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Basic Properties of Soil of Bhaktapur Pottery

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Abstract- Ceramic object was developed from the very beginning of the Neolithic time. The culture of crafting ceramic object transferred from people to people and country to country. Nepal also has a long history in producing ceramic objects. Bhaktapur serves remarkable service in maintaining the glory of pottery history. People use different types of soil for the manufacturing of ceramic. The use of soil based on the past experience and mathematical modeling help in enhancing the quality of the product. So soil sample from six different places of Bhaktapur district were collected and Atterberg limit, hydrometer analysis and specific gravity were tested. From the analysis the soil were categorized as inactive soil however range from 15% to 50% clay should be added in different soil sample to increase the quality of ceramic product.

Keywords- *Pottery, Ceramics, Atterberg, Hydrometer, Kaolinite, Bhaktapur*

I. INTRODUCTION

Pottery is an art of formation of ceramic object of required shape which is then heated in high temperature so as to form hard and permanent object. Ceramics is an ancient craft. From the evidence of sedentary village life of north and central China, ceramic vessels were discovered in all the regional Neolithic culture [10]. Nepal carries long history on ceramics; contributed to a great extent by Bhaktapur district which has high concentration of pottery production like flower vas, piggy bank, tea pot, plates, bowls. The four figures; Figure 1, Figure 2, Figure 3 and Figure 4 shows the general overview of process of manufacturing ceramic in Bhaktapur district. Potters in Bhaktapur use different color type soil; black, grey and yellowish grey for the production of these ceramics. Potters categorize black color soil for thin section ceramics and grey color soil for thick section ceramics. The selection of soil is done as per the past experience. Scientific and mathematical facts will help to enhance the quality of the ceramics. Other than the color, fineness and grain size distribution of soil provide information on the property and workability of soil.

Grain size distribution of soil classify gravel and sand as coarse grained soil and, silt and clay are categorized as fine grained soil (ASTM-2487, 2011). Soil, particle size < 2 µm is the most determining factor which gives plasticity to soil and are called clay particles [14]. Clay gains plastic property when appropriate amount of water is mixed and hardens when dried or fired [5]. When fired in kiln, permanent physical and chemical changes takes place causing the clay to be converted into ceramic material and because of different minerals and firing conditions the material changes to earthenware, stoneware or porcelain [9].

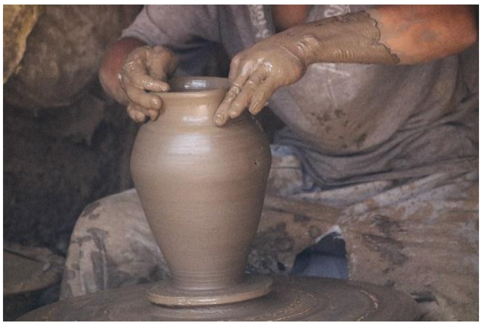

Figure 1. Crafting Ceramic Piggy Bank

Figure 2. Drying of the Piggy Bank

Figure 3. Firing of Piggy Bank

Figure 4. Marketing of the Piggy Bank

Clay contains kaolinite, illite, montmorillonite and chlorites minerals. Out of these minerals, Montmorillonite clay mineral exhibits higher volume change as it has higher ion exchange capacity, thus increasing the hydration ability and becoming the most reactive clay type [13]. Volume change potential of soil with change in moisture can be measured and estimated by several methods. Clay content, Plasticity Index (PI) and surcharge provides the strong and reliable correlation foe swelling percent of clay [16]. Also, activity of soil can be considered to estimate the swelling potential which can be judge from PI and the percentage finer than 2 µm [11]. Merwe also proposed the same method: PI and percent clay to determine the activity of soil [9]. Physical characteristics of soil such as plasticity, particle size distribution, specific gravity, PI, drying shrinkage are the various factors that make clay suitable for wide variety of industrial usage [6]. Using these index properties helped to determine suitability for industrial usage of pottery at Bhaktapur district. Direct method was used to evaluate PI, Liquid Limit (LL), Plastic Limit (PL) and percentage of the clay. Where indirect method was used to evaluate shrinkage index.

