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Physical Properties of Clay and Bricks in Nyagatare, Rwanda

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Abstract: *The proportion of Rwanda population that will be living in urban centres will be 35% by the year 2017. The extra buildings will definitely be made of bricks because of its abundance in the country. The objectives of the study were: firstly, to determine brick production at the site, secondly, was to determine depth of borrow pits for clays. Thirdly to determine Atterberg limits for clay at 300mm and 500 mm depths. Lastly, was to determine percentage losses in bricks. Methodology involved use of questionnaires to determine brick production and losses, measurements of depths of clay borrow pits and laboratory work for Atterberg limits of clay. The results showed that the cumulative brick production at the site was 58.12 million bricks during 2000 to 2013 period with average production of 4.15± 0.55 bricks per year. The depth of borrow pits varied from 29 cm to 43 cm with an average depth of 34 cm. The values of Liquid Limit, Plastic Limit and Plastic index were 49.15%, 19.78% and 29.37%, respectively at 500mm depth. There were more bricks that were broken during burning than drying. The average losses for the study site were 27.13 ± 3.67% during the brick manufacturing process.*

I. Introduction

Bricks which are ceramic materials are one of the building materials used in the world for construction as they are locally available (Ahmad *et al.*, 2008). Despite mechanization of brick making which started in 1885, brick making is still hand made in many parts of Africa including Rwanda. Chemical weathering which is aided by higher temperatures in the tropics where Rwanda is, results in production of soil like clay (Mueller *et al.*, 2008). Clay in is black due to Manganese MnO_2 and is often referred as a problematic soil because it has parameters that lead to certain behaviours that need research (Gharib *et al*., 2012) . A good quality of clay with high degree of plasticity when mixed with water results in a long lasting and strong brick (Mueller *et al.*, 2008). Furthermore, clay has grains of sizes less than 2µm.

Brick production is now well documented. However, the leading countries in brick production are China, India, Pakistan and Bangladesh producing 54%, 11%, 8% and 4% of the world brick production, respectively (Baum, 2010).

Manufacturing of bricks starts by mixing clay soil with water, putting the mixture in moulds to form bricks of sizes 210mm x 100mm x 60mm or 210mm x 100mm x 70mm. The moulded mud is sun dried for about 3 to 6 days and then they are stack in a kiln for burning for about 6 to 9 days at temperatures between 900^{o}C to 1200^{o}C (Jackson and Ravindra, 2000) . Tar is used to reduce the velocity of fire.

Burning of bricks in Nyagatare has been an environmental concern because brick makers quarry near the river banks and thus destroy the natural vegetation like *acacia kirkii* (Technical Report 2011).

During the brick making, loss of bricks occurs right from the time clay is excavated to the time bricks are removed from the kiln and no such study has been done for Nyagatare kilns in Rwanda. Therefore, there is need to study the clay and brick properties so as to understand percentage losses in Barija, Nyagatare in Rwanda. This is because the quality of fired brick depends on physical chemical mineralogical changes that occur during drying and burning bricks (Alam *et al.*, 2013). A good soil for brick making in Nepal should have clay content of between 20-35%, liquid limit of 25-38%, Plastic Index of 7 to 16 % and volumetric shrinkage of 15 to 25% (Mueller, 2008).

The study had four specific objectives: Firstly, to determine brick production at the site, secondly, was to determine depth of borrow pits for clays. Thirdly to determine Atterberg limits for clay at 300mm and 500 mm depths. Lastly, to determine percentage losses in bricks.

II. Methodology

2.1 Study site

In Eastern province of Rwanda, manufacturing of bricks is done in Nyagatare district at Rwimiyaga, Karama and Barija. Barija site is adjacent to River Muvumba. Barija kilns started operating in 1996 where firewood (Prasertan and Theppaya, 1995) was used in burning bricks but nowadays saw dust locally known as *gasenyi* and rice husks are been used. There are 24 kilns at Barija site with the capacity of between 50,000 and 400,000 bricks covering an area of 8 Ha.

2.2 Brick production and depth of borrow pits

Interview questions were administered to the owner's of different kilns asking them their past production. The production for each year were then determined.

During the brick production season of January, 2014, measurements of depths where clay was being obtained was determined for different kilns.

2.3 Atterberg's Limits

Sampling of clay was done by following the 9-grid system. In 9-grid system, the area used to obtained clay was divided into nine equal grids and soil samples were picked in the middle of the grid at the depths of 300mm and 500mm.

Clay properties of liquid limit and plastic limit was done following the procedures of Atterberg's. Liquid limit is the state in which soil moves from plastic to liquid while plastic limit is where the soil becomes dry. Liquid limit was done by taking 500 grams of air dried clay that passed 425 µm sieve, mixing it with water and putting in Atterberg apparatus. 5 samples were taken and put in the bowl and a groove made. The number of times the cup was dropped was noted for each sample. The water content at which the groove closed was done. A graph of moisture content against number of blows in logarithmic scale was done. The moisture content corresponding to 25 blows was taken as the liquid limit of the sample.

Plastic limit was done by taking 500 grams of clay which was air dried and passing 425 µm sieve was mixed with distilled water until it became like a ball. About ten grams of the ball was taken and rolled into threads with fingers. Rolling and remoulding was done until the thread crumbled at diameter of three millimetres. The water content of the crumbled thread was determined. The difference between liquid limit and plastic limit resulted in the plastic index.

