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Cite as: AIP Conference Proceedings **2232**, 050006 (2020); https://doi.org/10.1063/5.0002382
Published Online: 22 April 2020

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The Characterization and Physical Properties of Paving Block Products over Basalt Minerals

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Abstract. This study assessed the effect of paving blocks product using basalt minerals with variation concentration. The raw material for producing paving blocks such as cement, sand, andesite, and water. The paving block was made with and without basalt over concentration 5 %, 15 %, 25 %, and 35 %. The powder was sifted using mesh sieve of 60 and 80. Then, the paving block product was analyzed by XRD, XRF. The analysis physical properties of the paving block such as compressive strength (SNI 03-2493-1991), density (ASTM D-854), absorption (SNI 1969-2008), porosity (SNI 1969-2008). The characterization from XRD showed the formed phase such as Gismondine, Calcite, C-S-H, and Quartz. Based on the XRF characterization, the content of CaO was decreased in the paving block because of the addition of basalt as a cement substitute. The results from compressive strength showed a paving block without basalt addition has 8.612 MPa compressive strength and 8.89 % absorption. While the addition of a basalt concentration of 5 % with 60 mesh has compressive strengths of 9.684 MPa and absorption of 9.29 %. With basalt concentration 10 % over 80 mesh, it compressive strengths of 9.748 MPa and absorption of 9.48 %.

INTRODUCTION

The industrial sector is one of the important sectors of economic development in Indonesia. Various types of industries have experienced rapid development. Especially, one of the developing industries is the construction industry [1]. With infrastructural development in Indonesia, the demand for paving blocks is increasing day by day. Paving blocks for floors are artificial stamping stones that are well known in the community and are widely used for building needs [2]. The process of making paving blocks which is mostly in Indonesia is a home industry with a conventional suppression system and uses a hydraulic press machine [3]. Paving blocks are mainly used for sidewalks, pedestrians and sidewalks. In addition, it can also be used in special areas such as container port areas, parking lots, open areas and industries [4].

Basalt stones can be used in the construction sector. According to the Energy and Mineral Resources, Data and Information Center of mineral resources in 2011 found that there were 5.571.251.56 tons of non-metallic mineral resources in Indonesia. According to sources from Mining and Energy Agency Lampung, deposits of basalt are scattered in Lampung amounted to 318.480.000 tons. A large amount of reserves so far has only been used as a basis for housing construction [5]. In Lampung province, basalt stones are dispersed in various districts, one of them is in East Lampung district with the characteristic of having a hollow shape [6]. Basalt is a type of igneous rock formed from the freezing of magma on the surface of the earth, it's alkaline, and has blackish gray color [7-8]. Basalt stone mostly used only as a foundation for roads, bridges, buildings, and as an aggregate. The composition of basalt stone such as 56,15 % SiO_2, 17,37 % Al_2O_3, 4,62 % Fe_2O_3, 8,25 % CaO, 6,90 % MgO, 3,28 % K_2O, 0,99 % TiO_2 and 0,46

Proceedings of the 3rd International Seminar on Metallurgy and Materials (ISMM2019)
AIP Conf. Proc. 2232, 050006-1–050006-6; https://doi.org/10.1063/5.0002382
Published by AIP Publishing. 978-0-7354-1991-9/$30.00

% MnO_2 [9]. Basalt stone can be used as a pozzolan because of the high composition of $SiO_2 + Al_2O_3 + Fe_2O_3$ more than 70 %, according to ASTM C 618-92a. Silva et al., [10] have investigated using fly ash as additional material on concrete at 20 % and it shows increase compressive strength until 16.198 %. Ahirrao et.al., [11] have reported that incorporating 20 % of waste glass in place of sand in concrete paving block gives acceptable mechanical properties and replacing of 25 % fly ash against cement, provides desirable compressive strength and flexural strength. In this study, we assessed the effect of paving blocks product using basalt minerals with variation concentration. The size of the paving block was $5 \times 5 \times 5$ cm^3. It was tested for compressive strength, density, absorption, and porosity.

MATERIAL AND METHODS

Material

Basalt stone was obtained from Mataram Baru, East Lampung. Composite Portland Cement (PCC) from Baturaja, sand from Maringgai, East Lampung, coarse aggregate in andesite stone form from South Lampung, and water.

