

The material from Lampung as coarse aggregate to substitute andesite for concrete-making

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Abstract. Andesite stone is usually used for split stone material in the concrete making. However, its availability is decreasing. Lampung province has natural resources that can be used for coarse aggregate materials to substitute andesite stone. These natural materials include limestone, feldspar stone, basalt, granite, and slags from iron processing waste. Therefore, a research on optimizing natural materials in Lampung to substitute andesite stone for concrete making is required. This research used laboratory experiment method. The research activities included making cubical object samples of 150 x 150 x 150 mm with material composition referring to a standard of K.200 and w/c 0.61. Concrete making by using varying types of aggregates (basalt, limestone, slag) and aggregate sizes (A= 5-15 mm, B= 15-25 mm, and 25-50 mm) was followed by compressive strength test. The results showed that the obtained optimal compressive strengths for basalt were 24.47 MPa for 50-150 mm aggregate sizes, 21.2 MPa for 15-25 mm aggregate sizes, and 20.7 MPa for 25-50 mm aggregate sizes. These results of basalt compressive strength values were higher than the same result for andesite (19.69 MPa for 50-150 mm aggregate sizes), slag (22.72 MPa for 50-150 mm aggregate sizes), and limestone (19.69 MPa for 50-150 mm aggregate sizes). These results indicated that basalt, limestone, and slag aggregates were good enough to substitute andesite as materials for concrete making. Therefore, natural resources in Lampung can be optimized as construction materials in concrete making.

1. Introduction

Lampung has mineral resources which can be used as industrial materials, but mineral optimizing in Lampung is not yet optimal because minimum information for industry players related to those minerals. Natural minerals that can be used as materials for industries include limestone, granite, feldspar, basalt, and iron. These minerals, if they are optimized, can substitute split stone coming from andesite. This andesite split stone is usually used as a material for concrete making, but its availability in nature is decreasing.

Concrete making technology development is closely related to using local potentials which are needed to be improved to be more useful for local people [1]. Previously “ape” stone from North Sulawesi was used as a non-sand concrete aggregate material with the ratio of 1:6 by using cylinder object sample and it produced 7.67 MPa compressive strength, which was applied to non-sand conblock concrete [2]. Another concrete making research used fly ash, slag and limestone which were mixed with PCC cement and they produced 41.37 MPa compressive strength [3]. The concrete making by using fine aggregate from limestone (25%) and sand (100%) in West Sumba Island in the form of cylinder object sample of 15 x 30 cm at 28 days of testing age produced the compressive strength of



28.28 MPa and tensile strength of 2.92 MPa [4]. High strength concrete making by using sand and gravel aggregate from North Sulawesi in the form of cubical object sample of 150 x 150 x 150 mm at 28 days of testing age produced a compressive strength of 62.64 MPa. These research results indicate that the longer the age of testing, then the stronger is the compressive strength value [5].

The next concrete making used the following compositions. Composition A: CEM= 300 gr, water = 150 ml, sand of 0.4 mm = 603 gr, limestone 4-31 mm = 1344 gr and super plasticizer = 1.8 gr; composition B: cement= 108 gr, fly ash = 162 gr, water = 139 ml, sand of 0.4 mm = 656 gr, and super plasticizer = 3 gr; and composition C: cement = 108 gr, fly ash = 162 gr, water = 139 gr, sand of 0.4 mm = 400 gr, slag 4-31.5 mm = 1628 gr, and super plasticizer = 3 gr. The testing object sample was in the form of cubic of 150 x 150 x 150 mm. The compressive strength values for composition A, B, and C was 23.9 MPa, 30.7 Mpa, and 33.7 respectively. The flexural strength values for composition A, B, and C was 30.6 Gpa, 35.7 Gpa, and 39.3 Gpa respectively MPa respectively, while the specific gravity test results for composition A, B, and C were 2346 kg/m³, 2358 kg/m³, and 2782 kg/m³ [6]. The coarse aggregates of river gravel and split gravel and sand fine aggregate were used for making cylindrical concrete of 10 mm and 20 mm height. The results of compressive strength values of 3, 7, 14, and 28 days showed that at 28 days, the concrete by using split gravel aggregate produced the highest compressive strength value of 30.74 MPa and 24.60 MPa for the concrete using river gravel [7].

