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Research Article

Evaluation Of The Physico-Chemical Characterization Of Panruti Clay Deposit, Tamilnadu, India

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ABSTRACT

In this paper, the physico-chemical characterization of clay from Panruti have been studied for possible utilization in various industrial application. The clay had a specific gravity of 2.6, linear shrinkage of 4.16%, bulk density of 2.34 g/cm^3, porosity of 20.22%. A cold crushing strength of 17.51 MN/m^2 was obtained with modulus of rupture of 2.8 MN/m^2. The thermal shock resistance not exceed 30 cycles and the refractoriness was 1666˚C. The sample was analyzed for its chemical compositions, and it was revealed that it contained 31.70 %.of alumina (Al_2O_3), 51.58 % of silica (SiO_2) and iron impurities (Fe_2O_3) of 2.17 %. The evaluation of the industrial potential of the studied clays based on their physical and chemical characteristics revealed that they are suitable for refractory application. Suitable processing would be compulsory if they are to meet the requirements for other industrial application such as ceramics, rubber, paper, paint, cosmetics and fertilizer industries.

Keywords: Clay, Panruti, Tamilnadu, India, Physico-chemical characterization, Refractory.

1. INTRODUCTION

Clay minerals are infrequently mono-mineralic and have no genetic significance, as it is used for residual weathering products, hydrothermally altered products, and sedimentary deposits [1]. Kaolinite is an economically important clay mineral that is common in the weathering, diagentic, hydrothermal, and very low grade metamorphic environments. Kaolinite is one of the most abundant aluminosilicate minerals, occurring primarily as a clay sized particles with high surface-area to volume ratios [2]. Clay is a noticeably happening composed matter chiefly of fine-grained mineral deposits, which is generally plastic at appropriate water contents and will harden when dried or fired [3]. They have varying chemical composition depending on both the physical and chemical changes in the environment where clay deposits are found. Natural clay minerals are well known and familiar to mankind from the earliest days of civilization. Because of their low cost, abundance in most continents of the world, high sorption potential for ion exchange, clay materials are strong candidates as adsorbents [4]. Clay is composed mainly of silica, alumina and water, frequently with appreciable quantities of iron, alkalies and alkali earths [5]. Clays are used as raw materials in many industrial fields such as refractory, ceramics, paper, paint, petroleum industry, clarification of various effluents, catalysis etc, [6].Their applications are tightly dependent upon their structure, composition, and physical attributes. The most common commercial clay minerals are kaolinite, montmorillonite, and illite. Natural clays such as fire clay, ball clay and other clays comprise several clay minerals with one or more impurities. The most common impurities are, free iron oxide minerals, amorphous silica, alumina, quartz grain, limestone and gypsum.

1.1 Study Area

Clays are found in many locations in Tamilnadu and most of them have not been fully mapped and characterized. The clay deposit of Panruti area have been selected for systematic investigations. In the study area, clays are generally observed as outcrop in ravine cuttings and occur below lateritic soil cover and lateritised sandstone as overburden ranging from 1.5 to 2mts thick. The lateritised soil or lateritised sandstone found to overlie the clay bed in the areas of Maligampattu, Thalampattu, Kangiruppu and Mampattu..The thickness of the clay bed varies from 1..5-2 m. The objective of this investigation is to characterize the clay for evaluation of its suitability for various industrial application.

2. MATERIALS AND METHODS

The representative clay samples were collected in lumps form from the deposit site at Pauruti area, Tamilnadu, India. The clay lumps were sun dried for a week to reduce moisture content and enhance grinding. The clay lumps were then crushed, ground and sieved. The ground clay sample was dried and the chemical composition in wt% of SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, K_2O, and Na_2O were determined by using X-Ray Fluorescence Spectrometer(XRF) model PW1660 XRA. The loss on ignition (LOI) of the clay (mainly volatile matter) was determined by measuring the weight loss of a known mass of the sample after firing in furnace at 1000 ˚C for 1 hour 30 minutes. Loss on ignition (LOI) was calculated using this relation

$$LOI(\%) = \frac{W_i - W_f}{W_i} \times 100$$

Where, W_i, and W_f are initial and final weight respectively.

