RECYCLING OF PRODUCTS OF BRICK PLANTS IN NIGERIA

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Abstract
A large number of modern and ancient buildings have been demolished in Nigeria, during the last two decades, mostly termed "illegal" structures as a result of building without the necessary certification, and sometimes demolished because of proposed Government new public facilities in the area. The resulting demolition wastes around the cities are not only a serious threat to the environment but also results in unpleasant landscapes.
While up to 90% of concrete wastes are recycled, not up to 5% of the brick wastes are recycled, probably due to ignorance of its use as concrete aggregate. Also, its high water absorption and low strength in comparison to rock makes it difficult to meet concrete specifications.
This paper presents laboratory results to show that clay bricks from demolition waste can be crushed and used as aggregates to produce quality concrete, in terms of its compressive and tensile strength.

INTRODUCTION

Hedizadeh (2005) has shown that urban population growth may result in environmental degradation and pollution; which in turn, constraints growth and development of large cities. Like Nigeria, and many third world countries, about 0.5million tons of demolition waste are produced annually (e.g report of Municipality of Mashhad, RTMO 2005), of which 20% is recyclable brick. It is a severe social and environmental problem to dispose the huge quantity of construction and demolition waste. It is therefore necessary to recycle the waste as aggregates in concrete production.
At present, only about 10% of demolition bricks are being reused in new masonry buildings, because of ignorance of the performance of crushed bricks in some application such as road base material (Balouri 2005).
Nigerian bricks are all of very high quality as the production plants are all on capital and energy intensive lines using very conventional equipments (Chinwah and Otoko 1988), and so are suitable as concrete aggregate and for road layer construction.
All the bricks plants in Nigeria were visited by the author and samples from each plant tested for compressive strength, water absorption, efflorescence and warpage in accordance with the Nigerian industrial standard 74:1976. Fig.1 shows the location of the brick plants.

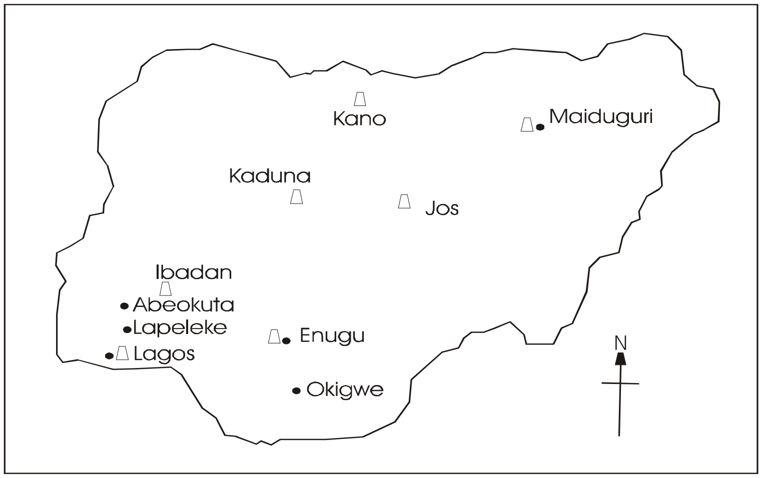

Fig. 1 BRICK PLANTS IN NIGERIA

Key
Δ Brick plants owned by the Nigerian Mining Corporation
● Brick plants owned by Private entrepreneurs

Table 1: Quality of Brick Products in Nigeria

BRICK PLANT		**Quality of Brick Products**					
Location	**Owner-ship**	**type**	**Compressive Strength (N/mm^2)**	**Efflorescence**	**Water absorption (&)**	**Warpage Concave**	**% Convex**
Ibadan	NMC*	Perforated Solid	13.55 21.41	Nil Nil	8.2 12.7	0.4	0.6
Ikorodu	NMC	Perforated Solid	14.64 28.15	Nil Nil	14.5 21.2	0.4 0.4	0.8 0.8
Jos	NMC	Perforated Solid	18.7	Nil	21.0	0.4	0.8
Enugu	NMC	Perforated Solid	19.53 20.5	Nil Nil	12.1 14.0	0.4 0.4	0.8 0.8
Kaduna	NMC	Perforated Solid	10.94 21.43	Nil Nil	14.5 20.8	0.83%	1.0%
Kano	NMC	Perforated	8.12	Nil	15.5	0.2	0.4
Maiduguri	NMC	Perforated	17.13	Nil	8.9	0.4	0.6
Oregun Lagos	Private	Perforated	12.8	Nil	13.7	0.4	0.8
Enugu	Private (PRODA)	Solid	16.4	Moderate	18.9	0.4	0.8
Okigwe	Private	Perforated Solid	17.3 22.3	Slight Slight	3.7 5.6	0.46	0.9
Abeokuta	Private	Solid	20.5	Nil	12.8	0.4	0.8
Maduguri	Private	Solid	18.8	Nil	14.3	0.4	0.8

* NMC – NIGERIAN MINING CORPORATION

MECHANICAL PROPERTIES OF CLAY BRICK

Compressive strength

The quality of brick products in Nigeria is presented in table 1 (after Chinwah and Otoko 1988). Since aggregates govern the strength of hardened concrete, rock aggregates will obviously produce stronger concrete than brick aggregates. Randomly selected engineering (not perforated) bricks were loaded to failure at rate of 0.3MPa/s in accordance with the Nigerian Industrial Standard 74: 1976. The results are summarized in table 2. Data gathered from different sources (Bowles, 1988 and Bolouri 2004) are also shown in table 2.

