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Investigating Why Burnt Brick Making is Not Carried out in Budondo Sub-county, Jinja District (Uganda)

Harriet Nandugwa[1], Manaseh Angurini[2], Joel Mubiru[1,*], James Fenekansi Kisule[1]

[1]Department of Civil and Building Engineering, Kyambogo University, Kampala, Uganda
[2]Department of Road Development, Uganda National Roads Authority, Kampala, Uganda

Abstract This study was conducted to investigate why burnt brick making is not possible/favored in Budondo sub county (Jinja District, Uganda), and how the prevailing problem of temporary housing in the area can be reversed. 36.3% of the dwellings in the sub county are temporary houses, and the outstanding contributor to this big number of temporary houses in the area is due to lack of bricks. For many years, burnt brick making has been absent in the area, which has translated into the use of non-enduring and temporary wall building materials, a high cost of construction; if one is to transport the bricks from the far neighbouring sub counties, low levels of development, low income levels and unemployment among the area youth. Previous attempts to make bricks using local soil in the area have not been successful. Local soil was sampled and taken to the laboratory for analysis of the physical and chemical properties that make soil suitable for making burnt bricks. The soil was found to contain 96.3% silt/clay and 3.7% sand. These soil characteristics when compared to the recommended soil properties, the soil was found unsuitable for brick making. Bricks were made using this soil, and they all failed during curing, due to shrinkage cracking. The characteristics of the local soil were adjusted by blending the soil with sand/gravel soil, in a ratio of 1:2 (local soil sand/gravel fraction). The blended soil was analysed, and found to contain 67% sand, and 37% silt/clay. The characteristics of the blended soil fairly satisfied the recommended soil properties suitable for burnt brick making. Bricks were successfully produced from the blended soil and fired without failing. The fired bricks were tested for Compressive Strength and Water Absorption Ratio (WAR), and the bricks passed the recommended threshold for strength with an average strength of 1.9N/mm^2. The average WAR of the bricks was recorded as 20.5%, though this was slightly above the recommended maximum of 20%. It was concluded that the local soil of Budondo Sub-County possesses properties that don't favour its suitability for burnt brick making, but when the soil is blended with a sand/gravel soil fraction in a ratio of 1:2, the soil acquires properties that favour it for burnt brick making.

Keywords Burnt Brick, Compressive Strength, Water Absorption Ratio

1. Introduction

Bricks are one of the oldest known building materials dating back to 7000 BC [4]. The earliest brick structures discovered in Nepal is at Maya Devi Temple (Birth place of Lord Buddha) from the 3rd century Before Christ (BC) and Archaeological excavation of Handigaun Satyanarayan Site (1984-88) discovered the bricks in foundation, pavement and wall ranging from 1st century BC. Burnt bricks are the most popular building material, with a current demand estimated at 55 billion per year [3]. Burnt clay bricks are one of the most widely used house building materials in Uganda and elsewhere because of low cost, availability of raw materials, good strength, ease of construction with less supervision, good sound and heat insulation properties, and availability of skilled manpower.

The stages in brick making, according to [5], are; winning the clay and preparing it, shaping the bricks, drying the green bricks, and firing the bricks. Earth brick is derived from the disintegration of igneous rocks and a good earth brick should be easily moulded and dried without cracking and warping. According to [12], the chemical composition for a good earth brick making material constitutes of Alumina (Al_2O_3) or Clay (20-30 percent by weight), Silica (SiO_2) or Sand (35-50 percent by weight) and Silt (20-25 percent by weight).

As a recommendation to address the minimum percentage of clay, a value of not more than 50 percent by weight should be achieved [6]. For soil to be suitable for brick making, it must meet some requirements in terms of physio-chemical properties. The most direct test method for assessing the suitability of a soil material as a raw material for brick production, used successfully for thousands of years, involves visual inspection and the feel of the soil, and the carrying out of brick making trials [7].

* Corresponding author:
mubirudalt@yahoo.com (Joel Mubiru)
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The brick making industry employs low technology, manual and “less-efficient” methods such as hand moulding, air drying and open clamp burning, making it cheap. Despite the above advantages associated with brick production, the rural people of Budondo Sub-County (Jinja District) have for many years not been making bricks in the area. With the high poverty rate in the area, it remains that without an intervention directed towards solving this prevailing problem so that people can be able to practice this cheap and highly valuable economic activity, the residents will continue staying in structures (houses) made out of non-enduring and temporal building materials. Additionally, this being a rural area, non-practice of the brick production in the area makes the residents to lose out on the high employment and economic potential that accrues from this activity [8].