Paving Block Processes and Product Characterization

Basalt stone was prepared by destroying the stone over jaw crusher and grinding in the ball mill for 3 h. Then, the powder was sifted using mesh sieve of 60 and 80. The raw material composition of paving block with the ratio of cement: sand: coarse aggregate (1:3:3.5, and 100 ml of water). The weight variation of basalt concentration of 5, 15, 25, and 35 % and also without basalt addition. First, the paving block was created by mixing all ingredients in each composition into a mixer container. Then, add water into the mixer and stirred until homogenous. After that, put the mixture into a cube size ($5 \times 5 \times 5$ cm^3). The sample was dried for 24 h and moved from the mold. The sample was put into a bucket filled with water and left for 14 days. After 14 days, the sample of the paving block was tested for compressive strength, density, absorption, porosity, and fuel shrinkage. Then, the paving block was analyzed by XRD (PANalytical X'Pert^3) and XRF (XRF Epsilon^{3XLE}). The physical properties of andesite stone and sand as aggregates based on ASTM and SNI standard with the following the type of test such as density (ASTM D-854), absorption (SNI 1970-2008), moisture Level (ASTM D-2216), mud Level (SNI 03-2461-2002) [12-15]. The physical properties of the paving block such as compressive strength (SNI 03-2493-1991), density (ASTM D-854), absorption (SNI 1969-2008), porosity (SNI 1969-2008) [15-17].

RESULTS AND DISCUSSION

Characterization of Basalt Mineral

The composition of basalt mineral is listed in Table 1. As can be seen in Table 1, basalt compounds have the highest oxide compounds such as SiO_2 of 48.463 %, Al_2O_3 of 20.143 %, Fe_2O_3 of 11.510 %, CaO of 9.608 %, and MgO of 4.269 %. The amount of SiO_2+Al_2O_3+Fe_2O_3 basalt mineral reach 80.116 %, it indicated the chemical requirement as cement substitution material or pozzolan, which is the requirement for pozzolan is the content of SiO_2+Al_2O_3+Fe_2O_3 higher than 70 % (ASTM C618-92a) [18].

TABLE 1. The composition of basalt mineral

Oxide Compounds	Percentage (%)
SiO_2	48.463
Al_2O_3	20.143
Fe_2O_3	11.510
CaO	9.608
MgO	4.269
TiO_2	3.559
K2O	1.266
P_2O_5	0.605
MnO	0.195
Total of $SiO_2 + Al_2O_3 + Fe_2O_3$	80.116

The XRD spectra of basalt mineral as shown in Fig. 1. The diffractogram of basalt mineral is dominated by the phase of anorthite (2θ= 27.7879°), augite (2θ= 29.7377°), forsterite (2θ= 29.4753°), and quartz (2θ= 26. 6691°). This phase consists of compounds such as calcium, silica, alumina, iron oxide, and magnesium. The results are also supported by XRF analysis.

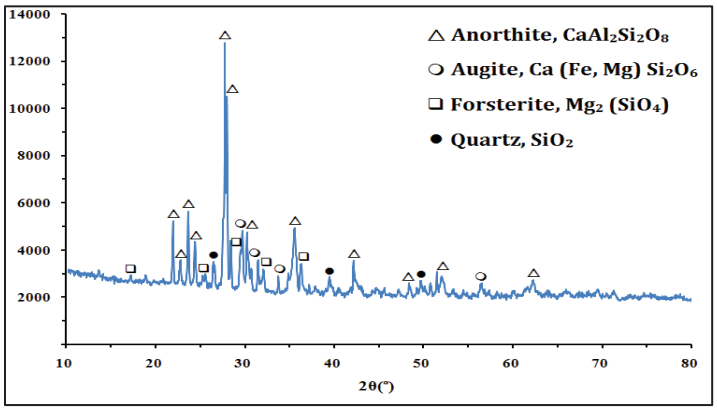

FIGURE 1. XRD pattern of basalt mineral

The Physical Test of Andesite Stone and Sand

The physical test of andesite stone and sand are shown in Table 2. From Table 2, andesite stone and sand showed that overall fulfill the standard as aggregate for paving block mixture.

