International Journal of Engineering & Technology, 7 (3.24) (2018) 375-378

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Properties of Permeable Block According to Replacement ratio of Fly ash

Sang-Soo Lee*[1], Won-Gyu Lee[1], Een-Seok Jo[1]

[1]*Dept. of Architectural Engineering, Hanbat National Univ., Korea*
*Corresponding author E-mail: Sslee111@hanbat.ac.kr

Abstract

Background/Objectives: The mass production of cement is a problem of environmental pollution, and the permeable block is made of cement, causing many problems such as efflorescence and CO_2 generation.
Methods/Statistical analysis: The existing permeable block is made of cement, resulting in efflorescence, resulting in clogged pores and shortening the replacement cycle, which is an economical problem. It is a chemical component of cement which is the main cause of efflorescence. It is considered that fly ash can be used as a cement replacement to prevent efflorescence and can be environmentally improved by recycling industrial by-products.
Findings: As a result of the basic experiment, the fluidity, the air content, the flexural strength and the compressive strength of the paste were measured. As the fly ash replacement rate increases, the fluidity and air content tends to increase and the strength tends to decrease. The characteristics of the fly ash improve the workability, but the initial strength is reduced. In this experiment, the aggregate is added to the paste, and the density and the water absorption tend to decrease. Porosity and permeability coefficient increase until a certain replacement ratio, and then decrease. The strength tended to decrease in the same manner as in the basic experiment, and the optimum replacement ratio was within the range of 10-20 (%).
Improvements/Applications: In order to increase the strength that is insufficient in this experiment, other mixing materials will be added in the next experiment.

Keywords: Permeable Block, Efflorescence, Fly ash, Coefficient of permeability, Industrial by-products

1. Introduction

In the construction industry, cement is one of the most commonly used materials to form structures inside and outside of buildings. However, since cement generates a large amount of CO_2 during the manufacturing process and requires heating at about 1,450°C. In order to calcine the raw limestone ($CaCO_3$), there is a disadvantage that global warming problems such as enormous energy are required [1]. Korea has been under the "Low Carbon Green Growth Basic Law" under the national vision of "Low Carbon Green Growth". The Republic of Korea has set its goal to reduce its CO_2 emissions by 5.2% compared with the 1990 level, as it is incorporated into the target country of CO_2 reduction obligations from 2012. [2,3] As a representative method of reducing the amount of cement used, there is a method of using an admixture. Typical admixtures are industrial by-products fly ash. Fly ash is one of the residues from a thermal power plant and is collected in an electric filter. When fly ash is used as an admixture, it has advantages such as improvement of workability, reduction of hydration heat, improvement of long-term strength, and improvement of economy, but there are problems such as initial strength drop and delay of coagulation. It is considered that replacing cement will help to improve environmental pollution.[2,4,5]

At present, most of the concrete structures in Korea are cement. Cement is being used not only for construction structures but also for brick and block materials. It is used in many other places, and the pitcher block is also made of cement. [6] The permeable block made of cement reacts with the $Ca(OH)_2$ component of the cement as the atmospheric CO_2 is melted into the rainwater and penetrates into the permeable block. As a result of the occurrence of efflorescence, the pore of the permeable block is clogged and the permeability is lost. The life span of the product is reduced, and the replacement cycle is also shortened, making economic efficiency a problem. [7]

Since the 1960s, Korea has been rapidly densely populated due to industrial developments, and as the population of urban areas and the densification of residential areas have become denser, the size of green areas has decreased. As a result, the flowability of the rainwater has changed and have different flowability from the natural river basin. 8,9,10]

In order to solve these problems, studies on permeable block or porous concrete are under way. Although the number of installation cases is increasing, the countermeasures against efflorescence are not clear and research is needed. In this study, we try to make a product to prevent efflorescence by fabricating a permeable block with reduced cement usage by using fly ash.[8,11,12]

In this study, the use of fly ash, which is an industrial by-product, was used to reduce the amount of cement used to reduce the whitening phenomenon occurring in the permeable block made of cement base. Reduction of cement usage will reduce the amount of CO_2 generated, and the use of industrial by-products is expected to improve the environmental aspect. It is possible to prevent the air gap clogging by reducing the occurrence of efflorescence and extend the frequent replacement period. Since the use of fly ash improves the workability, characteristics depending on the amount of binder used were examined. As a test item, the flowability and air content and strength of the paste were measured to confirm the characteristics of the binder. The permeability block measured density, water absorptance, coefficient of permeability, porosity, flexural strength and compressive strength.

2. Materials and Methods

2.1. Experiment Plan

This study is an experiment to prevent efflorescence of permeable block. The purpose of this study was to investigate the physical properties of permeable blocks while replacing fly ash in order to reduce cement usage by using industrial by-product.

