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Properties of permeable blocks according to replacement ratio of activated alumina

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Abstract: Conventional permeable blocks are subject to efflorescence by acidic water and are unable to maintain consistent water permeability. Accordingly, the object of the present study is to produce permeable blocks using the activated alumina with known anion adsorption properties, determine the performance of such blocks, and examine their functionality and potential for use as building materials. Test results showed that whereas the permeability coefficient and anion adsorption performance tended to improve as the activated alumina replacement rate increased, the strength tended to decrease. It is determined that improvement of the permeability coefficient and adsorption performance owe to the porous nature of the activated alumina.

Keywords: *Activated alumina, Anion adsorption, Compressive strength, Efflorescence, Flexural strength, Permeable block.*

1. Introduction

Rainwater runoff is increasing as a result of increasing impervious areas and more frequent torrential rains during monsoon season due to global warming. Accordingly, soil and dust (non-point pollutants) accumulated on the surface of paved roads are flowing into rivers, exacerbating environmental pollution by contaminating the water and disrupting ecosystems in public water bodies such as non-urban rivers. Therefore, there is an urgent need to replace impervious surfaces with water-permeable surfaces to reduce the runoff of non-point pollutants into rivers.

Permeable blocks are a promising solution to this problem. Permeable blocks are more porous than non-permeable blocks, and provide numerous benefits including reducing the heat island effect, reducing runoff, reducing noise pollution and preventing freezing of road surfaces. However, permeable blocks which rely on pores in the blocks themselves mostly lose their water permeability at 3 to 6 months after installation[1, 2]. This is because rainwater dissolves the acidic components in the atmosphere, causing acidic water to permeate the permeable blocks and chemically react (Efflorescence) with the cement component[2, 3, 5]. The foreign substances generated by this reaction block the pores of the permeable blocks, reducing permeability and rendering them impervious. As permeable blocks are only tested for water permeability at production, it is not possible to accurately determine by how much their water permeability decreases. Research to address the above-described problem is necessary.

The object of the present study is to address the problem of loss of permeability due to efflorescence, which is a problem of conventional cement-based permeable blocks. In the present study permeable blocks using activated alumina with known anion adsorption properties will be made. The performance of these blocks will be tested, and their functionality and potential for use as building materials will be examined [4].

2. Experimental plan and materials

The object of the experiment is to examine the properties of permeable blocks depending on the activated alumina replacement rates. The test factors and levels are shown in Table 1. Ordinary portland

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cement was used as the binding agent, and the aggregate with particle diameter, absorption rate and density or 5~10 (mm), 2.74% and 2.65g/cm^3, respectively, was used. Multi-porous activated alumina with particle diameter and density of 5mm and 1.59g/cm^3, respectively, was used [4]. The W/C was 25% and the ratio of natural aggregate to cement mass was 200%. Testing was carried out at four different replacement rates of activated alumina relative to the coarse aggregate: 0, 10, 20 and 30 (%). Test items were flexural strength, compressive strength, permeability coefficient, absorption rate, density and anion adsorption. All experiments were conducted in accordance with KS standards. A simplified anion adsorption test was carried out using pH test paper. A cured adsorption specimen of 50×50×50 (mm) was immersed in distilled water in which 5% aqueous solution of sulfuric acid was dissolved, and pH was measured for 60 minutes at 15-minute intervals.

Table 1.
Experimental factor and level.

Experimental factor	Experimental level	Remarks
Binder	OPC[1)]	1
Adsorption material	AA[2)]	1
W/C	25 (%)	1
Aggregate to binder ratio	200%	1
Replacement ratio of AA[2)]	0, 10, 20, 30 (%)	4
Curing condition	Relative humidity (60±5)%, Temperature (20±2)℃	1
Experiment items	Flexural strength, compressive strength, permeability coefficient, absorption, density, anion adsorption	6

Note: 1) OPC: Ordinary portland cement, 2) AA: Activated alumina

3. Experimental results and analysis

3.1. Absorption

Figure 1 shows the absorption rate of the permeable block according to the activated alumina replacement rate. The absorption rate tended to increase with the activated alumina replacement rate. Whereas the absorption rate of typical permeable blocks is around 4%, the permeable blocks prepared for the present study exhibit absorption rates approximately 1.6 to 2.8 times greater. This is determined to be due to the high porosity of activated alumina.