The brick waste from demolished building could be recycled and reused as coarse aggregate material for concrete. It was made in the form of cubic of 40 x 40 x 60 mm and it was tested for compressive and flexural strength at 28 days. The results were 35.73 MPa of compressive strength and 6.63 MPa of flexural strength [8]. Types of cement and aggregates influence concrete compressive strength. A research was done on cement types of Portland type I (PC I), pozzolan Portland (PPC), composite cement (PCC) with gravel and split stone aggregates of max 20 mm. The concrete object sample was cubic of 150 x 150 x 150 mm with the testing age of 3, 7, 28, and 90 days. The compressive strength test results showed that the highest values were obtained at 90 days for gravel aggregate and cement of PC I = 49.78 MPa, PPC cement = 52.50 MPa, and PCC cement = 54.67 MPa. The compressive strength values for split stone aggregate and PC I cement = 54.36 MPa, PPC cement = 56.67 MPa and PCC cement = 57.47 Mpa [9].

Volcanic ash from volcanic mountains could be used as concrete mixture based on micro silica by making the following mixture compositions. Composition A = cement paste + fine aggregate (sand) + coarse aggregate (small size gravel); composition B = cement paste + 100 mesh volcanic ash + sand aggregate + small size gravel aggregate; composition C = cement paste + micron volcanic ash + sand aggregate + small size aggregate with ratio of 1:5; composition D= epoxy resin + micron volcanic ash + sand aggregate + small size gravel aggregate with ratio of 1:5; and composition E = epoxy resin + micron volcanic ash + fine aggregate + small gravel aggregate with ratio of 1:3. All composition were made into the cylindrical concrete of 27.5 mm and 55.0 mm height. It was dried in an autoclave for 2 hours at 121°C and then heated in the oven at 100°C for 24 hours. Compressive strength test results for composition A, B, C, D, and E were 36.72 MPa, 52.23 MPa, 62.14 MPa, 801.73 Mpa, and 850.50 Mpa respectively. Standard value for normal concrete is 196.1 – 490.3 kgf/cm² and high quality concrete is > 490.3 kgf/cm² [10].

Solid waste from construction in the form of small size concrete fragment could be used as coarse aggregate for concrete making. Concrete object samples of 10 x 10 x 40 cm were made with the following compositions; composition A = 50% waste, water = 7.90 kg, cement = 17.37 kg, sand 25.73 kg, split stone = 26.77 kg, waste 4.76 kg; composition B: water = 7.90 kg, cement = 25.73 kg, split stone = 26.77 kg, and waste = 9.51 kg. The compressive strength test was conducted at 3, 7, and 28 days. Compressive strength results at 3 days for composition A and B were 2.14 MPa and 1.61 MPa respectively. Compressive strength result at 7 days for composition A and B were 2.93 MPa and 2.40 MPa respectively. Compressive strength result at 28 days for composition A and B were 4.00 MPa and 3.33 MPa respectively [11]. In the concrete construction, 75% of the volume is aggregate; both rough and fine aggregates. There are two types of aggregate. Fine aggregate (sand) is less than 5 mm and

coarse aggregate (gravel/split stone) is more than 5-63 mm. The higher the aggregate size, the smaller is the surface width to wet with water, so that it will reduce cement water factor and produce increasing compressive strength of the concrete (Figure 1 and Figure 2). The best maximum size of aggregate to concrete compressive strength with different cement contents is aggregate size more than 38.1 mm [12].