The basic experiment was to measure the flowability and air content of paste made only with water and binder. The cured specimens were cured at relative humidity 80%, temperature 20 ℃, and the strengths were measured at 3, 7 and 28 days after aging. The flexural strength was tested according to KS F 4419 and the compressive strength according to KS L ISO 679. Flowability and air content of the fly ash replacement ratio were measured.

This experiment is cement and fly were used as binders, and the fly ash replacement rates were 5, 0, 10, 20, 30, 40 (%). W / B was fixed at 20%, and the experimental factors and levels are shown in [Table 1] below. In this test, the flexural strength was measured with a specimen of 40 × 40 × 160 (mm) according to KS F 4419 standard. 160 × 160 × 40 (mm) The specimens were measured for density, water absorption, porosity and permeability. The flexural strength and compressive strength of the cured specimens were measured after 3, 7, and 28 days.

Table 1: Experiment plan

Experimental factor	Experimental level	
W/B	20 (wt.%)	1
Binder	C[1], FA[2]	3
Aggregate : Binder	5 : 1	1
FA Replacement ratio	0, 10, 20, 30, 40 (%)	5
Curing conditions	Relative humidity 80±5%, Temperature 20±2℃	1
Test items	Density, Water absorption, Flexural strength, Compressive strength, Porosity, Coefficient of permeability	6

1) C : Cement

2) FA : Fly ash

2.2. Materials Used

2.2.1. Cement

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

Table 2: 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 blaine of 4,125 cm^2/g. [1]

2.2.3. Aggregate

The aggregates used in this study were crushed stone with a particle size of 5 ~ 10 mm and a density of 2.70 and a water absorption rate of 10%. [Table 3] is the physical properties of aggregate. [8]

Table 3: Physical properties of aggregate

Assortment	Density (g/ ㎤)	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. Basic Experiment

3.1.1. Flowability and Air Content

[Figure 1] is a graph showing the density and the absorption rate according to the fly ash substitution ratio. The paste was made using cement and fly ash, and the w / b was fixed at 30%. The fly ash replacement rates are 0, 10, 20, 30 and 40%. As the replacement rate increases, the liquidity tends to increase. As the substitution rate of fly ash increases and the amount of cement used decreases, the fluidity is increased. The amount of air is shown to increase with increasing fly ash replacement rate. It is believed that air is generated due to the fly ash molecular structure and the amount of air in the paste is increased.

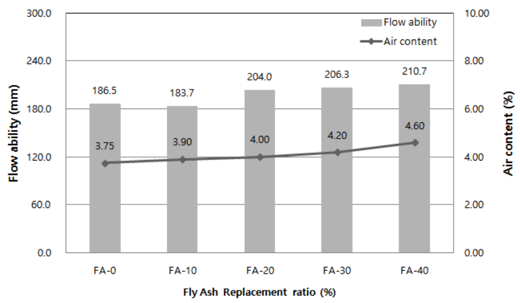

Figure 1: Flowability and air content

3.1.2. Flexural Strength and Compressive Strength

[Figure 2] and [Figure 3] show the flexural strength and compressive strength, respectively, and they are shown by the substitution ratio. The strength tends to decrease with increasing fly ash replacement ratio.

The flexural strength tends to decrease with increasing fly ash replacement ratio. However, as the substitution rate of fly ash increased, it was confirmed that the deviation of the strength was decreased.

The compressive strength is the same as the flexural strength, and the strength decreases as the substitution rate increases, but the variation of long - term strength decreases.

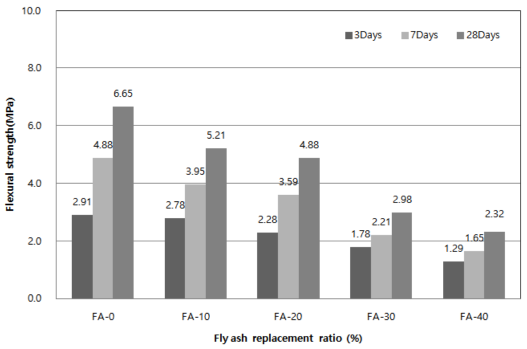

Figure 2. Flexural strength

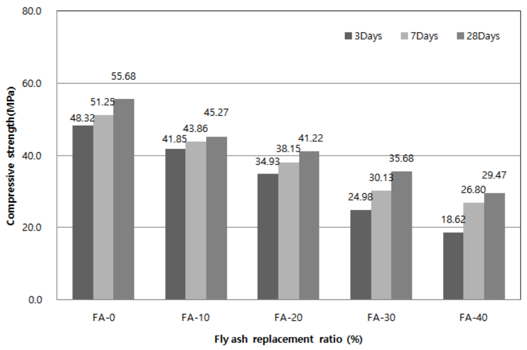

Figure 3: Compressive strength

3.2. Permeable Block Experiment

3.2.1. Density and Water Absorption

[Figure 4] is a graph showing the density and the absorption rate of the permeable block. The density tends to decrease with increasing fly ash replacement rate. As the fly ash is replaced by 10%, the density decreases by about 2 to 3%. The reason is that the density of fly ash is lighter than that of cement. As the amount of cement used decreased and the amount of fly ash increased, the density decreased as the replacement rate increased.

