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Evaluation of Indoor Air Quality Improvement of Matrix using Activated Clay as Adsorption Material

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Abstract.
BACKGROUND/OBJECTIVES: The importance of indoor air quality management has been greatly highlighted due to the recent increase in indoor life. Therefore, active white clay, known as porous adsorbent, was used as adsorbent to compare physical and adsorption properties and find appropriate mixing ratio.
METHODS/STATISTICAL ANALYSIS: This study is an analysis of the properties of matrix according to activated clay replacement rates, with W/B at 45 (%) and activated clay replacement rates at 0, 5, 10, 15, 20 (%) and conjugates usually use Portland cement. The experimental items were flexural strength, compressive strength, liquidity, air content, CO_2 concentration, fine dust concentration, and formaldehyde concentration. The concentration measurement was carried out with the small chamber method proposed by Hanbat University.
FINDINGS: The purpose of this experiment is to analyze the properties of matrix and improve indoor air quality by using activated white clay as an adsorbent. The experimental results are as follows. Flexural strength and compressive strength tend to decrease as the replacement rate of activated clay increases. This is believed to decrease due to high voids in activated clay. As the replacement rate of activated clay increases, liquidity decreases and air content increases. This is believed to have reduced liquidity as activated clay absorbed the moisture needed to matrix during the mixing process. The increase in air content is believed to have increased due to the high pore rate of activated clay. In addition, CO_2 concentration, fine dust concentration, and formaldehyde concentration are reduced. This is believed to be due to the physical adsorption performance and high air gap rate of activated clay. Therefore, it is expected that activated clay will greatly contribute to improving indoor air quality if it is used as a building material and adsorption of indoor air pollutants through precise experiments and verification in the future.
IMPROVEMENTS/APPLICATIONS: Porous active white clay has CO_2, fine dust, and formaldehyde adsorption performance, which is considered to contribute greatly to indoor air quality improvement if used as indoor air pollutant adsorption and building materials.

Keywords: Air quality, Active white clay, CO2, Fine dust, Formaldehyde

1. INTRODUCTION

Recently, the importance of indoor air quality management has been highlighted due to environmental problems such as indoor air pollution. The United States Environmental Protection Agency (EPA) announced that modern people live indoors more than 80 to 90 percent of the day, and that the air quality of the interior is 100 times more polluted than the outside world. It also published a study showing that indoor pollutants are about 1,000 times more likely to be transmitted to human lungs than air pollutants [1]. The United Nations (United Nations) announced that 4.3 million of the 8 million air pollution deaths as of 2012 were due to indoor air pollution [2]. In Korea, an analysis of indoor air quality measurement data for multi-use facilities in Gyeonggi-do showed that out of 125 daycare centers in Gyeonggi-do, 24.8% of them violated indoor air quality pollution standards [3]. Some of these indoor air pollutants are fine dust (PM10, formaldehyde (HCHO), carbon monoxide (CO2), carbon dioxide (CO2), volatile organic compounds (VOCS), radon (Rn), asbestos (Asvestos), ozone (O3) and nitrogen dioxide (NO2) [4]. Among them, carbon dioxide from cooking, heating, combustion, etc. causes brain damage due to lack of oxygen supply when exposed for a long time, resulting in forgetfulness, dementia, and memory loss. Acute poisoning can also cause vision disorders, headaches, vomiting and drowsiness, and chronic or repeated exposure can cause brain nerve and pulmonary damage, decreased motor skills, etc. [5]. Radon, which occurs in building materials, soil, and ground, is a harmful substance selected as a first-class carcinogen and a substance that causes lung cancer in the human body through breathing. Carbon dioxide and radon can be discharged from the inside through ventilation, but there is a limit to reducing the amount due to reduced conditions for ventilation due to the increase in indoor activity time such as daycare centers and large complex buildings. In addition, prolonged exposure to these substances can pose a great threat to infants and elderly people with weak immune systems. However, since these substances can be removed by adsorption from the gas phase, they can be used to reduce indoor air pollution. Therefore, the purpose of this study was to produce cement-based Activated clay adsorbent hardeners for carbon dioxide and radon adsorption among indoor air quality pollutants to improve indoor air quality. This work seeks to compare physical and adsorption properties and find appropriate mixing ratios by mixing the globular and powdered types of activated white clay known as porous adsorbent based on cement. Accordingly, the adsorption performance and mechanical properties of carbon dioxide and radon were analyzed to be considered as basic research data on the availability of indoor air-hazardous adsorbent hardeners in activated white clay.

