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Study of Petrography and Physicomechanical Characteristic of Batu Angus Lava, Mount Gamalama, Ternate Island, Indonesia : Implication for Its Uses as Construction Material

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Abstract. One of the sources of building materials in the Ternate area is Batu Angus. In the present study, the determination of the usage quality of Batu Angus as a construction material in accordance with the standards was carried out through several tests. The analysis carried out in this research was in the form of petrographic analysis as well as physical property and mechanical property analysis. Based on the physical properties testing, the effective density of Batu Angus was 2.53-2.81 gr/cm^3 and the absorption value was 1.42-2.00 %. Based on the analysis of its mechanical properties, the compressive strength of Batu Angus was 533.74-574.65 kg/cm^2 and wear resistance was 28.64-52.11%. The main mineral compositions of Batu Angus include plagioclase, pyroxene and groundmass. The rock encompassed micro porphyry aphanitic, inequigranular, hyalopilitic, and vesicular textures. Based on the engineering value, texture and mineralogical characteristics, Batu Angus can be used as per the SNI 03-0394-1989 standard as light building materials foundation, curbstone, pavements, as well as decorative stone in construction activities.

INTRODUCTION

Volcanic products have been used globally as source of natural aggregates to build and maintain the continuously expanding infrastructures in the world. Back to ancient Greek and Roman times, volcanic product as aggregate have been utilized as a construction material to road pavement. In fact, natural aggregates from volcanic product consisting crushed stone, gravel and sand, are globally the most important raw material used in construction industry.

Local residents that live around Batu Angus has been utilizing the rocks as aggregates in the constructions of civilian buildings and roads. The consumption of this rock is now increasing, driven by the rapid development of infrastructure and construction activities. Aggregate is the bulk material used as a construction material for both structure and infrastructure [1]. The use of natural ingredients in the form of aggregates is due to its easy access and low cost [2]-[3]. Excessive exploitation of aggregates (crushed stone) results in a decrease in quality and quantity [3]. Other uses of aggregates include portland cement, asphalt concrete, road construction, asphalt mixtures, filters for water purification, as well as materials for railroad ballast, landslide stabilization and slope stability [2],[4],[5]. In an asphalt mixture, the aggregate must have high strength against pressure from friction and impact, and be resistant to the effects of atmospheric temperature [1].

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The use of coarse aggregate has advantages such as a higher level of strength and less requirement of binder to achieve a certain level of strength. In this case, the use of coarse aggregate material in a pavement layer can be reduced with the same quality performance [1]. According to Koukis et al [2] and Korkanç & Tuğrul [4], the quality of an aggregate as a construction material is determined by the properties of the parent rock including its texture and mineralogical characteristics. Batu Angus is usually used in aggregate form. Previous research [6] reported that Batu Angus is generally composed of mafic minerals with the main constituent consisting of silica (28.98%) and iron (9.49%). To determine the feasibility of Batu Angus to be used as a supporting construction material, several analyzes need to be carried out in order to optimized its used. Some of the analyzes that was be carried out to achieve the objectives of this study were petrographic, physical and mechanical analysis.

EXPERIMENT

Research Area Geology

The research area is located in the north-eastern part of Ternate Island, precisely in Tabam and its surroundings, North Ternate district, Ternate City. This location is the place where the Batu Angus spreads, a rock formation formed from the freezing lava of from the eruption of Mount Gamalama in 1907 [7]. The morphology of Mount Gamalama is divided into the foot, body and peak areas. The foot is formed from the deposition of volcanic rock erosion, which has a relatively flat morphology. The body part, where Ternate City resides, is composed of volcanic breccia, tuff and sand. In this city there are two sources of freshwater, namely the lagoon lake and the Tolire Jaha lake which is the crater of Mount Gamalama. The slope is about 8 - 40%. While the peak morphology is characterized by a slope > 40% and an altitude above 1000 m [8]. Mount Gamalama is one of the mountain ranges formed in the Halmahera arc [9,10]. The formation of this mountainous arc was due to the subduction of the Maluku sea under the Halmahera islands [11].

