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THE X-RAY DIFFRACTION (XRD) ANALYSIS OF BASALT FROM MATARAM BARU VIA SLOW AND RAPID COOLING PROCESS

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ABSTRAK

Telah dilakukan proses peleburan batuan basalt dari daerah Mataram Baru, Lampung Timur dengan menggunakan tungku tegak mini dengan temperatur tercapai sebesar 1600˚C. Batuan basalt terlebur dilakukan modifikasi proses pendinginan dengan metode pendinginan lambat dan metoda pendinginan cepat. Hasil pengamatan menunjukkan terjadi perbedaan yang signifikan antara 2 metoda pendinginan yang diterapkan pada batuan basalt cair tersebut. Melalui proses pendinginan lambat, didapatkan struktur kristal yang tidak berubah dari aslinya tetapi mempunyai karakteristik mekanis yang meningkat dibandingkan bahan asalnya, sedangkan melalui pendinginan cepat, didapatkan struktur kristal yang amorf dan sifat mekanis yang getas dari aslinya. Dari hasil yang diperoleh, kedua produk mempunyai potensi untuk digunakan sebagai bahan material lanjut. Dengan diterapkannya proses pendinginan lambat, batuan basalt mempunyai potensi digunakan sebagai material tahan gesek sedangkan dengan diterapkannya proses pendinginan cepat, batuan basalt mempunyai kecocokan untuk digunakan sebagai material dekorasi keramik maupun campurannya.

Kata kunci: Basalt, peleburan, pendinginan, cepat, lambat.

ABSTRACT

The process of melting basalt stone from Mataram Baru, East Lampung has been carried out over a mini shaft furnace with a temperature of 1600 ˚C. Basalt stone with the smelting process was modified with slow and fast cooling methods. Based XRD result shows the methods were significant applied to the liquid of basalt stone. By a slow cooling process, the crystal structure is unchanged from the original material but the mechanical characteristics increased. While by a fast cooling process, the amorphous crystal structure and weak mechanical properties are obtained from the original material. The results show, both products have a great potential to be used as advanced material. With a slow cooling process, it can be applied as a friction resistant material while by fast cooling method, the products can be used as ceramic materials.

Keyword: Basalt, smelting, cooling, fast, slow

INTRODUCTION

Basalt is a volcanic igneous stone that comes from the freezing of the basic composition of magma on the surface or near the surface of the earth, with a melting temperature around 1500-1700 ^{o}C [1-2]. It usually forms an oceanic plate in the world, blackish gray and smooth due to the rapid cooling of lava at surface temperature. Basalt stones are usually massive and hard, aphanitic textures, consisting of volcanic glass minerals, plagioclase, pyroxene, amphibole, and black minerals, this volcanic mineral content can only be seen in the type of quartz grain-sized basalt stone, which is a type of basalt stone called Gabbro [3]. Gabbro is a stone consisting of minerals in the form of olivine and pyroxene. While the feldspar consists of feldspar plagioclase Ca. Its texture is rough or phanerite because it has a long enough cooling time in the lithosphere. If it freezes faster because it reaches the surface of the earth, the igneous stones that occur are basalt with a fine texture. So gabbro and basalt both have the same mineral composition, but the texture is different [4].

The basalt stone process technology was divided into three (3) categories: basalt fiber, basalt cast, and ceramics which have been developed in eastern European countries, China and Germany. In Indonesia, the recorded basalt stone reserves are over 1 billion tons. The existence of basalt stone deposits spread in various regions in Indonesia, starting from Sumatra, Java, Kalimantan, Sulawesi, and Papua. In Lampung province, basalt stones can be found in the Mataram Baru, Jabung, Bumi Agung, Marga Tiga, Sukadana, and Labuhan Maringgai which are the districts of East Lampung. The total deposit of basalt stones in East Lampung exceeds 10 million m^3. The potential of basalt stones in the East Lampung district has not been used optimally [5]. From the observations at the mining site, the basalt stones in this location are mined in the traditional way. There are recorded several mining companies that carry out basalt stone mining activities. In the end, the result of processing basalt stone in East Lampung is still limited which is used in building construction or civil construction so that the added value is very low. The potential of basalt to be used as advanced materials are promising. With the correct technology of material processing, basalt can be applied to become substitution of metal consumption in various fields, such as construction with its bars composites for steel substitution, isolation and heat resistant by applying basalt to become basalt wool and cast basalt isolation and many more. To increase the value of basalt stone, it was usually carried out by conducting a heat treatment process, either until there is smelting or simply heating or modifying the cooling process. The heat treatment process was intended to obtain a good crystal structure by the re-crystallization method because the crystal formation is a functional group between the chemical composition during the melting condition and the cooling rate [6] so, that the mechanical basalt properties are better. Fan et al [7] investigated basalt and found the main mineral component was labradorite and anorthite. It was used X-ray diffraction to analyze basalt. Makhova et al [8] determined the melting temperature of basalt above 1450 ^oC and obtained the chemical composition of basalt. They used differential thermal analysis (DTA) and thermogravimetric analysis (TGA) to analyze the basalt. Dzhigiris et al [9] found a melting temperature in a range of 1175-1350 ^oC. according to Militky et al [10] and Deak et al [11], the main chemical composition of basalt is SiO_2 and Al_2O_3.