2. ADSORPTION MECHANISM

2.1. ADSORPTION

Adsorption is a method of eliminating contaminated gases by chemical bonds on the surface of a solid consisting of molecular layers, or by using strong adsorption power to molecules and atoms in a gas due to physical filling in the micro-hole. Adsorption is largely divided into chemical and physical adsorption, which is the adsorption by secondary personnel, such as dipole interactions or induced interactions. This adsorption is more effective because it is faster to absorb and is possible at relatively low temperatures, as it is not needed separately compared to chemical scale adsorption, which requires activation energy to adsorption. To increase the performance of such adsorption, if a material with a large non-surface area and air gap rate is selected, it will play an important role in adsorption and contribute to the diffusion of the haemorrhagic substance through many air holes. Adsorption is used to remove high-concentration and low-concentration harmful gases generated in each industry, and it helps to maintain a pleasant environment by removing harmful gases and odors generated indoors[6].

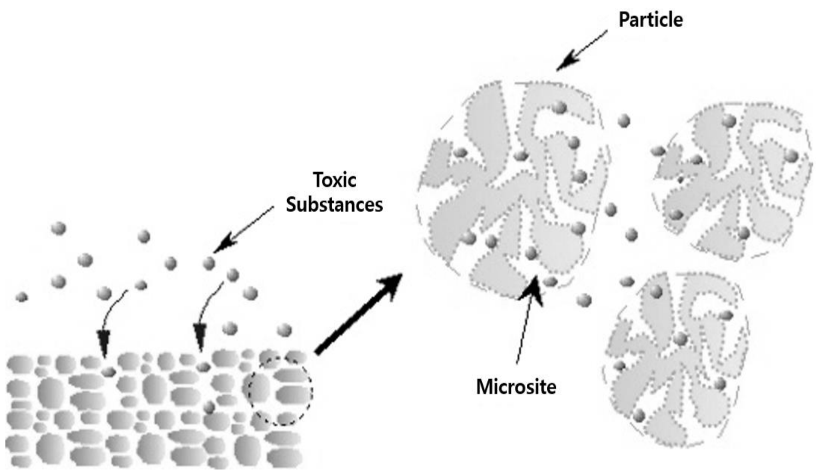

Figure 1. Adsorption mechanisms through the air gap

2.2. ACTIVATED CLAY

Activated clay is a highly adsorbed adsorption material by chemical processing on acid clay, which is mainly composed of the Ca-Montmorillonite clay mineral, which is equivalent to the "aging soil" of domestic legal minerals. Active white clay improves adsorption, bleaching, and catalyst capabilities, which are used as food retention, refining and adsorbing of petrochemical products, and catalysts. Clay minerals, which contain structural properties with adsorption power in the state of the tetrahedron and octahedral, and montmorillonite components with ion exchange capability, are used in organic solvent purification and bleaching processes, such as fats and oils. Activation of these minerals by chemical treatment is called active white clay, which has excellent adsorption power of organic compounds such as amines, glycol, glycerol, alcohol, etc. in addition to water and inorganic cations[7]. Active white clay, which is activated by treating with sulfuric acid, produces H+ ions to produce solid acid catalysts, which have a large surface area of porosity. This solid acid is used as a catalyst to remove olefin, an impurities generated during the refining process of BTX (Benzene, Tolune, and Xylene), the basic petrochemical products[8].