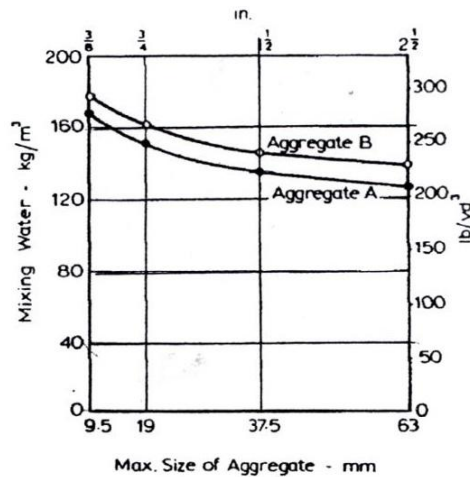


Figure 1. The influence of aggregate size to concrete compressive strength [12]

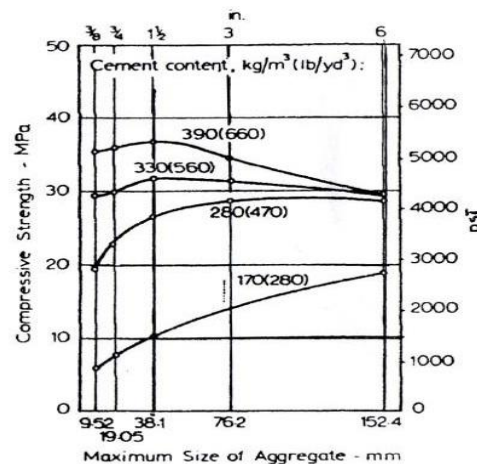


Figure 2. The influence of aggregate size to water need [12]

Conducting specific gravity test and water absorption test of the concrete and aggregate, the tests should in accordance with SNI procedure number 1969:2008 about the procedure of specific gravity test and water absorption of coarse aggregate [13]. The size of coarse aggregate influences concrete's compressive strength. Split stone sizes are divided into 5-10 mm, 10-20 mm, 20-30 mm, and combination between these three sizes. The compressive strength test results on the concrete samples of 150 x 150 x 150 mm showed that concrete mixture by using 5-10 mm split stone produced 31.63 MPa compressive strength; concrete mixture by using 10-20 mm split stone produced 32.75 MPa compressive strength; and concrete mixture by using 20-30 mm split stone produced 36.08 MPa compressive strength; and combined aggregates of split stone produced 38.29 MPa compressive strength value. The compressive strength test results which were converted into 28 days of concrete age showed improvement; where 7 days concrete improved 43%, 14 days concrete improved 13%, and 21 days concrete improved 5.1%. Sand Equivalent Test is a method to use to find out the relative

proportion of clay material containing of 4.75 mm passing filter aggregate as it is shown in Figure 3 [14].

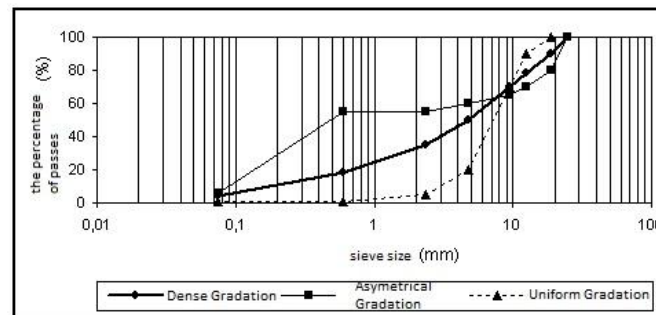


Figure 3. Types of aggregates [14]

2. Research methods

This was an experimental laboratory research by using the following parameters.

- Coarse aggregate variations: andesite, granite, slag, limestone, feldspar, and basalt.
- Aggregate size variations : A= 5-15 mm, B= 15-25 mm, and 25-50 mm
- Water/cement factor, $w/c=0.61$
- Compressive strength tests at 14 days
- Cubical object sample of 150 x 150 x 150 mm (3 sample for each variation)

Materials used came from Tanjung Bintang. Aggregate materials and PCC cement came from Lampung province. Tools were one set of the sieve to analyze sand gradation, concrete mixing machine, balance, cubic molding, laboratory glass equipment, and compressive strength test machine (universal testing machine).

