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Reduction of Hazardous Substances and review of Engineering Properties of Permeable blocks according to Diatomite Replacement rate

Hye-Eun Lee
Master`s course, Dept.of Architectural Engineering, Hanbat National University, Daejeon, 34158, S. Korea
sunsilver1215@naver.com

Min-Ho Kim
Master`s course, Dept.of Architectural Engineering, Hanbat National University, Daejeon, 34158, S. Korea
minh1564@naver.com

Jae-Gyun, Yoo
Master`s course, Dept.of Architectural Engineering, Hanbat National University, Daejeon, 34158, S. Korea
samil0805@hanmail.net

Sang-Soo Lee *
Professor, Dept.of Architectural Engineering, Hanbat National University, Daejeon, 34158, S. Korea
sslee111@hanbat.ac.kr

Abstract

Recently, the danger of fine dust has been rising all over the world. Accordingly, measures are needed to reduce harmful substances such as fine dust in the atmosphere. The goal of this study is to evaluate the basic property and hazardous substance adsorption performance of permeable blocks mixed with diatomite. The bending strength and permeable coefficient of the permeable blocks are evaluated in accordance with KS F 4419, the Korean permeable blocks standard, and the adsorption performance of hazardous substances such as fine dust and VOCs is based on the small chamber method proposed by Hanbat University. As a result of reviewing the Flexural strength and compressive strength of the permeable blocks that mixed diatomite, it was confirmed that the higher the mixing rate of diatomite, the lower the bending strength and compressive strength. According to existing literature, the porous properties of diatom absorb a large amount of water, resulting in a lack of moisture needed for cement hardening. Likewise, in this study, as the mixing rate of diatom increased, there was a lack of moisture in the mixing process. Accordingly, Flexural strength and compressive strength are determined to be reduced. As a result of reviewing the adsorption performance of harmful substances in permeable blocks mixed with diatomite, the concentration of fine dust PM10 and PM 2.5, VOCs, NOx, and SOx decreases as the diatomite mixing rate increases. This is believed to be caused by physical adsorption due to porous properties as harmful substances circulate inside the chamber through airflow and come into contact with a permeable blocks that contains diatomite. If the existing permeable blocks are replaced through the results of this study, it will be possible to contribute to improving public health as a solution to air pollution.

Keywords: Diatomite, Permeable block, Fine dust, NOx, SOx

1. Introduction

Recently, the risk of fine dust has emerged in Korea. In general, fine dust means particles smaller than 10㎛ and ultrafine dust smaller than 2.5㎛, and according to the HEI (Health Effect Research Institute) in 2015, Korea's ultrafine dust concentration is the second highest among OECD members[1]. The OECD estimates that by 2060, the number of premature deaths in the country from air pollution is 520,000 to 5.4 million[2]. Fine dust has been announced to increase the rate of hospitalization and death of patients due to lung disease, and in the case of ultrafine dust, the incidence of lung cancer increases, and ischemic heart disease death rate increases when exposed to ultrafine dust for a long time[3]. Accordingly, research is underway using the photocatalyst TiO_2 and the adsorbent diatomite as fundamental solutions to alleviate air pollution[4,5]. In addition, as the development of urban areas progressed due to rapid industrial development since the 1960s, the green area of Korea decreased due to the high density of residential spaces and the increase in the area of high-rise buildings[6,7]. As a way to solve this problem, the front permeable block is paved on the road to allow rainwater to flow into the groundwater. Accordingly, this study aims to develop a permeable block product with a combination of the photocatalyst TiO_2 and diatomite on the upper layer of the surface in a permeable block product consisting of the upper layer and the lower layer. Thus, in this paper, flexural strength, compressive strength, permeable coefficient, and hazardous material adsorption performance of permeable blocks mixed with diatomite conducted prior to this experiment are reviewed.