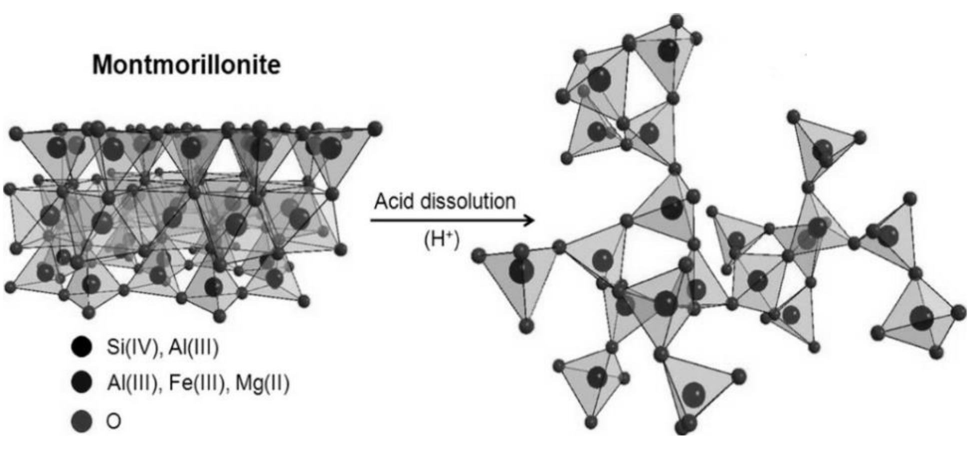

Figure 2. adsorption mechanism of clay minerals

3. MATERIALS

3.1. ORDINARY PORTLAND CEMENT

The cement used in this study is called KS L5201 portlant cement as the most commonly used cement. It has a density of 3.15 $g/cm^3$and a powder degree of $3.383cm^3/g$. Chemical components have the highest composition ratio of CaO63.8% and SiO_2 22.1%[9].

Table 1 : Portland cement chemical component

Density (g/cm^3)	Chemical component(%)						
	SiO_2	Al_2O_3	CaO	MgO	SO_3	TiO_2	Fe_2O_3
3.15	22.1	5.0	63.8	1.6	2.0	0.3	3.0

Figure 3. Ordinary Portland cement

3.2. ACTIVATED CLAY

Active white clay is divided into large globular active white clay (DC - BTX) and powdered active white clay (DC - A3). The globular active white clay used in this study is calcium-based montmorillonite (Ca-montmorillonite) activated and used for benzene, toluene, xylene, couen, and other petrochemical hydrocarbon refining and catalysts with improved non-surface area (BET) and hydrogen exchange capacity. Powder-type active white clay is highly absorbent with fine porous material by producing Activated clay with powder[10]. The chemical composition and type of active white clay are as shown in [Table 2, Table 3].

Table 2: Activated clay component

Chemical component(%)							
SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	IG- LOSS
65.2	13.0	6.0	1.7	0.5	0.5	0.5	9.0

Table 3: Components of globular and powder-type activated clay

Component	DC - BTX1)	DC - A32)
Free Moisture (%)	9.2	
Acidity (KOH mg/g)	3.48	3.59
Density (g/cm^3)	0.55	0.65
Specific Surface Area(m^2/g)	250	200~250
Particle Size Distribution (%)	(16~60) : 58.41 16 mesh More than : 0.38 60 mesh Less than : 1.21	200 mesh pass : 90.45

1) DC-BTX : Globular activated clay 2) DC-A3 : Powder-type activated clay

Figure 4. Powder-type activated clay

4. EXPERIMENTAL PLAN AND METHOD

4.1. EXPERIMENTAL PLAN

This experiment was fixed at 40% activated clay substitution rate and 45% W/B. Active white clay was made up of 0, 5, 10, 15, 20 (%) in proportion. For the test items, 40×40×160(mm^3) was used for measuring Flexural strength, CO_2, Fine dust, Formaldehyde concentrations, and 50×50×50(mm^3) was used for measuring Compression strength. The experimental factors and levels are shown in [Table 4].

