study, photocatalyst ZrO_2 was used as a material for the adsorption of fine dust. Experimental results of fabrication of fine dust adsorption-type matrix using photocatalyst ZrO_2 are as follows. As a result of the increase of the substitution rate of ZrO_2, the density and the absorption rate tended to decrease and the absorption rate increased. The fluidity test showed a tendency to decrease as the substitution rate of ZrO_2 increased. As a result of the thermal conductivity measurement, as the substitution rate of ZrO_2 increased, it decreased due to the increase of the porosity. As a result of fine dust measurement, as the substitution rate of ZrO_2 increased, the concentration tended to decrease due to the catalytic action. Compared with previous experiments using TiO_2, it was confirmed that the overall performance, such as strength and economics, was significantly reduced. There is a need for a solution.

Keywords: *Fine dust, Indoor air quality, Photocatalyst, ZrO_2, Adsorption.*

1. Introduction

Recently, regardless of the season, the smog phenomenon and fine dust are threatening our health, especially in the metropolitan area. Fine dust is one of air pollutants, which is generated by industrial development, and is produced in various combustion, production, and manufacturing processes such as oil and cement manufacturing processes, waste incineration processes, and hazardous material processing processes. Fine dust from nature, yellow dust and pollen are relatively large. On the other hand, the fine dust from automobile exhaust and factory chimneys is very small. The smoke of thermal power plants also contains sulfur dioxide and nitrogen compounds. [1] Fine dust is a suspended solid in the air that refers to dust whose particles are so small that it is indistinguishable to the eye, and can be classified according to its diameter. Dust less than 10μm is defined as fine dust (PM10), dust less than 2.5μm is defined as ultrafine dust (PM2.5). It is divided into components (sulfate, nitrate, ammonium) and mineral components. [2] At present, there are domestic causes of environmental pollution caused by the use of fossil fuels and automobile emissions, and the

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inflow of fine dust from China due to the relocation of factories. In 2015, the HEI Institute for Health Impact reported that Korea's ultra-fine dust concentration was the second highest among OECD countries. [3] Due to these problems, social interest in indoor air pollution is increasing. Many studies have been conducted to purify the pollution level of indoor air quality, and research is needed for the development of construction materials with self-purification ability. In this study, the characteristics of adsorptive cured product substituted with photocatalyst ZrO2 were evaluated. [4-6] [Fig. 1, 2] show pictures of fine dust and the causes of the occurrence of fine dust.

Figure 1. Korea's Fine dust(https://news.joins.com/article/22296275, http://www.hani.co.kr/arti/area/area_general/878485.html)

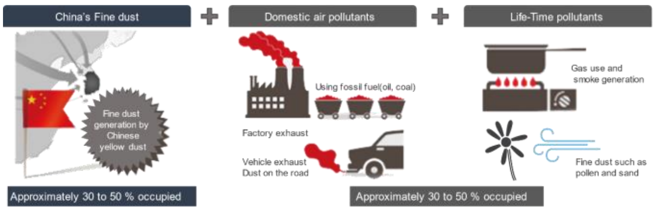

Figure 2. Fine dust generation factor(https://m.blog.naver.com/PostView.nhn?blogId=jaksa1104&logNo=221249024533&proxyReferer=https%3A%2F%2Fwww.google.co.kr%2F)

2. Experimental Plan and Method

When the photocatalytic reaction is subjected to ultraviolet rays such as sunlight or fluorescent lamps, electrons with negative charges and holes with positive charges are formed, as in the principle of solar cells. Holes form a strong oxidizing hydroxide, which has stronger oxidizing power than chlorine or ozone for sterilization. The former produces oxygen ions adsorbed on the photocatalyst to oxygen ions, which produce intermediates and peroxides in the oxidation reaction or water reaction through hydrogen peroxide. The result of this reaction is environmentally friendly effects such as water purification, air purification, sterilization and odor removal. [7,8]

2.1 Experimental Plan

In this study, the characteristics of the fine dust adsorption matrix were evaluated. The photocatalyst ZrO_2 for adsorption of cement and fine dust was used as a binder used to produce the cured product. W / B was set to 30%, and then ZrO_2 was substituted to 0, 5, 10, 15, 20 (%) levels. As test items, unit weight, water absorption, flowability, thermal conductivity, flexural strength, compressive strength, and fine dust concentration were measured. [Tab. 1] shows the experimental factors and levels.