2. Materials and Methods

2.1. *Diatomite*

Diatomite is an aggregate of the remains of siliceous components of diatom, a single-celled silver plant that reproduces in freshwater or seawater, deposited on the seabed or porcupine. Diatomite is a kind of fossil soil, and it contains a mixture of clay, sand, volcanic ash, plant humus, iron hydroxide, and iron sulfide, and contains a lot of moisture. Diatomite is a siliceous raw material produced as a powder, and it is a soft rock that is pressed and hardened by acupressure as a lump of soil in which the remains of diatoms are deposited. Although SiO_2 is the main component in the chemical composition of diatom remains, the actually produced diatomite is deposited on the seabed or porcupine, so the chemical composition differs depending on the type and amount of impurities mixed at this time, and the physical properties also vary depending on the type of diatom. different. The size of fossil diatoms is in microns, and can only be confirmed when magnified hundreds of times with a microscope, and its structure is an aggregate of porous cells such as round, needle-shaped, and semi-circular[8].

Figure 1. Picture of Diatomite

Figure 2. SEM of Diatomite

2.2. *Adsorption mechanism*

Diatomite has high porosity and water permeability due to the fine pores of the diatom skeleton, so it can filter fine solids such as liquids. Due to this, liquids or gases can easily pass through and solids can be filtered out. In addition, Diatomite has the property to maintain the powder state even after absorbing up to 0.5 to 4 times the liquid raw material. it is possible to maintain. The adsorption of diatomite generally involves the process of collecting the adsorbent on the surface of the adsorbent, and the adsorbed material is adsorbed into the diatomite by its physical adsorption properties. In addition, diatomite exhibits physical adsorption capacity, which is similar to condensation of gas molecules due to adsorption by secondary attraction by the force of van der Waals force. It is used to measure the total surface area, pore size, pore size distribution, etc. Physical adsorption can be non-selective adsorption[9].

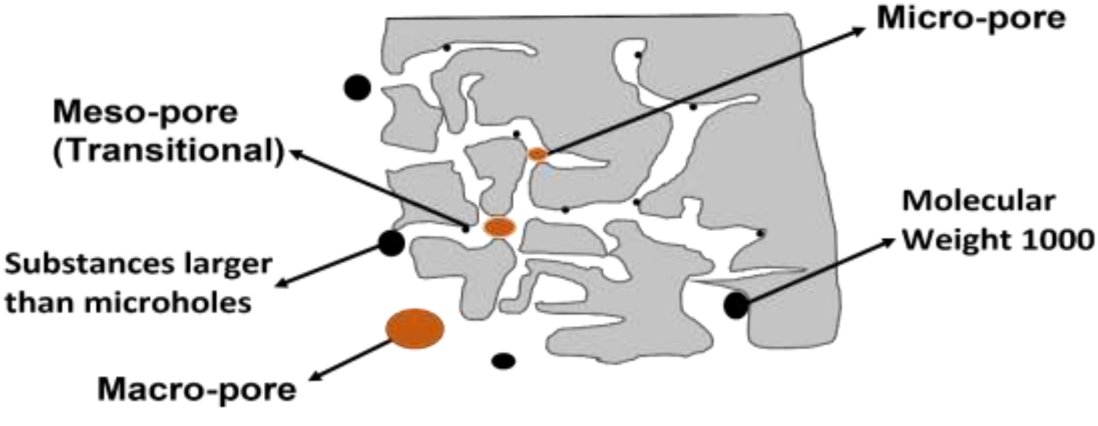

Figure 3. Adsorption mechanism of diatomite

3. Materials

3.1. Ordinary Portland cement

The cement used in this study is called KS L5201 portland 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%.

