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Experimental Study on The Infiltration and Compressive Strength of Porous Paving Blocks Composed of Fly Ash and Zeolite Mixture

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Abstract

Maximizing the absorption of water into the soil to reduce puddles in developing areas can be done by using porous paving blocks as cover for soil reports with water escape capabilities. Paving block porous materials need to be considered qualified quality according to their use. Fly ash as one of the coal-burning wastes can be used as a substitution material for cement. Zeolite instead of gravel is a source of considerable mining material, structured hydrate aluminum silicate with a high specific surface area and has a great potential for use as an absorbent material that can pass through water. This study investigates the use of fly ash as substitute of cement and zeolite as aggregates in porous paving block. The research aims to identify optimal composition of fly ash and zeolite for achieving desirable compressive strength and infiltration. Porous paving block were manufacture using ratio 1 (segment): 4 (grains) of binder to aggregate. Fly ash waste used in a mixture of porous paving block materials varies by 10%, 20%, 30% and 40% using rough aggregates of zeolite. Compressive strength tests are performed at 7 days, 14 days and 28 days and for infiltration tests at 28 days. Research showed compressive strength values of 31.40 MPa, 36.75 MPa, 37.50 MPa, 32.42 MPa, and 32.67 MPa, respectively, can be used as a parakeet cover layer. The infiltration coefficients are 0.0611 cm/s, 0.4376 cm/s, 0.1218 cm/s, 0.0621 cm/s and 0.1012 cm/s, respectively, which are capable of passing water from the surface to the ground. This study highlights the potential of utilizing waste material fly ash and zeolite in quality of porous paving blocks, contributing to sustainable construction and stormwater management in urban areas.

Keywords

Porous paving block, compressive strength, infiltration, fly ash, zeolite.

INTRODUCTION

In addition to being used for certain purposes, soil cover layers in residential areas are expected to be permeable pavements that can reduce puddles and increase water absorption into the soil. The porous paving block cover has a higher water passability than conventional paving blocks because of the mixture of cement, rough aggregates, water, and little/no sand. However, compared to conventional paving blocks, porous paving blocks have a lower pressing force. The porous paving block uses rough aggregates and has many cavities [1]. Porous paving blocks are one of the alternative surface pavement layers that can pass surface water into underground layers that can be used for yards, parking lots, sidewalks, and other outdoor areas by the public [2]. The porous paving block is one of the environmentally friendly paving blocks due to its ability to pass water into the ground, which can increase groundwater reserves in residential areas with less absorption area and green land. Producing good porous paving block quality is highly dependent on the material contained in it. Various studies have been conducted to obtain several alternative materials for manufacturing porous paving blocks. One way is by utilizing residual coal-burning and zeolite waste.

The use of waste sources that are a breakthrough in reducing environmental pollution is fly ash, which is waste from burning coal. The fly ash is used to replace cement in making porous paving blocks. The use of fly ash materials as a porous paving block is based on the properties of these materials that share similar properties to cement, such as similar chemical content because fly ash contains silica, aluminum, magnesium, lime, and others.

The mineral zeolite is one of the minerals from the quarry found in Indonesia. It has blue, white, and brown colors that are somewhat soft and light crystalline. Zeolite laboratory tests containing the main components of cement formations include silica (SiO2) 53.23%, Aluminum Oxide (Al2O3) 10.28%, Magnesium Oxide (MgO) 1.59%, and Calcium Oxide (CaO) 27.69% [3]. Under normal vacuum conditions, zeolite crystals are filled with free water molecules if zeolite is heated at 300ºC – 400ºC, then water will escape so that zeolite can serve as both a water absorbent and a gas [4]. Indonesia itself is estimated to have abundant zeolite supplies and has the ability to be developed.

ash: water, 2:1:3:0.5, 1:2:1.2, 1:3:3:1.1, 3:1.5. From this composition, the compressive strength is 5.93 MPa, 18.09 MPa, 8.29 MPa, and 15.89 MPa.