The research steps were as follows:

- Material preparations included taking aggregates, milling and filtering them by using sieves of # 15 mm, # 25 mm, and # 50 mm.
- Material testing included sand testing (tests of gradation, specific gravity, water absorption, and mud content) and coarse aggregate testing (tests of specific gravity and water absorption).
- Making concrete object sample by weighing materials, mixing, stirring, molding, and removing from the molding by referring to the composition of K.200 and $w/c = 0.61$.
- Maintaining concrete object samples in humid condition by covering the objects with a wet cloth for 14 days after they were made.
- Testing the object samples' compressive strengths with Universal Testing Machine.
- Analyzing testing result data to obtain conclusions from studied variables.

3. Results and discussions

3.1 Fineness Modulus of Sand

The influence of fine aggregate (sand) to resulted concrete quality is measured based on whether the concrete quality complied with requirements or not. The concrete quality is analyzed with Fineness Modulus of Sand to find out the fineness or hardness values of a particular aggregate. Fineness or hardness of aggregate will influence concrete paste adhesiveness. Too fine sand at the concrete mixture will make the fine parts will be lifted to the upper mixture and this will reduce concrete paste adhesiveness level. Data of Fineness Modulus of Sand analysis results are presented in Table 1.

Table 1. Results of fine aggregate gradation analysis

Sieve hole size (mm)	Retained weight (gr)	Retained weight (%)	Cumulative weight (%)	Passing sieve cumulative weight (%)	ASTM C 33 requirement
4.75	1.68	0.34	0.34	99.66	95-100
2.36	39.55	7.91	8.25	91.75	80-100
1.18	90.85	18.18	26.43	73.57	50-85
0.60	138.42	27.70	54.13	45.87	25-60
0.30	122.43	24.50	78.63	21.37	10-30
0.15	91.13	18.24	96.86	3.13	2-10
the rest of the sieve	15.64	3.13	-	-	
Sum	499.70	100	264.65	335.35	

The estimation of Fineness Modulus of Sand (FMS) (1)

$$\text{FMS} = \frac{\text{total of cumulative weigh}}{100} = \frac{264.65}{100} = 2.64\% \quad (1)$$

The values of Fineness Modulus of Sand (FMS) show that the gradation of sand coming from Tanjung Bintang belongs to moderate sand (FMS = 2.20 – 2.60% = fine sand, FMS = 2.60 – 2.90% = moderate sand, FMS = 2.90 – 3.20% = coarse sand). Considering the fineness level of the sand coming from Tanjung Bintang, the sand from Tanjung Bintang meets the requirement of fine gradation of ASTM with fineness modulus $\geq 2.30\%$ and $\leq 45\%$ (at a particular size of sieve), so that it can be used as a fine aggregate material for concrete making. The highest value from sand gradation test results with the percentage of retained weight is 27.70% with a sieve size of 0.60 mm. Further, the fine aggregate should also meet some requirements or characteristics as they are presented in Table 2.

Table 2. The characteristics of sand from Tanjung Bintang (in %)

Characteristics	Value	Requirement
Mud content (%)	4.13	< 5
Specific gravity (gr/cm ³)	2.50	-
Water absorption (%)	9.15	-
Fineness Modulus of Sand	2.65	1.5-3.8
Water content (%)	2.09	-
Bulk Density (gr/cm ³)	1.21	-

Table 2 shows that the sand from Tanjung Bintang, South Lampung district, has mud content 4.13% and it is below SII 0052 requirement value (< 5%). The water absorption value is 9.15% and it complies with the requirement that it does not exceed 10%. These results show that the sand from Tanjung Bintang can be used as fine aggregate for concrete making.

