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Properties of Matrix using TiO_2photocatalyst for Improving Air Quality

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Abstract*: Background/Objectives: Recently, the risk of fine dust, which is one of the causes of domestic air pollution, and the problem of air pollution, are serious. The purpose of this study is to fabricate cement matrix for reducing fine dust. Methods/Statistical analysis: The TiO_2 photocatalyst utilizes an oxidative decomposition mechanism to remove fine dust from the surroundings. The TiO_2 photocatalyst is used to remove particulate matter from the atmosphere. In this study, the performance of the matrix according to the replacement ratio of the TiO_2 photocatalyst is grasped and it is aimed to help the fine dust adsorption. Findings: As a result of this study, compressive strength, thermal conductivity and density tend to decrease as the replacemet ratio of TiO_2 photocatalyst increases. It was found that the absorption ratio increases with the repalcement ratio of the TiO_2 photocatalyst. In addition, the photocatalytic effect was not significant for the reduction of the concentration of radon, and the reduction of the fine dust concentration is considered to be large as the substitution rate increases. Improvements/Applications: Using the results of this study, it is necessary to further study the fine dust adsorption of the cured product using the TiO_2 photocatalyst. It is necessary to study the particle size of fine dust.

***Index Terms*: Air pollution, Air quality improvement, Fine dust, Absorption, TiO_2 Photocatalyst**

I. INTRODUCTION

Recently, the atmosphere in the Republic of Korea is filled with fine dust like [Figure 1]. As a result of the worst fine dust storm, the Seoul metropolitan area was the fourth country to take measures to reduce the fine dust emergency this year. The Ministry of Environment has strengthened the 24-hour environmental standard of ultra fine dust (PM 2.5) from 50㎍ to 35㎍/m3 since March 2018. This is a level that is raised to an alert level, not a state level, and it is necessary to wear a mask or to refrain from going out. The National Institute of Environmental and Environmental Sciences recommends that people who do not have prolonged or unreasonable outdoor activities, eye symptoms, or cough or neck pain should be avoided, especially if the fine dust shows an alarm level. However, exposure to fine dust can not be completely avoided even if the user stays indoors to avoid fine dust. Unlike large dust particles, ultra fine dust can penetrate into the room even when the window is closed. If the room is kept in a closed state, other air pollutants such as ultra fine dust, CO_2, VOCs, NOx and the concentration of indoor pollutants increases. Therefore, this study attempts to solve the problem that the concentration of pollutant increases as the enclosure ratio of indoor space increases. In order to solve such a problem, an adsorption type matrix is prepared by using a TiO_2 photocatalyst having a fine dust adsorption effect and the properties of the matrix are evaluated.[1][2][3]

Figure 1. Air raids on fine dust ··· Seoul sky in a week By J.S.Kim in hankookilbo

II. EXPERIMENTAL DESIGN

The photocatalytic reaction refers to a reaction in which a substance adsorbed on the surface of a photocatalyst is decomposed by a strong oxidizing power such as hydroxyl radicals and superoxide radicals generated on the surface of the photocatalyst irradiated with ultraviolet light. The photocatalytic reaction can be roughly classified into a heterogeneous photocatalytic reaction using an oxide semiconductor and a homogeneous photocatalytic reaction using an organic metal compound. In the heterogeneous photocatalytic reaction, the reactant is adsorbed on the catalyst, and the reaction proceeds on the catalyst surface and the product is desorbed from the catalyst. The photocatalytic reaction can be roughly classified into a heterogeneous photocatalytic reaction using an oxide semiconductor and a homogeneous photocatalytic reaction using an organic metal compound. In the heterogeneous photocatalytic reaction, the reactant is adsorbed on the catalyst, and the reaction proceeds on the catalyst surface and the product is desorbed from the catalyst. As shown in [Figure 2], Half the light energy above the band-gap energy.

