Locally available clays of Bangladesh as a replacement of imported clays for ceramic industries

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Abstract

In Bangladesh, generally imported clays are used as the main ingredient in ceramicware industries. Though locally available clays can be refined and used instead of imported ones to minimize the high manufacturing cost. In this research, 3 locally available clays were investigated both mechanically and spectrally. The XRF analysis of local non-refined clays in contrast to imported clays has indicated the presence of excess SiO_2 content (about 35%) in the form of free silica as well as TiO_2 and iron oxide but the Al_2O_3 content are presence in lower amount (around 8.7%). In ceramic body high amount of silica content shows low plasticity which create crack and iron oxide could adversely affect the translucency of ceramic ware. After the refining process from those local clays, the amount of SiO_2 content was reduced up to 40.2% along with 5.5% increment in Al_2O_3 content. From the mechanical analysis of those clays, hardness, impact and compressive strength shows very good results compared with imported clays.

Keywords: Clay Refining, Material Analysis, Ceramics, Bangladesh.

1. INTRODUCTION

In the perspective of Bangladesh as a developing country, recently the demand and use of cost-effective ceramicware and tiles (both wall and floor) is increasing tremendously. But the costs of these products are comparatively high, due to use of the imported clay raw materials. Hence, utilization of locally available raw materials for the production of quality ceramicwares is very important, because such step will obviously strengthen the economic condition of the country. The main reasons behind not using local clay are the lack of proper clay refining technology in the country.

Keeping this view in mind, clays of three different areas (Modhupur, Bijoypur and Sherpur) from Bangladesh are used to prepare the samples at three different temperature (1050°C, 1100°C and 1150°C). These non-refined treated clay sample, after being characterized (chemical and mechanical properties) compared with the properties of refined clay samples at 1100°C. Refined clays had showed better physical and mechanical properties, it can be used for the production of ceramic ware. Using the data of different physical, compositional and mechanical test, the investigation is aimed to use these refined local clay materials in ceramic ware and quality tiles by replacing imported clay in order to reduce cost.

2. RELATED WORKS

Study on Potentiality of Locally available Clay as Raw Material for traditional Ceramic Manufacturing Industries was done by Adnan Mousharraf, Md. Sazzad Hossain, Md. Fakhrul Islam [1]. The traditional whiteware manufacturing industries in Bangladesh use clay as the prime raw material which is mostly imported from abroad. The main reasons are the lack of proper clay refining technology in the country and in some part the unsuitable chemical and structural composition of the locally available naturally occurring clays. Moreover, particle size has also been identified as a major challenge in processing of naturally available clay. These two vital aspects affect plasticity and strength of clay during their processing.

Investigation on physical properties of Patia clay (Chittagong), Bangladesh is done by A. H. Dewan, S. Mustafi, M. Ahsan and M. S. Ullah [2]. The physical and microstructural characteristics of Patia clay of different areas (Hydgaon-1, Hydgaon-2 and Kanchannagar) were investigated. Patia clays were beneficiated by repeated sedimentation method. The chemical compositions of raw (unwashed) and washed clays was determined. The physical properties of fired Patia clay were measured. Chemical compositions of Patia clay unwashed and washed collected from different area of Patia were carried out using X-ray Fluorescence Spectrometer (XRF) (PANalytical XRF, Model PW- 2404 X-Ray Spectrometer) and the fired Patia clay sample (unwashed and washed) were subjected to various tests.

The firing shrinkage was examined by Eliche-Quesada et al., 2018 in an eco-friendly way. The method of beneficiation of the clay was adopted on the principle of washing and elutriation in a slow stream of water [3]. The unwashed clay contains high percentage of silica and low percentage of Alumina. These high percentage of silica and low percentage of alumina of the clays are not suitable for manufacturing better quality ceramic wares. The raw clays are suitable for manufacturing ordinary pottery. The washed clays contain low percentage of silica and high percentage of alumina compared to unwashed clays. Both the unwashed and washed clays contain small amount of CaO, MgO, Na_2O and K_2O which acts as fluxes in a ceramic body during firing due to the decrease of free silica during washing of raw clay.

Studies on the Physio-Chemical Properties of Ceramic Tiles Produced from Locally Available Raw Materials are done by S. A. Jahan, S. Parveen, S. Ahmed and M. Moniruz Zaman [4]. Due to the increasing demand of cost-effective tiles in Bangladesh, using the locally available raw materials five different batches of tiles have been prepared and their physical properties (firing shrinkage, bending strength, water absorption, bulk density etc.) as well as chemical properties were studied in order to evaluate the quality of the products. The investigation revealed that quality tiles can be manufactured using different ratios of the local raw materials (clay, quartz, feldspar and zircon) with molasses (a waste product of sugar industry) as binder. Particularly tiles specimen C and D satisfies the properties of quality tiles which reflect that among the five combinations investigated, the combinations of raw materials for these two varieties can be optimized for the production of quality tiles [5-7].