Analytic Method

Sampling was carried out at the location where the Batu Angus lava was found (Figure 1 and 2). Determination of the quality of Batu Angus lava as a construction material was done by performing several testings of petrographic analysis, physical, and mechanical properties analysis. Texture and mineralogical characteristics of the research sample were determined by observing parallel and crossed nicols using a Trinocular Polarization Microscope package model LV100POL + DS-Ri1 - U3 + NIS BR. This analysis was carried out at the Geology laboratory, Geological Engineering, Hasanuddin University. Analysis of physical properties using specific gravity and absorption testing was carried out at the Laboratory of Structures and Materials, Civil Engineering, Khairun University. Meanwhile, the determination of mechanical properties was done using the Los Angeles Abrasive Value and Uniaxial Compressive Strength (UCS) methods. The Los Angeles Abrasive Value (LAAV) test was carried out at the Khairun University Structure and Material Laboratory, while the Uniaxial Compressive Strength test was carried out at the Geomechanics Laboratory, Mining Engineering, Hasanuddin University. The testing of physical and mechanical properties was carried out based on standards [12] listed in Table 1. The results of the analysis were then correlated in order to obtain recommendations for optimal use of Batu Angus lava based on building quality standards [13].

TABLE 1. The standards test used

Type of testing	ASTM standard number
Density and Absorption	C-127
Los Angeles Abrasion Value	C-131
Uniaxial Compressive Strength	D-2938-95

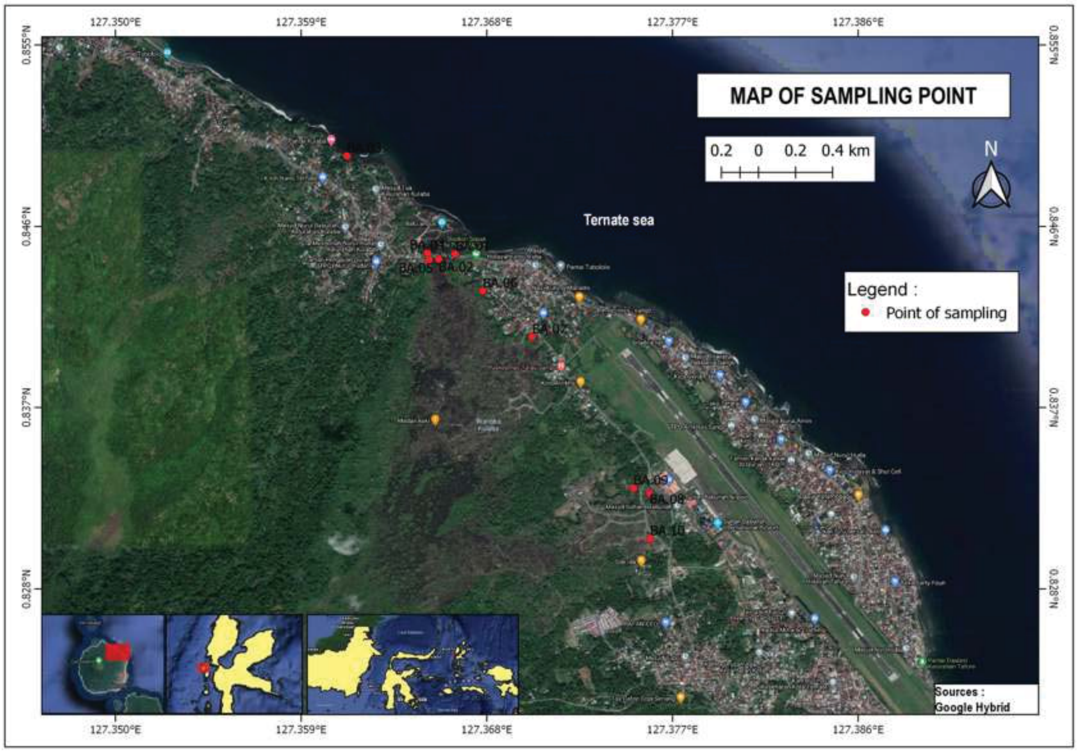

FIGURE 1. Map of sampling locations

FIGURE 2. Batu Angus appearance at the research location, a) Station BA.03, b) Station BA.05, c) Station BA.10