TABLE 2. Andesite stone and sand physical test result

Test	Sand	Andesite Stone
Density (gr/cm^3)	2.53	2.57
Absorption (%)	9.49	2.04
Moisture Level (%)	3.66	1.33
Mud Level (%)	3.69	0.95

The XRF Characterization of Paving Block

The composition of the paving block is shown in Table 3. The results showed that the paving blocks which have substituted with mineral basalt contain the highest compounds such as CaO with the concentration of basalt 5 % at 60 mesh and 80 mesh was 38.884 % and 39.098 %. While the lowest compound of CaO in paving block with a concentration of 35 % at 60 mesh and 80 mesh was 33.903 % and 34.094 %. The reduced compound of CaO caused by an increase in the percentage of basalt powder as a substitute for cement so that the use of cement decreased. The other highest compounds are SiO_2, Fe_2O_3, and Al_2O_3. The other compounds with a percentage below 2 % such as SO_3, MgO, TiO_2, K_2O, and MnO.

TABLE 3. The compositions of paving block

Oxide Compounds	Basalt Mineral Substitute Percentage (%)				
	Standard	Mesh 60		Mesh 80	
		5	35	5	35
CaO	51.265	38.884	33.903	39.098	34.094
SiO_2	31.202	39.791	44.953	39.836	44.991
Fe_2O_3	7.791	10.682	10.678	10.724	10.772
Al_2O_3	5.489	5.018	4.619	5.025	4.679
SO_3	1.023	1.589	1.597	1.603	1.615
MgO	0.924	1.286	1.380	1.298	1.385
TiO_2	0.812	1.250	1.372	1.287	1.376
K_2O	0.769	0.897	0.916	0.925	0.931
MnO	0.247	0.136	0.124	0.149	0.135

The XRD Characterization of Paving Block

The diffractogram of a paving block are shown in Fig. 2 and 3 with various concentration of 0 %, 5 %, and 35 %, with 60 and 80 mesh. From Fig. 2 and 3 with various concentrations, it can be seen that the phases formed are Gismondine ($CaAl_2Si_2O_8 \cdot 4H_2O$), Calcite ($CaCO_3$), C-S-H ($1.5CaO \cdot SiO_2 \cdot xH_2O$) dan Quartz ($SiO_2$).