3. MATERIALS AND METHODS

3.1. Methodology

The composition and particle size of locally available clay were investigated using X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) to reveal the potential of these clays for industrial purpose upon refining. A number of researches have been carried out so far on clays from various regions across the country in order to identify the compositional variation. Such analysis is usually performed with the X -Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) methods. The indigenous material is much higher in SiO_2, Fe_2O_3 and TiO_2 content and falling short in Al_2O_3 content. Typically, majority of Silica stay in free form as Quartz. Rest of the Silica content are associated with Alumina in bonded form, which forms phases like Kaolinite, Halloysite etc. Moreover, amount of impurities like Fe_2O_3 and TiO_2 are also high in most of the local clay types. Bijoypur Clay (White Clay) has high SiO_2 content, but at the same time it has substantial amount of Al_2O_3 and fairly low impurity content in it. Hence this clay possesses the greatest potential to be turned into industrially suitable raw material for traditional-ceramic manufacturing. Other local clays show the % Silica of the local clay are in the range of 65-73, % Alumina in 22-27, % Iron (III) Oxide in 1-9 and % Titanium Oxide within 1%, which present the challenges of dealing with local clay for the suitability of industrial application due to high Silica content. XRF analysis showed presence of excess SiO_2 content in the form of Silicate, Fe_2O_3 and TiO_2; all of which pose a challenge in the refining process. Moreover, the amount of Al_2O_3 in most of the compositions is also not up to the minimum level. Using the data based on statistics on particle sizes of raw materials of various origins, this experiment was aimed to reveal the composition and properties of locally available clay that can be projected for further refining to make suitable as raw material for white ware industries.

3.2. Refining

The composition and particle size of locally available clay were investigated using X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) to reveal the potential of these clays for industrial purpose upon refining. XRF analysis showed presence of excess SiO_2 content in the form of Silicate, Fe_2O_3 and TiO_2; all of which pose a challenge in the refining process. Moreover, the amount of Al_2O_3 in most of the compositions is also not up to the minimum level. This refining is aimed to reveal the composition and properties of locally available clay to make suitable as raw material for whiteware industries. The XRF analysis shows the percentile of chemical components of the raw materials. Table-1 shows the XRF data of the 3 samples along with imported clays [1].

Table-1: XRF analysis of local and imported clays

Composition (%)	Modhupur	Sherpur	Bijoypur	China	Ball
SiO2	69.5	70.4	72.8	50.4	48.3
Al2O3	24	22.5	22.2	32.8	33.1
Fe2O3	1.8	1.9	1.78	1.85	1.33
TiO2	1.33	1.4	1.32	0.6	3.57
Others	3.37	3.8	1.9	14.35	13.7

The composition of local clay and imported clay are investigated using X-Ray Fluorescence (XRF). The XRF analysis has indicated the presence of excess SiO_2 content in the form of free silica, TiO_2 and iron oxide but the Al_2O_3 content are presence in lower amount. In ceramic body high amount of silica content shows low plasticity which create crack and iron oxide could adversely affect the translucency of ceramic ware.

3.2.1. Primary Refining

At first, clay was mixed with pure water to form slurry. Then the slurry was kept in a pot for 24 hours. After that clay particles were settled down in the bottom of the pot and some clay impurities were floating upon top surface of the slurry.

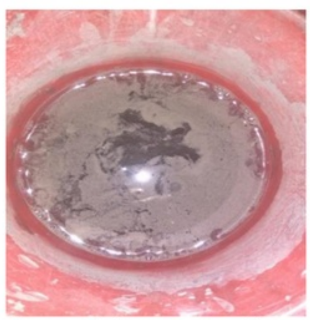

Figure-1: Primary refining

3.2.2. Addition of Deflocculant and flocculant chemicals

Suitable deflocculant such as sodium silicate was added to the slip and the slurry was continuously agitated. For deflocculating purpose, approximately 3.5- 3.75 kg of sodium silicate was added per ton of clay. When the clay particles become deflocculated, the dispersed clay slip was further diluted to approximately 10% to 20% solid content by adding pure water. Poly-acrylamide type anionic or nonionic flocculants were added to the slip at a proportion of 3.5-3.75 kg/ton of clay. Figure-2, shows the picture of used Deflocculant & Flocculant chemicals.

(a) (b)

Figure-2: (a) Sodium silicate deflocculant and (b) Poly-acrylamide flocculant.

