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EVALUATION OF SWAT CLAY COARSE FRACTION AS A RAW MATERIAL FOR CERAMIC BODIES

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Abstract. Successful studies were made on the utilization of Swat clay coarse-fraction (–72+200 mesh B.S.S.) as a raw material for ceramic bodies. The ceramic properties of about ten compositions containing predominant amounts of Swat clay were studied. A ceramic body composition with optimum properties has been recommended.

China clay, quartz and feldspar are essential raw materials required for the production of whiteware ceramics. Quartz and feldspar are abundantly available locally, for China clay Pakistan has to depend on foreign sources and this is due to the absence of any good China clay deposits in the country. The only huge clay deposits so far discovered, lie in Shah Dheri, Shalhan and Tagma area of Swat. The mineralogy of these deposits has been discussed in detail previously.[1] It was shown that raw Swat clay contained about 15–30% kaolinite and about 60–65% of various feldspars and small quantities of quartz, magnesium silicate and mica. Attempts were also made to upgrade the kaolinite content of this clay by a process combining washing and screening. The –200 mesh fraction of the clay was found to contain about 50–60% kaolinite and about 30–35% feldspars, showing a considerable improvement in the content of the former.

Further studies[2,3] were also carried out to have a better understanding of the chemical and ceramic properties of the clay. The studies were, however, concentrated on the finer fraction (–120 mesh and –200 mesh) with higher kaolinite contents. The purpose was to show their suitability for use as a substitute for imported China clay for ceramic purposes. The coarser fraction with higher contents of feldspar (about 65%) was not unexpectedly ignored because of its low kaolinite-content (about 30%). An elutriation plant has already been established near the site to recover the finer fraction, which will substitute the imported China clay, a major raw-material for ceramic industry in Pakistan. Popova[4] carried out studies on the behaviour of microcline (orthoclase) and plagioclase (solid solutions of albite and anorthite) in China clay pastes. In a series of experiments, various mixtures of microcline, albite and anorthite were fired, and the properties like viscosity of materials at high temperature, fusion temperature, deformation of pastes, and coefficient of light absorption, were determined. This study was undertaken to explain the behaviour of pegmatite spars found in the U.S.S.R. containing microcline and plagioclase, when used as raw materials for the production of porcelain.

China clay and feldspar are the two major components of the coarser fraction of Swat clay. It was, therefore, thought that with additions of suitable amounts of various constituents to this so-called waste of Swat clay (or sandy material), the latter could be profitably used as a principal raw material for the production of whiteware ceramics. The present study was, therefore, undertaken not only to develop such a composition but also to collect relevant data on the properties of the bodies so obtained.

Experimental

Washing and Size Separation. By a combined process of washing and screening, the Swat clay sample under study was obtained in various fractions of different particle-sizes viz. +18, —18+72,—72 +200 and +200 mesh (B.S.S.). These fractions were then air-dried.

Chemical and Rational Analyses. Chemical analyses of the above fractions of the clay were carried out by standard methods. The amounts of various mineral constituents present in these fractions were then calculated by the method of rational analysis (feldspar concentration).

D.T.A. DTA was carried out to ascertain the nature of the clay present in the sample.

Fusion Points or P.C.E. For the determination of fusion points, three-sided pyramid cone (2-7/6 in high and 9/16 in across the base of each face) were made from each fraction or composition by hand pressing. These cones were dried and fired side by side with standard pyrometric cones. The temperature at which any cone showed signs of bending, was taken as the fusion point of the material of the cone.

Preparation of Compositions. In all, ten compositions were prepared by adding various quantities of ground potash feldspar, quartz and clay (ball clay and China clay) to the coarser fraction (—72+200 mesh) of swat clay and thoroughly mixed. In four compositions the contents of ball clay, potash feldspar and quartz were kept constant while those of China clay and Swat clay were varied. Five compositions were prepared with Swat clay content of 60–70% and varying amounts of other constituents. One standard composition was prepared without the addition of any Swat clay for comparison purposes.

Shrinkage. Four-inch long rods with radius of ¼in were cast from various compositions. Two marks, 3 in apart, were made on each rod. The rods were dried first in air, then in an oven at 110°C for 24 hr. They were then fired at 900, 1200 and 1300°C in an electric furnace for 2 hr. The shrinkage was measured after cooling the samples.