Table 1. Experimental factors and levels

Experimental factor	Experimental level	
Binder	Cement, ZrO_2	2
W/B	30 (wt.%)	1
Replacement ratio of ZrO_2	0, 5, 10, 15, 20 (wt.%)	5
Curing condition	Constant temperature-Humidity curing (Temp. 20±2°C, Hum. 60±5%)	1
Assessment items	Unit weight, Water absorption, Flowability, Thermal conductivity, flexural strength, Compressive strength, , Fine dust concentration(PM 10, PM 2.5)	8

2.2 Using Materials

• Cement

The cement used in this experiment is a type of portland cement of general Korean products and used according to the standard of KS L 5201. The density of cement is 3.15 g/cm^3 and the specific surface area is 3,420 cm^2 /g. CaO is the highest, followed by SiO_2. CaO component of cement reacts with water to harden through hydration. [9] [Tab. 2] shows the chemical composition of the cement.

Table 2. Chemical composition of cement

Chemical composition (%)						
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2
21.1	6.5	2.9	62.9	3.3	2.2	-

• ZrO_2 in Photocatalyst

Photocatalyst technology is a technology that uses solar energy to obtain energy sources or decompose pollutants harmful to humans. As reported to date, semiconductor materials that can be used for photocatalytic reactions include TiO_2, ZnO, ZrO_2, and V_2O_3. Considering the conditions and activity, TiO2 has emerged as a representative material, and many studies have been published.1-2 Looking at the photocatalytic reactions revealed to date, electrons and holes are generated when light of 400nm or less is irradiated on the surface of TiO_2. It is known to decompose surrounding pollutants because redox reactions are formed at the surface to form highly reactive hydroxyl radicals. Unlike other ceramic materials, ZrO_2 is a material with very high resistance to crack propagation. In addition, ZrO_2 has a very high thermal expansion, and thus has an excellent effect on improving insulation performance. In addition, it has excellent thermal insulation and low thermal conductivity, which can also decompose pollutants through oxygen ion conduction. [10,11] [Tab. 3] shows the chemical composition of the ZrO_2.

Table 3. Chemical composition of ZrO_2

Chemical composition (%)						
ZrO_2	HfO_2	SiO_2	Na_2O	Al_2O_3	Fe_2O_3	TiO_2
97.68	1.88	0.15	0.01	-	0.05	0.02

2.3 Experimental Plan

Among the test items, density, water absorption, flowability, thermal conductivity, and strength were conducted according to the test method defined in KS standards. In the case of the fine dust concentration measurement test, there was no test method, so the self-measurement method proposed by Hanbat National University in Korea was used. The fine dust measurement method was produced by placing a fine dust adsorption-type matrix and put it in a closed chamber together with a fine dust measuring device and then injected the fine dust into the chamber using a fine dust generator and then measured. The measurement time was measured at 10 minute intervals and measured for fine dust of PM10 and PM2.5. [Fig. 3] shows the experimental equipment and method.

Figure 3. Experimental equipment and method

3. Experimental Result and Analysis

3.1 Unit Weight and Water Absorption

[Fig. 4] shows the unit weight and the water absorption of the cured product with the replacement ratio of ZrO_2. As the replacement ratio of ZrO_2 increases, the unit weight tends to decrease. And the water absorption tends to increase. It is considered that this is because the material of ZrO_2 has a high water absorption. When compared to plain, the unit weight of the matrix decreases, but the water absorption increases because of the high water absorption of the photocatalyst. but ZrO_2 may generate water through catalysis.