II. MATERIAL AND METHODOLOGY

A. Sample location

The samples were collected from pottery manufacturing places of Bhaktapur district: Pottery Square, Nekoshera and Thimi. The soil samples were processed and ready to manufacture pottery. The raw soil was collected from Sudal, Sipadol, Harisiddhi and Biruwa. Names to samples were given after the location of manufacturing places.

B. Lab tests

Hydrometer (ASTM H151) analysis and sieve analysis were done to find out the particle size distribution of the soil following ASTM D 422-63 and Sodium hexmetaphosphate was used as dispersant. Specific gravity of soil samples were determined following code ASTM D854-00. Atterberg limit test was conducted using ASTM D 4318 to determine the physical properties of the soil.

III. RESULT AND DISCUSSION

A. Specific gravity test

The specific gravity of the samples is shown in Fig. 5. The values of specific gravity of the tested soil sample lies between the ranges of 2.5 to 2.68. The soil with this range of specific gravity is Kaolinite clay [7][15].

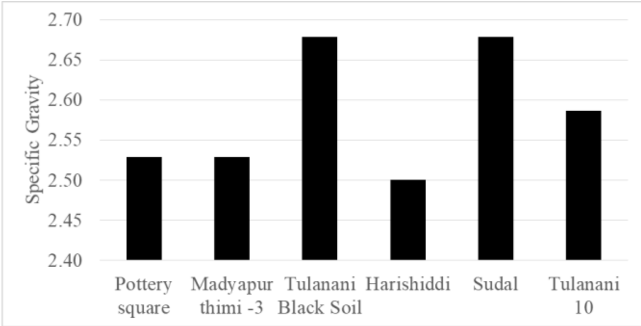

Figure 5. Specific gravity of the soil samples

B. Atterberg limit test

Atterberg limits of the soil sample are shown in Fig. 6. Plasticity of clay is determined using 'A-Line' classification chart (BS 5930:1999), which is based on liquid limit and plasticity index. Soil sample from Pottery square, Tulanani Black Soil and Sudal Soil can be classified as clay of low plasticity. Soil samples from Madyaphur Thimi-3, Harisiddhi and Tulanani-10 can be classified as clay of intermediate plasticity.

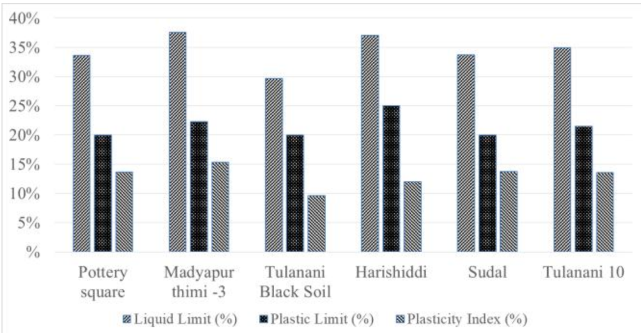

Figure 6. Atterberg limit

The compressibility chart [1] provides that the soil samples from Pottery square, Tulanani Black Soil and Sudal Soil have low compressibility and soil samples from Madyaphur Thimi-3, Harisiddhi and Tulanani-10 have medium compressibility.

The activity of soil is the ratio of PI and clay fraction which provides the information of capacity of soil to hold water which is dependent upon the fraction of clay particles. So, the volume change that results swelling and shrinkage depend upon the activity of soil (ASTM-D4318, 2010). The activity of clay is categorized as inactive clay, normal clay and active clay [11]. From the ratio of PI (Fig. 6) and clay fraction (Fig. 7), the activity of the soils of Pottery Square, Madyaphur Thimi-3, Harisiddhi and Tulanani-10 are 0.29, 0.34, 0.29, 0.41 and 0.40 respectively. The activity of these clay are < 0.75, so they are inactive clay and also the clay mineral can be categorized as Kaolinite [11][12]. The activity of soil of Tulanani Black Soil is 0.82 which lies in the range of 0.75 to 1.25, so the soil is normal clay and clay of Tulanani Black Soil is Illite [11][12]. Comparing the specific gravity and activity of the soil, the mineral composition of the soil is Kaolinite except Tulanani Black Soil, which is Illite. As they are inactive clay, they can be used in ceramic industry. Some modification however can be made as suggested by [3]: soil with the composition of 40-50% clay fraction, prevalently Illite-Chlorite, 15-25% carbonates and 35-45% silt is good for ceramic production. Also he had proposed 55-70% clay fraction for the ceramic industry.