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When irradiated onto a conductor, the photon excites electrons from the valence band to the conduction band. Leaving an electronic vacancy in the valence band called a positive hole. In this case, and electrons in the conduction band react with materials adsorbed on the TiO_2 surface. The photocatalytic phenomenon is the same as the general catalytic phenomenon, but the charge of the hole-electron pair generated by the excitation of the semiconductor material used as the catalyst is separated, and they are respectively oxidized and reduced on the surface, (redox mechanism).[4][5]

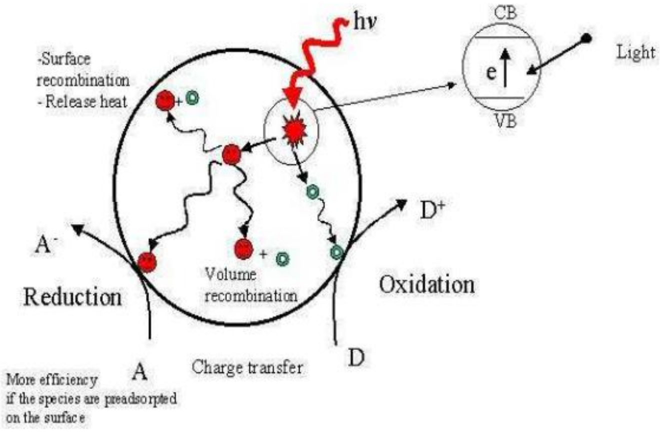

Figure 2. Basic principle of TiO_2photocatalyst

A. Experimental plan

This study was carried out to investigate the adsorption properties of radon gas and fine dust on board using TiO_2 photocatalyst in [Table 1]. The binder was composed of portland cement and TiO_2 photocatalyst with of 0, 5, 10, 15, 20 (wt.%). The curing conditions are constant temperature and humidity curing (temperature 20 ± 2 ℃, humidity 80 ± 5%). Experimental items are compressive strength, thermal conductivity, water adsorption, radon gas concentration measurement and fine dust concentration measurement

Experimental factor	Experimental level	
Binder	Portland cement, TiO_2 photocatalyst	1
W/B	30(wt.%)	1
Replacement ratio of TiO_2 photocatalyst	0, 5, 10, 15, 20 (wt.%)	5
Curing condition	Constant temperature-Humidity curing (Temp. 20±2℃, Hum. 80±5%)	1
Test items	Compressive strength, Thermal conductivity, Density, Water adsorption, Radon gas concentration, Fine dust concentration(PM 2.5, PM 10)	6

B. Experimental materials

1) Portland cement

Portland cement is currently the most used cement, accounting for more than 75% of total cement production. The main ingredients of Portland cement are composed of calcareous raw material, silica, iron oxide raw material and so on. The cement manufacturing process consists of three steps. The first stage is the raw material process, the limestone that has been shredded is crushed through the 1st and 2nd shredder, the raw materials such as limestone, clay, and iron oxide raw materials are blended in appropriate ratios and transferred to the storage silo. In the second step, the finely pulverized mixed material is fired in a rotary kiln at 1,400 to 1,500 through a preheater, and discharged in the form of a clinker. The third step is to add a proper amount of gypsum to the clinker in the finishing process, crush it with a cement mill in a cement mill, and finally produce cement.[6]

2) TiO_2photocatalyst

TiO_2(anatase), TiO2(rutile), ZnO, CdS, ZrO_2, SnO_2, V_2O_3, WO_3, and perovskite type composite metal oxide ($SrTiO_3$) are examples of materials that can be used in the photocatalyst. In contrast, ZnO and CdS adsorb light, which causes the catalyst itself to be decomposed by light to generate harmful Zn and Cd ions, while TiO_2 itself does not change even if it receives light, and can be used semi-permanently. In addition, TiO_2 oxidizes all organic materials and decomposes them into carbon dioxide and water. However, WO_3 is only effective as a photocatalyst for specific materials, and other areas are not as efficient as TiO_2. TiO_2 is excellent in durability and abrasion resistance as a photocatalyst and does not change itself because it functions as a catalyst. TiO_2 is safe and non-toxic, and there is no concern about secondary pollution even if disposal. In addition, Ti (titanium) is the ninth most element in the earth's crust, and TiO_2, which is an oxide, is very abundant in resources and therefore is inexpensive. Thus, the TiO_2 photocatalyst has many advantages in economy, marketability, and practicality.[7]