RESULTS AND DISCUSSION

Petrographic Features

Microscopic analysis results of Batu Angus are as shown in Figure 3. Generally, these rocks were micro porphyry aphanitic, inequigraular and vesicular with a phenocrystic composition of plagioclase (Pl) and pyroxine (Prx). Phenocrysts of plagioclase is <3 mm in size, euhedral-subhedral form, labradorite and slightly andesine in composition. Mostly, plagioclase is generally still fresh, although in some parts it has been corroded. Pyroxene phenocrysts mainly found as clinopyroxene whereas orthopyroxene group were smaller in size. These phenocrysts are surrounded by groundmass of microcrystalline plagioclase, mafic minerals (pyroxene), ore minerals and glass minerals (amorphous), showing a hyalopilitic texture. Accessory minerals consists of magnetite (Mt) minerals, iron oxides replacing pyroxene and magnetite, and clay-sericite (Ser) minerals which occur as alteration product of plagioclase. Based on the classification [14] from its mineral composition and texture, Batu Angus is classified into Basalt Rocks.

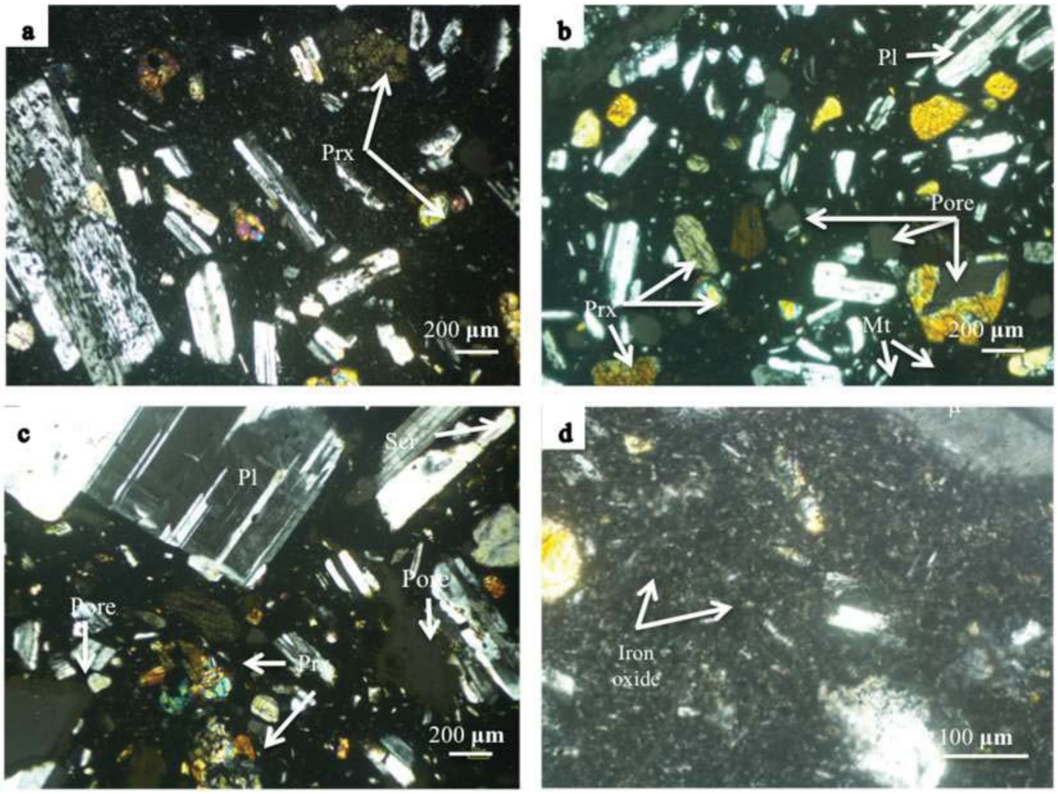

FIGURE 3. Photomicrographs (XPL) of Batu Angus from Mount Gamalama, Ternate : a) and b) Micro porphyry aphanitic texture with plagioclase (Pl) and pyroxene (Prx) phenocrysts surrounded by groundmass (sample BA.03 and BA.05), c) vesicular texture and altered phenocrysts plagioclase (Pl) to sericite and pyroxene (Prx) to iron oxide (sample BA.05), d) groundmass forming a hyalopilitic texture (sample BA.10).

