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# Properties of Magnesia Composites According to Replacement Ratio of Perlite

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**Abstract:** Recently, passive and zero-energy construction has increased in Korea due to the government`s continuous application of budget-conscious policies for establishments. Accordingly, construction materials are being advanced, and the required performance standards for insulation materials are increasing. However, problems such as fire vulnerability and degradation of physical properties for organic and inorganic insulation materials are shown, so it is necessary to solve this problem. The objective of this research is to examine the properties of the composites by analyzing the flexural breaking load, impact resistance, density, VOCs concentration reduction rate, and fine dust concentration reduction rate of the composites manufactured based on the perlite substitution rate of the magnesia composites. The flexural breaking load test of the composites was assessed according to 'KS F 3504', a gypsum board standard and the impact resistance was assessed according to 'KS F 4715'. The performance evaluation of adsorption performance of air pollutants of the VOCs and fine dust in the context of the small chamber technique suggested by Hanbat University. The results of this study are as follows: The flexural breaking load according to the perlite replacement rate tended to decrease as the perlite replacement rate increased. It is determined that the flexural breaking load is reduced by generating a large amount of pores inside due to the perlite porous structure characteristics. In the case of impact resistance, the impact resistance tended to increase as the perlite displacement rate increased. It is determined that the volume of the binder in the board is reduced, and pores inside the board are generated due to perlite, which is a porous material, thereby reducing the overall bonding force of the board. In the case of VOCs and fine dust concentrations, the VOCs and fine dust concentration reduction rates tended to increase as the perlite replacement rate increased. In the case of the perlite displace rate of 30%, the VOCs concentration decreased by 82.6%, and the fine dust concentration decreased by 87.9%. It has been established that the porous properties of perlite used to create a huge number of pores in the hardened body cause the concentration to be lowered physically through adsorption. This study's findings are thought to be fundamental information for securing the engineering properties and air pollution absorption of magnesia composites blended with perlite.

**Keywords:** eco-friendly; finishing materials; indoor air quality; magnesia composites; perlite

## 1 INTRODUCTION

In 2020, the Korea Energy Corporation, the Ministry of Land, Infrastructure, Transport, and the Ministry of Trade and Industry will emphasize the significance of cutting carbon emissions, saving energy, and improving efficiency due to the arrival of the fourth industrial revolution. Due to the government's continuing application of energy reduction programs, the performance requirements for building materials have increased, and passive and zero-energy construction has expanded. Accordingly, construction materials are being advanced, and the required performance standards for insulation materials are increasing. Demand for organic insulation is high due to high insulation and economy, but the problem of fire safety of organic insulation materials continues to be raised. In 2015, a fire broke out in an apartment in Uijeongbu-si, and the cause of the spread of the fire was pointed out as a problem with dryvit construction. The fire begin on the ground floor extensively expand along the outer wall, casualties occurred because of the smoke and toxic gases [1]. Most of the finishes currently used for internal finishes are organic materials such as cork and wooden boards, but organic sound-absorbing finishes have a high risk of fire. As a result, fire safety is emphasized, and there is growing need for inorganic insulation [2]. ALC panels and blocks are often produced as an inorganic insulation material, and the majority of them are used extensively as lightweight or insulating materials. However, inorganic insulating materials are susceptible to moisture, which can lead to mold growth owing to condensation and the deterioration of physical qualities [3]. In order to balance the fire risk of organic insulation with the economics and moisture sensitivity of inorganic insulation, this study will analyze the properties of the composites based on the perlite replacement rate.

**Table 1** Experimental factors and levels

| Experimental factors | Experimental levels | |
|---|---|---|
| Binder | Magnesia, Potassium phosphate | 2 |
| Magnesia: Potassium phosphate | 1 : 0.8 (%) | 1 |
| Replacement rate of perlite | 30, 35, 40, 45, 50 (%) | 5 |
| Additional rate of retardant | 5 (%) | 1 |
| Additional rate of water reducing agent | 0.1 (%) | 1 |
| W/B | 45 (%) | 1 |
| Curing condition | Temp. 20±2°C, Hum. 60±5% | 1 |
| Experimental item | Flexural breaking load, Impact resistance, Density, VOCs reduction, Fine dust reduction | 5 |