The TiO_2 photocatalyst used in this study is anatase type and shows excellent stability at low temperature. The anatase type TiO_2 photocatalyst is a tetragonal crystal and has a specific gravity of 3.9. The refractive index is 2.52(%) and the hardness is about 5.5 ~ 6. The permittivity is 31%, and when placed in a high temperature environment (when the melting point is exceeded), it is transferred to rutile. [Figure 3,4] show the crystal structure of anatase and rutile TiO_2 photocatalyst. The red arrow indicates cis-coordination and the blue arrow indicates trans-coordination. [8]

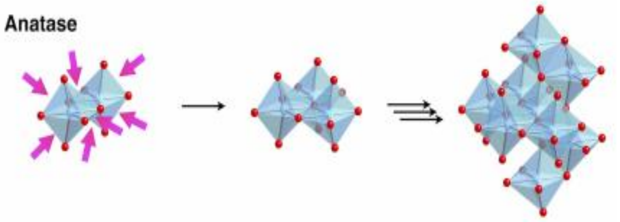

Figure 3 Crystal Structure of Anatase TiO_2photocatalyst

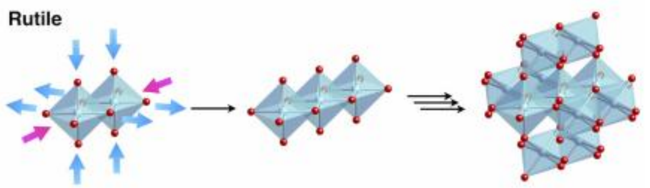

Figure 4 Crystal Structure od Rutile TiO_2photocatalyst

C. Experimental method

As the test method of this study, the compressive strength was tested in accordance with KS L ISO 679, and the size of the matrix was measured to be 40 * 40 * 160 (mm). For the thermal conductivity, the test matrix was made with 50 * 50 * 50 (mm) according to KS L 9016, and the thermal conductivities at 7 and 28 days were measured. The measurement of the concentration of radon and the measurement of the fine dust concentration were carried out using the measurement method of indoor harmful substance concentration at Hanbat National University in Korea. Test is carried out after putting harmful substances, adsorption type matirx, concentration measuring instrument, fan, etc. in a chamber made of SUS material. The test matirx of the radon gas and fine dust concentration test shall be tested in the size of 40 * 160 * 160 (mm). The concentration stabilization period in the chamber is set to about 3 days and measurement is started like [Figure 5]. The measurement period can be classified into short term and long term, and the test factors of the longevity and fine dust concentration are somewhat similar.[9][10]

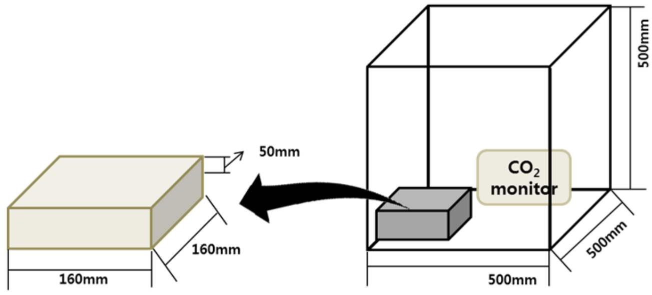

Figure 5 A test method for mesuring the concentration of radon gas and fine dust

III. EXPERIMENTAL RESULT AND ANALYSIS

A. Compressive stength

As shown in [Figure 6], the compressive strength of cement matrix with the replacement rate of TiO_2 photocatalyst tends to decrease. It seems that this is the result of the absorption of the water content of the TiO_2 photocatalyst and it is expected that the hydration of cement particles is insufficient while absorbing a large amount of water during the compounding process. As the hydration reaction of the matrix proceeds, the water absorbed by the TiO_2 photocatalyst is discharged, and the intensity is gradually compensated. It is expected that the intensity of the TiO_2 photocatalyst substitution will be increased by a certain amount in the future.