Table 2. compressive strength of bricks in original form and rock (after Bolouri 2004)

Material	Unconfined Compressive Strength (UCS), kg/cm^2	Specific gravity (gr/cm^3)
Brick (in original form)	30 - 70	1.9-2.0
Basalt	1750-4200	2.8-2.9
Granite	700-2800	2.65-2.75
Limestone	350-1750	2.65-2.75
Sandstone	280-1400	2.3-2.4

The test results clearly show that the unconfined compressive strength of rock is much higher than that of brick, so will concrete made of rock aggregates be much stronger than that made of bricks. More so, the water absorption of bricks is about 12 times more that rock.

Porosity and water absorption

Chinwah and Otoko (1988) gave water absorption for perforated normal bricks (Table 1); whereas, the water absorption for crushed bricks and natural aggregate was about 26 and 1.3% respectively (Table 3). Test were done in accordance with ASTM 128 and the Nigerian Industrial standard 74: 1976

Table 3. Water absorption and specific gravity of materials

Aggregate type	Water absorption	Dry unit weight (gr/cm^3)
Brick (in original form)	24 - 27	--------------
Crushed brick	25 - 28	950 - 1050
Natural rock	0.5 - 1.9	-------------
Natural aggregate	1.0 – 2.5	1500 - 1700

Aggregate Soundness

Soundness test of aggregates when subjected to weathering action was carried out in accordance with ASTM C88 and AASHTO 104. Soundness of the aggregates were obtained by repeated immersion of the aggregates in saturated solution of sodium and magnesium sulphate followed by oven drying to dehydrate the salt precipitated in permeable pore spaces. Fine and coarse aggregate sizes were selected according to ASTM C33 (fig 1).

After the final cycles, the loss in weight in proportion of the initial weight (as a percentage), known as aggregate soundness, is computed and shown in table 4.

Table 4. Water absorption and specific gravity of materials

Aggregate type	Coarse (9.5 mm to 50 mm)	Fine (0.3 mm to 9.5 mm)
Loss in weight (%) for crushed brick	10.5	4.0
Loss in weight (%) for cement mortar/concrete	65.5	38.0

Table 4 indicates that the performance of concrete productions is very weak which may be due to the destructive effect of sulphate on cement mortar/concrete.

Aggregates resistance to freezing and thawing

The freeze - Thaw tests were carried out in accordance with AASHTO T103. In the test, the saturated sample was immersed in water and placed in a freezer (temperature > -23^{0}C) for 24hours, after which it was placed in a moisture room (temperature 21^{0}C) for 24 hours i.e one cycle. After the completion of 10 cycles, the loss in weight of the samples was determined like in the soundness test. Results obtained are presented in table 5.

Table 5. Freezing and thawing test results of crushed brick

Aggregate type	Loss in weight (%)
Coarse crushed brick (9.5 mm to 50 mm)	2.5
Fine crushed brick (0.3 mm to 9.5 mm)	12.5
Coarse crushed cement mortar/concrete (9.5 mm to 50 mm)	44.0
Fine crushed cement mortar/concrete (0.3 mm to 9.5 mm)	35.0

Table 5 shows that the durability of concrete made with crushed brick is better when suggested to freezing weather in comparison with concrete made with crushed concrete/cement mortar.

Aggregates resistance to abrasion

Abrasion test, using the Los Angeles testing machine was carried out in accordance with ASTM C131 (or AASHTO T96). In this test, a specified quantity of aggregates smaller than 37.5mm ($1^1/_2$in) was placed in a steel drum containing steel balls, the drum was rotated, and the percentage of material worn away was measured. Table 6 shows the test results for crushed bricks and for concrete/cement mortar.

Table 6 clearly shows that the resistance of recycled crushed bricks to abrasion is relatively low in comparison with crushed concrete/cement mortar, which is about 5 to 10% (Khaloo 1994), which in turn, lowers the compressive strength of concrete with recycled brick aggregates.

Table 6. Abrasion resistance of materials in Los Angeles test

Aggregate type	Abrasion (%)
Crushed brick	49.5
Crushed concrete/cement mortar	46.3

MECHANICAL PROPERTIES OF CONCRETE MADE WITH CRUSHED CLAY BRICKS

The practice of recycling concrete as aggregate in concrete in some European and American countries has been reviewed by Desmyster & Vyncke (2000), while Khaloo 1994 reviewed the use of crushed bricks as aggregate.