The objective of this research is studying the effect of slow and fast cooling methods in the process of smelting basalt stone. It will be analyzed with XRD to determine the differences that occur both of the characteristic properties and potential uses.

MATERIALS AND METHODS

Sample material

Basalt stone was obtained from Mataram Baru, East Lampung, Sumatera. With the sponge morphology of basalt rock, it easier to differentiate with another type of basalt rock which resembles andesite rock or gabbro.

Methods

The smelting process of basalt stone was carried out in a mini furnace with coke as a fuel. The preparation of basalt stone begins with the destruction of basalt stone to obtain dimensions of 3-5 cm. The reaction temperature was carried out in a batch system at a temperature of 1450 ^oC until 1600 ^oC. The liquid basalt pouring process was varied by the slow and fast cooling process. Then, the product was analyzed using XRD to determine the effect of the cooling process.

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Characterization of Basalt stone

The Crystallinity and phase of basalt stone were measured by X-Ray Diffraction (XRD: Panalytical Xpert 3 Powder XRD) with a Cu-Kα as a source of X-ray operating at 40 kV and 30 mA. The sample was scanned in the range 2θ of 0-80^o. The chemical compositions of basalt stone were characterized by X-Ray Fluorescence (XRF Epsilon 4 XRF Spectrometer from Malvern Panalytical) with operating at 50 kV and 3 mA.

RESULTS AND DISCUSSION

The preliminary preparation process of this study was to analyze basalt stone from Mataram Baru, East Lampung using XRD and XRF which can be seen in Figure. 1 and Table. 1. The difference between of basalt, andesite, and gabbro stone is very difficult to distinguish. Especially in the field, the stone types of each region have differences, thus increasing the difficulty in determining the classification of stones.

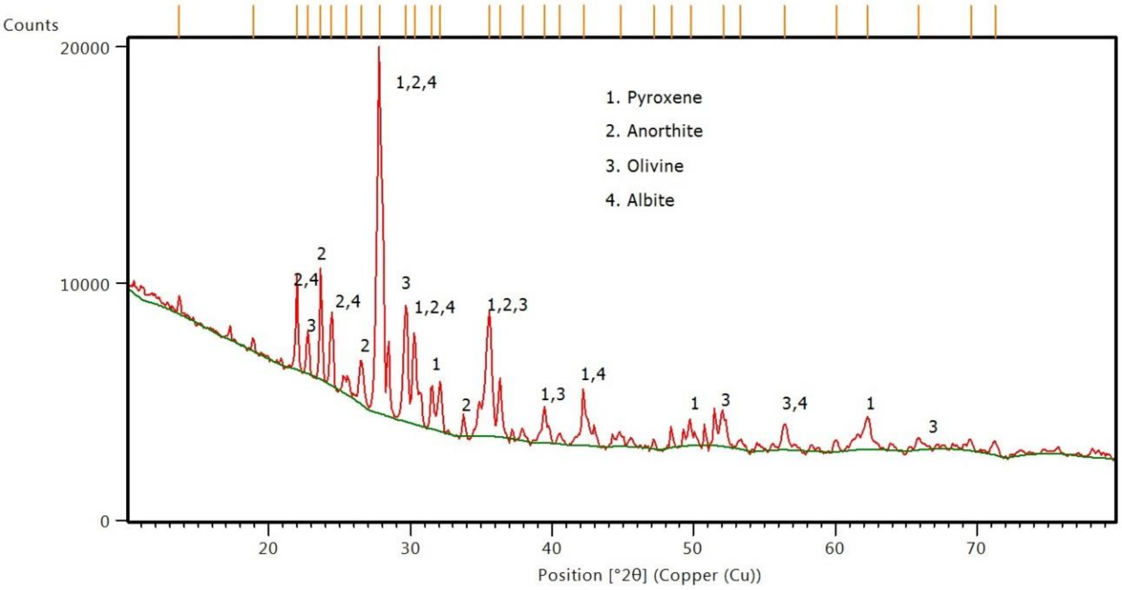

Figure 1. XRD analysis results of Basalt Mataram Mataram, East Lampung

Table 1. The characterization of Basalt Stone from Mataram Baru, East Lampung with XRF