Table 1. Total Number of Material Requirements

Sample	Material	7 days age (kg)	14 days age (kg)	28 days age (kg)	Material Requirements Total (kg)
V_0	coarse aggregate	3,687	3,687	7,374	14,748
	cement	2,322	2,322	4,644	9,288
V_1	zeolite	3,573	3,573	7,146	14,292
(10% FA+90%	cement	2,091	2,091	4,182	8,364
cement and zeolite)	*fly ash*	0,189	0,189	0,378	0,756
V_2	zeolite	3,573	3,573	7,146	14,292
(20% FA+ 80%	cement	1,857	1,857	3,714	7,428
cement and zeolite)	*fly ash*	0,381	0,381	0,762	1,524
V_3 (30% FA+70%	zeolite	3,573	3,573	7,146	14,292
cement and zeolite)	cement	1,626	1,626	3,252	6,504
	fly ash	0,570	0,570	1,140	2,280
V_4 (40% FA + 60%	zeolite	3,573	3,573	7,146	14,292
cement and zeolite)	cement	1,395	1,395	2,790	5,580
	fly ash	0,762	0,762	1,524	3,048

Table 2. Number of Sample

Variation of Sample	Material Age (days)			Number of Sample
	7	14	28	
V_0	3	3	6	12
V_1	3	3	6	12
V_2	3	3	6	12
V_3	3	3	6	12

Research on the use of fly ash waste in paving block mixture binding materials, namely 0%, 5%, 10%, l5%, 20% and 25% resulted in a firm press value of l8.52 MPa, l8.47 MPa, l9.67 MPa, l7.23 MPa, l6.93 MPa and l4.6l MPa [5]. Research into using fly ash as a filling material for paving blocks [6] by a ratio (1:4) of 30% FA resulted in an average compressive strength of 31.25 MPa. Research the intense compressive strength and absorption of water paving blocks with cement replacement fly ash [7]. It uses a variation percentage of fly ash of 0%, 10%, 15%, and 20% of cement weight, an optimum compressive strength of 15% variation of 97.92 kg/cm^2 and a decrease in fly ash addition of more than 15%.
Paving block manufacturing research using zeolite as a cement substitute material [8] with variations in zeolite 0%, 2.5%, 7.5%, 10%, 12.5%, and 15% against cement weights over 14 days is 15.64 MPa, 16.62 MPa, 15.38 MPa; 12.64 MPa, 12.69 MPa, 9.70 MPa and 9.53. The study of lightweight concrete bricks by adding zeolite [9] with variations in addition to 0%, 10%, and 20% zeolite by weight of cement, optimum compressive strength occurs in adding 20% zeolite to filter No.80 consecutively of 22.33 kN, 26.33 kN, 30.33 kN and 31.33 kN and filter No.200 of 27.67 kN, 32 kN, 33 KN, and 35. Research on the effect of zeolite as a rough aggregate and coal ash as a cement mixture material on the strong press of paving blocks [3] with the composition of zeolite mixture: sand: cement: coal

RESEARCH SIGNIFICANCE

This study used fly ash material as cement and zeolite as a substitute for rough aggregates to increase the compressive strength and infiltration of porous paving blocks so that it could produce an optimum value of the effect composition of fly ash and zeolite variations that could be one alternative to overcome material puddles for environmentally friendly waste and contribute to sustainable construction and stormwater management in urban areas.

METHODOLOGY

A. PROPORTION OF POROUS PAVING BLOCK

This study used a mixture of fly ash material as a substitution of cement and zeolite as a substitute for aggregates. Mix design uses a comparison of 1 (cement): 4 (aggregate) with variations in comparison of 0%, 10%, 20%, and 30% fly ash (FA) of cement substitution with zeolite rough aggregate. The test variation consists of a normal paving block V0 and a mixture of V1, V2, V3, and V4. The porous paving block test object measures 20 cm by 10 cm by 6 cm. 72 samples of test items were used for compressive strength tests at 7, 14, and 28 days old and for water absorption or absorption tests at 28 days old. The material requirements for the mix design are calculated based on the unit weight and the material volume, which are then calculated as many as the number of test items. The number of material weight requirements required in this study is in Table 1 and the number of samples of test items is presented in Table 2.

B. RESEARCH PROSESS

Research consists of several stages, including preparation, material testing, test object manufacturing (mix design), test object testing, data analysis, and conclusions. The preparation stage is in the form of data collection and basic theory about materials used as mixed porous paving blocks and data collection and preparation of testing apparatus. The preparatory material testing stages include type weight, water level, and filter analysis. The stages of manufacturing a test object include the determination of a porous design block, the manufacture of a trial object, and the manufacture of a test object. The strong compressive strength testing phase of porous paving blocks is 7, 14, and 28 days old and infiltration is 28 days old. In the analysis stage, data based on data obtained from the test can then be drawn conclusions related to the purpose of the study.

RESULTS AND DISCUSSIONS

The material used in the mixture of porous paving blocks was tested to obtain parameters through physical testing. The following figures illustrates preparation materials, physical test of materials, compressive strength test, and infiltration test of porous paving block test in laboratory.