Water absorption tends to decrease with increasing replacement ratio. As the amount of binder increases, the pores become clogged and water absorption decreases.

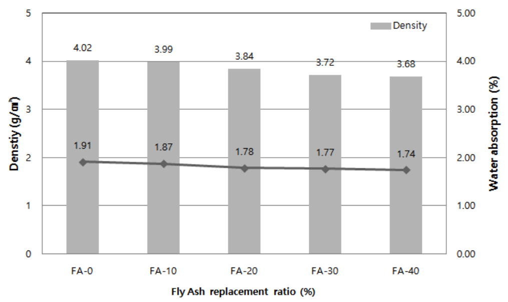

Figure 4. Density and Water absorption

3.2.2. Porosity and Coefficient of Permeability

[Figure 5] is a graph showing porosity and coefficient of permeability. The porosity tends to increase when the fly ash replacement ratio is 20%, and then to decrease thereafter. Due to the workability of the fly ash, it is judged that the air gap is blocked after a certain usage amount. The coefficient of permeability increases with increasing porosity. It is considered that the coefficient of permeability increases with the pores of the specimen.

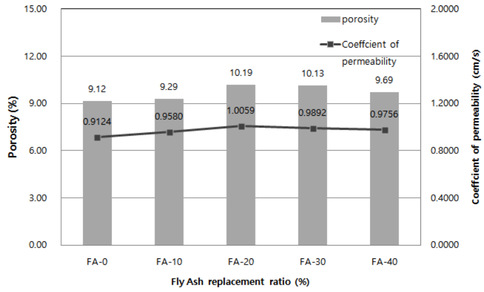

Figure 5: Porosity and coefficient of permeability

3.2.3. Flexural Strength and Compressive Strength

[Figure 6] and [Figure 7] are graphs showing the flexural strength and compressive strength of the permeable block according to the replacement ratio of fly ash. The permeability block was fabricated using fly ash, and the strength decreased with increasing fly ash replacement ratio. As in the basic experiment, it was confirmed that the intensity decreased with the replacement rate, but the deviation decreased with the long-term strength. The strength of fly ash is lower than that of cement, fly ash is considered favorable for long-term strength. However, the amount of cement used will be reduced to prevent the occurrence of efflorescence, and it will be an eco - friendly product. However, since it is difficult to commercialize it due to low strength, it is necessary to carry out research to increase the strength.

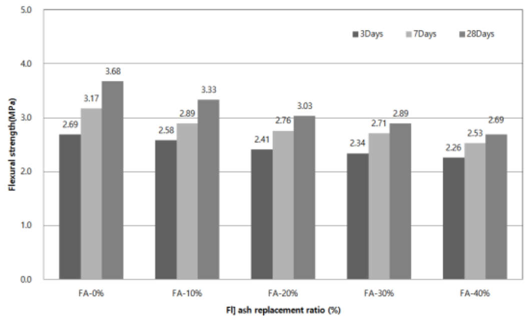

Figure 6: Flexural strength

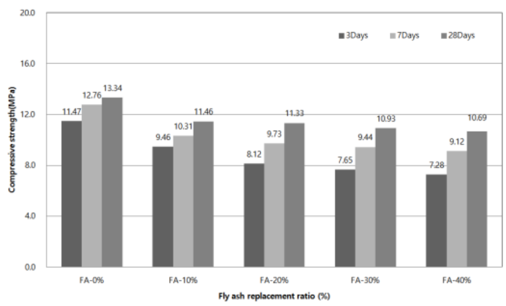

Figure 7: Compressive strength

4. Conclusion

This study was carried out to investigate the physical properties of permeable blocks according to the replacement rates of cement and fly ash.

