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Research paper

Properties of Polymer Addition Ratio for Efflorescence Reduction in Permeable Blocks

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Abstract

Background/Objectives: In Korea, rapid industrial development has changed the flow of rainwater, and flooding of rivers and depletion of groundwater have become problems.
Methods/Statistical analysis: The permeable block was manufactured, and the existing permeable block has the disadvantage of efflorescence. The efflorescence affects not only strength but also product life. In order to prevent the efflorescence, the use of cement, which is the main cause of the efflorescence, was reduced and fly ash as an alternative to cement was used as an industrial byproduct. Polymers were used to increase strength and durability.
Findings: The test items were density, water absorption, flexural strength, compressive strength, porosity, permeability coefficient, and efflorescence state.

Density and water absorption decrease as the polymer addition rate increases. The flexural strength and compressive strength increase as the addition rate of polymer increases. Porosity and permeability coefficient decrease as the addition rate of polymer increases but satisfy the KS standard. When the amount of efflorescence was observed, it was confirmed that the amount of efflorescence decreased as the addition rate of polymer increased.
Improvements/Applications: Future experiments predict that non-cemented permeable blocks will be produced and will not produce efflorescence completely.

Keywords*: Permeable Block, Efflorescence, Permeability coefficient, Polymer, Industrial by products*

1. Introduction

Since the 1960s, the development of the downtown area has progressed with rapid industrial development. Due to the rapid industrial development of the Republic of Korea, the population became densely populated, the urban population and densification of residential space, and the area of high-rise buildings increased. On the contrary, the area of green space was reduced. As the area of green area decreased, the circulation structure of rainwater changed and the rainwater runoff characteristics of urban area changed. The amount of groundwater inflow from rainwater was reduced and the amount of rainwater flowing into urban areas increased. Due to the effect of urbanization, there is not enough way to deal with a large amount of rainwater due to lack of processing facilities.[1,2]In the case of Korea, precipitation is concentrated in summer, rain water storage capacity is insufficient, and most of the rainwater flows into the sea or flows into the river, causing the problem of river flooding. In addition, the groundwater is depleted due to insufficient inflow of groundwater, and there is a problem in the habitat environment of microorganisms and plants in the ground. In order to store rainwater, the increase of the green area, the road and the delivery should be done with the permeable pavement.[3] Domestic pavement roads can be divided into impermeable pavement and permeable pavement. Current roads are mainly impermeable pavement. Most of the impermeable pavement is not able to enter the groundwater, so the groundwater is depleted, and when it rains, it may flow into the river and cause flood damage. In addition, the slip resistance of the road is lost, causing a problem of accident.[4,5] To overcome these disadvantages, permeable blocks have been developed and used as sidewalks, open spaces, parking lots, etc. However, the existing permeable block is a component of cement because the acid component in the air is dissolved in the rainwater, and due to the chemical reaction with the acidic water, the pore is clogged and the pore is clogged, the permeability is lost and the service life is decreased. It is pointed out as a problem. [6-8] As a method to improve this, the usage of cement is reduced, the cement is replaced by industrial byproducts, and the addition of polymer has the expected effect of improving the strength and permeability of the permeable block in order to prevent efflorescence of the permeable block [9- 11] In this study, we tried to prevent efflorescence of existing permeable blocks made of cement. Fly ash (FA), an industrial byproduct, was used to reduce cement usage. By using industrial byproducts, slag recycling and CO_2 emissions of cement were reduced, efflorescence was prevented and pore clogging was reduced. Thereby increasing the service life of the permeable block. The final goal was to increase the strength of the reduced specimens due to industrial byproducts by using polymer (VAE) with excellent durability, water tightness and adhesion. Density, water absorption, flexural strength, compressive strength, porosity and permeability coefficient to investigate the relationship of the binder to the test specimens.

2. Materials and Methods

2.1. Experiment Plan

The purpose of this study is to investigate the strength and physical properties of permeable block by reducing the amount of cement and adding polymer by using industrial byproducts. W/B was fixed at 30%, and after replacing the FA replacement ratio with 10% on the basis of BFS. The experiment was carried out with 7 levels of VAE addition rate 0, 10, 12, 14, 16, 18, 20 (%) The experimental factors and levels are shown in the [Table 1] below.