## 2 EXPERIMENTAL PLAN

Perlite was swapped out for a level made of MPC in order to create an insulating composite based on non-cement in this experiment to test the production of an environmentally friendly inorganic finishing material. In the MPC, light burned magnesia and monopotassium phosphate was combined at a ratio of 1.0:0.8 as a binder, and borax was added as a delay material because it did not have a sufficient time for punching due to the initial heat generation. In addition, when perlite was mixed into MPC, the absorption rate of perlite was high, and a reducing agent was added 0.1% compared to the binder due to the reduction in the number of constraints required for the hydration reaction. The perlite replacement rate range was divided into five levels from 30 to 50 (%), and on the 28$^{th}$, post-curing flexural breaking load, impact resistance, density, VOCs reduction, and fine dust reduction tests were conducted. Accordingly, the experimental factors and levels are as follows in Tab. 1 [4].

## 2.1 Materials
### 2.1.1 Perlite

Perlite refers to an extremely lightweight aggregate obtained by grinding and firing perlite or graphite. When the perlite gemstone is pulverized below 8 to 12 mesh and high heat of 1000 °C or higher is rapidly applied, the contained volatile components gasify and expand inside the softened particles, forming internal pores. In addition, it has excellent moisturizing power and is lightweight with 0.15 g/cm$^3$, so it is easy to work, and it has excellent insulation, fire resistance, air permeability, and sound absorption. Since Ph is neutral, it is harmless to the human body and is used as an insulation material, spray material, and sound absorbing material [5].

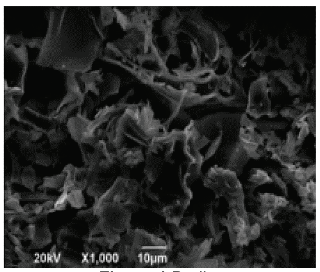


**Figure 1** Perlite


**Figure 2** SEM of perlite

**Table 2** Physical properties of perlite

| Density (g/cm$^3$) | Porosity (%) | Thermal conductance (kcal/mh°C) | Available temperature (°C) | pH | Fineness modulus |
|---|---|---|---|---|---|
| 0.15 | Around 90 | 0.03-0.05 | –250-1,000 | 6.5-7.5 | 2.94 |

### 2.1.2 Light Burned Magnesia

In this experiment, light burned magnesia, which is used as an alternative material for cement, is fired at a low temperature of 600-1000 °C from the magnesia mined at the bottom of the mine or magnesia separated from seawater. Accordingly, the density of light burned magnesia used in this study is 3.46 g/cm$^3$ and the fineness is 2,591 cm$^3$/g [6].

**Table 3** Physical properties of light burned magnesia

| Fineness (cm$^3$/g) | Porosity (%) | Density (g/cm$^3$) | Grain size (%) | Volumetric specific gravity (%) |
|---|---|---|---|---|
| 2,591 | 0.50 | 3.46 | –200 mesh ≥ 97 | 1.25 |

**Table 4** Chemical properties of light burned magnesia

| Composition ratio (%) | | | | | | |
|---|---|---|---|---|---|---|
| MgO | CaO | $SiO_2$ | $Fe_2O_3$ | $SO_3$ | $Al_2O_3$ | Cl |
| 93.30 | 2.06 | 3.14 | 0.60 | 0.11 | 0.52 | 0.06 |

### 2.1.3 Monopotassium Phosphate

Monopotassium phosphate is a colorless crystalline or white granular crystalline powder. When monopotassium phosphate is heated, it is dehydrated at 400 °C and produces potassium metaphosphate. It dissolves in water and its aqueous solution is weakly acidic and does not dissolve in ethyl alcohol. The physical composition of monopotassium phosphate used are shown in the following table.

**Table 5** Physical properties of monopotassium phosphate

| Molecular Weight (g) | Melting point (°C) | Boiling Point (°C) | Density (g/mL) | pH | Solubility (g/100 mL) |
|---|---|---|---|---|---|
| 136.09 | 253 | 450 | 2.338 | 5.7~7.5 | 1.05 |

### 2.1.4 Borax

Borax used as a condensation retardant of the magnesia composites is an inorganic mineral extracted from a mine or salt lake, and the chemical structural formula is expressed as $Na_2B_4O_7 \times 10H_2O$. The specific gravity is 1.7, and when the crystal contains 10 molecules of water and is heated to 350-400°C, the crystal water is lost and expanded to become anhydride. The properties of borax are shown in the Tab. 6 [7].