Table 1 : Portland cement chemical compenet

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

3.2. Diatomite

Most of the diatomite composed of amorphous silica, and a small amount of crystalline silica is present. Diatomaceous earth has a large pore volume of the particles themselves and has the property of absorbing liquids about 2-3 times the weight due to its high specific surface. It is mainly composed of silic acid and is white or grayish-white. Since there are many voids, it has excellent heat resistance and lightness. The density of diatomite used in this study is 2.22 g/cm3, and the powder density is 4,125 cm3/g. Table 2 shows the chemical components of diatomite.[10]

Table 2: Activated clay compenet

SiO2	Al_2O_3	Fe_2O_3	CaO	MgO	SO3	CL
89.5	4.1	1.5	0.6	0.3	-	-

4. Experimental plan and method

4.1. Experimental plan

An experiment was conducted to select the ratio of diatomite to be mixed into the permeable block. As a basic experiment, the diatomite substitution rate was 0, 5, 10, 15, and 20%, and a total of five levels were conducted. W/B was fixed at 25%, and the base layer aggregate was 5 to 8 mm, and the surface layer aggregate was 1 to 3 mm. As experimental items, flexurl strength, compressive strength, VOCs concentration, fine dust concentration, NOx concentration, and SOx concentration were measured. [Table 3] is a table showing the experimental factors and levels.

Table 3: Experimental factors and levels

Experimental factor	Experimental level	Note
Binder	OPC[1)]	1
Agreggate : Binder	5 : 1	
W/B	25%	1
Ratio of Ditomite	0, 5, 10, 15, 20 (%)	5
Curing condition	Constant temperature-Humidity curing (Temp. 20±2℃, Hum. 60±5%)	1
Experimental item	Flexural strength, Compressive strength, VOCs concentration, Fine dust concentration(PM 10, 2.5), NOx concentration, Sox concentration	7

1) OPC : odfddfdfdfdfd

4.2. Experimental Method

4.2.1 Flexurl and Compressive strength

The flexurl strength test is conducted in accordance with KS F 4419. After immersing the sample in water for 24 hours, test it immediately after taking it out. Take the point-to-point distance as 140mm and apply the load to the center between points. The dimensions of the sample are 40x40x160 (mm). The formula associated with the calculation of flexural strength is given in [Equation 1].

$$R_f = \frac{3Pl}{2bd^2} \quad (1)$$

R_f : Load applied to the center of the footnote in case of destruction (N)
P : Maximum breaking load indicated by the testing machine
l : Distance between supports (mm)
b : The side of the incision that forms a right angle to the leg (mm)
d : Average thickness of the block.

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].

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

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

4.2.2 Hazardous substance concentration

Since there is no standard for measuring the concentration of hazardous substances, the experiment was conducted using the small chamber method proposed by Hanbat University. Hazardous substances filled while continuously operating the pan in the closed empty chamber are convectively moved by the wind of the pan and move throughout the interior to finally reach the surface of the hardened body. At this time, the concentration of hazardous substances is kept constant, and after inserting the test specimen, it is measured in the same manner as in Figure 4 using a hazardous substance concentration meter. The measurement time was 3 hours, and the concentration of hazardous substances was checked every 10 minutes. However, this method has a point that it is difficult to maintain a certain concentration of harmful substances in the fan. Therefore, it is necessary to devise a method for injecting a certain amount of harmful substances when injecting harmful substances. In addition, when artificially generating convection movement using Pan, measures should be taken to generate wind from various angles rather than from one direction so that harmful substances can move throughout the chamber.

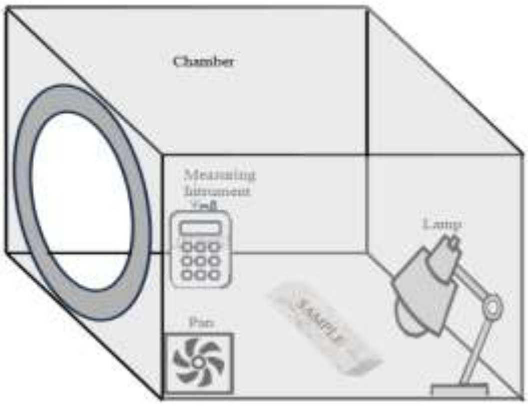

Figure 4. Adsorption measurement

5. Experimental results and analysis

5.1. Flexural strength and compressive strength

Figure 5 and Figure 6 show the experimental results for flexural strength and compressive strength according to the replacement rate of diatomite. In the case of flexural strength and compressive strength tests, experiments were carried out in accordance with KS F 4419 and KS L 5105. As a result of the experiment, as the replacement rate of diatomite increased, the flexural and compressive strength tended to decrease. It is judged that the strength is lowered because the diatomite absorbs a large amount of moisture during the mixing process and the moisture required for hardening is insufficient.