Therefore, it’s on this premise that the present research study undertook to investigate and establish facts and technical causes that have restrained the brick making activity in Budondo Sub-County for several years, which has been highlighted as one of the leading contributors to the low standards of living, poor housing conditions, high poverty rates, high unemployment levels and high crime rates among the residents who are jobless and idle, in the area.

2. Materials and Methods

2.1. Study Area

Budondo Sub-County is one of the rural sub-counties in Jinja District with a total population of 50,508 people as per Uganda Bureau of Statistics, 2012. The population and housing census, 2012 indicated that the number of households by the type of construction materials for the dwelling units was 10,084 in the area, of which 36% had temporal walls and 21.1% had temporal roofs. The current practice, is of people buying burnt bricks from surrounding Sub-Counties of Butagaya, Buwenge and Busedde at a unit price of 90UgShs excluding loading and transportation cost which on average costs 180UgShs up to the construction site. This price is relatively high for a rural poor prospective house owner [8].

2.2. Preparation of Unblended Brick Samples

The reddish brown sub soil layer below the ground level was excavated manually at longitude 0.496509, latitude 33.20401, elevation 1260.0m and stock piled in a heap and divided in two portions. Drinkable water was added to one portion of the unblended soil sample, and thoroughly mixed manually until a homogeneous paste was observed. The paste was left for 24 hours and then placed into a wooden mould of 220 mm x 110 mm x 150 mm and 30 bricks were moulded. The green bricks were kept under room temperature for three (3) days. The turning of bricks was done after the three (3) days to enable all sides of the bricks to dry uniformly and again left for two (2) more days for further drying. After five (5) days, the bricks were stacked on a raised platform around 300mm above the ground level and in such a way that there is free air circulation between each individual brick to facilitate uniform drying, and the drying process continued for a period totalling to four (4) weeks.

2.3. Preparation of Blended Brick Samples

The second portion of the stock piled soil was blended with sand and fine gravel, in a ratio of 1:2. Water was added to the blended soil sample, and thoroughly mixed manually until a homogeneous paste was observed. The paste was then placed into a wooden mould of 220 mm x 110 mm x 150 mm and 30 bricks were moulded. The green bricks were kept under room temperature for three (3) days. The turning of bricks was done after the three (3) days to enable all sides of the bricks to dry uniformly and again left for two (2) more days for further drying. After five (5) days, the bricks were stacked on a raised platform around 300mm above the ground level and in such a way that there is free air circulation between each individual brick to facilitate uniform drying. The drying process continued for a period totaling to four (4) weeks. After completion of proper drying, bricks were fired in a local furnace for six (6) hours with little access of free air. All the 30 bricks were successfully fired but during the removal of bricks from the kiln, eight of them had failed due to the burning effect. The remaining 22 bricks were used for the compressive strength test as well as water absorption test.

2.3.1. Strength and Water Absorption

A total of ten (10) bricks were first marked/coded for the purpose of identification. The dimensions of each brick were taken using a measuring tape and then weighed. A sample brick was carefully centered on the lower platen of the testing machine, ensuring that the load is applied on the top and bottom sides of the brick. The compressive strength test machine was then started and the loading increased at a uniform rate of 3KN/s until the test bricks failed on compression. The maximum load at failure (w) was recorded. The average cross-sectional area (A) in mm^2 of the brick’s loaded face was determined from the measured dimensions of the sample bricks as A=L*B. The compressive strength (C) in N/mm^2 of each tested brick was obtained by:

$$C = w/A. \tag{1}$$

The average compressive strength of the ten samples was calculated and reported as the compressive strength of the bricks [1].