3.2 Water Absorption

Coarse aggregates in this research come from varying minerals coming from Lampung which include granite, feldspar, andesite, basalt, limestone and slag from iron smelting waste. The coarse aggregate quality is valued based on the values of water absorption and specific gravity. The water absorption and specific gravity tests are conducted based on SNI 1969:2008. The testing results are presented in Table 3.

Table 3. The results of water absorption test of coarse aggregate mineral coming from Lampung

Types of coarse aggregate	Water absorption test (%)			Aggregate surface condition
	Size A	Size B	Size C	
Andesite	1.89	0.56	0.42	Coarse
Granite	2.07	1.52	0.95	Coarse
Slag	0.32	0.22	0.04	Slippery, glassy
Limestone	0.37	0.21	0.13	Coarse
Feldspar	1.20	1.19	0.71	Coarse
Basalt	3.62	3.05	2.63	Rough with holes

Note: Size A = 5-15mm. Size B = 15 – 25 mm. Size C= 25 – 50 mm

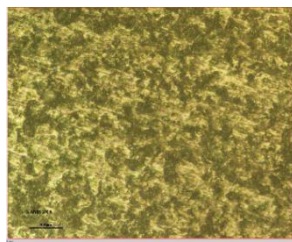
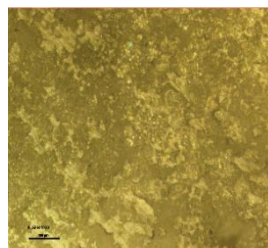
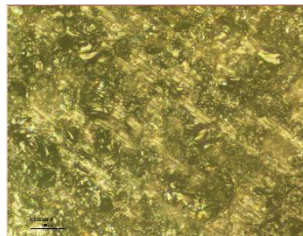
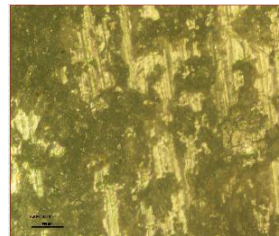
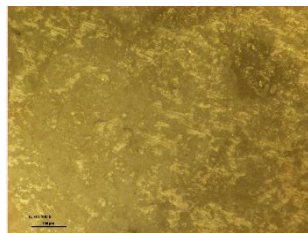
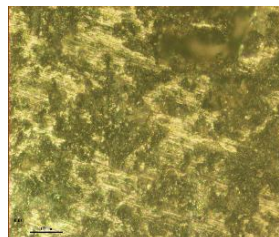
**Figure 4.** Andesite surface**Figure 5.** Granite surface**Figure 6.** Slag surface**Figure 7.** Limestone surface**Figure 8.** Feldspar surface**Figure 9.** Basalt surface

Table 3 shows the slag water absorption value is the lowest value compared to other coarse aggregates (andesite, granite, limestone, feldspar and basalt) for all sizes of A, B, and C. This is because slag has a very smooth and glassy surface and it has small pores so that water is less absorbed into the slag. Basalt has higher water absorption compared to other types of minerals. The water absorption values of basalt for size A, B, and C are 3.62%, 3.05% and 2.63%, respectively. This is because basalt has rough surface and holes so that water is easy to enter basalt and it makes high water absorption. Water absorption on pores aggregate is 5-20% and 2% for coarse aggregate. The water absorption value will influence concrete making. The higher the pores numbers, the more water is required in concrete making. The water amount or water ratio will influence the duration of concrete drying and concrete thickness. In addition, concrete compressive strength and wear resistance will be reduced because of aggregate porosity. So that aggregate granule resistance ability against cement will be reduced. The influence of size according to Table 3 shows a tendency that the bigger the aggregate

size, the smaller is absorption ability. This tendency occurs in all types of aggregates. This is because of the bigger the aggregate size in a stone form, the smaller is the surface or the lesser is the pores so that water is less absorbed. The smaller the size of a stone, the wider and the more is the surface so that more water will be absorbed by more pores. An aggregate with the coarse surface will have more absorption ability than an aggregate with a slippery surface.