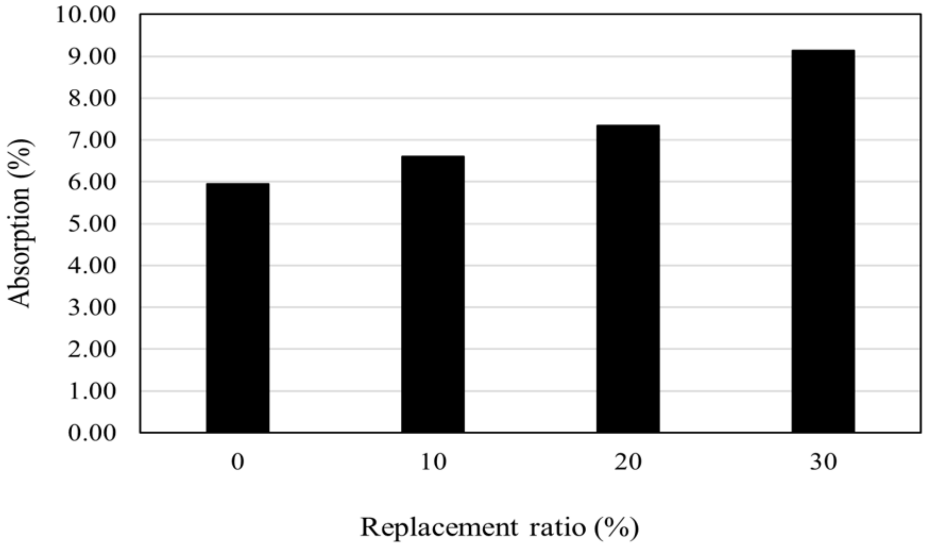

Figure 1.
Absorption.

3.2. Density

Figure 2 shows the densities of the permeable blocks according to the activated alumina replacement rate. Density tended to decrease as the activated alumina replacement rate increased. This is determined to be due to the lower density of the activated alumina (1.59g/cm^3) compared to the natural aggregate (2.65g/cm^3), leading to a high porosity of the material itself as well as the cured specimens.

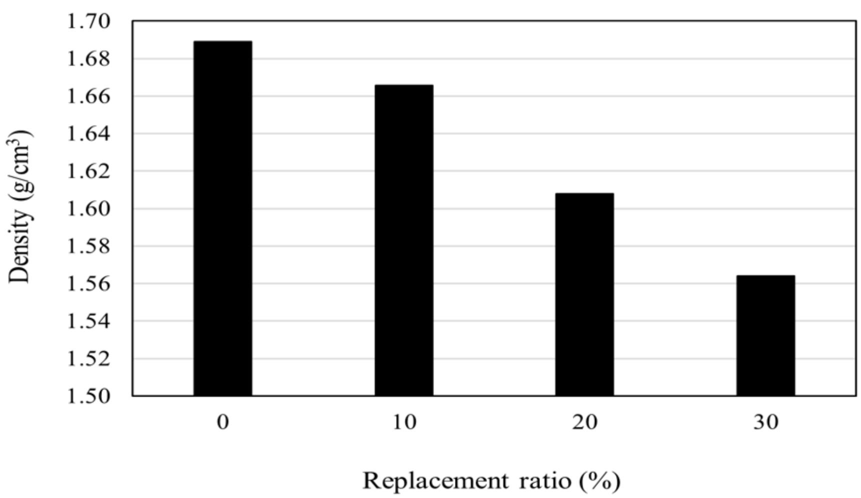

Figure 2.
Density.