The physical properties, i,e., specific gravity, bulk density, apparent porosity, cold crushing strength, thermal shock resistance, the water of Plasticity, atterberg number, pH and dry linear shrinkage were determined using standard procedure [7-9]. Modulus of rupture(MOR) was determined on dry and fired samples of $15 \times 2.5 \times 2.5 cm^3$ size using universal testing mechine(Zwick) 1445) with a span length of 10 cm [10,11]. The pyrometric cone equivalent (PCE) was determined as per standard procedure [12].

3. RESULTS AND DISCUSSION

3.1. Results

The results of physical properties and chemical analysis of Panruti clay and comparison of the properties with established standard are as shown in Tables 1-3 respectively.

3.2 Discussion of Results

3.2.1. Specific Gravity

The specific gravity result of Panruti clay obtained was 2.6 and this was closed to range of 2.6 - 2.7 required for high heat duty fireclay refractory as shown in Table 2. According to Bowles [13] classification, clay of specific gravity less than 4.0 is classified as inorganic.

3.2.2 Linear Firing Shrinkage

The result of the linear firing shrinkage of the clay determined was 4.16% and less than the recommended range standard of 7% - 10% for refractory clays (Table 2). However, the low value obtained in this study could be due to the fact that 90% of the brick composition was made of grog, which is thermally stable and also serves as anti-shrinkage agent [9].

Table-1 Physical properties of Panruti Clay

Properties	PC1	PC2	PC3	PC4	PC5	Average
Specific Gravity	2.55	2.60	2.65	2.59	2.58	2.60
Linear Shrinkage (%)	4.05	4.25	4.15	4.10	4.28	4.16
Bulk Density (g/cm^3)	2.40	2.38	2.25	2.32	2.35	2.34
Apparent Porosity (%)	20.10	20.25	20.20	20.40	20.15	20.22
Cold Crushing Strength (MN/m^2)	17.40	17.55	17.60	17.48	17.50	17.51
Modulus of Rupture (MN/m^2)	2.6	2.8	2.9	3.0	2.7	2.8
Thermal Shock Resistance (cycles)	25	26	28	29	27	27

Refractoriness (◦C)	1650	1670	1700	1680	1630	1666
p^H	7.40	7.35	7.38	7.45	7.42	7.40
Plasticity	Good	Good	Good	Good	Good	Good
Atterberg Number	26	27	25	27	26	26
PCE Values	32	31	32	32	31	32
Water of Plasticity (% dry basis)	30	29	30	31	30	30

PC1-Maligampattu,PC2-Thalampattu,PC3-Kangiruppu,PC4-Mampattu,PC5-Panikkankuppam

Table-2 Comparison of the average determined properties of Panruti clay with some established refractory standard

Properties	**Panruti clay (Average)**	**Fire Clay**
Specific Gravity	2.60	2.6-2.27**
Linear Shrinkage (%)	4.16	7-10*
Bulk Density (g/cm^3)	2.34	1.71-2.1*
Apparent Porosity (%)	20.22	20-30*
Cold Crushing Strength (MN/m^2)	17.51	14-84**
Modulus of Rupture (MN/m^2)	2.8	-
Thermal Shock Resistance (cycles)	27	25-30*
Refractoriness (◦C)	1666	1500-1700*

* Gilchrist [14] ** Misra [9].

Table-3 Chemical analysis of Panruti Clay

Composition (wt%)	**Panruti clay (Average)**	**Reference Refractory Bricks [18]**	**Ceramics (Singer and Sonja, [19]**

SiO_2	51.58	51-70	67.50
Al_2O_3	31.70	28-44	26.50
Fe_2O_3	2.17	0.5-2.40	0.5-1.20
TiO_2	1.36	1.0-2.80	0.10-1.0
CaO	0.38	0.1-0.2	0.18-0.30
MgO	0.25	0.2-0.7	0.1-0.19
K_2O	0.16	-	1.10-3.10
Na_2O	0.23	0.8-3.50	0.20-1.50
LOI	12.20		

3.2.3. Bulk Density

The bulk density of the clay was 2.34 g/cm^3 and this value was slightly greater than the typical bulk density for fire clay refractories which was 2.1 g/cm^3 as suggested by Gilchrist [14].The high bulk density obtained that was above the typical one could be explained by the level of grittiness or coarse size of the grog fractions used.