**Table 6** Physical properties of borax

| Molecular weight (g) | Melting point (°C) | Boiling point (°C) | Specific gravity (g/mL) | Solubility (g/100 mL) |
|---|---|---|---|---|
| 381.36 | 75 | 320 | 2.338 | 6.025 |

## 2.2 Experimental Methods
### 2.2.1 Density and Flexural Breaking Load

Density test method is carried out according to 'KS F 3503', and the flexural breaking load test method is carried out in accordance with 'KS F 3504'. The test piece is dried in a dryer adjusted to a temperature of 40±2 °C until it is shaped and tested immediately. The span shall be 350 mm and the concentrated load shall be applied to the full width of the center of the span. The average load speed shall be 250 N/min ± 20%.

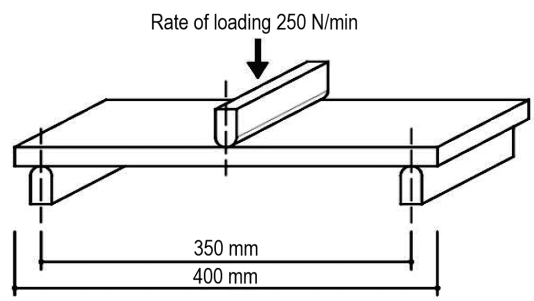


**Figure 3** Test method for flexural breaking load

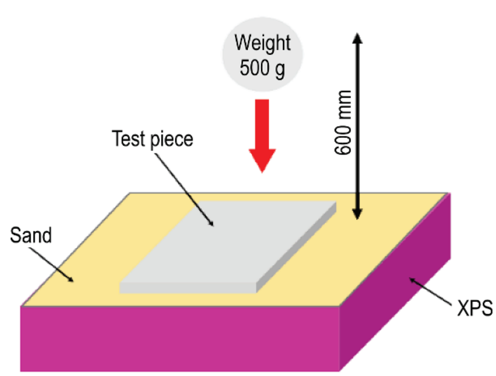


**Figure 4** Test method for impact resistance

#### 2.2.2 Impact Resistance

Impact resistance test method is carried out in according to ‘KS F 4715’. Measure a weight of 500 g away from the top of the test specimen at a height of 60 cm, and conduct the test at three locations that are more than 5 cm apart, and visually check for cracks, swelling, deformation, and peeling.

#### 2.2.3 Reduction of Pollutants

Evaluation of the reduction performance of the sound-absorbing finishing material mixed with perlite measures the amount of VOCs and fine dust reduction on its own. VOCs and fine dust reduction measurements are carried out in the manner proposed by Hanbat University because there are no standards. For the first time, a substance that generates pollutants is put inside an empty chamber that is sealed and the reference concentration is adjusted inside the chamber. After adjusting the reference concentration, remove the contaminant-producing substance, put the test specimen in, measure it for a certain period of time, analyze and calculate how much it has decreased in the reference concentration, and evaluate the pollutant purification performance [8-12].

