IOP Conference Series: Materials Science and Engineering

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To cite this article: M Amin *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **478** 012038

IOP Conf. Series: Materials Science and Engineering 478 (2019) 012038 doi:10.1088/1757-899X/478/1/012038

Addition of feldspart minerals as a substitution material on ceramics clay manufacture

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Abstract. The use of clay minerals as the main raw material for pottery and sand additives has many weaknesses, among others, easy to crack, have high water absorption and low compressive strength. Therefore it is necessary to develop a better method of making traditional ceramics by providing additional materials such as mineral feldspar. Mineral feldspart can be used as a ceramic raw material because it is functional as filler and glass forming phases. Clay and mineral feldspart raw materials were analyzed using XRF method, followed by mixing with the composition of clay soil mixture as much as 65% compared to feldspart by 35%, printed with the shape of cube size 50x50x50mm. Drying in oven with temperature 110°C for 8 hours. Combustion in muflle furnace at temperature variation is 800ºC, 900ºC, 950ºC and 1000ºC and holding time is 2 hours, 3 hours, 4 hours and 5 hours. Test of compressive strength and porosity is done to see the physical properties of pottery ceramics and characterization by using XRF and XRD. The result of compressive strength test shows the temperature of 1000ºC with 3 hours reaches the optimum value of compressive strength which is 9.52 Mpa, while the porosity value reaches the optimum point at heating temperature 1000ºC with time of 5 hours that is equal to 16,19%. Characterization of XRF shows that ceramic pottery contains SiO_2 of 64.074%, and Al_2O_3 of 25.287% according to XRD characterization indicates the dominant phase formed by mineral quartz or silica oxside (SiO_2).

1. Introduction

Ceramic clay (earthenware) is a part of ceramics, this term in the modern context encompassing a very large inorganic material, ceramic clay containing nonmetallic and metallic elements made with various manufacturing techniques (the traditional ceramic is clay) that is burned at a certain temperature up tothe chemically has been transformed into a permanent form. The mechanical properties of ceramics clay are usually a strong material,hard but fragile and easy to broken. Furthermoreceramic claycorrosion resistance,have low density and high melting point. The quality of ceramic clay affected by raw materials used and temperature heating [1]. Main raw material of ceramic clayare clay or clay minerals. This is according to Jone et.al (2015), the quality of pottery depends on the physical properties of clay minerals as the main raw material and sand as an additional raw material [2]. In the wet conditions clay mineral have plastic properties, but in a dry conditionsbecome hard and when it burned become solid and strong [3]. The clay composed of oxide compounds such as SiO_2 and Al_2O_3 which are materials for the skeleton and form the ceramic body. Aplication of clay minerals as a main material for ceramic clay and sand as additives has many weaknesses,such as easy to crack, have high water absorption and have low compressive strength [4]. Therefore it is necessary to develop a better method of making traditional ceramics by providing additional materials such as mineral feldspart.Mineral feldspart can be used as ceramic material because it is functional as filler and glass forming [5]. Feldspart stone is the raw material needed for the production of ceramic tiles, household appliances, glazes, etc., because when it burned at temperature 1120-1300°C give effect of porosity change, bulk density and water absorption on pottery [6]. The industrial of ceramics and glass are the main consumers of feldspart. In the manufacture of glass, feldspart used as a flux agent and as a source of alumina (Al_2O_3), alkali (Na_2O and K_2O), and silica [7]. When ceramic clay mixed with feldspart minerals are molded and burnedthe microstructure will be changefrom the pottery product to mullite ($3Al_2O_3.2SiO_2$) and insoluble quartz crystal (SiO_2) that functioning into glass phase formation [8]. Based on the research of Indiani et.al (2009) the use of feldspart minerals in the manufacture of ceramics are useful as a melting agent to form glass phase at temperatures below 1100ºC [9]. Research conducted by Rivai (2016), reported that after passing temperature 600ºC physical and chemical clay will changes to be hard, solid and can't be destroyed by water [1]. This change is called ceramic change. This conclusion is reinforced by research conducted Ratri et.al (2008), at temperatures between 400-600°C chemically bonded water and other substances in clay minerals will evaporate [4]. After the temperature more than 600°C clay will change into a solid, hard and permanent mineral. In the range oftemperature 900°C the mullite phase will be formed. Mullite is a very stable compound that makes ceramic clay are hard, compact, and solid. So the ceramic clay has a high compressive strength and low absorption

2. Methode

In this research, raw material of clay used from Rejosari, Natar, Lampung Selatan, and the feldspart mineral from Nyukang Harjo, Lampung Tengah. Those raw materials were analyzed using XRF method as seen at theTable 1.