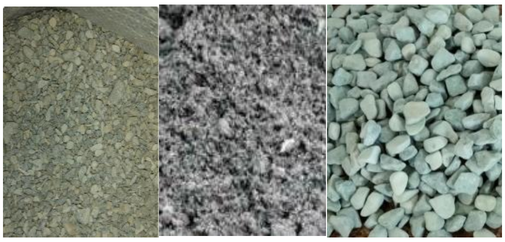

Figure 1. Preparation Materials

Figure 1 shows the various materials used in the porous paving block mixture, including coarse aggregate, fly ash, and zeolite.

Figure 2. Physical Test of Material

Physical tests on the material tested include aggregate gradation analysis [10], sludge content examination [11], aggregate wear resistance examination [12], aggregate water level test [13], aggregate unit weight, aggregate type and absorption weight [14], and aggregate type weight [15] cement and fly ash. Rough aggregates are pebbles for normal variations and zeolites for other variations. The results of material testing in the laboratory are shown in Table 3.

Table 3. Results of Materials Testing in the Laboratory

Material	Material Testing	Testing Result
Cement	Density	3,226 gr/ml
Fly Ash	Density	2,64 gr/ml
Aggregate	Mud Content	0,664%
	Aging Resilience	33,48%
	Water Content	3,95%
	Unit Weight	1.280,09 kg/m3
	Density	2,37
	Density (SSD)	2,47
	Water Absorption	4,412%.
Zeolite	Aging Resillience	28,32%
	Water Content	6,157%
	Unit Weight	1.241,12 kg/m3
	Density	1,684
	Density (SSD)	1,753
	WaterAbsorption	4,104%

Figure 3. Mix Design Variation Porous Paving Block

Figure 3 shows the mix design and making sample of variation porous paving blocks based on the specified ratio proportions. Figure 4 illustrates the compressive strength and infiltration test variation of porous paving blocks.

Figure 4. Compressive Strength and Infiltration Test

Gradation analysis tests of rough aggregates include gravel and zeolite to show variations in the shape of aggregate sizes. The results of the gradation test of gravel and zeolite aggregates are shown in figures below.

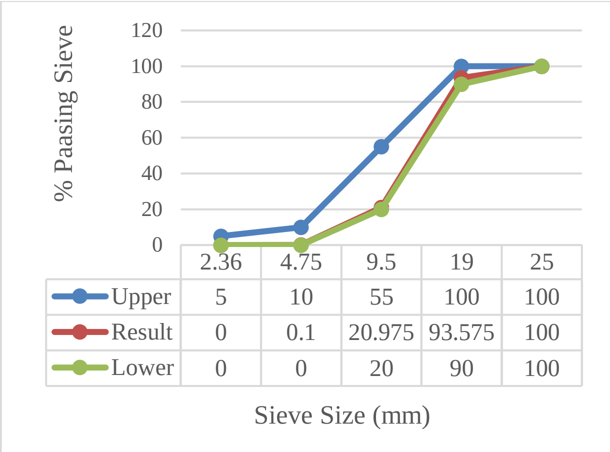

Figure 5. Size Analysis of Aggregate

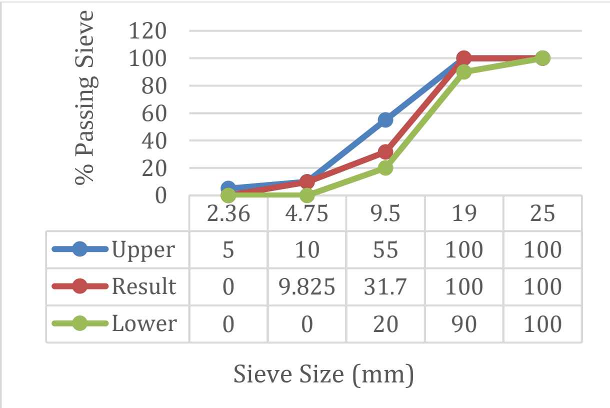

Figure 6. Size Analysis of Zeolite

According to the results of a gradation test, gravel has a varying size shape, with a maximum size of 19 mm, which is above the lower limit. The yield for the smooth modulus was 3.85. The results of the zeolite gradation test showed that the zeolite had a varying size, with a maximum size of 19 mm, which was above the lower limit. The yield for the smooth modulus was 3.58.

In addition to the test, the fly ash material was subjected to an X-ray fluorescence (XRF) test by UPJ PLTU Banten 3 Lontar, which gave results of Sio¬2 (63.15%) + Al2O3 (16.88%) + Fe_2O_3 (9.23%) obtained by 89.2% > 70% and CaO 4.49%, so this class is included in F. Class F is a low calcium fly ash (LCFA) and does not have cementious properties but is pozzolanic [16].