Meanwhile for water absorption test, ten (10) bricks were first marked/coded for the purpose of identification. The dimensions of each test sample brick was taken using a measuring tape and recorded to calculate the rate of water absorption. The samples were placed in a drying oven at 110±5℃ for 24 hours. After oven drying the bricks were left to cool at room temperature and then weighed to give the oven dry mass (W_d) in grams. The bricks were then fully immersed in a soaking tank maintained at 30°C for 24 hours. The bricks were removed from the soaking tank, wiped with a dump cloth and their mass after immersion in water was weighed and recorded as, W_w. The water absorption was computed using equation [1].

$$\text{Water absorption} = [((W_w - W_d)/W_d)*100]\ \%. \quad (2)$$

3. Results and Discussion

3.1. Particle Size Distribution

The results from the particle size distribution test (sieve analysis) are presented below using a logarithmic graph.

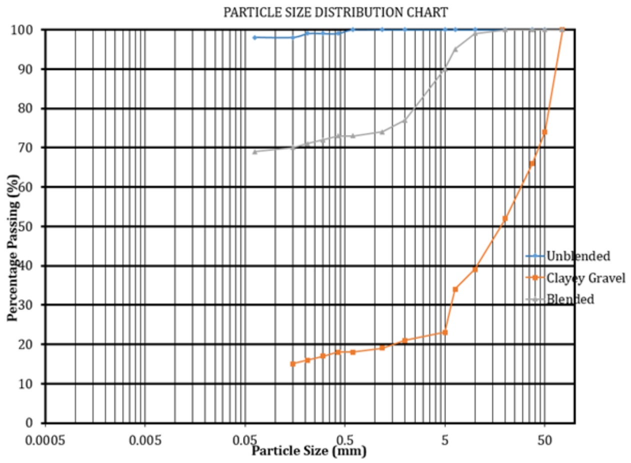

Figure 1. Particle size distribution for initial un-blended soil, Clay gravel and blended soil

From the grading curve above in Figure 1, it is observed that 96.3% of the unblended soil was constituted by the silt-clay fraction and the remaining 3.7% was constituted by fine sand fraction. From this result, the soil was classified as silt-clay. According to [7], soil material suitable for burnt brick production must desirably contain: 25%-50% clay/silt, and 25%-45% sand, and preferably the soil must contain particles of all sizes. This means that the present soil material was not passing this criterion for particle size proportions. This deficient particle size nature of the soil is what prompted the blending of the natural soil with sand and fine gravel, so as to improve the particle grading, such that the soil meets the minimum required criterion.

The samples used for blending of the original soil, introduced 92.7% of coarser particles other than clay and silt (7%) from the sand and 80.6% of coarser particles other than clay and silt (3.2%) from the fine gravel. The grading curve for the blended soil shows that 67% of the soil particles was constituted by the sand fraction and the remaining 37% was constituted by silt clay fraction. From this result, the soil was classified as clayey sand. The percentages of the particle sizes obtained after blending passed the criterion for suitable soil material for brick making as according to [7].

The hydrometer results for unblended soil material indicated that the soil constituted of 0% gravel, 2% sand, 36% silt and 62% clay. Meanwhile the blended material results showed that 23% of the soil was gravel, 8% sand, 28% silt and 41% clay. The high constituent of clay and silt >50% gives the reason for the early shrinkage crack of the green bricks during their drying process.

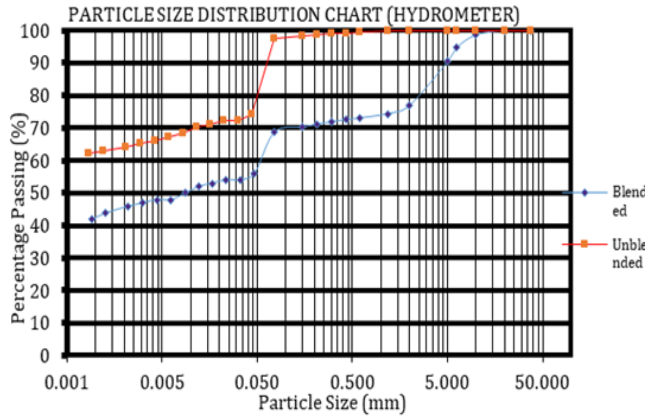

Figure 2. Hydrometer analysis results for both blended and unblended samples

3.2. Atterberg Limits

Table 1. Atterberg limits results for the silt clay soil

Soil Property	Value (%)
Liquid Limit	49.2
Plastic Limit	32.3
Plasticity Index	16.9
Linear Shrinkage	9.9

Table 2. Atterberg limits results for the gravel soil

Soil Property	Value (%)
Liquid Limit	39.7
Plastic Limit	29.1
Plasticity Index	10.5
Linear Shrinkage	8.6