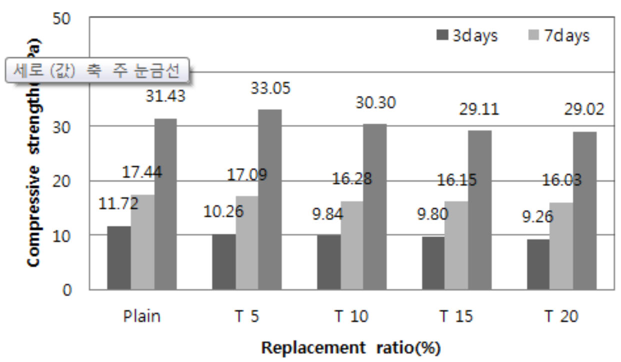

Figure 6. Compressive strength according to TiO_2photocatalyst replacement ratio

B. Thermal conductivity

[Figure 7] is a graph showing measured values of the thermal conductivity of the matrix according to the TiO_2 photocatalyst replacement ratio, and shows a tendency to decrease the thermal conductivity as the repalcement rate of the TiO_2 photocatalyst increases. The rate of thermal conductivity according to the TiO_2 photocatalyst replacement rate was larger than that at the age of 28 days. The thermal conductivity at 28 days was 0.93 M/wK for Plain and 0.76 M/wK for 20% of TiO_2 photocatalyst substitution rate. Because of the high water absorption ratio of the TiO_2 photocatalyst, the initially absorbed compound water is discharged through the hydration reaction, and voids are formed in the matrix. It is considered that the thermal conductivity is decreased due to various size pores generated inside the matrix, and the adsorption and elimination reaction of the TiO_2 photocatalyst is activated inside the pore.

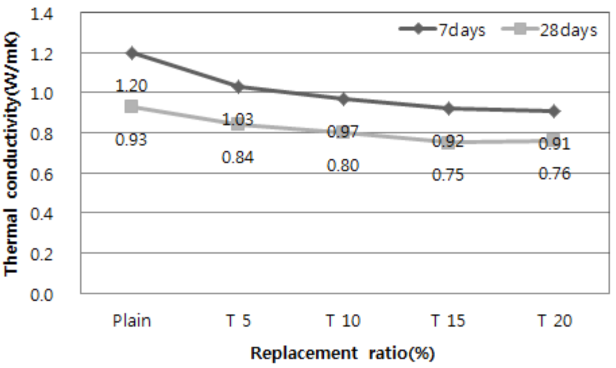

Figure 7. Thermal conductivity according to TiO_2photocatalyst replacement ratio

C. Density and Water adsorption

[Figure 8] is a graph showing the density and the absorption rate of the cemented matrix with the TiO_2 photocatalyst replacement ratio. As the TiO_2 photocatalyst replacement ratio increased, the density decreased and the absorption rate tended to increase. This seems to be due to the high water absorption rate of the TiO_2 photocatalyst, and it seems that the characteristics depend on the TiO_2 photocatalyst replacement ratio.

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It is considered that the water absorption ratio of the matrix increases when a large amount of the TiO_2 photocatalyst is substituted, but the water absorption ratio is not higher than that of the plain.