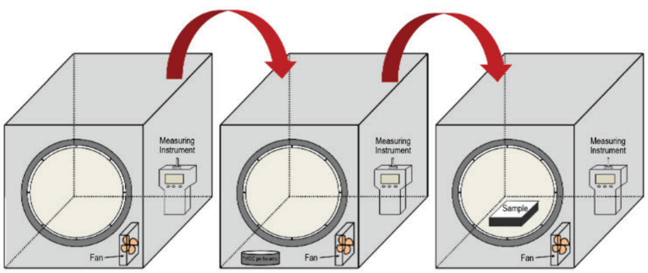



**Figure 5** Test method for VOCs and fine dust reduction

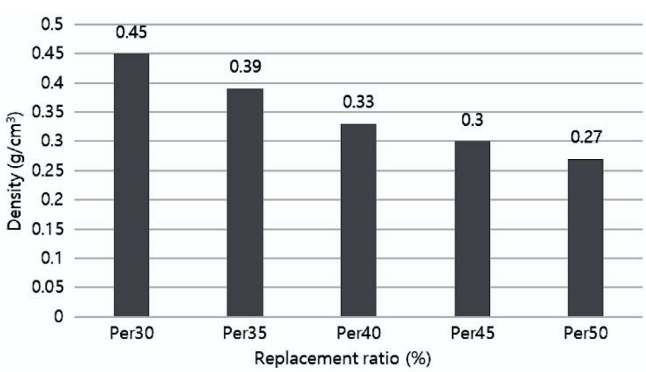



**Figure 6** Density

## 3 EXPERIMENTAL RESULT AND ANALYSIS

### 3.1 Density

The graph showing the density based on the perlite replacement rate is shown in Fig. 6. The density have a tendency to lessen as the perlite replacement rate augmented. When comparing a unit weight, the density of the magnesia composites is smaller than that of the magnesia cured body, and the density of the perlite is much lower than that of the light burned magnesia and the monopotassium phosphate, so that the density is decreased as the perlite replacement rate increased [13].

### 3.2 Flexural Breaking Load

The graph showing the flexural breaking load according to the perlite replacement rate is presented in Fig. 7. As the perlite displacement rate increased, the flexural breaking load tended to decrease. Because of the properties of the porous structure of perlite, it is believed that developing a large number of pores inside reduces the flexural breaking load.

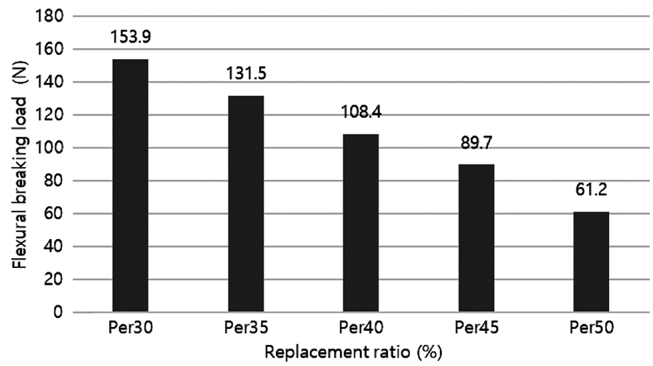
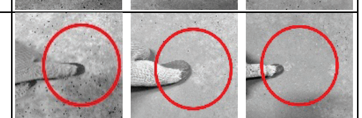
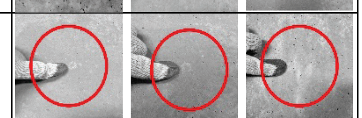
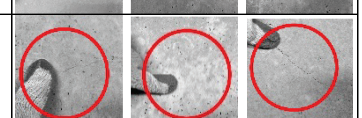
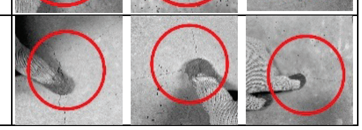



**Figure 7** Flexural breaking load

**Table 7** Impact resistance

| Replacement rate of perlite (%) | Diameter of the concave portion (mm) | Picture |
|---|---|---|
| 30 | 14.3 |  |
| 35 | 21.2 |  |
| 40 | 26.8 |  |
| 45 | Crack occurred |  |
| 50 | Crack occurred |  |

### 3.3 Impact Resistance

The graph showing impact resistance according to the perlite replacement rate is presented in Tab. 7. As the perlite replacement rate increased, the impact resistance have a tendency to increase. It is determined that the volume of the binder in the board is reduced, and pores inside the board are generated due to perlite, which is a porous material, thereby reducing the overall bonding force of the board [14, 15].

### 3.4 VOCs Concentration Reduction Rate

The graph showing the VOCs concentration reduction rate according to the perlite replacement rate is shown in Fig. 8. The VOCs concentration reduction rate have a tendency to increase as the perlite replacement rate increased. When it approaches the surface, mutual attraction by the dipole acts, drawing the contaminant to the surface when it approaches, and accumulating it inside the perlite pores by electrostatic attraction. Accordingly, it is determined that the VOCs concentration reduction rate rises as the perlite replacement rate increases.