Before Polyacrylamide addition, pH should be maintained in the range of 8.0-9.5; for the removal of TiO_2 and the remaining Fe_2O_3 impurities. At this pH level, the impurity particles got selectively flocculated with the poly-acrylamide polymer to form heavy flocs; which quickly settle at the bottom and the suspended clay was removed either by gravitational or centrifugal forces. On the other hand, for the removal of fine SiO_2 particles, alkali like ammonium hydroxide should be added at a proportion of 0.5 kg/ton of clay; to maintain pH above 11.5. At this pH level, clay particles got selectively flocculated with the polyacrylamide polymer to form heavy flocs and settle at the bottom. The suspended Quartz particles were then removed either by gravitational or centrifugal forces. Finally, the processed clay was dried to achieve marketable clays.

3.3. Experimental procedure

Having acquired the knowledge about the chemical constituents of the raw materials, compositions of five different batches of tiles body were formulated as shown in Table-2.

Table-2: Chemical composition of experimental samples.

Different Clays	Feldspar (% wt)	Quartz (% wt)	Local Clay (% wt)	Ball Clay (% wt)	China Clay (% wt)	Water (% wt)
Modhupur	30	20	40	10	0	80
Bijoypur	30	20	40	10	0	80
Sherpur	30	20	40	10	0	80
Bijoypur (Re.)	30	20	40	10	0	80
Standard	30	20	0	30	20	80

Following the above proportions of the ingredients, 500 gm of each batch composition was prepared and subjected to ball milling for 1 day, which was then followed by drying on hot plate. It was then ground very well in order to achieve very fine powder with particle size less than 200 meshes.

Particle size is an important factor since smaller particle size is very much desirable to obtain a quality product. Several circle samples were prepared at a pressure of 8-10 ton using a hand pressing machine. Such pressure helped to achieve the sample with compact shape which was first dried at 110°C. followed by firing at 1050°C temperature (normal firing temperature of commercial wall tile bodies), 1100°C and 1150°C in a furnace to get the finished fired products. A flow diagram of the above-mentioned preparation procedure is shown in Figure-3.

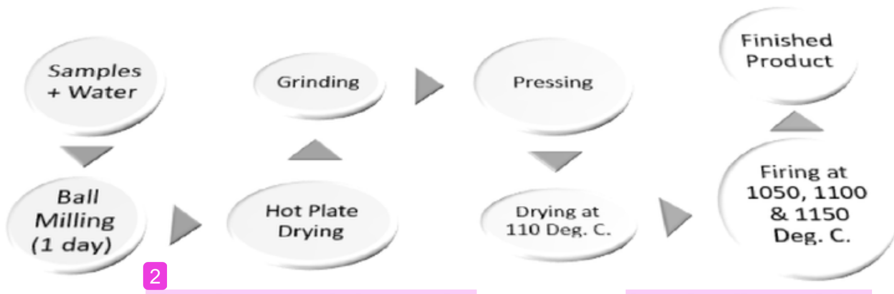

Figure-3: Flow diagram of tile samples preparation from locally available raw materials

From the refined firing sample density, firing shrinkage, water absorption, hardness, compressive strength & impact testing were carried out.

4. RESULTS AND DISCUSSIONS

A number of researches have been carried out so far on clays from various region across the country in order to identify the compositional variation. Such analysis is usually performed with the X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) methods. Table-1 lists the XRF analysis of some locally available clay types. In reference to the data in Table-1, a comparison of local clay to imported material (standard compositions) would make obvious that the indigenous material is much higher in SiO_2, Fe_2O_3 and TiO_2 content and falling short in Al_2O_3 content. Typically, majority of Silica stay in free form as Quartz. Rest of the Silica content are associated with Alumina in bonded form, which forms phases like Kaolinite, Halloysite etc. Moreover, amount of impurities like Fe_2O_3 and TiO_2 are also high in most of the local clay types.

Figure-4 shows the X-Ray Diffraction pattern for three types of clay. Figure 4(a) shows the pattern for standard Bijoypur Clay and the existence of Quartz and Kaolinite in the composition. Figure 4(b) and 4(c) shows the pattern for locally available Modhupur Clay and imported China Clay respectively. The XRD patterns indicate the presence of higher amount of Quartz or free Silica and relatively lower Kaolinite (bonded Silica) content in locally available clay in comparison to those in China Clay. Hence, substantial refining action is necessary to make the indigenous material suitable for industrial manufacturing.