Porosity. The oven-dried pieces of the above compositions were fired at 1100, 1200 and 1275°C. Porosity of these fired pieces was then determined by boiling them in distilled water for 2 hr and finding the amount of water absorbed.

Translucency and Colour. Both the properties were studied by visual comparison.

Results and Discussion

The +200 mesh fraction of Swat clay was further sieved to yield various fractions. The amount and mesh size of each of these fractions are +10(3%), —10+18(13%), —18+36(15%), —36+72 (7.6%), —72+100 (15%), —100+120 (6.0%), —120+150 (5.0%), and —150+200 (35.0%). The fraction with a size of —72+200 mesh, which constitutes about 60% of the total +200 mesh fraction, was mostly used for the present studies for the reasons to be described later.

The chemical analysis of raw Swat clay and some of the fractions obtained above were carried out, the weight percentages of various oxides are given in Table 1. The nature of the minerals present in Swat clay has already been confirmed by Faruqi *et al.*[1] using DTA and X-ray diffraction techniques. The quantitative mineral composition of the clay was calculated by the method of rational analysis. Because of the nature of the minerals already known, the quantities of minerals present in clay, were assumed to be reasonably accurate, inspite of the limitations of the method used. The nature of mineral containing magnesium oxide, however, could not be ascertained and therefore, it has been described as MgO in Table 2. Albite, anorthite and orthoclase percentages are given separately and not in terms of plagioclases (like labradorite and bitonite) because the rational analysis was only meant to estimate the relative amounts of Na_2O, CaO and K_2O in the feldspars. It is conceded, however, that they are present in the form of solid solutions called plagioclases.

The fraction with a mesh size of —72+200 mesh was considered to be the most suitable for further work. It was preferred because of relatively high content of kaolinite, as compared to other fractions. The present study was, therefore, wholly concentrated on this fraction. It was however, ground to —200 mesh size for further experiments.

To study the suitability of the above fraction as a raw material for white ceramic bodies, various compositions containing a predominant amount of this fraction were prepared. Suitable additions of other materials like ball Clay, china clay, quartz and feldspar were made to impart desired properties to the body so prepared. The compositions are given in Table 3. One of these compositions, i.e. No.1 contained quartz, feldspar and clay without any inclusion of Swat clay. This represented a composition typical of a porcelain body. This was taken as reference material for comparison with other compositions. These compositions were then fired to high temperature and various ceramic properties, viz. fusion points, shrinkage, porosity, reversible thermal expansion, and translucency of ware determined.

TABLE 1. CHEMICAL ANALYSES.

Composition	Swat clay (total %)	—72+200 mesh fraction (%)	+200 fraction (%)
Loss on ignition	7.12	7.25	7.06
SiO_2	45.68	47.45	46.54
Al_2O_3	33.57	34.60	32.55
Fe_2O_3	0.67	0.12	0.62
CaO	9.13	7.21	10.22
MgO	1.03	1.00	1.10
Na_2O	1.55	1.63	1.65
K_2O	1.03	0.08	0.09

TABLE 2. RATIONAL ANALYSES.

Mineral	Swat clay (total %)	—72+200 mesh fraction (%)	+200 fraction (%)
Albite	13.10	13.60	13.60
Anorthite	45.26	36.14	50.70
Orthoclase	0.47	0.50	0.50
Kaolinite	36.02	46.98	28.25
Fe_2O_3 H_2O (LM)	0.75	0.125	0.623
Quartz	0.98	0.324	1.80
MgO	1.03	1.00	1.10
Water	2.07	0.686	3.05

TABLE 3. COMPOSITIONS OF VARIOUS MIXTURES STUDIED.

No.	Swat clay (—72+200)	Ball clay	Kaolin	Feldspar	Quartz
1	—	15	50	15	20
2	30	15	40	5	10
3	40	15	30	5	10
4	50	15	20	5	10
5	60	15	10	5	10
6	70	15	—	5	10
7	70	10	—	15	5
8	60	10	—	20	10
9	60	10	—	25	5
10	60	15	—	15	10

TABLE 4.