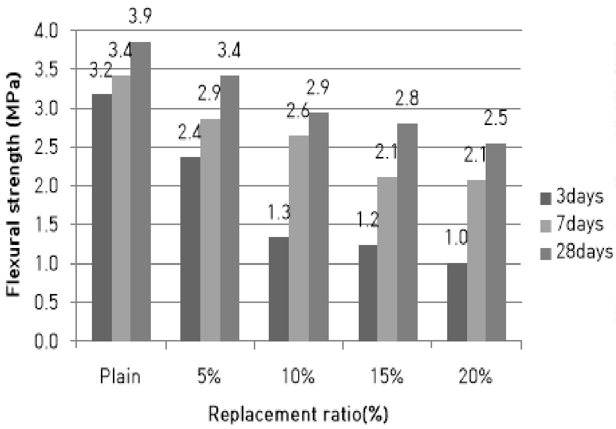

Figure 5. Flexural strength

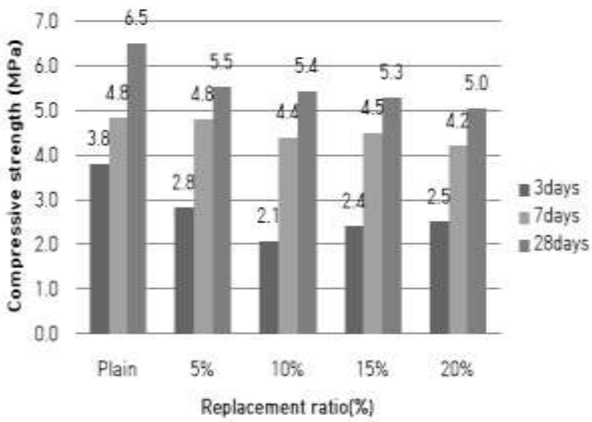

Figure 6. Compressive strength

5.2. NOx and SOx concentration

Figure 7 and Figure 8 show the concentrations of SOx and NOx according to the replacement rate of diatomite. As a result of the experiment, both NOx and SOx showed about 50% reduction performance at 15% mixing rate of diatomite. This shows about 40% lower efficiency than the TiO_2 catalysis conducted in the previous experiment. Therefore, although the physical adsorption mechanism of diatomite also exhibits adsorption of NOx and SOx gas, it is considered that the catalytic action of TiO_2 exposed to light exhibits higher efficiency than the physical adsorption performance of diatomite.