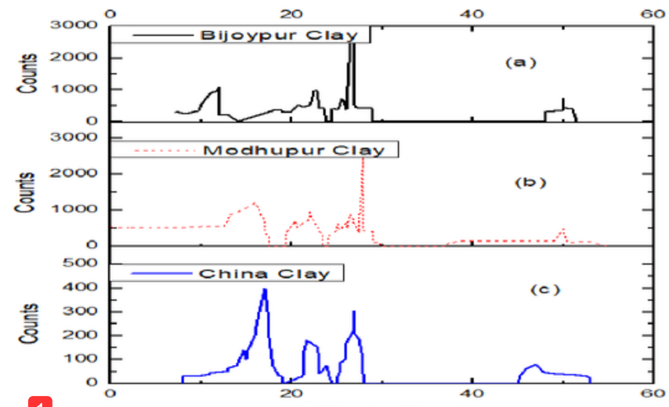

Figure-4: XRD analysis of Bijoypur Clay (a) [1], Modhupur Clay (b) [1] and China Clay (c) [7]

For a comparative analysis total 5 types of clays are taken under consideration. From those 5 types of clays, 3 (Bijoypur, Modhupur & Sherpur) types were experimented both mechanically and chemically. From the chemical tests before refining it showed about 35% excess SiO_2 content in contrast to imported china and ball clays but after refining the SiO_2 content was reduced up to 42.01% and Al_2O_3 content was increased up to 5.5% from the 3 samples. Figure-5 (a) to (d), shows the comparative and percentile analysis of refined and non-refined clay samples.

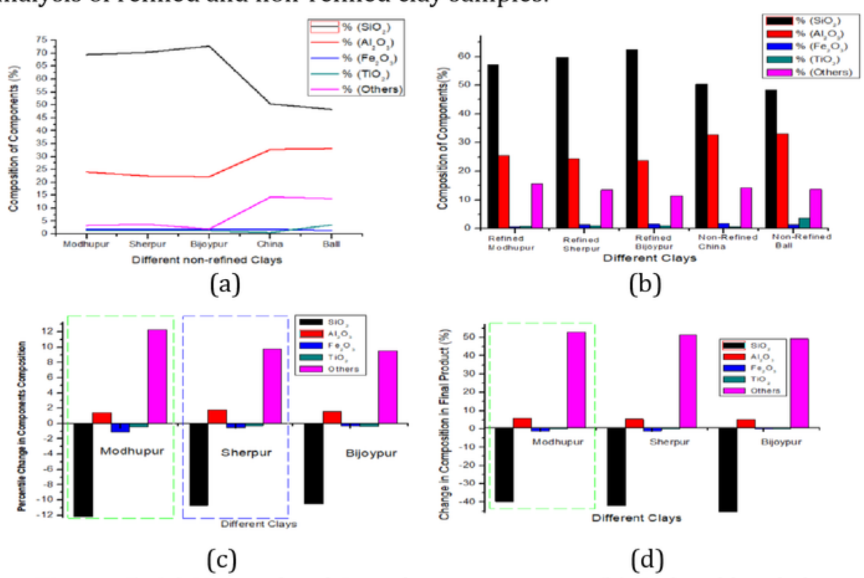

Figure-5: (a) Non-refined Samples composition, (b) Refined local clay samples in contrast to imported china and ball clay, (c) Percentile point change in new refined local clay samples and (d) Change in composition in refined local clay samples from the non-refined samples.

From Figure-5 (c), it can be seen that Modhupur (Green Dashed) and Sherpur (Blue Dashed) after refining shows almost same compositional change with respect to percentile point from the non-refined ones. But in Figure-5 (d), from the compositional percentile change, the refined Modhupur clay (Green Dashed) sample shows the best likely compositions with the imported clays. So, the refined Modhupur clay has the best quality to be used instead of conventional imported clays.

6. CONCLUSION

The main motive of this thesis was to reduce the cost for producing ceramic ware and to ensure the proper utilization of local clay resources. The compositions of locally available clays were determined by using X-Ray Fluorescence (XRF). Due to high percentages of impurity content in local clay, these clays were refined. The samples were made by the traditional method of tiles production using hydraulic press machine. To fulfill the objectives of the experiment three types of non-refined local clay (Modhupur, Bijoypur and Sherpur) sample of three different temperatures (1050°C, 1100°C and 1150°C) were used. Then some basic physical and mechanical properties such as firing shrinkage, water absorption, density, impact strength, compressive strength, and micro hardness had been tested. Various properties of Modhupur clay at 1100°C was similar or higher than standard clay sample but both Bijoypur and Sherpur non-refined clay shown lower properties than both standard and Modhupur non-refined clay sample. So 1100°C was the optimum temperature for Modhupur local clay. At 1150°C all non-refined local clay shown good chemical properties which was comparable with standard clay but their volume shrinkage was high for what we could not use them for prepare ceramic tiles.

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