Table 3. Atterberg limits results for the blended soil

Soil Property	Value (%)
Liquid Limit	42.3
Plastic Limit	25.4
Plasticity Index	16.9
Linear Shrinkage	8. 1

From the results in Table 1, it is observed that the initial silt clay soil material had a Liquid Limit of 49.2%, a Plastic Limit of 32.3%, a corresponding Plasticity Index of 16.9% and a Linear Shrinkage of 9.9%. From Table 2 for gravel soil, the Liquid Limit was 39.7%, the Plastic Limit was 29.1%, the Plasticity Index was 10.5% and Linear Shrinkage was 8.6%. According to [9], soil material suitable for burnt brick production must suitably possess: 30% to 35% Liquid Limit, 12% to 22% Plastic Limit, 7% to 18% Plasticity Index and about not more than 7% Linear Shrinkage. Comparing the results with the recommended values, this material was not passing the criterion for a suitable soil material for the brick making purpose.

From the results in Table 3, it is observed that the sand-blended soil material possessed a Liquid Limit of 42.3%, a Plastic Limit of 25.4%, and corresponding Plasticity Index of 16.9% and a Linear Shrinkage of 8.1%. The results for the blended soil are still not in line with the recommended values for atterberg limits for soil material suitable for burnt brick production except for only Plasticity Index.

3.3. Chemical Analysis of Soil

Table 4. Soil chemical analysis results for the un-blended soil

Parameter	Results (ppm)	Result (%)
Magnesium	277.27	0.028
Iron Oxide	53429.00	5.34
Calcium Carbonate	263.47	0.026
Silica	106729.10	10.813
Sodium	88.28	0.009

Table 5. Soil chemical analysis results for the blended soil

Parameter	Results (ppm)	Result (%)
Magnesium	368.10	0.99
Iron Oxide	71445.01	9.21
Calcium Carbonate	425.34	0.45
Silica	268992.34	50.19
Sodium	101.07	0.10

From Table 4 above, the predominant mineral among those that were tested was silica, constituting about 10.8% in the initial soils. However, according to [32], suitable soil for producing earth bricks should desirably contain between 50-60% silica. It therefore follows that the initial soils were having a deficit of silica content whose major source is sand.

Table 5 above shows results for the chemical analysis carried out on the soils that were blended with sand. The predominant mineral among those that were tested was silica, constituting about 50.1%. This level of silica content is between the desirable silica content range of 50-60% recommended in soils suitable for earth brick production [32]. The increase in silica content can be attributed to the increase in sand content that occurred after blending with sand and fine gravel.

3.4. Green Bricks

It was observed that after 3 days, the moulded bricks from un-blended soil started developing cracks and the cracks increased with increase in time period for air drying. At the end of the drying period, twenty-eight (28) bricks had completely failed by cracking and breaking into parts, and only 2 managed to maintain shape, though still with a great number of cracks over the surfaces. Failure of bricks was attributed to high composition of fine soil fraction i.e. 96.3% of silt-clay, which encouraged rapid shrinkage and consequent cracking.

3.5. Compressive Strength Results

Table 6. Comprehensive strength results for the blended soil

Brick Code	Density (kg/m^3)	Ultimate Compressive Strength (N/mm^2)
B-C1	1226.4	1.87
B-C2	1221.2	1.85
B-C3	1270.5	1.98
B-C4	1244.6	1.91
B-C5	1218.5	1.84
B-C6	1259.2	1.93
B-C7	1232.8	1.89
B-C8	1231.4	1.88
B-C9	1256.7	1.95
B-C10	1225.3	1.88
Average Compressive Strength		1.90