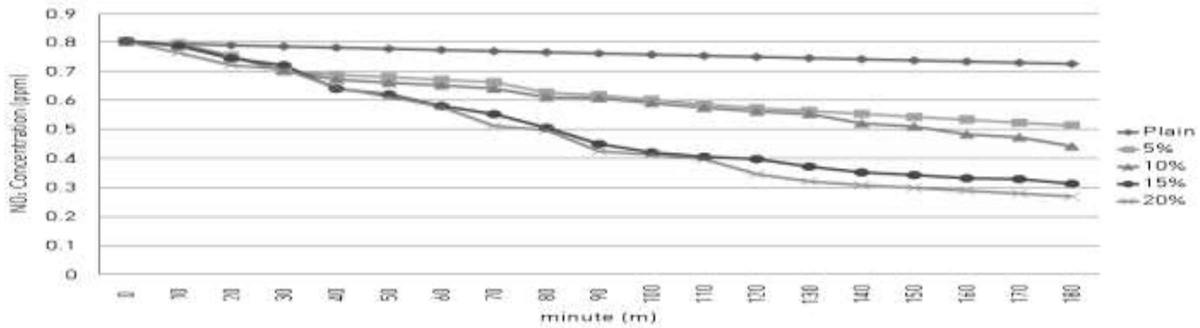

Figure 7. NOx concentration

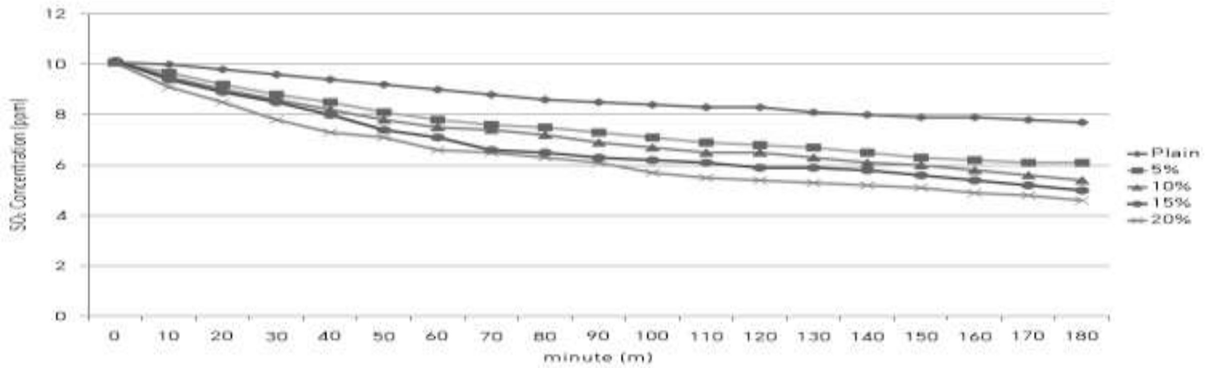

Figure 8. SOx concentration

5.3. VOCs concentration

Figure 9 is a graph showing the concentration of VOCs according to the replacement rate of diatomite. As a result of the experiment, as the substitution rate of diatomite increased, the concentration of VOCs showed a tendency to gradually decrease.

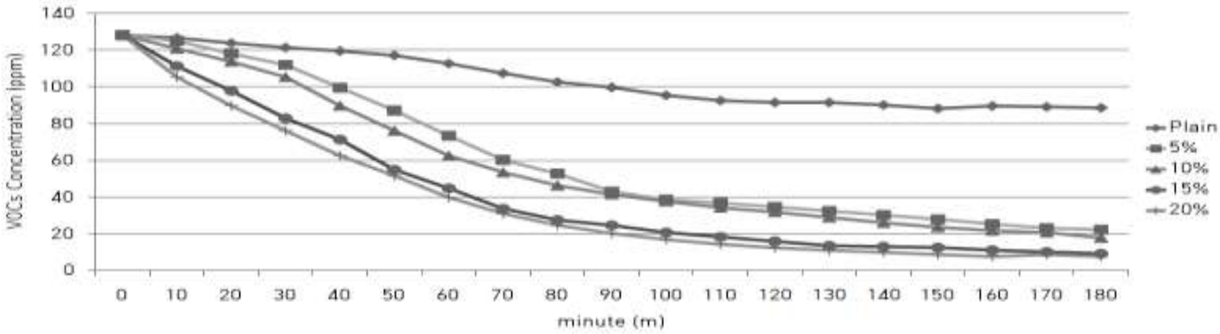

Figure 9. CO_2 concentration

5.4. Fine dust concentration (PM 10, PM 2.5)

Figure 10 and Figure 11 are graphs showing the concentration of fine dust (PM10, PM2.5) according to the replacement rate of diatomite. As a result of the experiment, as the replacement rate of diatomite increases, the adsorption performance of fine dust per hour tends to improve. In the case of PM2.5, it was found that the concentration reduction was faster than that of PM10, which is judged to be a difference in the size correlation between fine dust particles and the adhesion between the adsorption-type permeable block surface.

