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Process of andesite stone as material of cement substitution in making paving block

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Abstract. This study was conducted to determine the effect of andesite stone substitution on compressive strength paving block. The percentage of andesite substitution of cement by 10, 20, 30, 40, and 50% by weight of cement. Andesite rock after calcination was characterized using XRD (X-Ray Diffraction). The results of XRD analysis after calcination at the calcination temperature of 900°C have formed muscovite, hedenbergite, and microcline phases. The highest compressive strength of the paving block is found in the substitution of andesite stone of 10% of age 28 days and the lowest compressive strength is in the substitution of andesite 50% of 7 days. This decrease is due to the excessive SiO_2 content will bind to the free CaO contained in the cement and form $Ca(OH)_2$. $Ca(OH)_2$ causes reduced paving block density due to the formation of air cavities. Besides the high FAS factor and the gradation of sand size also affect the decrease of compressive strength of paving block.

1. Introduction

Paving blocks or concrete bricks for floors are a component of building material made from a mixture of hydraulic cement or the like, aggregates and water with or without other additives which do not reduce the quality of the paving block [1]. The advantages of paving block that has good water absorption, through the installation of paving block can keep the ground water balance [2]. However, the high consumer demand for paving is not matched by the availability of adequate quality in terms of strength, wear life, and durability paving. Many paving found on the surface of the road are cracked, easily broken, overgrown with moss, because paving is brittle. This is due to the quality of materials that are not appropriate, scouring rainwater, material composition that does not comply with the standards, the different levels of compaction (pressing) paving, even shock loads (impact resistance) is very large on the track wheels of the vehicle [3]. With reference to the above explanation, as the growing of the cement industry while the raw materials will also decrease as it continues to be used so that alternative material is needed as substitution of cement [4].

A lot of research has been developed to get new materials that can be used as an alternative or substitution of materials to reduce the use of cement. Triyono [5] conducted research on palm oil shell waste as cement substitution for making paving block with percentage 0%, 5%, 10%, 15%, 20% and 25% of cement weight. Soehardjono et al [5] conducted a study on the effect of using bottom ash as a substitute of cement to the compressive strength and water absorption ability of structure paving, the test object was made 9 variations ie 0%, 25%, 30%, 35%, 40%, 45%, 50 %, 55% and 60% by weight of cement. Nurzal and Mahmud [6] utilize fly ash for mixed paving block, composition fly ash in making paving block is 0%, 5%, 10%, 15% by weight of fly ash plus material paving block (cement and sand). According to Sari [7] the contents of andesite stones contain the chemical composition of $SiO_2$by 62.30%, Al_2O_3 by 14.70%, Fe_2O_3 by 4.04%, MgO by 2.78%, CaO by 4.26%, Na_2O by 2.95%, K_2O of 6.06%,TiO_2, 0.98 P_2O_5 of 0.81%, 0.07% MnO and Cr_2O_3 of 0.014%. Andesite added to the cement material with clinker preparation will have an effect on decreasing the combustion temperature which should not be high at a temperature of $800^{o}C$ longer time combustion [8]. With the chemical composition of SiO_2 + Al_2O_3 + Fe_2O_3 > 70%, the andesite can be used as pozzolan in cement substitution in accordance with ASTM C 618-92a.

2. Experimental Procedures

2.1. Materials

This study began with andesite stone milling using ball miles for 10 hours until the andesite rocks were completely smooth. After going through the process of ball milling, andesite stone that has passed mesh 200 through the process of calcination using electrical furnace panel until the temperature of $900^{o}C$ then with a hold time of 2 hours. After cold, the result of andesite stone calcination is characterized by XRD (X-Ray Diffraction) to determine the phase of crystal structure that is formed. Andesite stone before milling and calcined calcite andesite as shown in Figure 1.

(a) **(b)**

Figure 1. (a) Rocks of despite before milling, (b) After milling and calcination

Subsequently performed gradation test on sand beach by sifting 400 gr with mesh 2 mm, 0.5 mm, 0,42 mm, 0,354 mm, 0,25 mm and 0,149 mm. Gradation of sand obtained by calculating the cumulative percentage of sand grains that pass on each sieve. Sand fineness modulus can be calculated by the following equation.

$$\text{MHB} = \frac{Total\ \ cumulative\ \ \ weig\ ht}{100} \tag{1}$$

In general, the sand can be grouped into three kinds, namely the level of refinement of fine sand with MHB 2.20 to 2.60, the sand being with MHB 2.60 to 2.90 and sand rough with MHB 2.90 - 3.20.

