Comparative Analysis of Ceramic Product Manufactured from Traditional Raw Materials and Local Raw Materials in Bangladesh

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ABSTRACT

Ceramic industries in Bangladesh are using raw materials imported from abroad. For this reason, manufacturing costs of the ceramic products are quite high. Now a day, the demand of the ceramic products in Bangladesh is very high. To reduce the cost of these ceramic products, different types of local clays can be used as raw materials with quartz and feldspar to manufacture ceramic ware, tile, and sanitary ware. In this research, locally available clay of nine different areas had been used to prepare the sample. Their physical and mechanical properties were tested and studied to evaluate the quality of the products. Khagrachari (canal) and Padma (north) clay have shown better physical and mechanical properties. This clay is suitable for the production of ceramic ware and Khagrachari (Hill) and Padma (South) clay for quality tiles. The compositions of locally available clays were determined using X-Ray Fluorescence (XRF). XRF analysis showed the presence of excess SiO_2 content in the form of Silicate, Fe_2O_3, and TiO_2 but the amount of Al_2O_3 in most of the compositions was also not up to the minimum level. Observing the physical and mechanical properties, it is found that the local clay materials are suitable to use in ceramic industries by replacing the imported/traditional clay to reduce cost and make a perfect use of our natural resources.

Key words

Clay, porosity, compressive strength, ceramic products

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INTRODUCTION

The ceramics is a class of inorganic, nonmetallic solids that are subjected to high temperature in the manufacture and use. The most common ceramics are composed of oxides, carbides, and nitrides. Silicides, borides, phosphides, tellurides, and selenides also are used to produce ceramics. Ceramic processing involves high temperatures, and the resulting materials are heat resistant or refractory (www3.epa.gov/ttnchie1/ap42/ch11/final/c11s07.pdf; Kirk 1992; 1987 Census of Manufactures, 1990; Ullman's Encyclopedia of Industrial Chemistry, 5th Ed). The main ingredient of ceramic is different types of clay. Clay is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. Clays are plastic due to their water content and become hard, brittle and non–plastic upon drying or firing (Guggenheim & Martin, 1995). Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure (Science Learning Hub).

Geological surveys indicated that Bangladesh has deposits of both residual and sedimentary types of clays. Some places across the country is better for the sources of various types of ceramic raw materials. Notable locations are Bijoypur in Mymensingh, Barapukuria, and Maddhyapara in Dinajpur, etc. The clays that are available in these sources are mainly China Clay, White Clay, Red Clay, Black Clay, Brick Clay, etc. (Adnan et al, 2011). In this paper, other than these clays, nine different clays from different sites of Bangladesh are characterized. Those locations are Khagrachari (canal), Khagrachari (hill), Khagrachari (plain land), Padma (south), Padma (north), Padma (river), Isamoti (ataikula), Isamoti (bera), Isamoti (pabna). The aim of the research is the study of chemical composition, physical properties and mechanical properties of the ceramic product and their firing behavior.

MATERIALS AND METHODS

Beneficiation of Local Clay

When using the local clay, clay refining is an important and first step of methodology. 2 kilograms of clay lumps were crushed into small size particles by crusher machine. Then crushed particles were soaked in water for about a week. In the soaked clay, heavier and fine particles were formed in a suspension with some impurities. The clay suspension was washed through a sieve ASTM-200. Then larger size particles were separated and fine particles were mixed with the water in the final slurry. Also a magnetic separator was used to separate the magnetic particles in the mixture. The final mixture was dried in the sun for initial drying. Finally, it was dried in a dryer for 24 hours to get fine clay particles.

Formulation and preparation of different batches

Table 1 shows the batch composition of different clay. In the mixture feldspar was used 30%, quartz 30%, and different types of clay was used 40%. Small amount of molasses was used as binding agent.