Table 1. XRF analysis results of the raw materials ceramic clay

	Chemical Composition (%)	
Elements	Clay	Feldspart
SiO_2	50.55	67.30
Al_2O_3	32.61	14.02
Fe_2O_3	2.43	2.24
K_2O	0.53	4.59
TiO_2	0.19	0.13
CaO	0.77	2.25
P_2O_5	0.14	3.20
NiO	0.12	0.020
SO_3	0.018	0.069
MnO	0.006	0.044
MgO	0.15	0.059
Cr_2O_3	0.003	0.015
SrO	0.002	0.020
PbO	0.004	0.006
CuO	0.001	0.007
Na_2O	1.05	0.005

Next, ceramic clay material is cleaned from impurities, dried in the oven with temperature 110ºC or with sunl for 3 hours and sieved with 20 pass mesh sifting.

Be pondered according to the mixing composition between clay and feldspart with ratio clay: feldspart = 65%:35%, stirring using mixer machine for 5 minutes with 10% water added from it weight.And printed with cube shape size 50x50x50mm. Drying in oven with 110ºC temperature for 8 hours. Heating in the muflle furnace at temperature variation of 800ºC, 900ºC, 950ºC and 1000ºC and the holding time 2 hours, 3 hours, 4 hours and 5 hours, It cooled and compressive strengthtested, at the Civil Engineering laboratory in University of Lampung, The porosity test and characterization with XRF and XRD methods were performed in the laboratory of BPTM – LIPI Lampung.

3. Result and Discussion

The results of ceramic clay compressive strength testing can be seen at the graphic bellow in Figure 1.

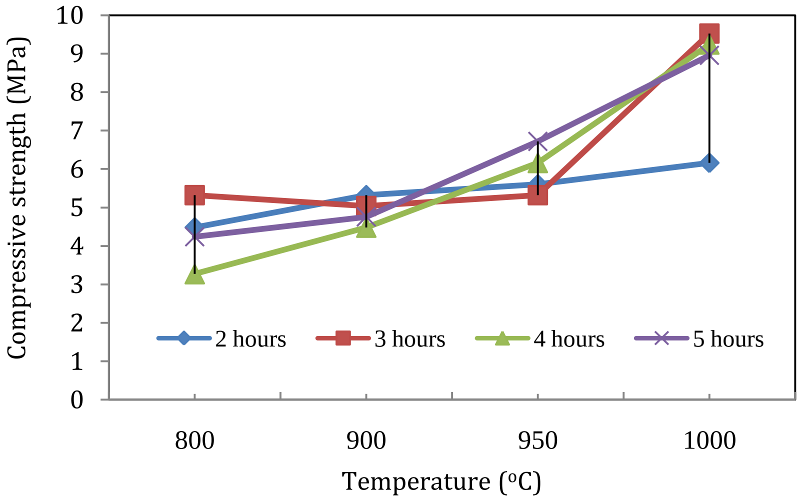

Figure 1. Graph of the comparison between compressive strength value to the temperature and heating time of ceramic clay

Testing porosity of physical properties in ceramic clay is to know the empty space in the sample. Yafie et.al (2014), reveals that shaft is an empty space or cavity formed in a compacting process that causes air to be trapped between powders during sintering [11]. The existence of a shaft inside a material will affect its mechanical properties. At 5hour variation time have porosity value respectively, at heating temperature 800ºC with 5 hours is 20.85%, its value down at heating temperature 900ºC with 5 hours is 20.43%, and back down at heating temperature 950ºC with 5 hours is 18.89% and reached the optimum value at heating temperature of 1000ºC 5 hours is 16.19%. The porosity value of an object greatly affects the value of its compressive strength. The more pores on the ceramic clay the strength of a material will decrease. The results of a study published by Gonggo et.al (2013) explain that the magnitude of the porosity value is due to the feldspart minerals that act as a fuser not yet completely fused to fill the cavities between the clay mineral granules [12]. Ceramic that have been heating at 900ºC still contain minerals from feldspart. To reduce the porosity of ceramic required combustion at temperatures above 900ºC, because the felders of feldspart begin to melt at a temperature of 900ºC-1100ºC. This is in accordance with this study, where the increasing temperature and heating time decreases the porosity percentage. Because there has been a good melting process to fill other pore spaces on ceramic, although the melting process has not been perfect.

Ceramic clay XRF characterization as performed to determine the amount of oxide contained in the sample in percent are presented in Table 2.

Table 2. X-ray fluorescence characterization results of ceramic clay with some variations of temperature and heating time.

Elements (%)	Heating Time (ºC)				
	800 (3 hours)	900 (3 hours)	950 (3 hours)	1000 (3 hours)	1000 (5 hours)
SiO_2	61.169	58.218	60.066	60.162	64.074
Al_2O_3	29.138	30.661	28.918	27.901	25.287
Fe_2O_3	4.863	5.208	5.252	5.732	5.358
TiO_2	0.732	0.742	0.779	0.732	0.719
CaO	0.641	0.961	1.182	0.681	0.635
K_2O	2.695	2.971	2.958	2.532	3.114
P_2O_5	0.466	0.477	0.488	0.481	0.469

Based on the analysis in Table 2, it is also known that the ratio of the highest compound content of SiO_2 and Al_2O_3 this proves that there is no significant phase change. For at each combustion temperature with 3 hours, the percentage of both compounds is in cosmetic numbers. At 800ºC temperature the amount of SiO_2 and Al_2O_3 is compounds 90.307%, at 900ºC the amount of SiO_2 and Al_2O_3 is compounds 88.899%, at 950ºC the amount of SiO_2 and Al_2O_3 is compounds 88.984% and at 1000ºC the amount of SiO_2 and Al_2O_3 is compounds 89.361%. The high compounds of Fe_2O_3, in the range 4.863%, 5.208%, 5.252% and 5.358% are the oxide that gives red color when heatting as evidenced in the reddish sample [12]. This is also supported by the XRD characterization results in the sample.