The cut section images of aggregates to use in this research were taken by using a microscope to see the surface differences between these 6 types of aggregates clearer. The results are presented in Figure 4 to Figure 9.

3.3 Specific Gravity

The specific gravities of coarse aggregates are presented in Table 4.

Table 4. The results of specific gravity test of coarse aggregates from Lampung

Type of coarse aggregate	Specific gravity (gr/cm ³)	Aggregate surface condition
Andesite	2.69	Coarse
Granite	2.61	Coarse
Slag	2.72	Slippery. glassy
Limestone	2.73	Coarse
Feldspar	2.47	Coarse
Basalt	2.44	Rough with holes

Table 5. The compressive strength test results of coarse aggregate from object samples at 14 days with composition of K.200 and w/c = 0.61

Types of aggregates	Compressive strength test (MPa)			Aggregate surface condition
	Size A	Size B	Size C	
Andesite	19.69	18.93	14.39	Coarse
Granite	16.16	14.89	14.64	Coarse
Slag	22.72	14.64	13.13	Slippery. glassy
Limestone	19.69	18.68	8.58	Coarse
Feldspar	18.93	16.91	12.12	Coarse
Basalt	24.74	21.20	20.70	Coarse with holes

Note: Size A = 5-15mm. Size B = 15 – 25 mm. Size C = 25 – 50 mm

Table 4 shows that basalt mineral has the lowest specific gravity of 2.44 gr/cm³. This is because basalt has pores and holes so that the porosity of basalt makes its light weight. Limestone and slag have higher specific gravities because they have small pores and high densities. The level of density makes bigger weight. The more mass weight increases specific gravity. Higher density makes the stone weightier. The higher the mass, the higher is the specific gravity. The higher the specific gravity of coarse aggregate used in concrete making, the weightier is the produced concrete and vice versa.

The concrete strength or the concrete compressive strength is also influenced by types and sizes of aggregates. Table 5 shows mean results of concrete compressive strength test with the material composition of K.200 and w/c = 0.61 at 14 days in the form of cubic object sample test of 150 x 150 x 150 mm by using Mykehan Farance universal machine test.

Table 5 shows that the highest compressive strength value is (24.74 MPa) obtained by the concrete using basalt aggregate with the size of 5-15 mm. The compressive strength values for concrete by using slag and limestone are 22.72 MPa and 19.69 MPa respectively. The compressive strength value for concrete by using andesite aggregate as a standard is 19.69 MPa. These results indicate that basalt, limestone, and slag aggregate with the size of 5-15 mm have higher compressive strength values than andesite, while granite and feldspar have lower values (16.16 MPa and 18.93 MPa respectively).

Table 5 shows that aggregate size A, B, and C have compressive strength value below 19.61 MPa according to standard K 200. Compressive strength values more than standard value occurs not only in basalt aggregate. The higher aggregate size, the lesser is the mixed paste coating the aggregate so that this causes lower compressive strength value. In basalt aggregate, mixed paste filling pores in aggregate so that it makes more compact and stronger concrete. The smaller the aggregate size according to the requirement of aggregate sizes, the more aggregate amount in the concrete and aggregate particles will mutually fill and bind each other. Mutually binding aggregates produce more compact, intense and stronger concrete compared to bigger aggregate sizes. Too many aggregate pores may also result in lower compressive strength value.

4. Conclusions

The best aggregate used as coarse aggregate in the concrete making is the basalt material with size 5-15 mm. Slag and limestone aggregates also have compressive strength values which are more than andesite material (19.69 MPa). Compressive strength values of feldspar and granite aggregates are lower than 19.61 MPa. Therefore, basalt, limestone, and slag materials as coarse aggregate in the concrete making have a good quality of compressive strength. The research results show that industrial materials from Lampung (especially basalt) can be optimized to be aggregate material for concrete making.

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