Table 1: Batch composition

Batch of different clay	Feldspar (wt%)	Quartz (wt%)	Local clay (wt%)	Water (wt% of batch)
Khagrachari (Canal)	30	30	40	60%
Khagrachari (Hill)	30	30	40	60%
Khagrachari (Plain land)	30	30	40	60%
Padma (South)	30	30	40	60%
Padma (North)	30	30	40	60%
Padma (River)	30	30	40	60%
Isamoti (Ataikula)	30	30	40	60%
Isamoti (Bera)	30	30	40	60%
Isamoti (Pabna)	30	30	40	60%

Experimental procedure

Each composition was subjected to ball milling for 20 hours to get fine particles. Then it was dried at room temperature. The particles size is an important criterion for the quality of the product. The mixture was grinded to fine powder to achieve particles size less than 200 meshes. At this stage the powder was mixed with small amount of molasses. The molasses is the waste product of sugar mills available in local area. The mixture was then wrapped in polythene to prevent moisture loss or absorb. After a week the mixture was ready to prepare the samples. Several square shaped samples (50mm x 50mm x 10 mm) were prepared at a pressure 250 bars using a hydraulic press. The pressure used to achieve compact shaped samples. The green samples were first dried in open air for 2 hours. Then it was dried in an oven at 110 ˚C. Finally, it was fired at three different temperatures (1050 ˚C, 1100 ˚C, and 1150 ˚C) to see the effect of sintering temperature. The soaking period was 90 minutes. A flow diagram of the above mentioned preparation procedure is shown in Figure 1.

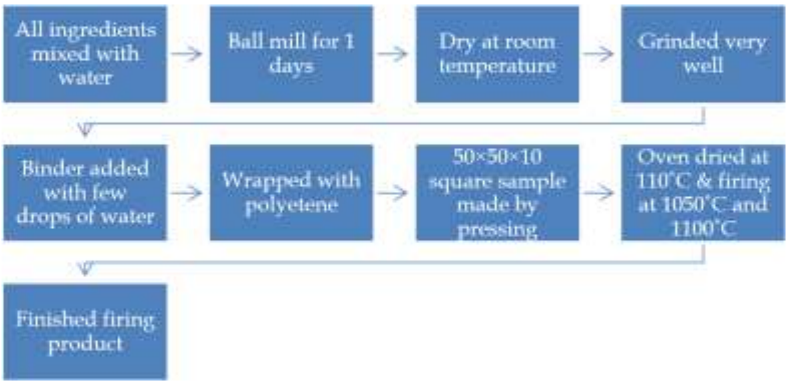

Fig 1: Flow diagram of tile samples preparation

RESULTS AND DISCUSSIONS

Fig 2-5 represents the XRF patterns of several clays used in the analysis. Table 2 summarizes the elements found in the analysis of different clays. In the analysis, SiO_2 found the maximum percentage in all the samples. Aluminium oxide (Al_2O_3) was the second highest amount for the samples where other elements like TiO_2, iron oxide, and other components found in the analysis in small percentage.