As the replacement rate of fly ash increases, the fluidity increases. It is judged that the flowability is increased because the characteristics of the fly ash are good in workability. In addition, since the fly ash has many pores, the amount of air increases as the substitution rate increases. However, as the replacement rate of fly ash increases, the strength tends to decrease. Fly ash had lower strength than cement, but it showed increase in strength after long - term strength (28 days). Because of the lower density compared to cement, the weight of the product is lighter, the workability increases, and the absorption rate decreases. The porosity increases to a replacement rate of 20%, but tends to decrease thereafter and the coefficient of permeability tends to decrease as the replacement rate increases. Since the workability of the fly ash is advantageous, it is considered that the coefficient of permeability decreases when the amount of binder used exceeds a certain amount. The use of fly ash reduces overall strength, but has the effect of increasing strength after 28 days, It is possible to reduce the weight of the product and to prevent the efflorescence. As a result of this experiment, the optimum replacement ratio of the permeable block with fly ash is in the range of 10 ~ 20 (%) and it is considered that curing is necessary for 28 days or more to reach the permeability block reference strength value.

It is considered that the permeable block can be commercialized only when additional experiments are carried out to replace the fly ash and increase the strength by using additional admixture.

References

[1] Paik, S.G., Kim, Y.M., Lee, S.S., Lightweight Properties of Matrix using Paper Ash according to Replacement Ratios of Fly Ash and Polysilicon Sludge. Journal of the Korean Recycled Construction Resources Institute. 2014; 2(2): 166-171. Retrieved from http://www.dbpia.co.kr/Article/NODE07020135

[2] Han, C.G., Park, Y.K, Effect of Performance Materials on the Affecting Early-Age Strength of Concrete Replacement Fly Ash. JOURNAL OF THE ARCHITECTURAL INSTITUTE OF KOREA Structure & Construction. 2011; 27(12): 139-146. Retrieved from http://www.dbpia.co.kr/Article/NODE01759315

[3] Cho, Y.J., Concrete Technology at an the Era of Green Growth. Magazine of the Korea Concrete Institute. 2009; 21(5): 22-27. Retrieved from http://www.dbpia.co.kr/Article/NODE02262437

[4] Kim, J.H., Park, B.S., Jung, S.H., Choi, Y.C., Effect of Properties of Fly-ashes on the Characteristics of Fly-ash Mortars. Journal of the Korean Recycled Construction Resources Institute . 2016; 4(4): 439-445. Retrieved from http://www.dbpia.co.kr/Article/NODE07107606

[5] Kim, Y.U., Kim, S.J., Kim, H.J., Jeong, S.B., Choi, H.Y., Choi, S.J., The Fluidity and Compressive Strength of Non-Cement Porous Block Using High Volume Blast Furnace Slag Powder. The Korean Institure of Building Construction. 2017; 17(A): 212-213. Retrieved from http://kiss.kstudy.com/thesis/thesis-view.asp?key=3535336

[6] Kim, B.G., Performance evaluation of eco-concrete block using non-cemented inorganic binder (Masters dissertation). ChonBuk National University. Korea. 2017. 47p.

[7] Choi, S.M., Kaug, E.G., Shin, H.C., Cho, S.H., Choi, S.J., Kim, J.M., An Experimental Study on the Surface Stability of Concrete Tile. Architectural Institute of Korea. 2004; 24(2): 387-390. Retrieved from http://www.dbpia.co.kr/Article/NODE00813590

[8] Yoo, B.Y., Performance Evaluation of Polymer Block using Artificial Permeable Pipe (Masters dissertation). HanBat National University. Korea. 2018. 69p.

[9] Park, D.G., Jung, W.K., Jeong, D.W., Baek, J.E., Lee, J.W. Evaluation of Field Permeability and Material Characteristics of Permeable Block for Roadway Pavement. Ecology and Resilient Infrastructure. 2016; 3(2): 110-116. Retrieved from http://dx.doi.org/10.17820/eri.2016.3.2.110

[10] Jun, S.M., Park, J.H., Kim, Y.D., Quantitative Analysis of the Permeability of Water Permeable block. . The Korean Society of Civil Engineers. 2012; 38(1): 224-227. Retrieved from http://www.dbpia.co.kr/Article/NODE02300291

[11] Kim, D.B., Kim, Y.U., Kim, S.J., Kim, H.J., Jeong, S.B., Choi, S.J., Performance Evaluation of Trial Product of Amorphous Metallic Fiber Reinforced Porous Block Using High Volume Blast Furnace Slag Powder. The Korean Institure of Building Construction. 2017; 17(2): 81-82. Retrieved from http://kiss.kstudy.com/thesis/thesis-view.asp?key=3562586

[12] Yu, B.Y., Lee, W.G., Lim, T.H., Lee, S.S. Basic properties of polymer permeable sidewalk paver using artificial permeable pipe. Korea Concrete Institute. 2017; 29(2): 729-730. Retrieved from http://www.dbpia.co.kr/Article/NODE07267830