Recycling of Burnt Clay Rubble as Structural Concrete

Ibrahim Semambya[1] and Michael Kyakula[2]

[1]Design Assistant, MBW Consulting Engineers Ltd, Kanjokya Street, Kampala, Uganda
Corresponding author email: mkyakula@gmail.com
[2]Senior Lecturer, Department of Civil and Building Engineering, Kyambogo University, P. O. Box 1 Kyambogo, Uganda

ABSTRACT
A base line survey of manufacturers of clay products revealed that up to 20% of the total burnt clay products may turn out as waste. A small percentage of this waste is used in stabilizing raw clay of relatively low plasticity, swamp reclamation and pothole filling. An investigation was therefore conducted to establish and compare the water absorption and compressive strength of concrete cubes from crushed burnt clay rubble with that from the normal weight coarse aggregates from igneous rock. For target design strength of 20Mpa, characteristic cube compressive strength for burnt clay rubble and igneous rock aggregate was found to be 21.60Mpa and 23.40Mpa respectively. It can therefore be concluded that aggregates made from burnt clay rubble can be used to make structural concrete with the benefit of a slight reduction in weight and better environment preservation. Also from the beautiful appearance of the crushed cubes it was concluded that burnt clay rubble can be used to make decorative blocks for load and non-load bearing walls respectively.

Keywords: Burnt clay rubble, recycling, structural concrete

1.0 INTRODUCTION

Concrete is a synthetic building material, made by mixing cement (or any other binder), fine aggregates (usually sand) Coarse aggregates (usually gravel or crushed stone) and water in properly predetermined proportions. Concrete has been classified into four distinct type namely heavy weight concrete, normal weight, light weight and ultra light weight concrete. Since aggregates occupy up to three quarters of the total volume of concrete, its quality is of considerable importance for good. Aggregates cab be classified by size, for example coarse and fine aggregates, by origin for example metamorphic, sedimentary and igneous rock aggregates, by weight for example dense and light weight types, The dense class includes all the aggregates normally used in plain and reinforced concrete, such as sand, gravel, crushed rock and slag, while the light weight class includes both natural light weight aggregates such as pumice, scoria, volcanic cinders, tuff, and diatomite, and artificial light weight aggregate such as expanded clay, shale, slate. The aggregate materials available for making light weight concrete in Uganda are Scoria from Kisoro and burnt clay rubble.

For structural lightweight concrete (air-dried unit weight of 1,440 to 1,850 kg/m^3), any lightweight aggregate is suitable that has a crushing strength sufficient to have reasonable resistance to fragmentation, while enabling concrete strength in excess of 20N/mm^2 to be developed and to produce a finished concrete in the dry density range of 1500 – 2000 kg/m^3. This means that where the concrete uses fine aggregates from natural sources (sand), the particle density of the coarse aggregate should vary between 650 kg/m^3 and 1850 kg/m^3, Clarke (1993). On the other hand, normal-weight concretes have a typical dry unit weight of 2,300 to 2,400 kg/m^3. The advantages of using lightweight aggregates include the reduction of product weight. Reduction in weight means less need for structural steel reinforcement, smaller foundation requirements all of which lead to improved economy of structural components because there will be less dead load for the structure to support. In addition, lightweight concrete is thermally efficient, has good fire-resistance properties, especially when artificial aggregates like burnt clay rubble is used. This is because these aggregates have already been pre-fired and is stable; therefore they do not easily decompose when subjected to high temperatures. Lightweight concrete absorbs energy well in that sense it serve as an insulation material. Its major disadvantages include; high drying shrinkage, low resistance to abrasive forces, mixing, handling and placing require considerably more care and attention than ordinary concrete.

Figure 1: Heaps of burnt clay rubble

Research has shown that lightweight concrete is such a multipurpose building material. This investigation therefore was intended to look into the possibility of using natural lightweight aggregates in form of broken burnt clay rubbles, and comparing the results with concrete made with normal weight aggregates. Information from one of the leading producers and suppliers of burnt clay products indicate that these factories produce up to 20% waste in form of damaged bunt clay products, for which a small percentage is used in stabilizing raw clay of relatively low quality. Other uses included in filling potholes and swamp reclamation, recycling of construction and industrial waste material is very important for both environmental protection and economical production. These broken burnt clay products could possibly be put to a more economic use by making light weight concrete out of them since they seem lighter. An investigation was therefore conducted to establish and compare the water absorption and compressive strength of concrete cubes from crushed burnt clay rubble with that from the normal weight coarse aggregates from igneous rock.