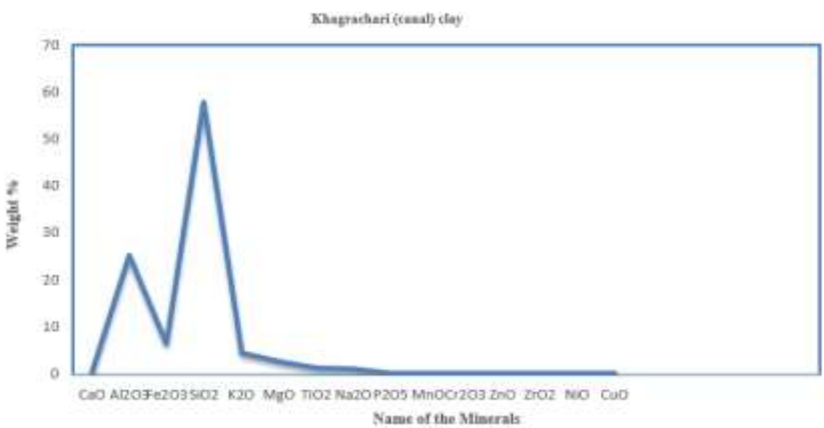

Fig 2: XRF analysis of Khagrachari (canal) clay

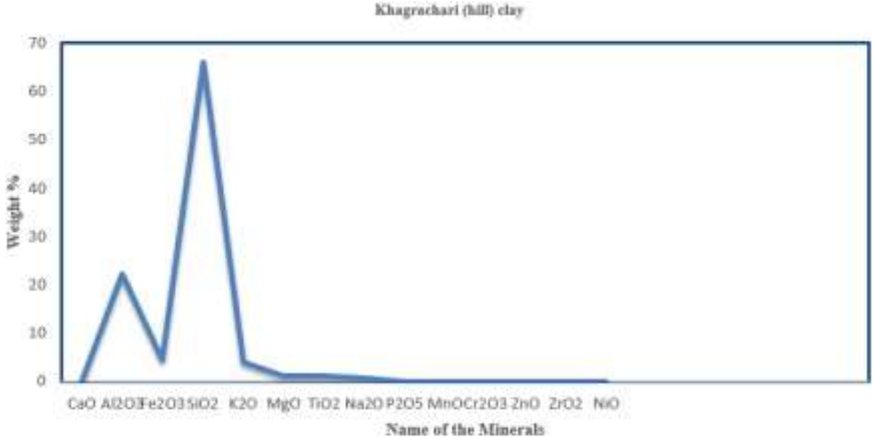

Fig 3: XRF analysis of Khagrachari (hill) clay

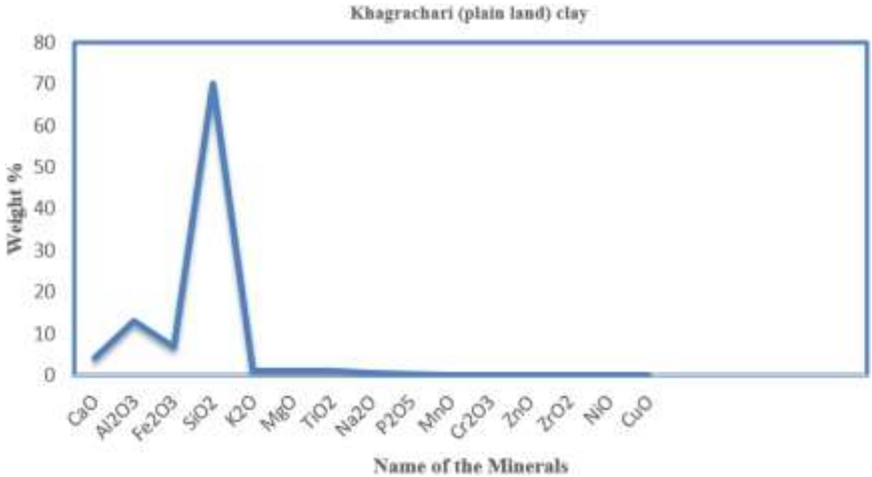

Fig 4: XRF analysis of Khagrachari (plain land) clay

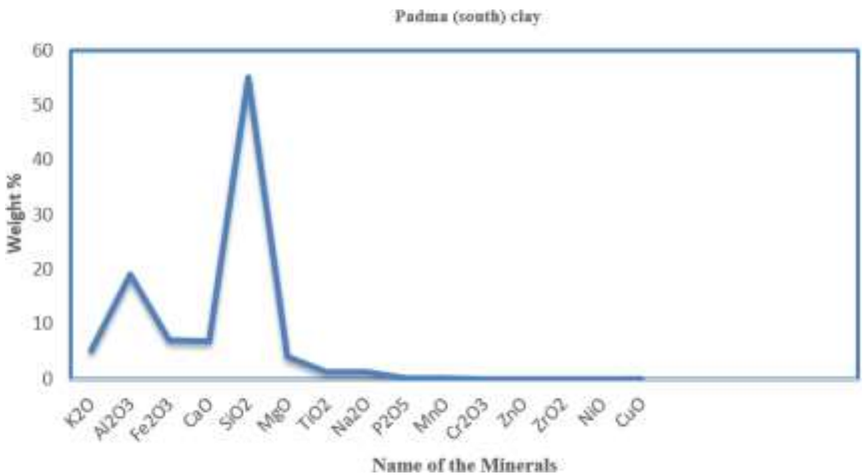

Fig 5: XRF analysis of Padma (south) clay

Table 2: XRF analysis of locally available clay and imported clay

Composition (%)	Ball Clay	China clay	Khagrachari (canal) clay	Khagrachari (hill) clay	Khagrachari (Plain land) clay	Padma (South) clay	Padma (North) clay	Padma (River) clay	Isamoti (Ataikula) clay	Isamoti (Bera) clay	Isamoti (Pabna) clay
SiO_2	44.63	50.18	57.91	65.96	69.91	55.00	52.64	62.01	57.60	62.61	59.65
Al_2O_3	36.93	33.34	25.13	22.28	13.13	19.11	17.90	12.11	15.55	11.92	10.90
Fe_2O_3	0.96	1.88	6.44	4.40	6.92	6.99	7.96	7.01	8.61	8.62	8.42
TiO_2	3.57	0.01	1.33	1.14	1.16	1.18	1.27	1.39	1.26	1.15	1.20
Others	13.91	14.59	9.17	6.19	8.88	17.69	20.20	17.48	16.95	15.70	19.83

Physical and mechanical properties

Physical and mechanical characteristics were considered to examine the quality of the products. Tiles of nine different clays were prepared, and their physical properties such as porosity, moisture content, plasticity, density, firing shrinkage, water absorption, hardness, compressive strength were tested to evaluate the quality of the products.