Shrinkage limit was done by taking about 500 grams of air dried clay passing 425 µm with distilled water and put in shrinkage dish coated with grease inside. The dish was oven dried for 24 hours and the difference in volume between the wet clay and dry clay was noted as the shrinkage limit.

2.4 Brick losses

Interview questions were used to get the number of bricks before burning and number of bricks from ten kilns during the 2012/2013 season. Ten kilns were used because they were the only kilns working at that time of interview.

III. Results

3.1 Brick production and depth of borrow pits

Table 1: Brick production in Barija in Nyagatare district of Rwanda from 2000 to 2013

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Number of bricks in millions	4.70	4.60	4.712	4.50	4.87	4.25	3.00	4.00	3.50	4.50	3.80	4.20	3.50	4.00

Table 1 shows brick production in Barija, Nyagatare district of Rwanda. Brick production has been moving up and down during the period 2000 to 2013 with an average value of 4.15± 0.55 million bricks. The highest number of bricks produced was in 2004 where 4.87 million bricks were produced. The lowest number of bricks was produced in 2006 where 3 million bricks were produced. From Table 1 it shows that many bricks were produced in the first five years. It also shows that brick production has been below average in the last four years. Cumulative total bricks produced in the period 2000 to 2013 was 58.132 million bricks.

3.2 Depth of borrow pits and drying times

Depths of borrow pits in 10 kilns are shown in Table 2.

Table 2: Depth top soils at site

Kiln Number	1	2	3	4	5	6	7	8	9	10
Depth of borrow pit (cm)	43	28	33	38	42	34	29	31	30	32

The depths for which clay is obtained had an average depth of 34cm and ranged from 29 cm to 42 cm. This shows that the top soil varies from 29 cm to 43 cm in the study area.

3.3 Atterberg's Limits

Liquid limit, Plastic limit and shrinkage limit for soil samples is shown in Table 3.

Table 3: Atterberg's limits of clay at the study site at depths of 300mm and 500mm

Parameter	Liquid limit (%)	Plastic limit (%)	Plastic index (%)
At 300 mm depth	90.85	41.53	49.32
At 500 mm depth	49.15	19.78	29.37
Expected values from Mueller et al., 2008	25-38		7-16

The depth of 300mm falls into the top soil which is not good for clay production because the liquid limits and plastic index are very high. The values of LL PL reduce as you go down deeper. Therefore good quality clays are found in depths greater than 500 mm in the site.

3.4 Brick losses

Breakages occurred before burning and after burning and are presented in the Table 4

Table 4 Percentage Brick losses in ten kilns in Barija 2012/2013 season.

Kiln No.	1	2	3	4	5	6	7	8	9	10
Initial number of bricks In 000's	69.00	72.00	82.00	59.74	73.95	90.00	100.00	69.57	93.48	74.8
No. of bricks before burning in 000's	65.55	66.24	73.8	55.86	65.08	84.60	96.00	64.71	85.07	66.57
% loss before burning	**5.0**	**8.0**	**10.0**	**6.5**	**12.0**	**6.0**	**4.0**	**7.0**	**9.0**	**11.0**
No. of bricks after burning in 000's	52.44	52.33	59.78	43.57	54.01	62.18	80.64	47.24	65.50	53.92
% loss after burning	20.0	21.0	19.0	22.0	17.0	26.5	16.0	27.0	23.0	19.0
% Total loss	24.0	27.3	27.1	27.1	27.0	30.9	19.4	32.1	29.9	27.9

Breakages occurred in the manufacturing of bricks in Barija where average percentage loss of was 27.3 ± 3.6% observed. From Table 1, it can be seen that more bricks were broken when burnt than when dried. Kiln 7 had the lowest breakages while Kiln 8 had the highest breakages of all the other kilns.

IV. Discussion

The proportion of Rwandan people living in urban areas will be 35% by 2017 (RDB website). This demands that more houses will be needed for the urban dwellers. Majority of these houses will definitely have brick walls. The higher number of bricks produced at the site can be attributed to the construction boom in Nyagatare town which had increased population owing to the return of refugees after the 1994 genocide and migration from other regions of Rwanda.

The site has been in operation for close to 19 years which is greater than 5 years required for a site to be economically viable for brick production (Muller *et al*., 2008).

The liquid limits (49.15%) at 500mm depth was higher than 33.23% Tokat-Turhal Cayli site in Turkey (Karaman *et al.*, 2005) and higher than (20-33%) required for clay soils in Nepal (Mueller *et al*., 2008). This means that suitable clay can be found in depths greater than 500 mm.

Breakages in bricks can be minimized by having well trained staff who know how to choose the clay, compact, dry and burn bricks as was observed in Kiln 7. Kiln 8 had highest losses because the clay was being obtained from top soil due to new unskilled labour. This emphasizes that casual labourers should be taught first before going to work in the brick industry.

In addition, breakages in bricks can be attributed to black soils which are known to have high degree of shrinkage consequently leading to cracking during the drying process if not protected. Therefore there is need for more time to dry because high shrinkage in clay drying and firing destroys bricks (Karaman *et al*., 2005).

Areas that no longer contain good clay should be reclaimed by planting acacia trees which are the main trees along River Muvumba (Technical report, 2011).

V. Conclusions and Recommendations

Barija site has produced over 58 million bricks. The depth of topsoil is 34 cm. Plastic index at depths of 300 mm and 500 mm are higher than those recommended for good quality bricks. The average brick losses in the study area are around 27.3 ± 3.6 %. Brick makers are advised to go for deeper clay as it is likely to have plastic index close to the one required so as to avoid losses.

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