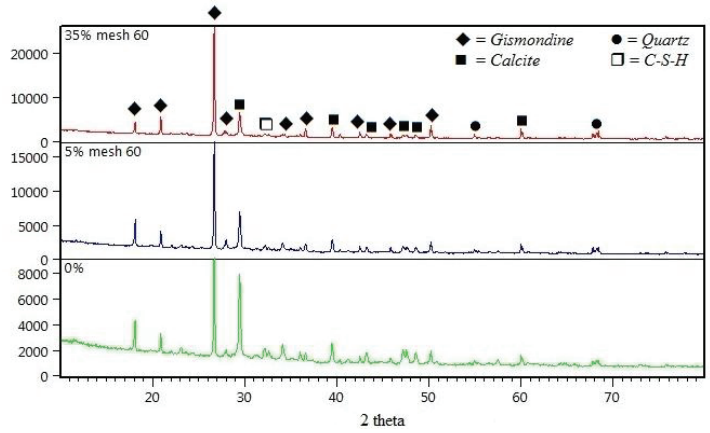

FIGURE 2. XRD pattern of the paving block with 60 mesh

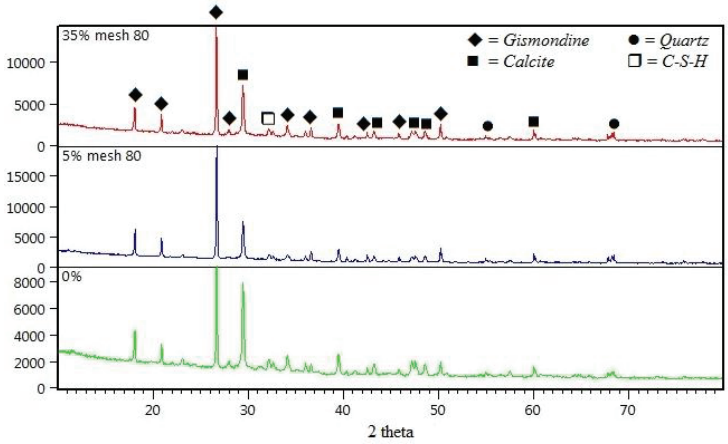

FIGURE 3. XRD pattern of the paving block with 80 mesh

Physical Test of Paving Block

The Compressive Strength of Paving Block

The compressive strength of the paving block is shown in Fig. 4. A compressive strength test was carried out on the test of paving block material (5 x 5 x 5) cm^3 with 14 days of dyeing age over a compressive strength testing machine. The results show that the compressive strength of the paving block standard of 8.612 MPa. The compressive strength of paving block with variation concentration basalt (5 %, 15 %, 25 %, and 35 %) at 60 mesh was 9.684 MPa, 9.684 MPa, 6.876 MPa, 4.520 Mpa, and 2.068 MPa, respectively. Then, with variation concentration basalt (5 %, 15 %, 25 %, and 35 %) at 80 mesh, the result of compressive strength was 9.748 MPa, 7.056 MPa, 5.084 MPa, and 2.884 MPa, respectively. It shows that basalt with variation concentration affects the compressive strength of the paving block. The decreasing in compressive strength of the paving blocks in this study was caused by excessive amounts of SiO_2 in the mixture. The excessive amount of SiO_2 will strap of CaO in the cement and form of $Ca(OH)_2$. $Ca(OH)_2$

caused paving block density decreases due to the formation of the air cavities. This cavity will be filled with water during the dyeing period of the sample. Therefore, the higher percentage of basalt substitution causes the compressive strength of lower paving blocks. The compressive strength of a paving block is affected by the age of the paving block, the cement water factor (FAS), the density, the amount of cement paste, the type of cement and the aggregate properties.

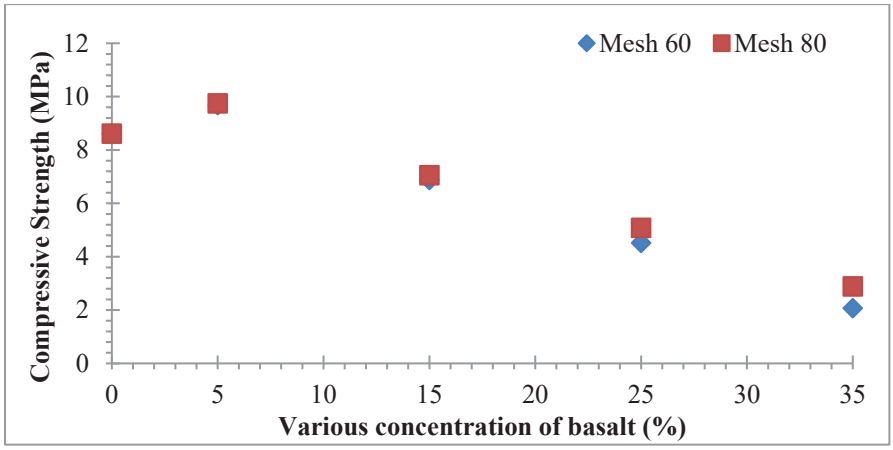

FIGURE 4. The compressive strength of the paving block with various concentration of basalt

The Density of Paving Block

Density test has been done on (5x5x5) cm^3 paving block material test with 14 days of immersion age. The density of the paving block is shown in Fig. 5. The density test of paving block material (5 x 5 x 5) cm^3 with 14 days of dyeing age. The result shows the density of paving block with basalt powder concentration of 5 %, 15 %, 25 % and 35 % at 60 mesh was 2.80 gr/cm^3, 2.72 gr/cm^3, 2.58 gr/cm^3, and 2.36 gr/cm^3, respectively. While at 80 mesh, the density of paving block was 3.00 gr/cm^3, 2.83 gr/cm^3, 2.67 gr/cm^3, and 2.50 gr/cm^3, respectively. The results of density are directly proportional to the results of the compressive strength of the paving block. This is because the soft aggregate volumes are used which makes it easier and faster to pass through or absorb water. To be fewer aggregates bonded with Portland cement, paving block pores should be larger. Between the porosity and density are interconnected. With greater of the porosity, the density will smaller because the many pores are inside.