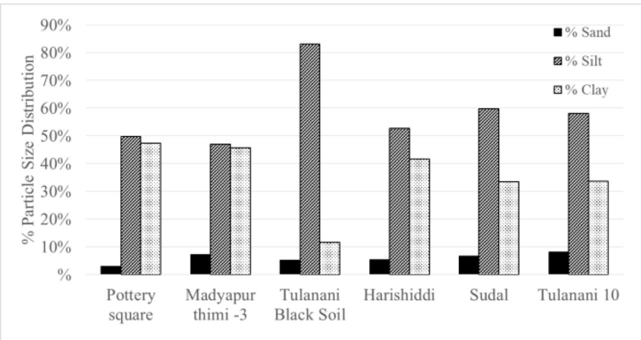

Figure 7. Particle Size Distribution Chart

Workability of the soil is not governed by testing but appears to be qualitatively deduced as no better than the ‘potter’s feel’ and it requires a clay body to be non-sticky and readily deformable without introducing defects such as cracks [2]. Using PL and PI (Fig. 6) and workability chart [1] it is found that the soils from Pottery Square, Harisiddhi, Sudal and Tulanani have acceptable molding properties. The soil from Tulanani Black Soil have molding properties in the verge of acceptable molding condition and poorer cohesion. Whereas the soil from Madyapur Thimi-3 have best workability condition and have optimum molding properties.

C. Particle size distribution test

Hydrometer analysis was done to find out the particle size distribution of 0.075 mm diameter soil. Sieve analysis was done for the soil with diameter greater than 0.075 mm. Three sets of experiment was done for every soil sample and average of them were taken (ASTM-D4318, 2010) and (IS:2720-1985). The particle size distribution curve along with the particle size distribution is shown Fig. 8. The particle size distribution of silt and clay have well graded curve. Lame quantity of sand is present in the soil samples. The soil particle consist mostly of silt and clay particles.

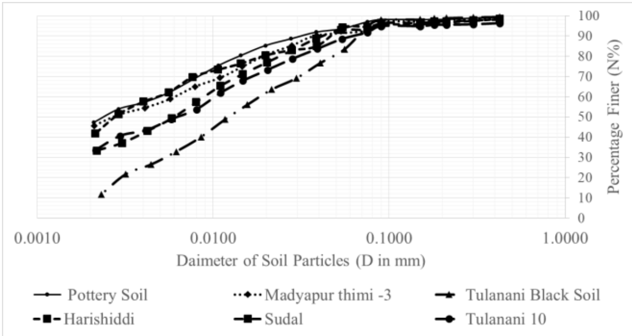

Figure 8. Grain Size Distribution Curve

The grain size distribution (Fig. 4) and texture triangle [4] is used do define the soil properties. The Pottery Square soil, Madyapur Thimi-3 soil and Harisiddhi soil can be classified as silty clay. The Sudal soil and Tulanani 10 soil can be classified as silty clay loam. Whereas the Tulanani Black soil can be classified as Silty loam.

IV. CONCLUSION

The specific gravity of the soil lies within the range of kaolinite clay. The relation from Atterberg limit test and activity of soil supports that the soil contain Kaolinite clay which is inactive clay. The clay does not swell when in contact with moisture. Workability of the soil provides the information that the soil which are used for the pottery have acceptable molding properties. Madyapur Thimi-3 has optimum molding property while Tulanani Black Soil has poor molding property. For optimum molding capacity the PL should range from 15-25 and PI should range from 15-30. The condition can be achieved if the LL range of 30-55 could be achieved. The range of LL can be increased by increasing the percentage of clay content. Clay mineral kaolinite can be increased to enhance workability of the soil without compromising the ceramic product. Approximately 15% of clay should be increased in Pottery Square soil, Madyapur Thimi-3 soil and Harisiddhi soil whereas approximately 25% clay should be increased in Sudal soil and Tulanani 10 soil to increase the workability and quality of the ceramic product. The Tulanani Black soil should be highly modified by adding approximately 50% clay for the better quality ceramic product.

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ANNEX

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