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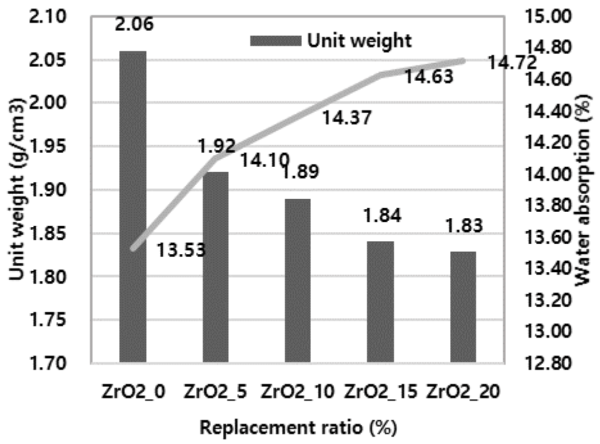

Figure 4. Unit Weight and Water absorption

3.2 Flowability

[Fig. 5] shows the flowability according to the substitution rate of ZrO_2. The flowability tended to decrease as the substitution rate increased. It is believed that the ZrO_2, which has a high absorption rate, absorbs water, thereby decreasing the flowability.

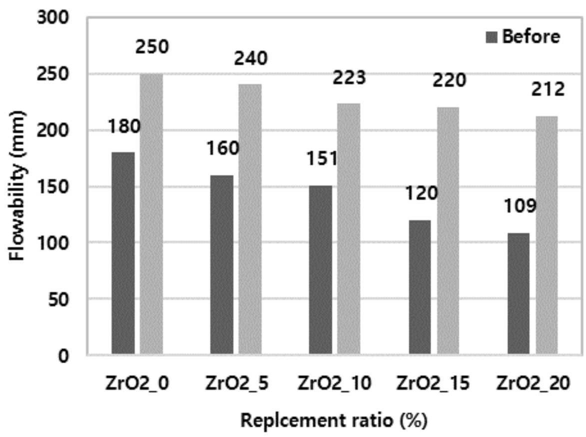

Figure 5. Flowability

3.3 Thermal Conductivity

[Fig. 6] shows the thermal conductivity according to the replacement ratio of ZrO_2. As the replacement ratio of ZrO_2 increases, the thermal conductivity tends to decrease. When the thermal conductivity is lowered, it can be seen that the adiabatic performance or the sound absorption property is improved. It is judged that the result is the result of the occurrence of pores inside. As curing progresses, the value of thermal conductivity decreases. As the water in the interior evaporates as it goes through the hardening, pores are generated.

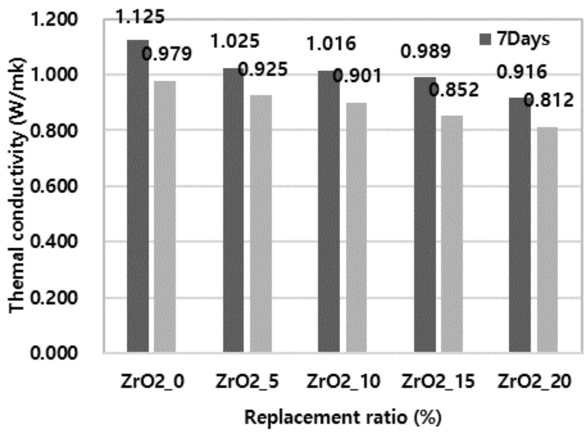

Figure 6. Thermal conductivity

3.4 Flexural Strength and Compressive Strength

[Fig. 7, 8] show the flexural strength and compressive strength according to the replacement ratio of ZrO_2. As the replacement ratio of rutile increases, the strength tends to decrease. According to the results obtained in 3.1 and 3.2, the density is decreased and the strength is decreased as the pore is generated inside. According to existing literature, it is recommended to use about 3 ~ 10% when using photocatalytic ZrO_2. If the substitution is performed up to 20%, the strength is greatly reduced, and it is considered that a proper replacement ratio should be used in consideration of economical efficiency.

3.5 Fine Dust Concentration (PM10, PM2.5)

[Fig. 9, 10] shows the fine dust concentration according to the replacement ratio of ZrO_2. The fine dust concentration tends to decrease as the ZrO_2 replacement ratio increases. It seems that the replacement rate of ZrO_2 increases and it affects the reduction of fine dust concentration. However, the reduction rate of the fine dust concentration is not large. It is considered that the