3.2.4. Apparent Porosity

Panruti clay gave an apparent porosity of 20.22%, which was within the range of 20% - 30% required for firebrick clay as reported by Gilchrist [14] in Table 2.

3.2.5 Cold Crushing Strength

The cold crushing strength of the clay determined is 17.51 MN/m^2, and is above the minimum recommended value of 14 MN/m^2 for dense fired brick reported as by Misra [9].This value, however, shows that Panruti clay can comfortably withstand impacts at low temperatures as the cold crushing strength is an indicator of the effect of firing on ceramic bond.

3.2.6 Modulus of Rupture

The modulus of rupture of the clay was 2.8 MN/m$^{2.}$ This was quite good as fireclay refractories whose strength ranged between 2 MN/m^2 and 4 MN/m^2 were believed to have performed well [15].

3.2.7. Thermal Shock Resistance

The result of the thermal shock resistance displayed in Table 2 shows that the number of cycles without failure is 27. This value falls within the 20 - 30 number of cycles recommended for fireclay refractories reported as by Gilchrist [14].

3.2.8. Refractoriness

The result in Table 2 showed that the refractoriness of the sample occurred at a temperature of 1666˚C. This high temperature might have been due to the appreciable amount of the alumina content (31.70%) in the clay. The alumina in the clay was a strong indicator of its refractoriness and the higher the alumina, the higher the refractoriness [8].

3.2.9 Hydrogen ion concentration (pH)

The clays of Panruti areas are basic in nature with their pH ranging from 7.35 to 7.45.

3.2.10 Plasticity

This is an important property on which entire use of clays in ceramic field is dependent on. Grim [5] defines plasticity as "the property of a material which permits it to be determined under stress without rupturing and also to retain the shape produced after the stress is removed. The plastic nature of clays of Panruti area was good.

3.2.11 Atterberg Number

Atterberg [16] called as plasticity index (Atterberg number). He group into four classes according to the number or index [in Mishra, 17] as mentioned following classes. Class I (17-27), II (5-15 (best quality), III (4-7) and IV (0-1 (bad quality). Atterberg number of Tertiary clays of Panruti are ranging from 25 to 27. Atterberg number indicates that the range of moisture content with relatively a low degree of rigidity. The high Atterberg values indicate the ability of clays to disperse into extremely small particles.

3.2.12 PCE Values

The PCE values of Panruti clays area are around 31 to 32.

3.13 Water Plasticity

The water of plasticity of clays of Panruti area ranging from 29.00 to 31.00%.

3.2.13. Chemical analysis of Panruti clay

The average chemical composition of Panruti clay presented in Table 3 showed that the alumina (Al_2O_3) content was 31.70 wt%, silica (SiO_2) 51.58 wt% and iron (Fe_2O_3) content was 2.17 wt%. The alumina in the clay was within the range of 28% - 44% required for refractory bricks [18]. The higher the alumina content in clay, the higher refractoriness [9].The Iron oxide (2.17%) is within the acceptable range of 0.5-2.40% for refractory applications. Similarly the low values of the fluxing oxides such as CaO, MgO further confirmed that the clay could be used for refractory applications, since high amount of these oxides are expected to cause adverse effects on the properties such as lowering the melting point of the clay[8]. The loss on ignition (LOI) is 12.20% and is also within the range of 9-

14% required in a fire clay [14]. The LOI is the organic or combustible or volatile matter loss on heating and this affect the values of shrinkage and porosity to some extent.

4. CONCLUSIONS

Panruti clay have been investigated in this work for is suitability as an industrial raw martial. It was revealed that on the basis of physico-chemical characteristics of this clay deposit. Appraisal of the industrial potential of the studied clays based on their physical and chemical characteristics revealed that they are suitable for refectory application. Appropriate processing would be necessary if they are to meet the requirements for other industrial application such as ceramics, rubber, paper, paint, cosmetics and fertilizer industries.

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Conflict of Interest

The authors declare, they have no competing interest.

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