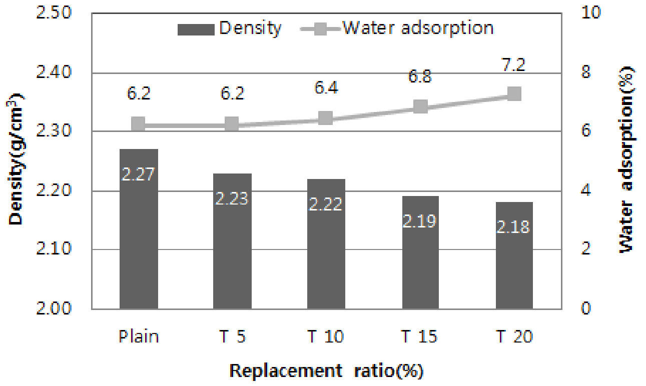

Figure 8. Density and Water adsorption according to TiO_2photocatalyst replacement ratio

D. Radon gas concentration

[Figure 9] is a graph showing the concentration of radon gas according to the TiO_2 photocatalyst replacement ratio, and the concentration of radon gas is constant regardless of the TiO_2 photocatalyst replacement ratio. The TiO_2 photocatalyst has the ability to decompose harmful substances through the redox mechanism, but this does not seem to affect the adsorption of radon gas. For the measurement of radon gas concentration, Plain was tested after inserting only cement matrix replacement and there was no significant difference from the case where only the concentration of radon gas was measured. However, the concentration of radon gas in the chamber is maintained at a certain level even though the number of test days is increased. Therefore, it is considered that the TiO_2 photocatalyst does not have a great influence on the reduction of the concentration of radon gas.

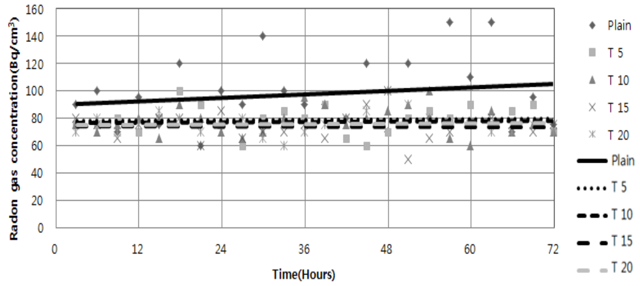

Figure 9. Radon gas concentation to TiO_2photocatalyst replacement ratio

E. Fine dust concentration

[Figure 10] shows the concentration of fine dust in the cement matrix according to the TiO_2 photocatalyst replacement ratio. As the TiO_2 photocatalyst replacement ratio increases, the concentration of fine dust in the chamber is reduced. As the TiO_2 photocatalyst replacement ratio increases, the time for measuring the concentration of fine dust in the chamber is shortened. As the TiO_2 photocatalyst replacement ratio increases, the concentration of fine dust in the chamber is reduced by decomposing the fine dust in the chamber using the oxidative decomposition mechanism of the TiO_2 photocatalyst.

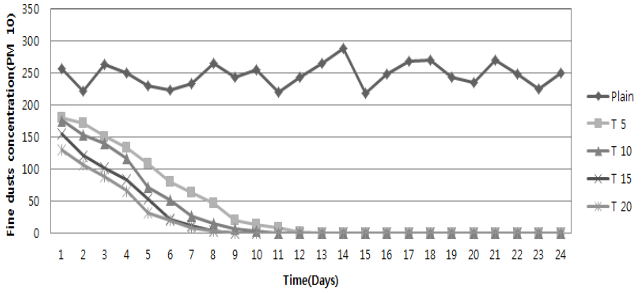

Figure 10. Fine dust concentration according to TiO_2photocatalyst replacement ratio

IV. CONCLUSION

The results of this study are as follows. As the repalcement ratio of TiO_2 photocatalyst increased, the compressive strength, thermal conductivity and density of the matrix decreased. It is considered that the performance of the matrix due to the material properties due to the high moisture absorption ratio of the TiO_2 photocatalyst particles. It also appears that voids of various sizes are formed inside the matrix. As the replacement ratio of TiO_2 photocatalyst increased, the absorption ratio increased. As the replacement ratio of TiO_2 photocatalyst increased, the adsorption performance of cyanide on radon gas did not appear to be significantly improved, but it was found to have a great influence on the reduction of fine dust concentration.

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