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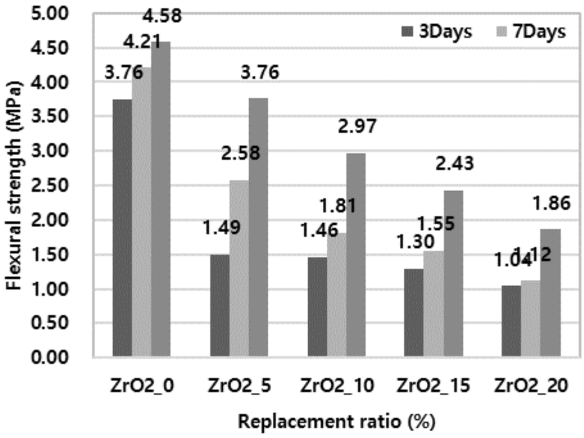

Figure 7. Flexural strength

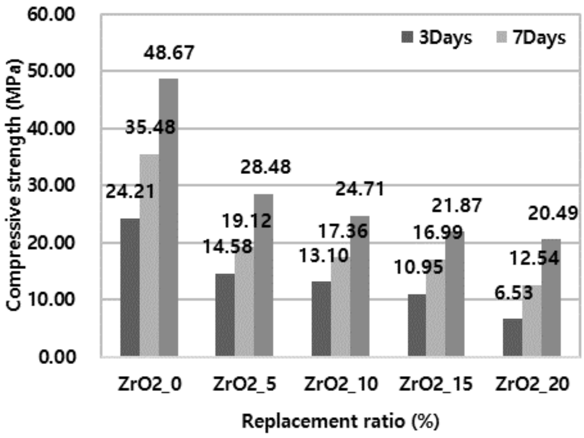

Figure 8. Compressive strength

TiO_2 type is more effective than the ZrO_2 type in reducing the pollutants. Although it has been effective in reducing fine dust concentration, it seems that the effect is not excellent. Considering economical efficiency, it seems reasonable to use TiO_2 type. excellent. Considering economical efficiency, it seems reasonable to use TiO_2 type.

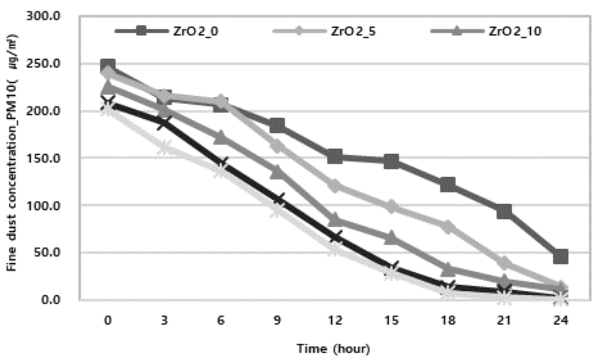

Figure 9. Fine dust concentration_PM10

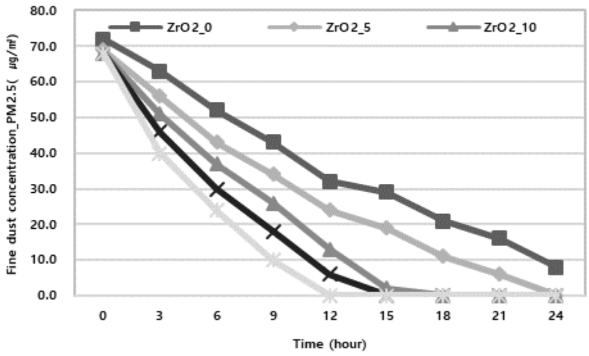

Figure 10. Fine dust concentration_PM2.5

4. Conclusion

This study is a basic experiment to solve the social problems of fine dust affecting air pollution by manufacturing fine dust adsorption products. Experiments were performed for the analysis of the matrix according to the replacement ratio of the photocatalyst ZrO_2. The result is as follows. As ZrO_2 increases, unit weight and water absorption decrease, and the water absorption increases. As ZrO_2 absorbs the blended water, the fluidity decreases. The thermal conductivity tends to decrease as the substitution rate of ZrO_2 increases due to the generation of pores as the curing proceeds. The strength tends to decrease as the substitution ratio of ZrO_2 increases. When using ZrO_2, catalysis occurred while lowering the fine dust concentration, but the effect was not good. However, unlike TiO_2, it does not need to be activated by ultraviolet rays during the experiment. Considering the resulting value and the unit price of ZrO_2, we believe that an appropriate replacement rate should be used at 5%.

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