Porosity

Porosity depends on temperature, as the temperature increases the amount of porosity of any sample decreases. Fig.6-8 represent the porosity of all samples at three different temperatures. The porosity behavior changes with sintering temperature. The minimum porosity is good for the quality of the products. When porosity is minimum the density of the products will be maximum and hence the strength will be high. At 1100˚CKhagrachari (Canal), Khagrachari (Plainn land), Padma (river) shows porosity about 16.35%, 21.38%, 20.44% respectively. But at 1150˚C the porosity percentage decreases.

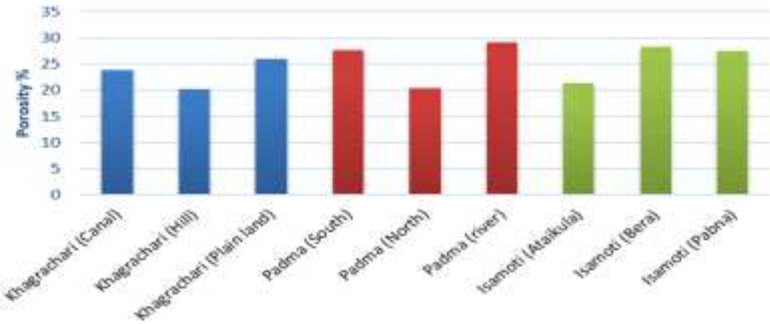

Fig 6: Porosity of the samples fired at 1050˚C

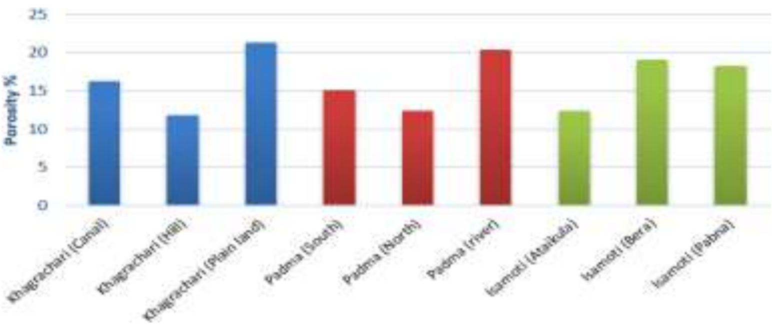

Fig 7: Porosity of the samples fired at 1100˚C

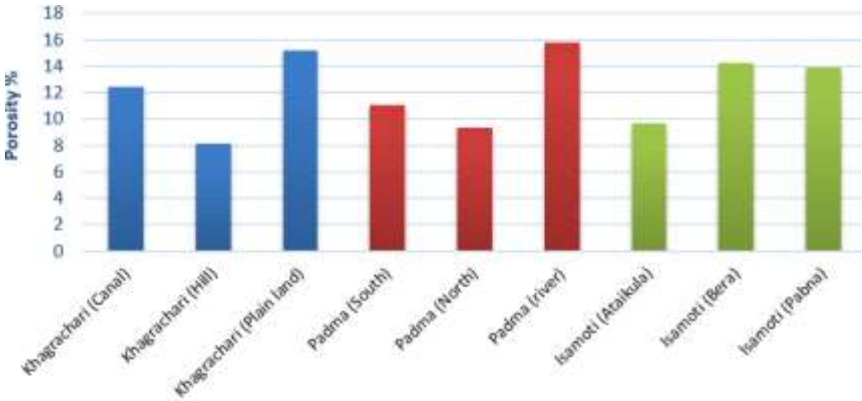

Fig 8: Porosity of the samples fired at 1150˚C

Compressive strength

The compressive strength values of all the samples in this work are shown in Fig.9-11. These values found by measuring different parameters in the equation. To measure the compressive strength at first, the samples are prepared according to the ASTM C773 - 88(2016) (50×14×8mm) and placed on the machine. Then a load is applied to the sample for some time. The final load was noted down where the fracture of the sample occurs.