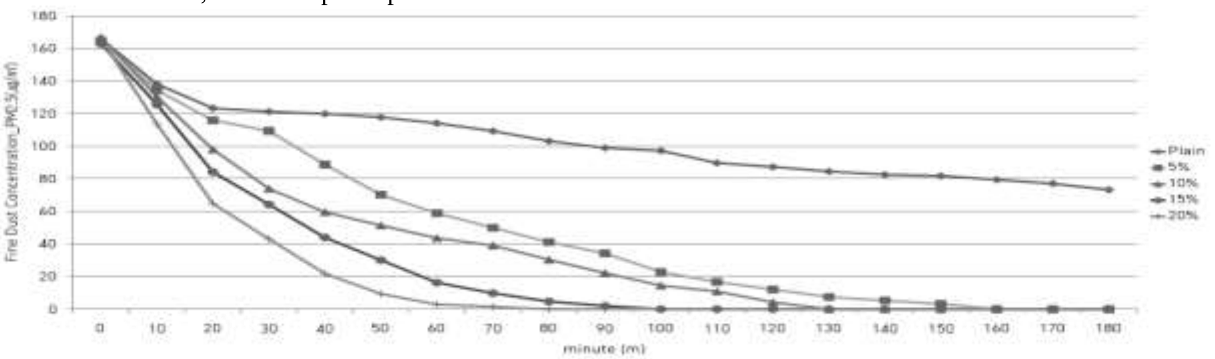

Figure 10. Fine dust concentration (PM 10)

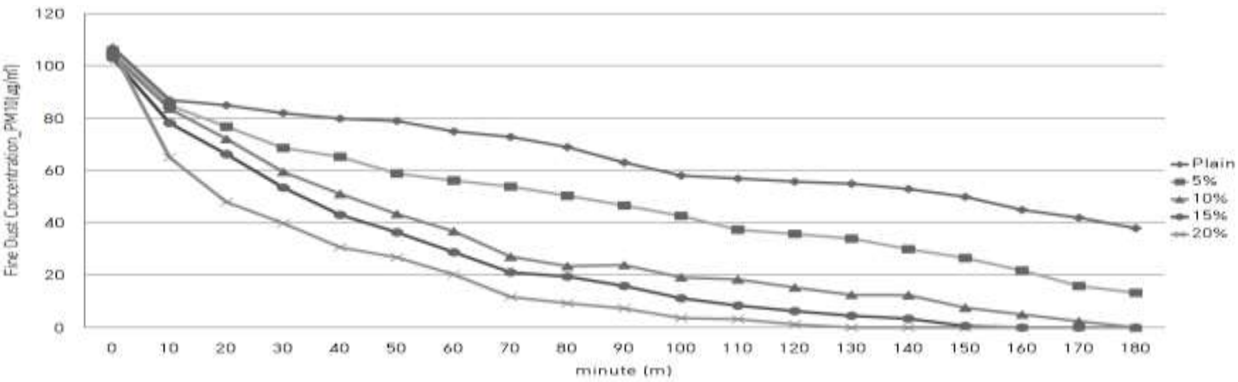

Figure 11. Fine dust concentration (PM 2.5)

6. Conclusion

In this study, the adsorption characteristics and mechanical characteristics of harmful substances in the permeable block according to the diatomite substitution rate were reviewed. As a result of the review, it was found that the higher the substitution rate of diatomite, the lower the flexural and compressive strength, and the higher the adsorption capacity of harmful substances. It is judged that the internal binding force decreased due to the reduction in the amount of cement due to the absorption of compound water and substitution of adsorbents due to the fact that the diatomite is porous. Accordingly, flexural and compressive strength appear to have decreased, and the adsorption performance of harmful substances has increased as the physical adsorption mechanism is activated. As a result of this study, the adsorption performance of harmful substances in the permeable block incorporating diatomite was reviewed, but it seems necessary to improve the experimental method to increase the objectivity and reliability of the experimental data. In addition, in order to improve the strength deteriorated by mixing diatomite, it is necessary to review the effect of enhancing the strength through reinforcement of PVA fibers, PP fibers, and cellulose fibers in future studies.

7. References

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