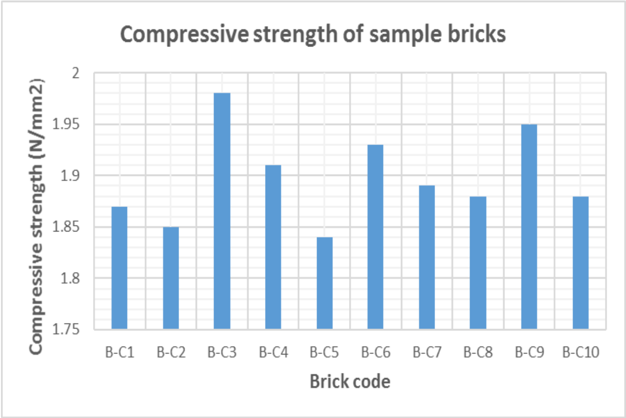

Figure 3. Graphical representation of the compressive strengths of the bricks

The sample bricks recorded an average dry density of $1238.7kg/m^3$. The highest compressive strength of the bricks recorded was 1.98 N/mm^2, while the lowest compressive strength recorded was $1.84N/mm^2$. The average compressive strength of the bricks was calculated as $1.9N/mm^2$. This level of strength is in the range $0.2N/mm^2$ to $15N/mm^2$ according to [11].

3.6. Water Absorption Results

Table 7. Water absorption results for the blended soil

Brick Code	Oven Dry Weight, W_d (kg)	Soaked Weight, W_w (kg)	Water Absorption Ratio, (%)
B-W1	4.325	5.194	20.1
B-W2	4.276	5.101	19.3
B-W3	4.213	5.043	19.7
B-W4	4.231	5.124	21.1
B-W5	4.310	5.206	20.8
B-W6	4.299	5.155	19.9
B-W7	4.312	5.209	20.8
B-W8	4.287	5.204	21.4
B-W9	4.298	5.213	21.3
B-W10	4.326	5.230	20.9

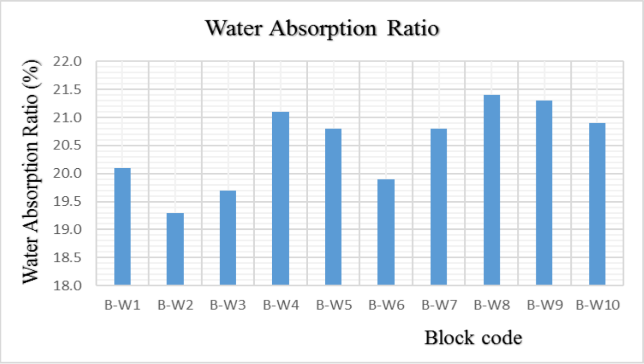

Figure 4. Graphical representation of the water absorption of the tested bricks

The lowest water absorption ratio (WAR) recorded for the sample bricks was 19.3%, while the highest was recorded as 21.4%. The average water absorption ratio recorded for the bricks was calculated as 20.5%. These results obtained for average water absorption of the bricks are comparable to those of other similar materials like; clay bricks (0% to 30%), concrete blocks (4% to 25%), calcium Silicate bricks (6 to 16%) [10]. However, according to [9], the recommended maximum value of WAR for handmade burnt earth bricks is 15%. This implies that the bricks were slightly above the recommended maximum value of water absorption.

4. Conclusions

The natural soil characteristics results therefore suggest that the soils in Budondo Sub-County are not suitable for burnt brick production without improvement being made to the soil. The local soil was blended with sand and fine gravel from a borrow pit, and this caused improvements in the soil properties, which made it suitable for burnt brick production. The blended soil constituted 67% sand and 37% silt/clay, and also recorded 42.3% as Liquid Limit and 16.9% as Plasticity Index. The improvement in the soil parameters of grading and atterberg limits by blending the soil with a coarser soil fraction of sand and fine gravel led to successful production of bricks which can survive both the drying and burning processes. The bricks survived shrinkage cracking effects due to the counter action against shrinkage provided by the added coarser soil fraction of sand and fine gravel.

The compressive strength test recorded an average strength in the range recommended for handmade burnt bricks according to [11]. Meanwhile the water absorption test revealed that water uptake for the bricks is slightly above the recommended according to [10]. It therefore follows that when the local soils of Budondo Sub-County are improved by blending them with a coarser soil fraction of sand/fine gravel in appropriate proportions, they can be used successfully to manufacture handmade burnt bricks fit for construction of local houses.

The method in this research should not be generalized but further research should be carried out to investigate the most optimum proportions of the blending soil material that can be appropriately combined with the existing silt/clay soil material of Budondo sub-county, to give bricks of maximum strength, minimum water absorption and acceptable durability. Another direction of research in line with the present study, is a research on other methods for improving the soil so as to acquire properties that suite the soil for production of burnt earth bricks of acceptable mechanical properties, and which can survive shrinkage cracking.

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