The flexural strength of specimens with dimensions of 40 × 40 × 160 (mm) according to KS F 44191 standard was measured and the specimens with dimensions of 50 × 50 × 50(mm) were used for compressive strength measurement. 160 × 160 × 40 (mm) The specimens were measured for density, water absorption, porosity and permeability coefficient. The specimens were cured in a mold for 24 hours, demolded and subjected to constant temperature and humidity curing. The flexural strength and compressive strength of the cured specimens were measured after 3, 7, and 28 days. Experiments were conducted to measure density, water absorption, porosity and permeability coefficient.

Table 1: Experiment plan

Experimental factor	Experimental level	
W/B	30 (wt.%)	1
Binder	C[1], FA[2], VAE[3]	3
Aggregate : Binder	5 : 1	1
FA Replacement ratio	10 (%)	1
VAE Addition ratio	0, 10, 12, 14, 16, 18, 20 (%)	7
Curing conditions	Relative humidity 80±5%, Temperature 20±2℃	1
Test items	Density, Water absorption, Flexural strength, Compressive strength, Porosity, Permeability coefficient, Comparison of efflorescence	7

1) C : Cement
2) FA : Fly Ash
3) VAE : Vinyl Acetate-Ethylene

2.2. Materials Used

2.2.1. Cement

Usually, Portland cement is used, and its density is 3.15 g / ㎤ and its powder grade is 3,420 ㎠ / g according to KS L 5201. The chemical composition is shown in [Table 2].

Table2: Chemical composition of Portland cement

Chemical composition (%)							
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2	Cl^-
21.1	6.5	2.9	62.9	3.3	2.2	-	-

2.2.2. Fly Ash

Fly ash is a high quality pozzolan ash taken from a flue gas from a pulverized coal boiler such as a power plant by a dust collector. It is used as a cement admixture and has an effect of increasing the fluidity of the mortar and reducing the volume shrinkage and heat generation at the time of solidification. The fly ash was mainly composed of SiO_2 and Al_2O_3, and had a density of 2.18 g/cm^3 and a powder grade of 4,125 cm^2/g.

2.2.3. Polymer VAE

The polymer VAE system is characterized by high molecular weight even at low viscosity, easy to manufacture with high solids content, excellent adhesive strength, ease of use with additives, and excellent usability. The VAE used in this study was a white powder having an average particle size of 90μm and a pH of 7, and a bulk density of 0.5g/Mℓ [5].

2.2.4. Aggregate

The aggregates used in this study were crushed stone with a particle size of 5 ~ 10mm and a density of 2.70 and a water absorption rate of 10%. [Table 3] is the physical properties of aggregate [3].

Table 3: Physical properties of aggregate

Assortment	Density	Water absorption (%)	Particle size (㎜)	Weight of unit volume (t/㎥)	Percentage of absolute volume (%)
crushed stone	2.70	10	5~10	1.51	59.6

3. Results and analysis

3.1. Density and Water Absorption

[Figure 1] is a graph showing the density and water absorption values according to the polymer addition ratio. The density shows a similar tendency when the addition rate of the polymer is increased. Since the ratio of binder and aggregate used for each test sample is the same, it is considered that there is no difference in the result even if the addition rate of polymer is increased.

Water absorption tends to decrease as the addition rate of polymer increases. The polymer is cured and the surface of the aggregate is coated. It is considered that the water absorption of the aggregate is reduced due to the coating effect of the aggregate surface [12].