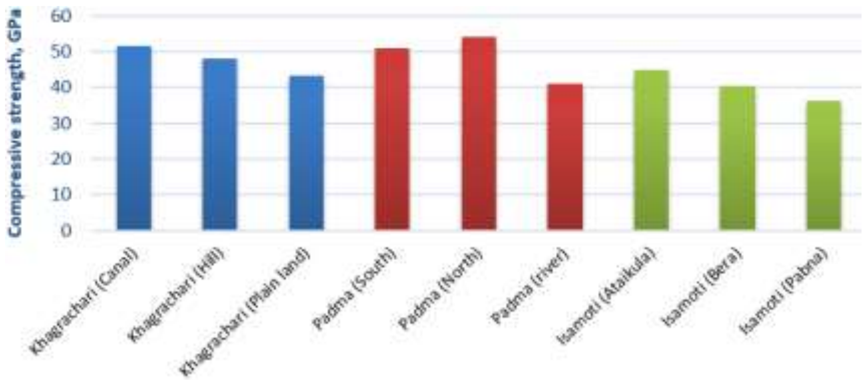

Fig 9: Compressive strength at 1100˚C

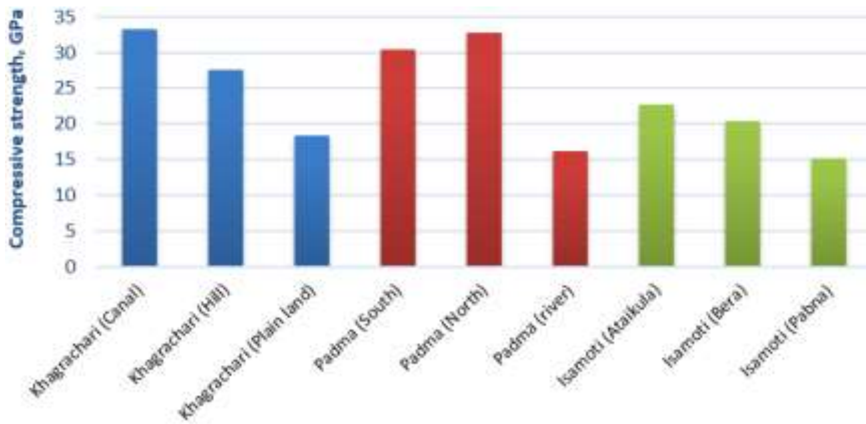

Fig 10: Compressive strength at 1050˚C

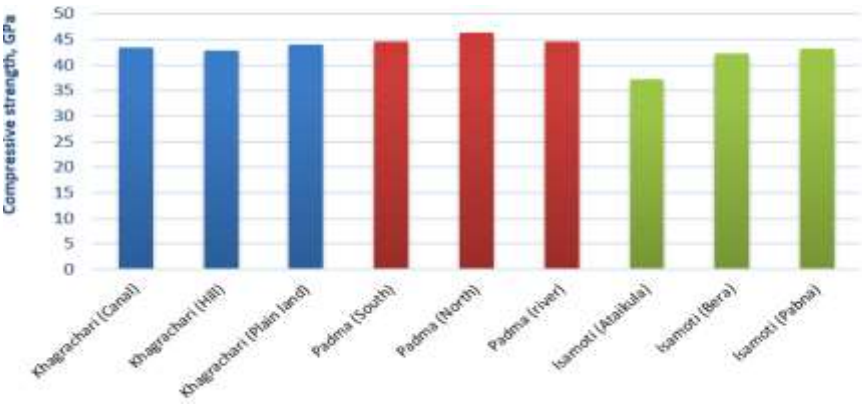

Fig 11: Compressive strength at 1150˚C

The compressive strength of all the samples increase with the increase of temperature which is representing in figure 9, 10 and, 11. At 1100˚C and 1150˚C Khagrachari (Canal), Padma (South) and Padma (river) show very high compressive strength.