Compound	Concentration	Unit	Compound	Concentration	Unit
Na	3,528	%	Na_2O	3,356	%
Mg	4.107	%	MgO	4,561	%
Al	15,527	%	Al_2O_3	18.82	%
Si	38,469	%	SiO_2	48,418	%
S	70.2	ppm	SO_3	90.8	ppm
K	1.038	%	K_2O	0.636	%
Ca	14.137	%	CaO	9,761	%
Ti	1.74	%	TiO_2	1,329	%
V	527.7	ppm	V_2O_5	418.7	ppm
Cr	907	ppm	Cr_2O_3	606.7	ppm
Mn	0.344	%	MnO	0.194	%
Fe	20,511	%	Fe_2O_3	12,595	%
Ni	488.5	ppm	NiO	237.6	ppm
Cu	238.2	ppm	CuO	116	ppm
Zn	307.9	ppm	ZnO	149.1	ppm

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Ga	40.1	ppm	Ga_2O_3	21	ppm
Rb	42.9	ppm	Rb_2O	17.7	ppm
Sr.	0.113	%	SrO	516.9	ppm
Y	37.3	ppm	Y_2O_3	18.2	ppm
Zr	183.5	ppm	ZrO_2	95.6	ppm
Sn	417.4	ppm	SnO_2	210.4	ppm
Te	160.3	ppm	TeO_2	80.4	ppm
Eu	0.137	%	Eu_2O_3	703.2	ppm
Re	37.5	ppm	IrO_2	9.9	ppm
Ir	22.1	ppm	Re	14.6	ppm

Based on Table 1, the main composition of basalt stone from Mataram Baru is SiO_2 which tends to be hard and brittle. It has 48.418% concentration and according to the Total Alkali-Silica (TAS) classification method that is recommended by the International Union of Geological Sciences (IUGS), generally for SiO_2 concentration in various weight percentage between 45–52%. Because basalt has a hard characteristic, it is not surprising in the field, basalt commonly used as a raw material for building or supporting construction. With simple technology applied such as the comminution process, basalt is ready to be used. As shown in Figure 1, the composition of basalt stone consists of pyroxene, olivine, and plagioclase (anorthite and albite) [12]. The two essential minerals of greatest importance are plagioclase and pyroxene since this makeup perhaps 80% of many basalts. The plagioclase involved is an intermediate member of the An-Ab series, and Bowen showed that a composition very near An_{50} occurs most frequently in basalts. The pyroxene is chiefly calcic, which is a member of the augite series, usually more magnesian than ferrous-rich (Mg/(Mg + Fe) > 0.5), and commonly not very far from diopside, although it ranges to subcalcic augite. Calcium-poor pyroxene, generally hypersthene, may or may not be present, depending on the abundance of silica relative to other constituents. Olivine is another critical mineral in basalt classification. In alkali basalt, it is commonly present instead of Ca-poor pyroxene. In olivine tholeiites, it is present in the company with Ca-poor pyroxene [3, 13].

As shown in Figure 2, the phase slices form the three types of stone are very identical, so advance analysis needs to be carried out such as analysis XRD and petrography. Generally, from chemical composition, we can determine the major differences in each type such as for andesitic rock have higher SiO_2 than the rest of rock. For basalt and gabbro, they almost have similarities such as for SiO_2, they're ranged between 45% to 52%, so it is not surprising if in the upper layer of we found basalt and in deeper layer gabbro was found. But for basalt rock, generally for mineralogy composition more homogenous. The difference between the two rock types is their grain size. Basalts are extrusive igneous rocks that cool quickly and have fine-grained crystals. Gabbros are intrusive igneous rocks that cool slowly and have coarse-grained crystals [14-15].