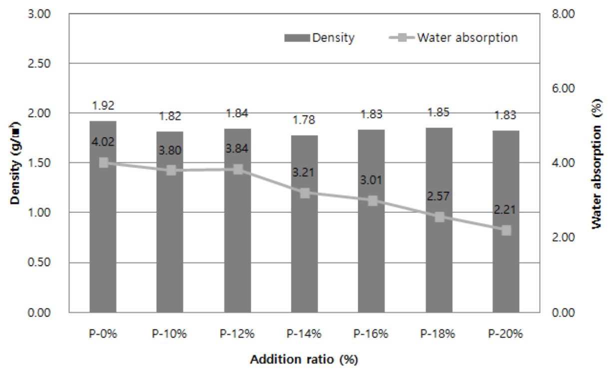

Figure 1: Density and water absorption

3.2. Flexural Strength and Compressive Strength

[Figure 2] is a graph showing the flexural strength and compressive strength values according to the polymer addition ratio. The flexural strength was increased as the addition rate of polymer increased. The flexural strength was increased as the addition rate of polymer increased. The ratio of BFS to FA is the same, and as the addition rate of polymer increases, the strength increases as the curing period becomes longer. As mentioned above, initially, the strength of cement only is manifested and there is no influence of polymer, As the cured polymer adheres to the cement hydrate, the cement hydrate coated on the polymer particles binds to the aggregate and has a great influence on the strength enhancement. As the addition rate of polymer increases, the strength tends to increase.

The compressive strength was similar to the flexural strength, and the strength was increased as the polymer addition ratio increased.

In the 3 day strength, the difference in strength was not much, but it was confirmed that the strength increased as the curing progressed.[Figure 3] is a graph of compressive strength.

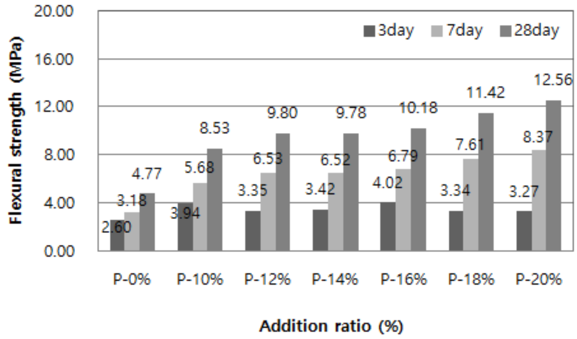

Figure 2: Flexural strength

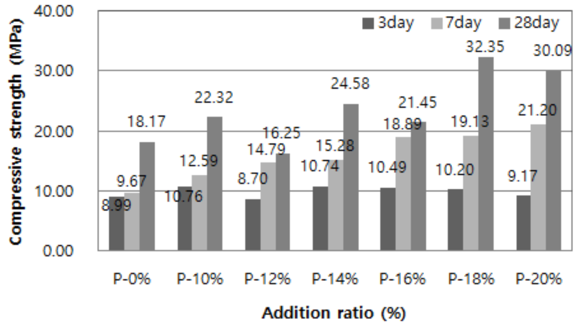

Figure 3: Compressive strength

3.3. Porosity and Permeability Coefficient

[Figure 4] is a graph showing the Porosity and permeability coefficient values according to the polymer addition ratio. The porosity is shown in [Figure 4] below, and porosity tends to decrease as the addition rate of polymer increases. As the addition rate of the polymer increases, the porosity decreases because the amount of the paste increases. The porosity is higher than when the addition rate is 0% in the addition ratio of 10 to 12 (%). Due to the nature of porous concrete, it is difficult to confirm the clear trend of pore generation due to the structure of aggregate and aggregate. However, porosity generally tends to decrease.

The permeability coefficient is shown in [Figure 5] below. The permeability coefficient tends to decrease as the addition rate of polymer increases. However, the increase of the permeability coefficient of polymer 10 ~ 16 (%) can be confirmed. It is judged that the permeability coefficient is increased due to the water resistance of the polymer up to the additive ratio of 16%. Thereafter, as the addition ratio increases, the porosity is clogged and the permeability coefficient is decreased due to the increase of the paste.