2.0 PRODUCTION OF LIGHTWEIGHT CONCRETE

There are three methods of producing lightweight concrete. First, porous lightweight aggregate of low apparent specific gravity is used instead of ordinary aggregates whose specific gravity is approximately 2.6.The resultant concrete is generally known by the name of the light weight aggregate used. The second method relies on introduction of large voids into the concrete mass. This type of concrete is variously known as aerated, cellular, foamed, or gas concrete. The third method is by simply omitting the fine aggregates from the mix so that a large number of interstitial voids are present. A coarse aggregate of ordinary weight is generally used. This concrete is described as no-fines concrete. The decrease in density is obtained in each case by the presence of voids, either in the aggregates, or in the mortar, or in the interstices between the coarse particles (Neville and Brooks, 1987).

3.0 RELEVANT PROPERTIES OF AGGREGATES

The following properties of aggregates are relevant to the light weight concrete produced in this research.

3.1 Soundness of aggregates

Neville and Brooks (1987) defined soundness as the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions. Such physical changes include; alternate wetting and drying, Thermal changes at temperatures above freezing, and freezing and thawing. When the volume changes induced by the above factors result in deterioration of concrete; such aggregate is said to be unsound.

3.2 Shape and surface texture classification

The particle shape and surface texture are of importance with regard to properties of both fresh and hardened concrete. Workability increases as aggregate particles become smoother and when the mix proportions and water/cement ratio is changed (Shetty, 2002).

3.3 Porosity and absorption

The porosity, permeability and absorption power of an aggregate influence such properties as bond between it and the cement paste, the resistance of concrete to freezing and thawing, as well as its chemical stability and resistance to abrasion (Neville and Brooks, 1987). Water absorption (WA) can be defined as the amount of water absorbed by a material when immersed in water for a stipulated period of time usually 24 hours, or the ratio of the weight of water absorbed by a material, to the weight of the dry materials.

3.4 Specific gravity/relative density

Specific gravity (SG) in its broadest sense is defined as the ratio of density of a substance compared to the density of fresh water at 4°C (39° F). The apparent specific gravity is the ratio of weight of 24 hour oven dry aggregates at a temperature of 100 to 110°C, to that of water occupying a volume equal to the same solid including impermeable pores.

3.5 Mechanical properties

Most of the mechanical properties of aggregates for example strength, abrasion, impact resistance and toughness are of crucial interest especially when the aggregate is to be used for such works as road/railway construction. It is proposed that concrete from burnt clay rubble be used to build lightly loaded structures.

3.6 Chemical properties

Aggregate must be chemically stable in presence of cement and must resist the action of weather particularly frost. Aggregates containing salts are not suitable for reinforced concrete because salts will corrode the steel, rendering the whole structure weak. Also salts may absorb moisture from air and cause efflorescence. Other chemicals also tend to reduce concrete's durability (Neville and Brooks, 1987). Burnt clay rubble aggregates are chemically stable.

4.0 METHODOLOGY

This research was carried out on two different types of aggregates, one of which were light weight hand crushed Burnt clay rubble aggregates (BCA) from Uganda clays Kajjansi, while the other was crushed normal weight aggregates from Muyenga igneous rocks . Burnt clay rubbles collected for this study included both broken max-spans and broken roofing tiles, with the latter constituting up 75% by volume. Rubble was crushed by hand in the laboratory to a maximum size of 19mm. Material finer than 5mm was discarded because the study opted to limit its investigations to only replacing normal weight coarse aggregates used in most normal weight structural concrete works, with light weight coarse aggregates. Normal weight coarse aggregates used were from Muyenga igneous rock quarry, and were of nominal sizes 10 mm and 20 mm. Lake Sand was used as fine aggregates. Stand pipe flowing water supplied by National Water and Sewerage Corporation was used throughout the study.

4.1 Laboratory tests

The two types of coarse aggregates used in this study were subjected to particle size distribution (grading), water absorption and flakiness index, burnt clay aggregates were further subjected to specific gravity laboratory tests. Fine aggregate; were subjected to silt/clay/dust content, particle size distribution (grading) laboratory tests.

4.2 Particle size distribution (grading)

This was determined in accordance with BS 812.1:1985, The method involved passing the aggregate sample through standard sieves arranged in a descending order of their apertures, with the largest on top as the first aggregate receiver. The weight retained on each sieve were then determined and recorded .From these weights, cumulative percentages of material passing each were calculated and used to plot a grading curve.