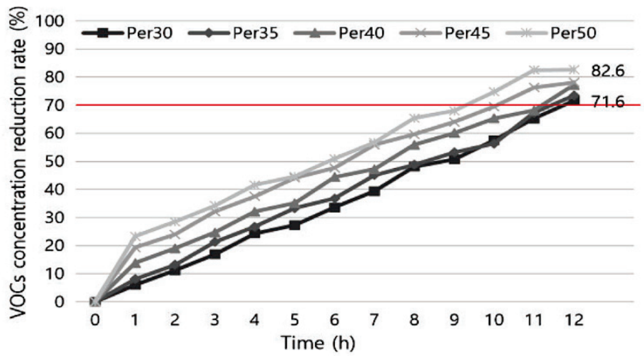



**Figure 8** VOCs concentration reduction rate

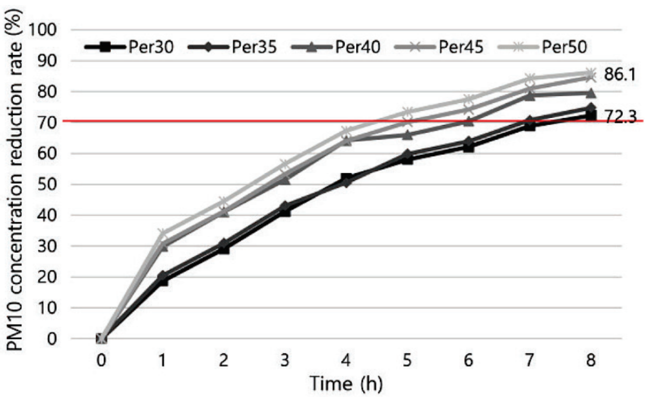



**Figure 9** PM2.5 concentration reduction rate

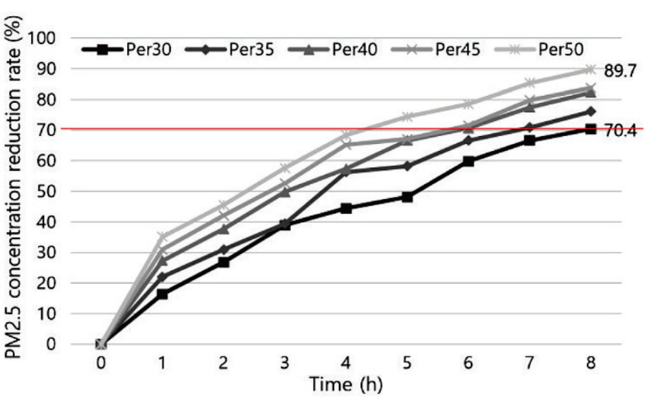



**Figure 10** PM10 concentration reduction rate

### 3.5 Fine Dust Concentration Reduction Rate (PM2.5, PM10)

The graph showing the rate of reduction of fine dust (PM2.5, PM10) concentration based on a perlite replacement rate is presented in Fig. 9 and Fig. 10. As the perlite replacement rate increased, the fine dust concentration reduction rate have a tendency to increase. The physical adsorption produced by creating a significant number of pores in the hardened body due to the perlite's porous structure properties is believed to lower the concentration of fine particles.

## 4 CONCLUSION

This research is to analyze the density, flexural breaking load, impact resistance, VOCs concentration, and fine dust concentration of magnesia composites manufactured according to the perlite replacement rate and examine the characteristics of magnesia composites as follows. Findings shows that, as the perlite replacement rate increased, the flexural breaking load decreased. Because of the properties of the porous structure of perlite, it is believed that developing a large number of pores inside reduces the flexural breaking load. For flexural breaking loads, it is deemed appropriate to have a perlite displacement rate of 35% according to 'KS F 3504'. In the case of impact resistance, the result showed that the diameter of the concave part defined in 'KS F 4715' was within 25 mm up to a perlite replacement rate of 35%. In addition, when the perlite replacement rate was 45,50%, cracks occurred, which is determined to reduce the overall bonding force of the board as voids inside the board occur due to the perlite, which is a porous material. In the case of VOCs and fine dust concentrations, the VOCs and fine dust concentration reduction rates tended to increase as the perlite replacement rate increased. In the case of the perlite replacement rate of 30%, the VOCs concentration decreased by 82.6%, and the fine dust concentration decreased by 87.9%. It is discovered that the concentration is decreased by physical adsorption accumulated in the pores of the perlite by electrostatic attraction when the pollutant approaches the surface and is attracted to the surface when it is close by a dipole. Therefore, the appropriate perlite replacement rate for the magnesia composites is considered to be the most appropriate 30%, it can be used as a fundamental data to secure the engineering characteristics and the air pollutant adsorption of the magnesia composites mixed with perlite. In addition, further studies such as fire stability evaluation and sound absorption coefficient are needed to evaluate the usability of magnesia complexes mixed with perlite in the future.

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