Table 4: Experimental factors and level

Experimental factor	Experimental level	Note
W/B	45 (%)	1
Adsorbent	Powder-type activated clay	1
ratio of PAC[1)]	0, 5, 10, 15, 20 (%)	5
Curing condition	Constant temperature-Humidity curing (Temp. 20±2°C, Hum. 60±5%)	1
Experimental item	Flexural strength, Compressive strength, Fluidity, Air content, CO_2 concentration, Fine dust concentration, Formaldehyde concentration	7

1) PAC : Powder-type activated clay

4.2. EXPERIMENTAL METHOD

The flexural strength test method is to use the specimen 40×40×160(㎣). To reduce the error of the test, three test specimens are manufactured and measured and compared on the 3, 7, 28 days of age. The formula associated with the calculation of flexural strength is given in [Equation 1].

$$R_f = \frac{1.5F_f l}{b^3} \quad (1)$$

F_f : load applied to the center of the footnote in case of destruction (N)
l : distance between supports (mm)
b : The side of the incision that forms a right angle to the leg (mm)

The compressive strength test method was used by specimen 50×50×50(㎣) in accordance with KS L 5105, and the formula for calculating compression strength is as follows in [Equation 2].

$$R_c = \frac{F_c}{A} \quad (2)$$

F_c: Maximum Destructive Load (N)
A : Area of the pressurized or auxiliary plate (mm^2)

In order to check the fluidity of the non-hard paste used in this experiment, the test was measured by referring to KS L 5111 Flow Table for Cement Test.

The air flow measurement method of KS L 3136 hydrophilic cement mortar was performed to measure the volume of air in the hardened paste used in this experiment.

In this experiment, indoor CO_2, fine dust, and formaldehyde concentrations were tested based on the small chamber method proposed by Hanbat University. Using fine dust, formaldehyde generators, fans, and measuring instruments, add a curing agent to the enclosed chamber and start measuring. The adsorbent curing agent was set to 40×40×160(mm^3) in accordance with KSL ISO 679 and was measured for one hour with a 10-minute cycle.

5. EXPERIMENTAL RESULTS AND ANALYSIS

5.1. FLEXURAL STRENGTH AND COMPRESSIVE STRENGTH

[Figure 5] shows the results of the flexural strength test. Tests show that flexural strength tends to decrease as the replacement rate of activated clay increases. This is believed to have reduced flexural strength due to the high pore rate of activated clay. [Figure 6] shows the results of the compressive strength test. Test results show that the compressive strength tends to decrease as the refinancing rate of activated clay increases, similar to flexural strength. This is believed to have reduced compressive strength by absorbing water needed for sign language during the mixing process.

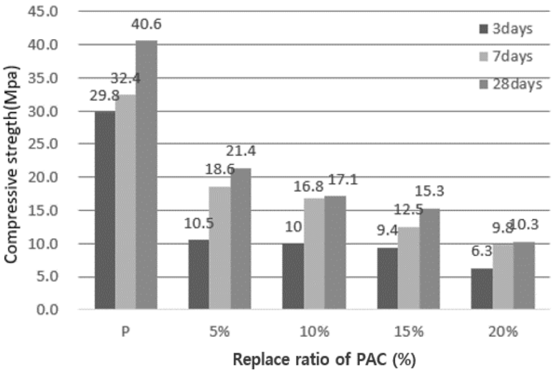

Figure 5. Flexural strength

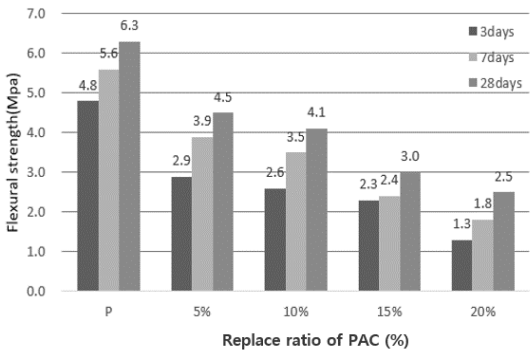

Figure 6. Compressive strength

5.2. FLUIDITY MEASUREMENT AND AIR CONTENT MEASUREMENT

[Figure 7] shows a graph of the fluidity according to the Activated clay replacement rate, which tends to decrease as the exchange rate increases. This is believed to reduce the number of compounds due to the high absorbance of Activated clay, resulting in lower liquidity.