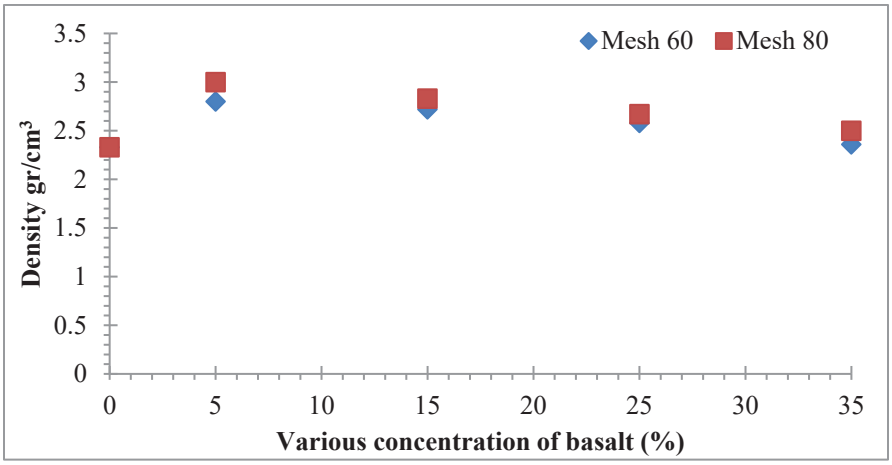

FIGURE 5. The density of the paving block with various concentration of basalt

The Porosity of Paving Block

The Porosity of the paving block is shown in Fig. 6. The standard porosity of the paving block was 0.77 %. The result shows the porosity of paving block with basalt powder concentration of 5 %, 15 %, 25 % and 35 % at 60 mesh was 0.84 %, 0.99 %, 1.05 %, and 1.07 %, respectively. While at 80 mesh, the porosity of the paving block was 0.87 %, 1.03 %, 1.11 %, and 1.13 %, respectively. The higher compressive strength showed the lower of the porosity. The porosity describes the size of the power to install paving block construction. Paving block solid showed a higher density, and it has greater compressive strength or the quality of the paving block [19].

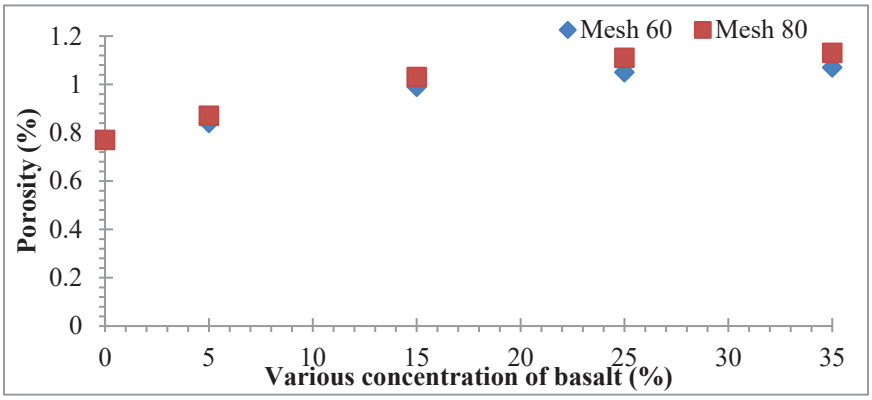

FIGURE 6. The porosity of the paving block with various concentration

CONCLUSION

The diffractogram of basalt mineral is dominated by a phase of anorthite, augite, forsterite, and quartz. The characterization of the paving block showed that the phases formed were gismondine, calcite, C-S-H, and quartz. The compressive strength showed the paving block without basalt addition has 8.612 MPa compressive strength and 8.89 % absorption. While the addition of a basalt concentration of 5 % with 60 mesh has compressive strengths of 9.684 MPa and absorption of 9.29 %. With basalt concentration 10 % over 80 mesh, it compressive strengths of 9.748 MPa and absorption of 9.48 %.

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