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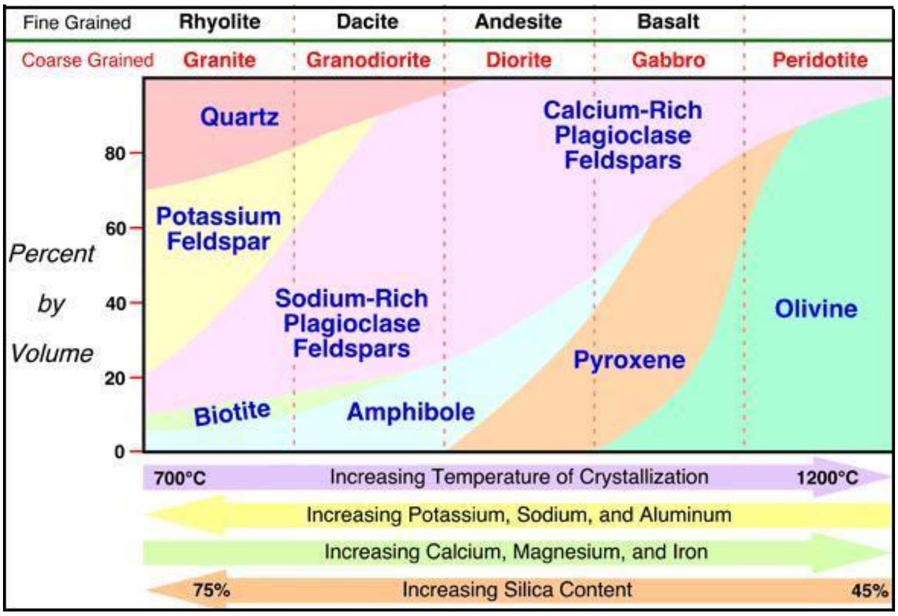

Figure 2. The petrograph classification of igneous stones [4]

The melting process of basalt stone as shown in Figure 3 was carried out in a mini shaft furnace with coke as a fuel. The smelting process begins by raising the temperature in a mini shaft furnace until it reaches a melting temperature of 1600 °C. Then, the furnace is heated with coke and blowing air supply from the blower. After the stable combustion is achieved, basalt stone is entered in a batch system mixed with raw coke materials with a ratio of 1:1.


Figure 3. The smelting process of basalt stone in a mini furnace at a temperature of 1500˚ C

The heating treatment process was applied when basalt liquid undergoes a tapping process. The variations in the cooling process of liquid were carried out to see the phenomena that occur in the results of casting products. As shown in Figure 4, the cooling process shows the product has the characteristic of black, not shiny, and lacking brightness. From mechanical properties of the product, basalt tend to have higher hardness and look more toughness when undergoing an impact

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treatment when the product is slammed down on the floor. Although it is not yet qualitative measurable, it is still give the potential to be used as friction-resistant material when basalt products are processed with correct advance processing.

Figure 4. Products with basalt casting with slow cooling

The XRD results of basalt with a slow cooling process are shown in Figure 5. The results show, the products with a slow cooling process have the same results from the original basalt stone. The phase formed on the casting product is not much different from the original basalt stone. However, the physical characteristic products harder and stronger than the original basalt stone. When each sample undergoes the same impact treatment at height 10 m, the sample with a slow cooling process has durable characteristics without breakage compared with raw basalt stones. The recrystallization process of basalt stone can improve the mechanical characteristic of products. Where the existence of the melting and cooling process, the atoms and atomic phases formed can be arranged and formed more perfectly with sufficient time allocation. With a slow cooling process, it give a lot of time for the atoms to formed more compact and shrink the distance between them so the result can improve the mechanical properties of basalt products [16]. With more time allocation, rearrangement of the atoms did not affect the re-establishment of the original phase which is a form in the basalt melting.