[Figure 8] shows a graph showing the volume of air in accordance with the Activated clay replacement rate and shows a tendency for air volume to increase as the exchange rate increases. This shows that in the case of Activated clay, air volume increases as the fluidity of particles in the paste decreases as the mixture is absorbed into the particle.

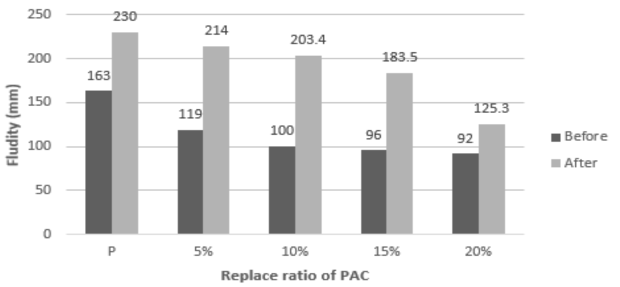

Figure 7. Fluidity measurement

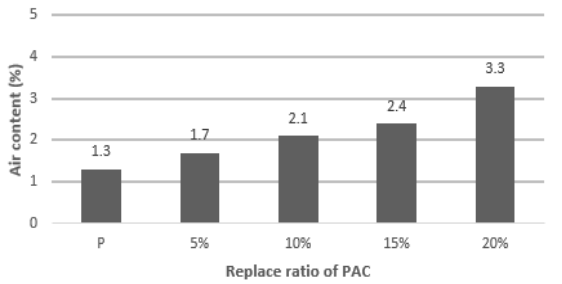

Figure 8. Air content measurement

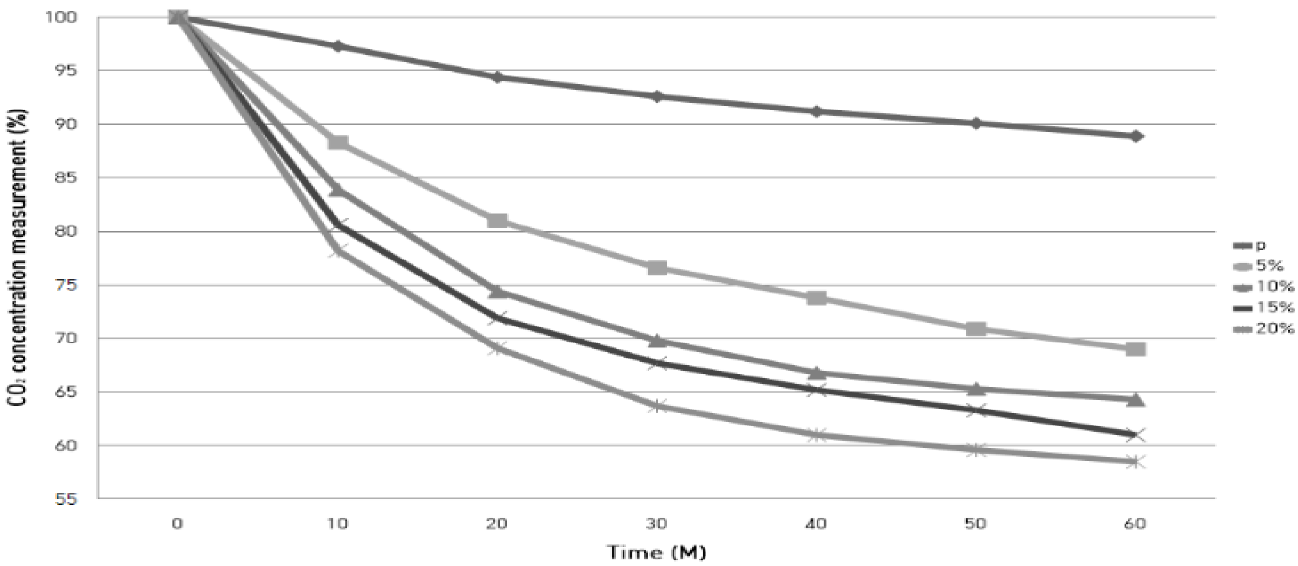

Figure 9. CO_2 concentration

5.3. CO_2 CONCENTRATION

[Figure 9] shows the rate of CO_2 reduction in active white clay over time. Except for Plain, carbon dioxide concentrations decreased over time, and as the replacement rate of activated white clay increased, carbon dioxide concentrations tended to decrease in greater amounts. This is believed to have reduced carbon dioxide concentration due to the high physical adsorption performance and air gap ratio of activated white clay, and it can be used as an eco-friendly material in the construction sector because it has a function to adsorb CO_2.

5.4. FINE DUST CONCENTRATION AND FORMALDEHYDE CONCENTRATION

[Figure 10] is a graph showing the concentration of fine dust according to the Activated clay replacement rate, which tends to decrease as the replacement rate increases. This is believed to adsorb fine dust due to the physical adsorption performance and void rate of Activated clay.