Compressive strength tests of porous paving blocks of all variations are performed at the ages of 7, 14, and 28 days. The results of the compressive strength test are shown in Figure 7.

Based on the results obtained, all variations' compressive strength increases over the ages of 7, 14, and 28 days. The compressive strength varies by 31.40 MPa, 36.75 MPa, 37.50 MPa, 32.42 MPa, and 32.67 MPa, respectively. Maximum compressive strength at V2 (20% FA+ 80% cement and zeolite). The compressive strength value of a porous paving block with zeolite is higher than that of the normal porous paving block (V0). The use of fly ash increases the pressing force until the addition of 20%, more than that, the pressing force decreases. On the 28-day-old compressive strength chart, zeolite increases the compressive strength from V2 to V3 by 2%, but when fly ash >20% decreases.

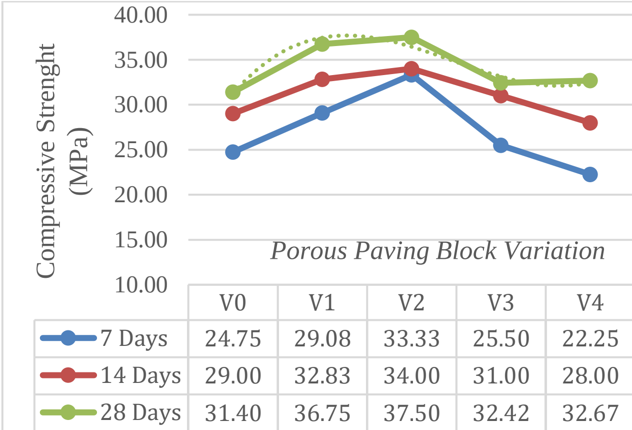

Figure 7. Compressive Strength of Porous Paving Block

Infiltration Test [18] is carried out at 28 days of concrete age. The results of all variations of the porous paving block infiltration test are presented in Figure 8.

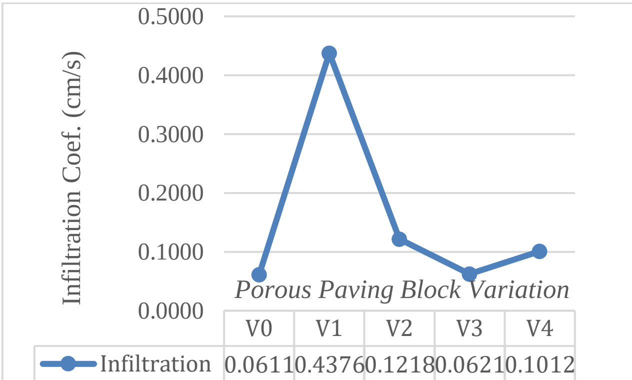

Figure 8. Infiltration of Porous Paving Block

Based on the graph, the infiltration value (permeability) of porous paving blocks using zeolite is higher than that of gravel. The infiltration coefficients were 0.0611 cm/s, 0.4376 cm/s, 0.1218 cm/s, 0.0621 cm/s and 0.1012 cm/s respectively and the highest at V1 (10% FA+90% cement and zeolite) was 0.4376 cm/s. Infiltration decreases with increased fly ash levels used because the more fly ash covers the pores in the porous paving block, the more water will be difficult to penetrate into the porous paving block.

CONCLUSIONS

This research aimed to investigates the use of fly ash as substitute of cement and zeolite as aggregates and identify the compressive strength and infiltration of porous paving block. The research methodology involved porous paving block with various propositions of fly ash as a cement substitute and zeolite as aggregates. Compressive strength tests were conducted at 7, 14, and 28 days, while infiltration test were performed at 28 days.

1. Based on the results of research and analysis conducted by porous paving blocks using zeolites on mixed variations, it can increase the compressive strength. The highest compressive strength at V2 (20% FA+ 80% cement and zeolite). The use of fly ash can only increase the compressive strength value if the addition of fly ash to 20%, if more, will decrease the compressive strength. This is because the fly ash used is class F, which tends not to be cementitious, so the binding could be better than cement. Based on the strength of the porous paving block, compressive strength was produced, including quality B, which can be used for parking lots.
2. The infiltration coefficient of porous paving blocks using zeolites with substitution flash variations is higher than that of gravel. Infiltration is highest at V1 (10% FA+90% cement and zeolite), which is 0.4376 cm/s. Infiltration decreases with increased fly ash levels used. This is because the more fly ash covers the pores in the porous paving block, the more water will be difficult to penetrate into the paving block.

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