2.2. Manufacture of test objects

The composition of the specimen used in this study is the ratio of cement to sand is 1: 4 with andesite substitution of 10, 20, 30, 40 and 50% of the weight of cement and FAS (Cement Factor) of 0.8. After each ingredient is weighed, then put all the ingredients into the mixer and stir until homogeneous and the dough is formed. Then put the dough into the cube mold (size 5 x 5 x 5 cm). Charging is done layer by layer and each layer is solidified 25 times. After 24 hours, open the mold and code the sample on the specimen. Treatment of the test object (curing) is done by immersing the test object into a bucket that already contains water until the age of 7 days, 14 days and 28 days. After soaking the specimen is ready to be tested for compressive strength. Calculation of compressive strength with equation 2 as follows:

$$f'c = \frac{P}{A} \qquad (2)$$

With: A = the cross-sectional area of the specimen (cm^2)
P = load (kg)
f'c = compressive strength (kg/cm^2)

3. Results and discussion

3.1. XRD characterization results (X-Ray diffraction)
The XRD characteristic results on andesite rocks that have been calcined at 900 °C are shown in Figure 2.

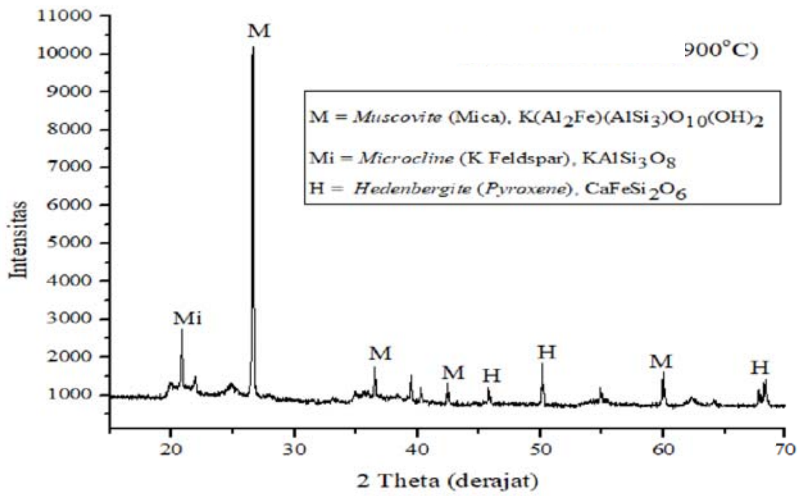

Figure 2. XRD results of andesite stone after calcination

Figure 2 shows the highest peak characteristics of fine andesite rocks after calcination is dominated by the Muscovite phase (Mica) with the chemical formula $K(Al_2Fe)(Si_3Al)O_{10}(OH)_2$, followed by the hedenbergite phase (pyroxene) with $CaFeSi_2O_6$ chemical formula and the Microcline phase (K Feldspar) with chemical formula $KAlSi_3O_8$. According to Stepanus et al (2014), the mineral content present in andesite rocks is potassium feldspar of <10% of total feldspart content, sodium plagioclase, quartz <10%, feldspatoid <10%, bornblende, biotite and pyroxene with mineral composition andesite is required in the formation of cement reactions.

3.2. Sand gradation test result
The result of sand grading test included in fine sand with the fine modulus of grain (MHB) of 2.3. The results of sand grading test are shown in Table 1.

Table 1. Sand Gradation Test Results

No	The Sieve Hole		Weight is Left Behind		Cumulative Weight (%)
	Mesh no.	mm	gr	%	
1	10	2.00	0.00	0.00	0.00
2	35	0.50	43.30	10.99	10.99
3	40	0.42	47.49	12.05	23.04
4	45	0.35	90.14	22.88	45.92
5	60	0.25	57.05	14.48	60.80
6	100	0.15	117.00	29.70	90.50
8	Left		38.93	9.88	
	Cummulative		393.91	99.97	231.25

MHB = $\frac{Total\ \ cumulative\ \ weig\ ht}{100}$ = 231/ 100 = 2.31 included in the fine sand group = 2.20 – 2.60

The sand gradation or sand beach size distribution used has an MHB (fine modulus of grain) of 2.31, with the MHB, the sand of the beach we use is included into the fine sand which tends to have uniform grains of sand. The grain size distribution influences the compressive strength of the paving block. In accordance with research conducted by Tugino [9], if the grain size of sand has the same size (uniform) then the volume of sand will be large. Conversely, if the size of the grains of sand varies, it occur small pore volume. This is because small grains will fill the pores between large grains so that the pores become slightly or in other words high congestion. In making paving block required sand that has granules with a high compression or which has a small pore volume.

3.3. Results test strong press

Results calculation test strong press on object test ages 7, 14 and 28 days at the show on Figure 3.