3.3. Flexural strength

Figure 3 shows the flexural densities of the permeable blocks according to their activated alumina replacement rates. The flexural strength at 28 days according to the active alumina replacement rate 4.14, 4.07, 3.87, and 3.74 (MPa) at 0, 10, 20, 30 (%), respectively. The respective flexural strength values tended to increase with age, and decreased as the activated alumina replacement rate increased. This is determined to be due to a loss of binding force between the activated alumina and the binding agent,

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caused by formation of a thick water film on the surface of the highly absorbent activated alumina during the curing process [3]. The activated alumina replacement rates satisfying the minimum flexural strength of 4.0MPa stipulated in KS F 4419 (concrete interlocking block for side walk and road) are determined to be 0 and 10%.

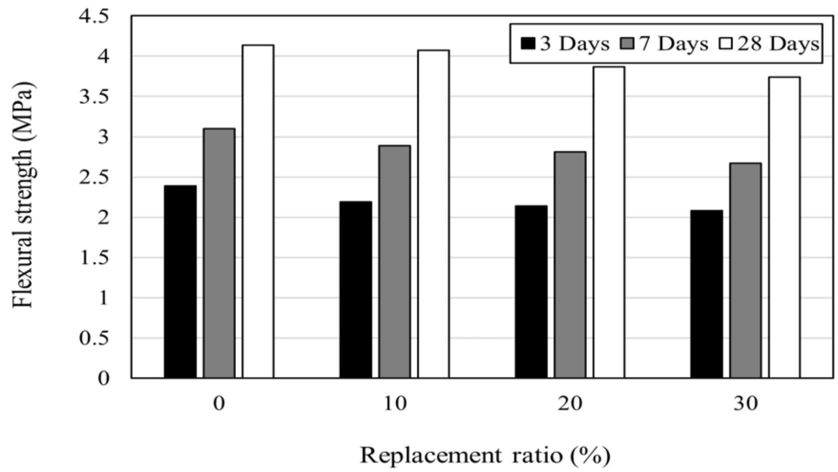

Figure 3.
Flexural strength.

3.4. Compressive strength

Figure 4 shows the compressive strength of the permeable blocks according to their activated alumina replacement rates. The compressive strengths at 28 days according to the active alumina replacement rate were 11.25, 10.76, 9.98, and 8.53 (MPa) at 0, 10, 20, 30 (%), respectively. The overall compressive strength values tended to increase with age, and decreased as the activated alumina replacement rate increased. This is determined to be due to the difference in density of the aggregate (2.65g/cm^3) and the density of the activated alumina (1.59g/cm^3) and the deterioration of the binding strength between the binding agent and the surface of the activated alumina as a result of the same reason as given in 3.3 [3].

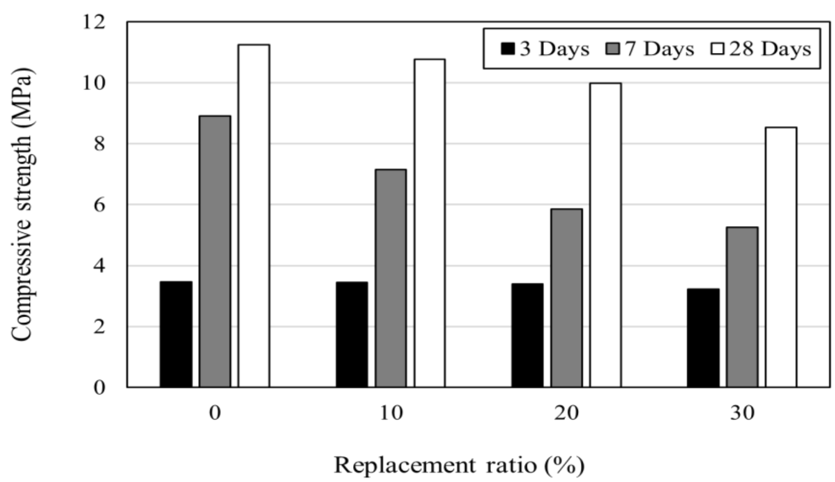

Figure 4.
Compressive strength.

3.5. Permeability coefficient

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Figure 5 shows the permeability coefficients of the permeable blocks according to the activated alumina replacement rates. The permeability coefficients according to the activated alumina replacement rate were 0.804, 0.903, 0.995, and 1.127 (mm/sec) respectively at 0, 10, 20, and 30 (%), with a tendency to increase with the activated alumina replacement rate. These results satisfied the KS F 4419. This is determined to indicate increased permeability as the porosity of the permeable blocks increases with the activated alumina replacement rate [5].