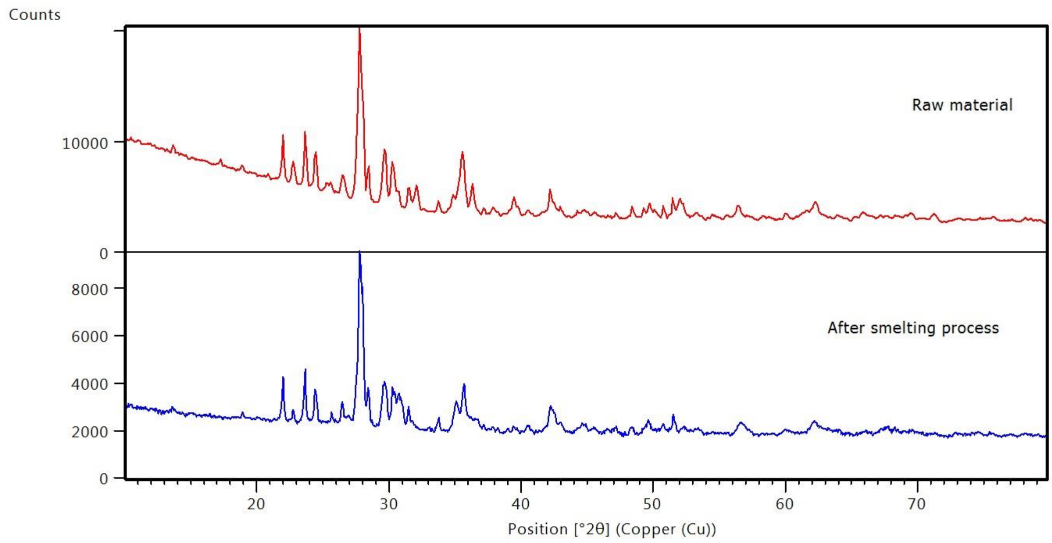

Figure 5. XRD analysis results between basalt stones before melting with melted basalt stones with slow cooling

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Furthermore, in the process of casting basalt stones with the fast cooling process, the liquid is put directly into the water. This causes the products become a small part. It is because the liquid still has a lot of heat energy so if the liquid suddenly cooled, it tends to break to release the energy stored. The physical products are green and shiny black with properties such as glass, as shown in Figure 6.

Figure 6. Results of basalt casting products with fast cooling process

From the results of the XRD analysis as shown in Figure 7, the fast cooling process products have amorphous characteristics like a glass product. The constituent of basalt stone is amorphous where only a few of the alpha phases are formed, iron and strontium. The atomic bonds become incomplete because there is not enough time to form and arrange the atoms so that the phase formed is amorphous. According to Zhang Y et al [16], at temperature 1500 ˚C, basalt melting still in the form of a glassy phase, it is still not homogenous in the form of fully liquid. If it wants to achieve full homogeneous, the melting temperature needs to be increased. At the basalt smelting process, when the liquid basalt undergoes a fast cooling process, the liquid still not fully melt, so when the liquid cools to room temperature, from amorphous structure still to be found incomplete crystallization in the form of the alpha phase. Based on Table. 1, the basalt stone from Mataram Baru, South Lampung has an abundant of iron content. It gives the potential for basalt casting products as raw material for glass and ceramic materials as a producer of a variety of colors [17]. For example, in glazed ceramic with the addition of basalt which is rich in a lot of minerals, when it heated and coat the surface of ceramic, it can give various patterns in the form of color degradation.

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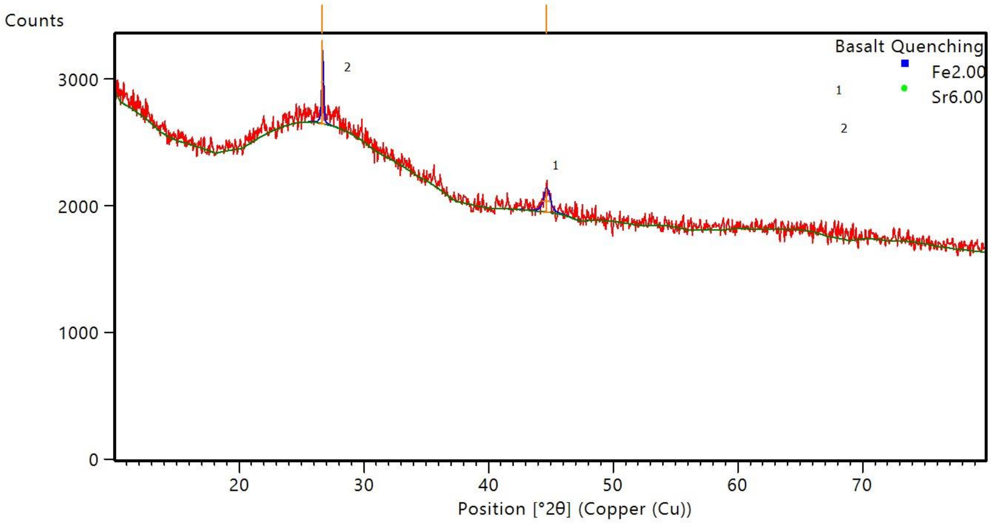

Figure 7. The analysis of XRD basalt stone casting products with rapid cooling.

CONCLUSIONS

The smelting process of basalt stone from Mataram Baru East Lampung has a variety of potential uses. By variation cooling methods (slow and fast cooling methods), the result has a significant difference. By slow cooling methods, the results show the characteristics of products harder than the original basalt stone. This lets the potential to be used as a friction-resistant material. The other process, fast cooling methods show the characteristic of basalt stone become like glass and have the potential to be used as ceramic raw materials because has abundant of minerals content.

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