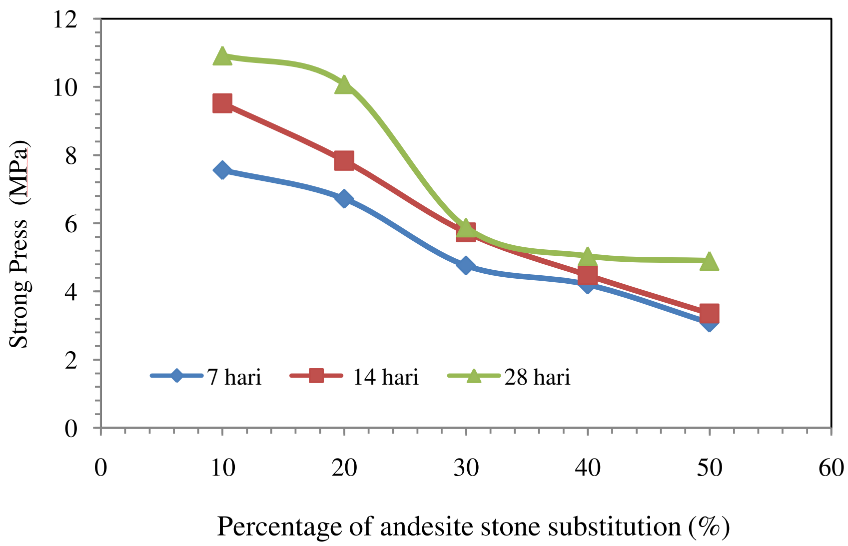

Figure 3. Relation percentage of andesite rock substitution with strong press paving block at age 7, 14 and 28 days

Figure 3 showing substitution relationship between the percentage of andesite with a compressive strength of paving blocks namely that the compressive strength of the paving block decreases with the addition of andesite stone content in the mixture. The highest compressive strength occurs in 10% andesite rock substitution, then the compressive strength will decrease to 50% of andesite substitution. The decrease in compressive strength of paving block in this study was due to the amount of SiO_2 content in the mixture disproportionate/excessive. SiO_2 is mostly contained in sand and andesite stones. In accordance with a study carried out by Hambali [10], the SiO_2 compound reacts with Ca $(OH)_2$ and produces calcium hydrate (CSH) which contributes to hardness in the paving block. The binding reaction of $Ca(OH)_2$ by SiO_2 takes place as follows.

$$x\,Ca(OH)_2 + SiO_2 + nH_2O \rightarrow xCaO.SiO_2.nH_2O \quad (3)$$

The excessive SiO_2 content will bind to the free CaO contained in the cement and form Ca $(OH)_2$.$Ca(OH)_2$causes reduced *paving block* density due to the formation of air cavities. These air cavities will be filled by water during the sample immersion period. $SiO_2$is the C_3S and C_2S forming oxide which is the main component in the cement. When C_3S and C_2S react with water again form Ca $(OH)_2$ compounds. The ongoing reaction is shown in equation 4 and 5 that is:

$$2(3CaO.SiO_2) + 6H_2O \rightarrow 3Ca(OH)_2 + 3CaO.2SiO_2.3H_2O \quad (4)$$

$$2(2CaO.SiO_2) + 6H_2O \rightarrow Ca(OH)_2 + 3CaO.2SiO_2.3H_2O \quad (5)$$

Therefore, the higher percentage of andesite rock substitution causes the compressive strength of the paving block to decrease. In addition, other factors that affect the compressive strength of the paving block are FAS (Cement Water Factor). The water-cement factor (FAS) is a number that shows the ratio between the water weight and the weight of the cement. In high-quality concrete, the definition of FAS can be defined as water to cementitious ratio, ie the ratio of water weight to total weight of cement and cementitious additives commonly added to high quality concrete mixtures [11]. FAS used in this research is 0.8, in accordance with the statement Mulyono [12] generally a minimum FAS value is given about 0.4 and a maximum of 0.65. The low water-cement factor is the most decisive factor in producing high quality paving blocks, with the aim of reducing to a minimum the porosity of the resulting paving block. The larger the water-cement factor (FAS) creates the lower the compressive strength of the concrete [11]. However, too low a water-cement factor (FAS) results in insufficient cement paste to coat aggregate [13].

4. Conclusion

Based on results research could be concluded that s increasing the substitution of andesite rocks makes the compressive strength of the paving block to decrease. This matter was due increasingly substitution stone andesite cause SiO_2 content increases. Gynecology SiO_2 the excess will bind to the free CaO contained in the cement and form $Ca(OH)_2$. $Ca(OH)_2$ causes reduced paving block density due to the formation of air cavities. These air cavities will be filled by water during the sample immersion period. In addition, other factors that affected the compressive strength of paving blocks namely FAS (Factors Water Cement) is high and gradation size sand.

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