Table 3: Physical and mechanical properties of prepared samples and comparison with commercial standard (For 1100 ˚C)

Properties	FARR	Fu-Wang	R.A.K	Brick field	Standard porcelain/Tiles	Khagrachari (Canal) Clay	Khagrachari (Hill) Clay	Padma (South) Clay	Padma (North) Clay	Isamoti (Ataikula) Clay
Density	1.76	1.54	1.68	1.03-1.5	-	1.83	1.81	1.76	1.85	1.69
Water absorption	8-10	16.7	12.10	20-22	-	14.41	11.22	12.69	9.20	10.61
Porosity	10-12	27.0	20.68	38.16	-	16.35	11.85	15.18	12.41	12.40
Hardness	-	-	-	1.765-2.55	5-10	4.7	3.88	6.26	6.49	5.13
Compressive strength	-	-	-	1.9-10.8	50-60	51.46	48.09	50.82	54.26	44.92

Table 3 shows the comparison of physical and mechanical properties of the finished products with the properties of commercially available tiles of several ceramic industries (Farr, Fu-Wang and, R.A.K) these values are collected from the respected factories. Table 3 shows the comparison of physical properties such as density, water absorption, porosity, hardness, and compressive strength with the standard values.

Conclusion

The motive of this investigation was to reduce the cost of producing ceramic ware and to ensure the proper utilization of local clay resources. The compositions of locally available clay are determined by using X-Ray Fluorescence (XRF). Due to high percentages of impurity content in local clay, these clays are refined. The samples were made by the traditional method of tiles production using hydraulic press machine. In the experiment nine different types of local clay samples and three different temperatures (1050˚C, 1100˚C, and 1150˚C) were used. The physical and mechanical properties of the produced tiles at

1100˚C was close to the properties of commercially available tiles. So 1100˚C is the optimum temperature for these local clays. Then some basic physical and mechanical properties such as firing shrinkage, water absorption, density, bending strength, compressive strength, and hardness had been tested and recommended as bellows:

- Khagrachari (canal) clay - ceramic ware and quality tiles.
- Khagrachari (hill) clay - quality tiles.
- Khagrachari (plain land) clay - low quality tiles and brick field.
- Padma (south) clay - quality tiles.
- Padma (north) clay - ceramics wares and quality tiles.
- Padma (river) clay - pottery and bricks.
- Isamoti (ataikula) clay - bricks and pottery.
- Isamoti (bera) clay - tiles.
- Isamoti (pabna) clay - bricks and pottery.

REFERENCES

1987 Census of Manufactures, U. S. Department of Commerce, Washington, D.C., May 1990.

Adnan Mousharraf, Md. Sazzad Hossain, Md. Fakhrul Islam. (2011), "Potential of Locally Available Clay as Raw Material for Traditional-Ceramic Manufacturing Industries", Journal of Chemical Engineering, IEB Vol. ChE. 26, No. 1, December 2011. www.banglajol.info/index.php/JCE/article/

Alam, M., & Quevauviller, P. (2013). A Comparative analysis of Bangladesh Water Management Practice with European Water Framework Directives. *Engineering International, 1*(2), 48-60.

Alam, M., Willems, P., & Alam, M. (2014). Comparative Assessment of Urban Flood Risks due to Urbanization and Climate Change in the Turnhout Valley of Belgium. *ABC Journal of Advanced Research, 3*(1), 15-24.

Alam, M., Willems, P., & Alam, M. (2014). Comparative Assessment of Urban Flood Risks due to Urbanization and Climate Change in the Turnhout Valley of Belgium. *ABC Journal Of Advanced Research, 3*(1), 14 - 23.

Guggenheim & Martin 1995, pp. 255–256, https://en.wikipedia.org/wiki/Clay#CITEREFGuggenheimMartin1995

Kirk-Othmer. Encyclopedia of Chemical Technology, Fourth Edition, Volume 5, John Wiley & Sons, New York, 1992

Masum, A., & Johora, F. (2015). Performance Evaluation of Selected Ceramic Companies of Bangladesh. *Asian Business Review, 1*(1), 37-48. doi: http://dx.doi.org/10.18034/abr.v1i1.335

Science Learning Hub "What is clay". University of Waikato. Retrieved 10 January 2016.

Ullman's Encyclopedia of Industrial Chemistry, Fifth Edition, Volume A6.

University College London Geology on Campus: Clays. Earth Sciences department. University College London. Retrieved 10 January 2016.

www3.epa.gov/ttnchie1/ap42/ch11/final/c11s07.pdf

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