4.3 Water absorption

This is represented by the weight of water that can be absorbed, expressed as a percentage of the dry weight of the sample. Sample of nominal size 6mm-19mm was thoroughly washed to remove finer particles and drained The samples were then placed in an oven at a temperature of 100 ± 5ºc for 24 hour. Oven dry samples were allowed to cool to room temperature, and then weighed to get A. About 1200 g of oven dry weight from each of these was then fully immersed in a metallic container with clean water at a room temperature for a period of 24 hours. The samples were then removed, wiped with a clean dry cloth to remove surface water, and weighed to get B. The water absorption (WA) is given by;

$$WA = \left(\frac{B - A}{A}\right) x100$$

Tests to determine the specific gravity were carried out at the ministry of works central materials laboratory using a pycnometer or specific gravity bottle.

4.4 Concrete mix design

For normal weight concrete "Design of Normal Concrete Mixes", published by the British Department of the Environment (DOE) was followed. Light weight design procedure was based on the equations for mix design of structural lightweight concrete in ACI 211.2-98. The parameters to be considered before using or applying a given equation include whether the concrete is to be air entrained or non -air entrained. The concrete used in this study was non air entrained, and the appropriate equations where were selected and used following the steps below;

- The nominal maximum aggregate size (mm) to be used; 19mm were used
- The slump range (mm)
- The compressive strength to be attained was 20N/mm^2
- The oven dry lose weight of coarse aggregates (Kg/m³)
- Water absorption (%)

Nine Concrete cubes were made from burnt clay rubble aggregates and from normal weight aggregates, 3 from each set were crushed at 7, 14 and 28 days.

5.0 RESULTS AND DISCUSSION

The results obtained were tabulated as shown below. From Table 1, The water absorption for the aggregates made from burnt clay rubble is found to be very high compared to the acceptable value of 2% for normal weight aggregates. From Table 2 the flakiness index for both aggregates was found to be less that 40%; the maximum acceptable value. From Table 3, the specific gravity for the burnt clay rubble aggregates is reasonably high. From Table 4, the compressive strength of both aggregates was found to be acceptable.

Table 1: Aggregate water absorption results comparison

Aggregate Type	Burnt Clay	Igneous Rock
Water absorption(Average percentage)	13.1%	0.856%
Comment	High	Low

Table 2: Aggregate flakiness index results comparison

Aggregate Type	Burnt Clay	Igneous Rock
Flakiness Index (percentage)	15.77%	14.73%
Comment	< 40% (Acceptable)	< 40% (Acceptable)

Table 3: Specific gravity

Aggregate Type	Specific gravity
Burnt clay aggregates	2.41
Normal weight fine aggregates (Clarke, 1993)	2.4-2.6
Normal weight coarse aggregates (Clarke, 1993)	2.6-3.0

Table 4: Compressive strength of aggregates

	7 days	14 days	28 days
Burnt Clay Aggregates	14	18.5	21.6
Igneous Rock Aggregates	15.2	19.7	23.4

6.0 CONCLUSIONS

The compressive strength of burnt clay rubble is high at $21.60\ \text{N/mm}^2$ while that made from igneous rocks from Muyenga was $23.40\ \text{N/mm}^2$ for a design concrete strength of 20N/mm^2. The water absorption for the aggregates made from burnt clay rubble is found to be high at 13.1% compared to the acceptable value of 2% for normal weight aggregates. This implies that these aggregates have to be soaked for 24 hours before casting concrete to permit full hydration to take place. And the concrete from burnt clay rubble aggregates should not be used under water.

7.0 RECOMMENDATIONS

It is recommended that Burnt clay rubbles be economically put to use by making structural concrete out of them ,moreover it is lighter than normal weight aggregate concrete hence a dead load reduction of suspended slabs. More research should be conducted to establish the suitability of using both burnt clay in the manufacture of decorative bricks or blocks.

8.0 REFERENCES

American Concrete Institute [ACI] *(1998), Equation for Mix Design of Light weight Concrete,* ACI 211.2-98

Clarke, J. (1993), *Structural Lightweight Aggregate Concrete*, Third edition, Blackie Academic and Professional, Glasgow.

Neville .A. M. & Brooks. K. M. (1987), *Concrete Technology*, Concrete association, London.

Shetty M.S, (2002), *Concrete Theory and Practice*, New Delhi.