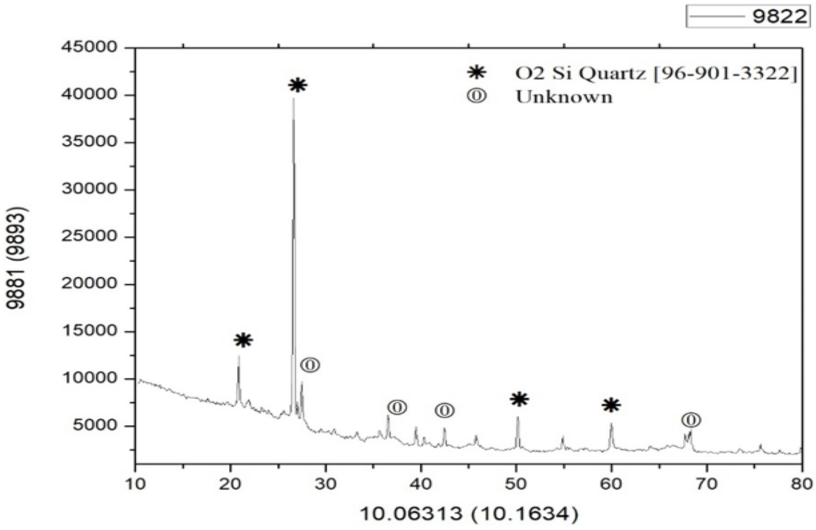

Figure 2. XRD Graph of ceramic clay with heating temperature 1000ºC 3 hours

The results of XRD characterization in temperature variation 1000ºC 3 hours indicating that the dominant phase formed just silica oxside (SiO_2) with the highest peak at $2\theta = 26.64^o$. The research of Ratri et.al (2008) also expressed opinion that regarding the formation of a mullite phase formed above a temperature of 1000°C [4]. But in this study,ceramic clayheatingat 1000ºC 3 hours only formed silica oxside. Based on the XRD graph, its known that the mullite phase ($2Al_2O_3.2SiO_2$) ceramic clay heating at 1000ºC 3 hours has not been formed. The glass phase is formed more by the feldspar grains ceramic clay will decrease on 1100ºC temperatures. The pores remained small the at 1150ºC, because the silica granules ocurs by causing more glass phase. At 1200ºC temperature, the ceramic body matures with a porosity almost toward zero. In the pseudomorphic form of the feldspar grains can be seen a large number of mullite needles formed resulting from alumina diffusing into the clay through the glass phase.

4. Conclusion

The value of the optimum compressive strength occurs at a temperature of 1000ºC with 3 hours time is 9.52 MPa. This is supported by the porosity value of 17.032%. Because the higher of compressive strengthvalue is that the lower of the porosity percentage. Based on of XRD analysisresultthat the heating optimum at 1000ºC with 3 hours and at 1000ºC with 5 hours mullite phase ($2Al_2O_3.2SiO_2$) not formed it just inversion change from low quartz to high quartz.

Acknowledgments

The authors are greatful the Head of BPTM - LIPI who has allowed the implementation of this research and provide support in the form of licensing the use of facilities and infrastructure needed in this study.

References

[1] Rivai M and Hartono S B 2016 *Jurnal TRAKSI* **16** 2
[2] Jone Y, Utamakno L, and Cahyono Y D 2015 *Jurnal Seminar Nasional Sains dan Teknologi Terapan III*
[3] Winarno T 2016 *Jurnal Teknik* **1** 37
[4] Ratri A K, Sriatun, and Darmawan A 2008 *Jurnal Kimia Sains dan Aplikasi* **11** 3
[5] Ajayi B A and Owoeye S S 2012 *International Journal of Science and Research (IJSR)* **3** 11
[6] Radomír Sokolář and Lucie Vodová, 2014 *International Journal Of Engineering And Science* **4** 10
[7] André C S, Sílvio D C, Débora N S, Elenice M, and Schons S 2018 *Journal of Material Reasecht and Technology* **2** 5
[8] Matthew G O and Fatile B O 2014 *Research Journal of Recent Sciences* **3** 9
[9] Indiani E, Ayu N, and Umiati K 2009 *Jurnal TELKOMNIKA* **7** 2
[10] Alaa S and Wijaya D 2015 *Jurnal Fisika* **1** 1
[11] Yafie M S and Widyastuti 2014 *Jurnal Teknik Pomits* **3** 1
[12] Gonggo S T, Edyanti F, and Suherman 2013 *Jurnal Akademika Kimia* **2** 2