[Figure 11] shows the concentration of formaldehyde according to the rate of Activated clay replacement. Plain tends to increase formaldehyde concentrations over time, but decrease formaldehyde concentrations as the exchange rate of Activated clay increases. This is believed to be more efficient for formaldehyde adsorption due to increased physical adsorption due to the high polar rate of Activated clay.

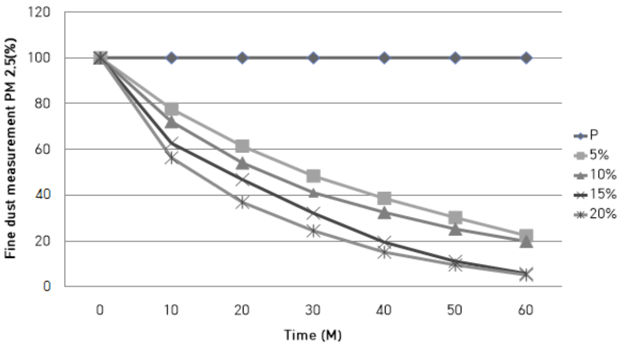

Figure 10. Fine dust concentration

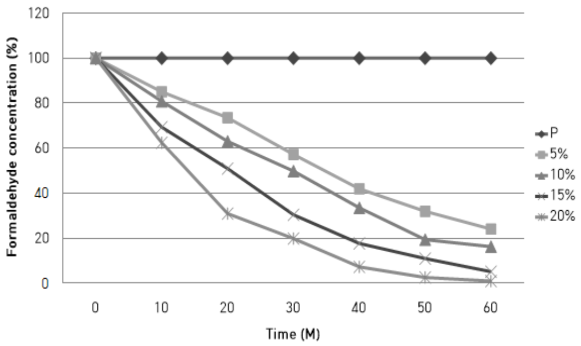

Figure 11. Formaldehyde concentration

6. CONCLUSION

This experiment aims to analyze the characteristics of hardeners using activated clay as adsorbent and improve indoor air quality. The experimental results are as follows. Flexural strength and compressive strength tend to decrease as the replacement rate of activated clay increases. This is believed to decrease due to the high pore rate of activated clay. As the replacement rate of activated clay rises, liquidity decrease and concentrations of CO_2, fine dust and formaldehyde decrease. This is believed to be due to the physical adsorption performance of activated clay. Therefore, if activated clay is used as an indoor air pollutant adsorption and building material through precise experiments and verification in the future, it will greatly contribute to improving indoor air quality.

7. 7. REFERENCES

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