Physicomechanical Properties

Physical (specific gravity or density and absorption) and mechanical properties (UCS and LAAV) on Batu Angus lava are shown in Table 2. The effective density of Batu Angus samples was 2.53-2.81 gr/cm^3. Sample from station BA.03 show the highest effective specific gravity (2.81 gr/cm^3), while the lowest effective density (2.53 gr/cm^3) was found in sample from station BA.10.

TABLE 2. Physical and mechanical properties tests summary of Batu Angus

Sample	Physical properties					Mechanical properties	
	Bulk density (gr/cm^3)	SSD density (gr/cm^3)	Apperent density (gr/cm^3)	Effective density (gr/cm^3)	Absorption (%)	UCS (kg/cm^2)	LAAV (%)
BA.03	2.75	2.79	2.86	2.81	1.42	533.74	28.64
BA.05	2.59	2.64	2.73	2.66	2.00	574.65	50.56
BA.10	2.47	2.51	2.59	2.53	1.94	574.04	52.11

The water absorption values ranges from 1.42% to 2.00%. The results of the UCS analysis showed the compressive strength of Batu Angus was 533.74-574.65 kg/cm^2. The compressive strength of BA.05 and BA.10 were almost the same (574.65 kg/cm^2 and 574.04 kg/cm^2), respectively. LAAV test results indicate the level of resistance to wear and fragmentation. LAAV values ranges for Batu Angus was 28.64-52.11%.

Correlation Mineralogy with Engineering Properties

The result of the abrasion test showed a highest value in BA.03. This was influenced by the presence of pores in the rock. Petrographic analysis in BA.03 showed the number of pores was less than the other samples. The existence of these pores is related to the texture of the rock in the form of vesicles. This texture is formed from the gas content trapped when basalt lava freezes. The less pore content in the rock, the higher resistance to weathering and abrasion processes will be. This is consistent with the report of Kazi and Al-Mansour [15] which stated that the level of abrasion and weathering of a rock aggregate is influenced by the grain size and volume of the space between pores in an igneous or acidic rock. Batu Angus, which is a basalt rock formation, when crushed, tends to form angular shales. However, the angled shape can produce a denser quality of concrete [4]. Batu Angus BA.03 with LAAV 28.64% (<40%) fulfills the requirements to be able to be utilized for uncovered road surface layers [16] and can also be used as aggeragat for foundation layers, sub-foundation layers and road material layers [17].

This rock aggregate density test obtained a fairly large value. This value was influenced by the mineral content of the rock. From petrographic observations, there were pyroxene and magnetite mineral contents present, which had an average density of > 3. The specific gravity of the minerals will affect the density of the aggregates. Aggregates with high density can exhibit segregation when used as concrete mixtures [4,18]. Meanwhile, the absorption value is also related to the resistance of a concrete aggregate material. Aggeregate generally has porous properties. These aspects need to be considered, especially when an aggregate is going to be used as a surface layer that binds to the asphalt. According to Shakoor et al. [19], absorption values > 3% are likely to suffer damage due to freeze-thaw phenomenon. Aggregates that are too porous when used as a mixture with an asphalt binder will tend to produce a dry mixture. Tests carried out on the samples all showed absorption value lower than 3%.

The UCS value obtained was 533.74-574.65 kg/cm^2. Compressive strength of an aggregate form does not always correlate with its intact form. This is because the effective strength of an aggregate is influenced by its shape and size [20,21]. The UCS of BA.03 has a lower value than BA.05 and BA.10. This is probably influenced by the presence of fractures in the rock. The value of the compressive strength affects the quality of the aggregate, especially when the aggregate is used as a mixture of concrete in building construction. Bieniawski [22] summarized the quality classification of a rock based on a single axis compressive strength value as seen in Figure 4. From the results of the