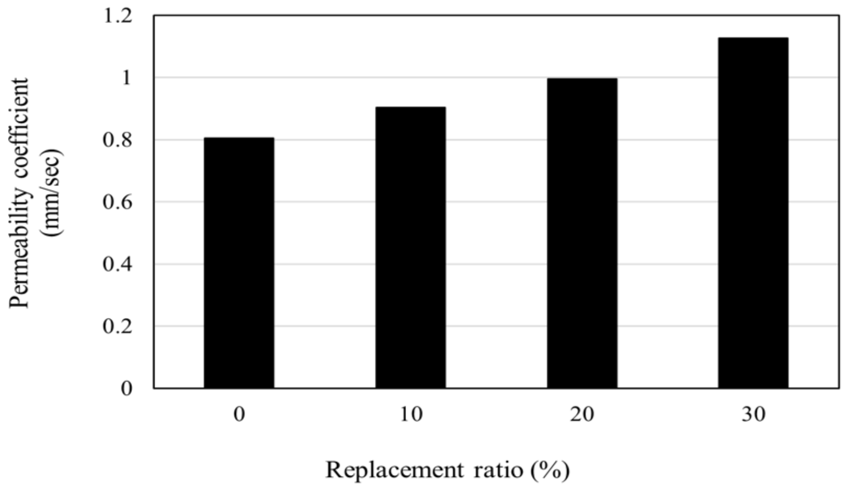

Figure 5.
Permeability coefficient.

3.6. Anion adsorption

Figure 6 shows the anion adsorption of the permeable blocks according to the activated alumina replacement rate. The final pH values according to the activated alumina replacement rate were 5.2, 6.77, 7.1, and 7.89 (pH) at 0, 10, 20 and 30 (%), respectively, with a tendency to increase with the activated alumina replacement rate. This is believed to be due to adsorption of the acidic component by the large pore structure and the large specific surface area of the activated alumina [4, 5].

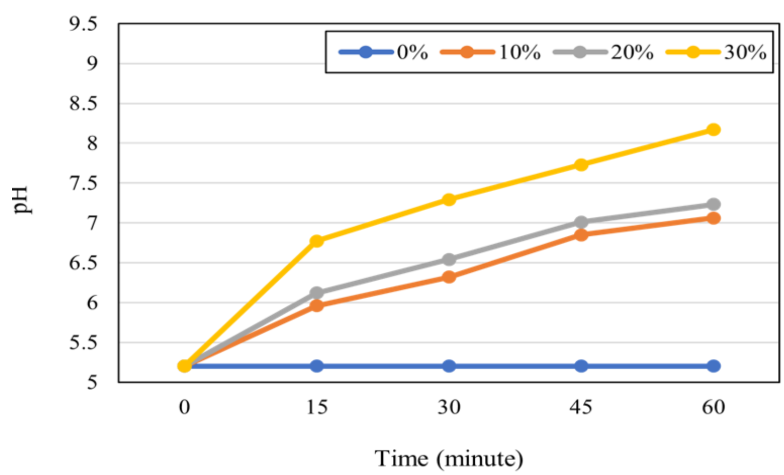

Figure 6.
pH.

4. Conclusion

The object of the present study was to analyze the properties of permeable blocks prepared with varying activate alumina replacement rates, and examine the functionality of permeable blocks thereby prepared.

Test results showed that whereas the permeability coefficient and anion adsorption performance tended to improve as the activated alumina replacement rate increased, the strength tended to decrease. It is determined that improvement of the permeability coefficient and adsorption performance owe to the porous nature of the activated alumina. Therefore, it is necessary to select an appropriate replacement rate. Based on the standard KS F 4419, a replacement rate of 10% was selected, at which reduction of efflorescence through adsorption can be expected. Future studies will analyze the progression of efflorescence and improvement of permeability coefficient according to the activated alumina replacement rate.

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