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Effect of Grain Size on Selected Physico-Chemical Properties of Clay

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Abstract: Problem statement: Mixture of the right proportion of expanding and non-expanding clays to improve plasticity (moldability) of clays used in the pot industry of Malaysia is yet to be well investigated. In addition, little is known about the choice of the right clay size to eliminate or reduce the content of undesirable compounds such as Fe_2O_3, Al_2O_3 to improve the strength of pots and roofing tiles in the country. The objective of this study was to investigate how selected physico-chemical properties of pottery clay relate to grain size of Nyalau series ((Typic Paleudults). **Approach:** Soil samples were refined into 25, 20 and 63 µm using size grading method. The mineralogical composition of the samples was determined using X-Ray Diffraction (XRD). The chemical composition of the samples was also determined using standard procedures. Firing was done at 800°C) in a muffle furnace and the cracks of the samples recorded. **Results:** The clay particles with sizes 20 and 25 µm were higher in LOI and total C than that those of 63 µm regardless of grain size, the clay investigated had quartz (SiO_2), illite-montmorillonite, Anatase ((TiO_2) and kaolinite. Grading affected the concentrations of Fe, Al and Si as clays with particle sizes 20 and 25 µm had higher contents of the aforementioned elements compared with those of 63 µm. The clay with particles 63 µm had the best strength and this was so because the clay particles had the lowest amount of Fe, Al and Si. **Conclusion:** The strength of Malaysian pots could be improved upon proper grading of the clay particles.

Key words: Clay mineralogy, ceramics, Malaysia, x-ray, iron oxides, aluminum oxides

INTRODUCTION

The pottery and ceramic related industries in the world have been in existence for many centuries. This has been possible because of the exploitation of important soil resources such as soil colloids and minerals. There are different types of soil colloids (crystalline silicate clays, noncrystalline silicate clays) and minerals (feldspars, micas and so on) with different composition, structure and properties[1,2]. Kaolinite, an example of non expanding crystalline silicate clay, is abundant in the tropics including soils of Sarawak, Malaysia. Even though it is non plastic, it is commonly used in the pottery and other ceramic related industries as the nonexpanding nature allows it to be fired or dried in the process of making pots or roofing materials without cracking from shrinkage[1]. The pottery industry is not only lucrative in Malaysia, China, India and Thailand but also in the rest of the world probably because of the industry's close association with civilization. The household and antique values of pots and roofing tiles in both the developing and developed countries cannot be overemphasized. The socio-economic aspect or contribution of the pottery industry to the Malaysian economy does not deserve underestimation. For instance, a small to medium scale pottery firm can employ 55 workers. Additionally, the export production of kaolinite of these firms is greater than those of Japan, Taiwan and the Philippines. The combined kaolinite export of only 3 Malaysian firms has been estimated at 144 kt $year^{-1}$. This quantity is greater than the combined export of the aforementioned countries. This indicates that if some of the kaolinite is locally used to produce high quality pots and roofing tiles that are less breakable, the socio-economic contribution of the pottery and ceramic related industries to the economy of Malaysia could tremendous than it is at the moment.

Despite the potential of Malaysia to take a leading role in the pottery market (being a country whose soils are dominated by kaolinite), among the pertinent problems in the use of Malaysian pots and roofing tiles

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is their fragility or strength. This may be so because of their chemical and mineralogical compositions and other factors such as the size of clay grains, temperature and so on during the manufacturing process[3]. As an example, a mixture of the right proportion of expanding (e.g., kaolinite) and non-expanding (e.g., montemorillonite) clays to improve plasticity (moldability) has not yet been well investigated in the country. In addition, the choice of the right clay size to eliminate or reduce the content of undesirable compounds such as Fe_2O_3 and Al_2O_3 not to mention the incorporation of some amount feldspars to increase the strength pots and roofing tiles have also not been dully researched in Malaysia. To improve upon the strength of pots and roofing tiles for a large scale commercial purpose in the country, there is the need to have some sound and sufficient knowledge about soil clays. With this information the quality of the clays in Malaysia could be improved to suit the pottery and other clay related industries. The objective of this study was to investigate how selected physico-chemical properties of Malaysian soil pottery clay relate to grain size.