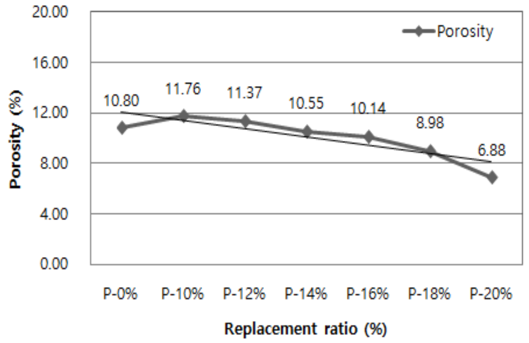

Figure 4: Porosity

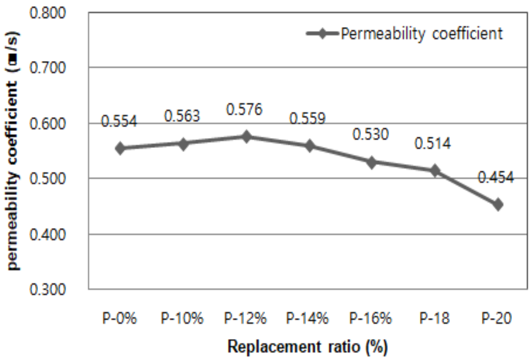

Figure 5: Permeability coefficient

3.4. Comparison of Efflorescence

Since there is no standard for efflorescence generation, the cross section of the specimen was cut and the efflorescence generated between pores was compared. [Figure 6] shows the comparison of the amount of efflorescence. Efflorescence was the most frequent in Plain, and as the addition rate of polymer increased, the occurrence of efflorescence decreased. It is considered that the occurrence of efflorescence is reduced while the contact between cement and CO_2 is minimized while the polymer is coated with the aggregate.

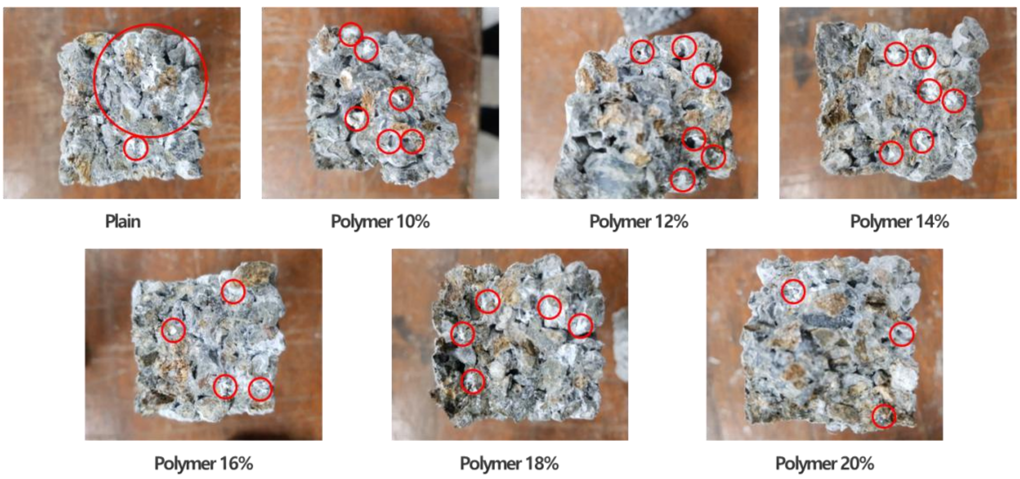

Figure 6: Comparison of efflorescence

4. Conclusion

This experiment was carried out to investigate the physical properties of permeable block according to the addition ratio of binder and polymer substituted with cement and fly ash. As the addition rate of polymer VAE increases, the density and absorption rate tend to decrease. Also, as VAE addition rate increases, flexural strength and compressive strength increase. It is considered that the polymer particles enclose the cement hydrate and increase the adhesion between the aggregates. As the VAE addition ratio increases, porosity and permeability coefficient decrease, but it has a value that meets the criteria of 'KS F 4419'. The flexural strength standard of the permeable block is 4MPa or more for the sidewalk. As a result of this experiment, the criterion is satisfied after aged 7 days or more. The optimum addition rate of VAE is judged to be 10% in consideration of economical efficiency. If additional use of industrial byproducts is increased to reduce the amount of cement used, it will be possible to commercialize the environmental pollution problem, the recycling of industrial byproducts, and Permeable block to prevention of efflorescence

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