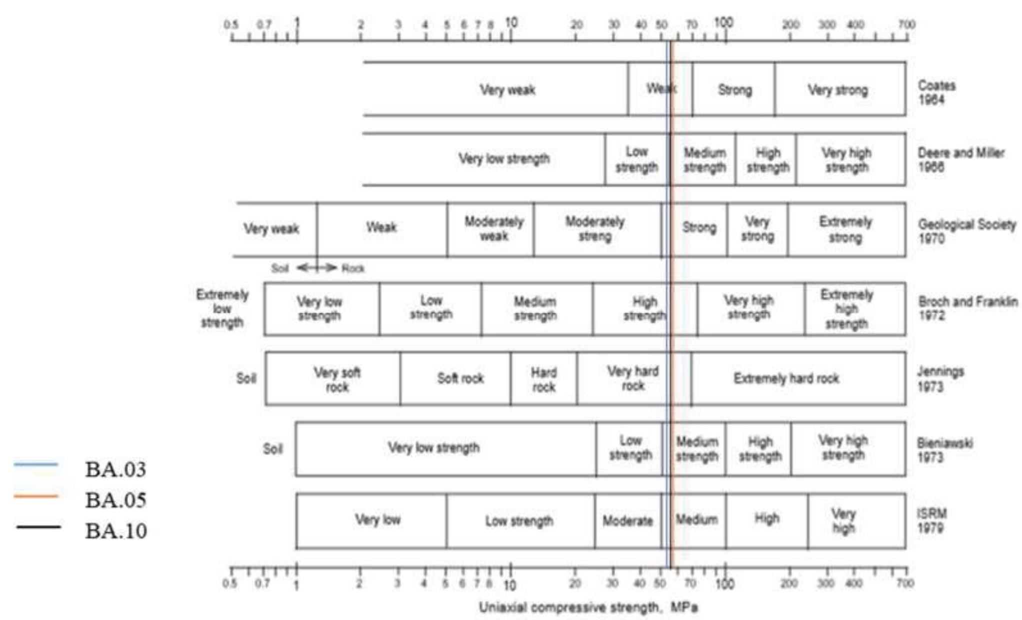

FIGURE 4. Classification of the quality of Batu Angus rocks of Mount Gamalama [22]

UCS test, it is known that the compressive strength value of BA.03 was 533.74 kg/cm^2, BA.05 was 574.65 kg/cm^2, and BA.10 was 574.04 kg/cm^2. Based on engineering classification [23] shown in Figure 4, the three samples of Batu Angus are included in the medium strength category.

Based on the comparison of results of the physical and mechanical properties of the samples and the SNI 03-0394-1989 [13] standard (Table 3), in general, Batu Angus can be used as a foundation for light building materials, pillars and curb stones, floor coverings, and decorative stones.

TABLE 3. Batu Angus Quality as per SNI 03-0394-1989 [13]

PARAMETER	NATURAL STONE UTILIZATION						BA.03	BA.05	BA.10
	BUILDING FONDATION			CURB STONE	FLOOR COVERINGS OR PAVEMENTS	DECORATIVE STONE			
	HEAVY	MEDIUM	LIGHT						
Uniaxial Compressive Strength min (kg/cm^2)	1500	1000	800	500	600	200	533.74	574.65	574.04
Los Angeles Abrasive, Strength maximum (%)	27	40	50	~	~	~	28.64	50.56	52.11
Bauschinger effect, mm/minute max	~	~	~	0.16	~	~			
Water absorption, max (%)	5	5	8	5	5	5* 12**	1.42	2.00	1.94
Resistance with Na_2SO_4									
a. Loss max	12	12	12	12	12	12			
b. Cracks, breaks, defects			No cracks and defects						

CONCLUSION

Batu Angus Lava, Mount Gamalama, Ternate Island has micro porphyry aphanitic, inequigranular and vesicular texture characteristics. Mineral contents were of plagioclase and pyroxene phenocrysts, ore minerals, sericite, iron oxides and glass minerals. The rock had an effective density of 2.53-2.81 gr/cm^3, with a maximum absorption value < 3 % (1.42-2.00 %), abrasive value (LAAV) of 28.64 – 52.11 % and a compressive strength of > 500 kg/cm^2. In general, the rocks can be used as materials for buildings, pavement, pillars and curb stones, as well as decorative stones.

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