MATERIALS AND METHODS

The traditional method of producing pots and roofing materials is that the clay material is saturated with water, kneaded and molded or thrown on a potter's wheel to obtain the desired shape. They are then hardened by drying or firing. When fired, the mass cohering clay platelets hardens irreversibly yet they are vulnerable to breakage[1]. To improve upon this problem, clay samples were refined into 63, 25 and 20 µm using size grading method[3]. This range of size grading was chosen so that any differences as a result of particle size in addition to pottery technological behavior could be examined. This screen sieving is also necessary to significantly reduce Fe_2O_3 Al_2O_3 and SiO_2 which are undesirable constituent in raw clays. The ash and C contents of the clay was determined by the combustion method. The Aqua Regia method was used to extract K, Na, Ca, Mg, Fe, Al and Si. Their concentrations were determined using Inductively Coupled Plasma. The mineralogical composition of the clay was determined using X-Ray Diffraction (XRD). The clay samples were wetted (sticks between thumb and forefinger). Rings of the clay samples made were fired at 800°C using a muffle furnace at for 5 h to observe their cracking strength.

RESULTS

The effect of grading on Loss On Ignition (LOI) and total carbon of the clay investigated in this study is shown in Table 1. The clay particles with sizes 20 and 25 µm were higher in LOI and total C than those of 63 µm. However, the sieve size difference of 5 µm between 20 and 25 µm particles had no significant effect on the quantity of LOI and total C (Table 1).

Qualitatively, regardless of particle size (sieve size), the clay investigated had quartz (SiO_2), illite-montmorillonite, Anatase ((TiO_2) and kaolinite. Quartz was dominant but kaolnite was prominent too.

Quantitatively, grading affected the concentrations of Fe, Al and Si as clays with particle sizes 20 and 25 µm had higher contents of the aforementioned elements compared with those of 63 µm (Table 2). For no apparent reason, a similar observation was made for K, Na, Ca and Mg (Table 3).

The effects of firing at 800°C for 5 h on the strength of clay with particles with 20, 25 and 63 µm are shown in Fig. 1-3. The molded clay with particles 63 µm had no cracks but there were cracks for particles 20 and 25 µm.

Table 1: Effect of grading on Loss On Ignition (LOI) and total carbon of clay

Sieve size (µm)	LO1 (%)	Total C (%)
20	5.71	1.48
25	5.71	1.47
63	4.58	1.36

Table 2: Effect of grading on iron, aluminium and silicon concentrations of clay

Sieve size (µm)	Fe (µg g^{-1})	Al (µg g^{-1})	Si (µg g^{-1})
20	14900	111650	288
25	15400	111350	405
63	13900	9436	261

Table 3: Effect of grading on potassium, sodium, calcium and magnesium concentrations of clay

Sieve size (µm)	K (%)	Na (%)	Ca (%)	Mg (%)
20	0.10	4.21	0.24	0.13
25	0.44	2.70	0.31	0.16
63	0.20	2.76	0.38	0.14

Fig. 1: Effect of temperature (800°C) on the strength of clay particles with 20 µm after firing for 5 h

Fig. 2: Effect of temperature (800°C) on the strength of clay particles with 25 µm after firing for 5 h

Fig. 3: Effect of temperature (800°C) on the strength of clay particles with 63 µm after firing for 5 h

DISCUSSION

The clay particles with sizes 20 and 25 µm had higher contents LOI and total C than those of 63 µm because organic substances such carbon associates well with relatively finer clay particles. However, this association seems not obvious when the particle sizes are relatively close. Hence the insignificant difference in the contents of LOI and total C contents observed for clay particles 20 and 25 µm.

Unlike K, Na, Ca and Mg whose contents were not significantly affected by grain size or grading, the contrary was true for Fe, Al and Si. Fine clay particles are known to effectively retain Fe, Al and Si compared with relatively coarse clay particles. A similar observation has been reported by Thiansem *et al*.[3].

The lower contents of Fe, Al and Si in the 63 µm clay particles may be one of the reasons why there were no pronounced cracks when they were moulded into rings and fired at 800°C. The reduction in the contents of the aforementioned elements may have improved the strength of the clay and hence the significant reduction in the breaking or cracking ability of 63 µm clay compared with those of 20 and 25 µm. Thiansem *et al*.[3] observed that significant reduction in the contents of Fe_2O_3, Al_2O_3 significantly improved the strength of white clays.

CONCLUSION

The clay with particles 63 µm had the best working quality and this was so because the clay particles had the lowest amounts of Fe, Al and Si_2. The quality of Malaysian pots can be improved upon proper grading of the clay particles.

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