Properties of Matrix using TiO$_2$ photocatalyst 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 replacement ratio of TiO$_2$ photocatalyst increases. It was found that the absorption ratio increases with the replacement 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, Adsorption, 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 50µm to 35µm/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

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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.
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]
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 matrix, concentration measuring instrument, fan, etc. in a chamber made of SUS material. The test matrix 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]

B. Thermal conductivity

[Figure 7] is a graph showing measured values of the thermal conductivity of the matrix according to the TiO2 photocatalyst replacement ratio, and shows a tendency to decrease the thermal conductivity as the replacement rate of the TiO2 photocatalyst increases. The rate of thermal conductivity according to the TiO2 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 TiO2 photocatalyst substitution rate. Because of the high water absorption ratio of the TiO2 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 TiO2 photocatalyst is activated inside the pore.

C. Density and Water adsorption

[Figure 8] is a graph showing the density and the absorption rate of the cemented matrix with the TiO2 photocatalyst replacement ratio. As the TiO2 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 TiO2 photocatalyst, and it seems that the characteristics depend on the TiO2 photocatalyst replacement ratio.
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$_2$ photocatalyst 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 concentration to TiO$_2$ photocatalyst 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$_2$ photocatalyst replacement ratio**

**IV. CONCLUSION**

The results of this study are as follows. As the replacement 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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