Comp. no.	Fusion temp. (°C)	% Porosity at (°C)			% Shrinkage at (°C)		Translucency at (°C)		Deformation at 1275°C a, 20%, b, 40%, c, 60%, d, 80%.
		1100	1200	1275	1200	1275	1200	1275	
1	1280	2–73	0–65	0–002	9–00	11–02	Little less than No.7	Little less than No.7	a
2	1260	3·01	0·97	0·040	10·05	11·03	Decreases	Decreases	c
3	1260	1·73	0·26	0·002	9·25	12·00	Decreases	Decreases	c
4	1260	2·75	0·66	0·010	9·25	13·01	Decreases	Decreases	c
5	1260	2·93	0·92	0·050	6·00	11·05	Decreases	Decreases	c
6	1275	2–71	0·64	0·002	6·50	12·41	Decreases	Decreases	b
7	1285	1·70	0·24	—	6·50	12·50	Maximum	Maximum	a
8	1290	2·00	0·35	0·001	5·54	12·22	Decereases	Decreases	a
9	1300	2·03	0·38	0·001	6·00	11·74	Decreases	Decreases	a
10	1280	2·53	0·51	0·001	6·00	11·53	Decreases	Decreases	a

a,20%; b, 40%; c, 60%; d, 80%

Fusion Points. The values of fusion points for various fractions of Swat clay are —10+18 (1440±5), —18+36 (1450±5), —36+72 (1460±5), —72+100 (1470±5), —100+120 (1470±5), —120+150 (1480±5), and —150+200 (1495±65). The fusion temperature increases with decrease in mesh size of the fraction. The low fusion temperatures of the coarser fractions can be attributed to the large amounts of sodium and calcium feldspars, which act as fluxes.

Fusion point determinations were also made on the various compositions and are given in Table 4. These values lie between 1260–1300°C. The first four compositions (nos. 2–5) show fusion points around 1260°, while the compositions Nos. 6–10 had fusion points in the range 1275 –1300°C which are comparable to standard composition (no.1). The former also had sharper and more abrupt fusion points—a serious defect from the ceramists point of view. Potassium feldspar is known to have higher and less sharp fusion point, because of the high viscosity of the liquid formed from it and slow reaction speed. Therefore, it is thought that greater amount of potash feldspar is mainly responsible for the improvement of these properties in compositions 6–10.

Shrinkage. Shrinkage values for all the compositions (1–10) are in general somewhat higher than those of the conventional ceramics (Table 1), which show a shrinkage value of about 11% (same as for standard composition No. 1).

Porosity and Translucency. The porosity values for all the compositions at temperature of 1100, 1200 and 1275°C are shown in Table 4. The compositions nos. 2–5 show higher porosity values relative to compositions nos. 6–10. The latter have porosity value even lower than the standard composition no.1. The lower values are most probably due to the greater amounts of all the feldspar added either as such or present as a component of the Swat clay fraction. Because of the flux action of feldspar, they help in the formation of liquid in the ceramic body. The greater amount of liquid thus formed is responsible for low porosity and high translucency values.

Deformation. Deformation figures in Table 4 were determined by finding out the percentage of pieces deformed, when a reasonable number of pieces of each composition, were fired at 1275°C. This is not claimed to be a very accurate method but gives a reasonable guess about the relative deformation properties of each composition. As is clear from the figures, compositions 6–10 showed much lower percentage deformation relative to compositions 2–5 inspite of higher lime-feldspar content of the former. However, the former also had a higher content of potash feldspar. The presence of potash feldspar is deemed to have increased the viscosity of liquid formed to such an extent that the undesirable effects of addition of lime feldspar were more than counterbalance.

Conclusions

The coarser fraction of Swat clay (—72+200 mesh) can be successfully utilized as a raw material for ceramic body. The undesirable effects of larger plagioclase content of the coarser fraction can be eliminated by the addition of potash feldspar. Composition containing 70% Swat clay fraction (—72+200 mesh) and 30% of ball clay, potash feldspar and quartz was found to be the best amongst those studied. The ceramic properties of this composition were found comparable or even better as compared to conventional ceramics, except for shrinkage, which was found to be a little higher.

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