The following sections, looks at use of crushed bricks aggregates in terms of size and material:

Fine and coarse crushed brick aggregates

Demolition bricks were crushed to fine and coarse aggregate sizes within the zone specified by ASTM (fig.1). A water cement ratio of 0.5 was used for the concrete mix for different cement content, with workability slump ranging from 45 to 85mm, and cured for 28days.

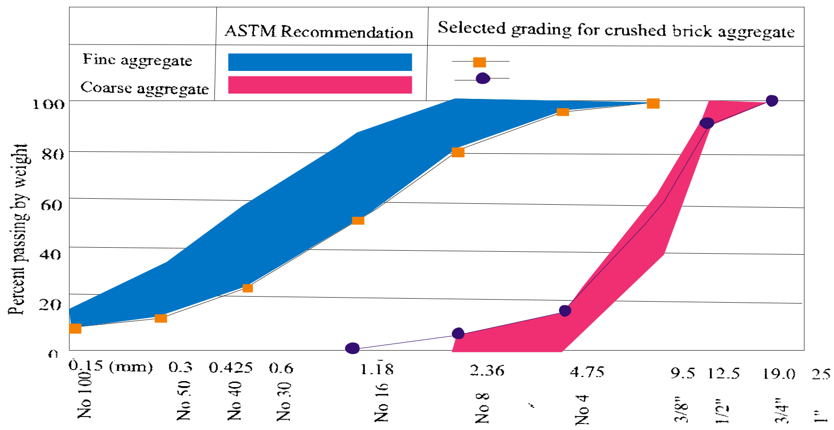

Fig.1 Fine and course aggregate grading according to ASTM C33

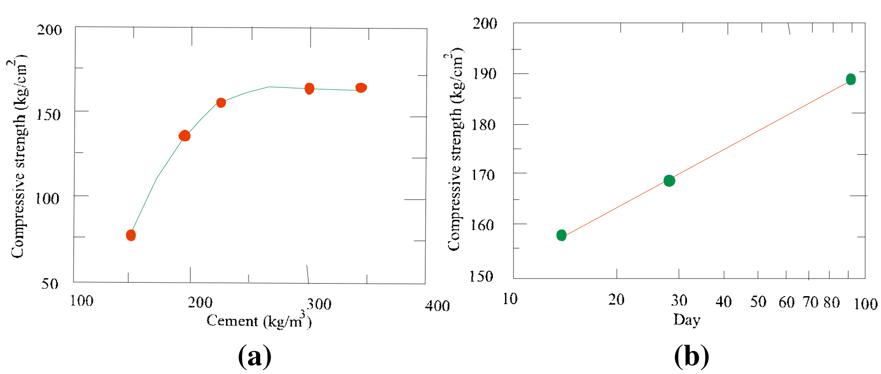

Fig. 2 compressive strength of concrete made with crushed brick as aggregate

Fig.2a Shows the relationship between compressive strength of crushed brick aggregate concrete and cement content, while **fig. 2b** shows the compressive strength growth with time for samples of 225 kg/m^3 of cement.

Replacement of fine granite chippings with fine crushed bricks

Fine crushed granite chippings was replaced with fine crushed bricks based on ASTM C33 Fig 1 and results compared with samples with 100% granite, using water cement ratio of 0.5 and cement content of 3500g/m^3. Table 7 shows the average compressive strength obtained for various samples of different aggregates

Table 7. 28-day compressive strength of concrete made with different aggregates

Aggregate type	Average compressive strength after 28 days (kg/cm²)
Fine and coarse aggregate from crushed brick	165
Fine aggregate from granite and coarse aggregate from crushed brick	250
Fine and coarse aggregate from crushed granite	450

Table 7 shows clearly, that about 50% increase in compressive strength was achieved by replacement of fine granite chippings with fine crushed brick.

Quality of concrete made of fine crushed brick aggregates

The quality of concrete made of fine crushed brick aggregates were examined using a cube crushing machine. Results obtained are plotted in Fig 3 and Fig 4.

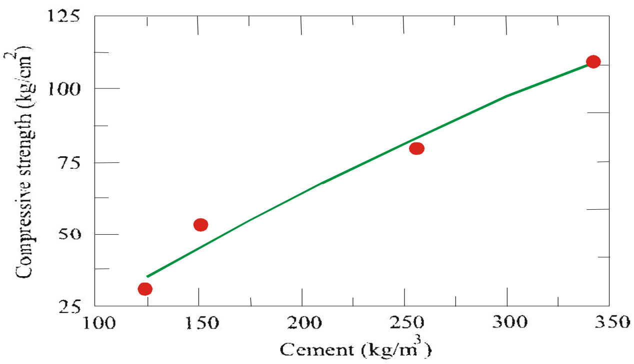

Fig.3 Compressive strength of concrete made with fine crushed brick (finer than 0.15 mm) as aggregate

While Fig 3 shows relationship between compressive strength and fine crushed brick (finer than 0.15mm) aggregates, Fig 4 shows relationship between compressive strength and fine crushed brick (coarse sand size) aggregates (see fig 1). In both cases, it is clear that compressive strength obtained after 28days is much higher than recycle bricks, particularly those of fig 4.

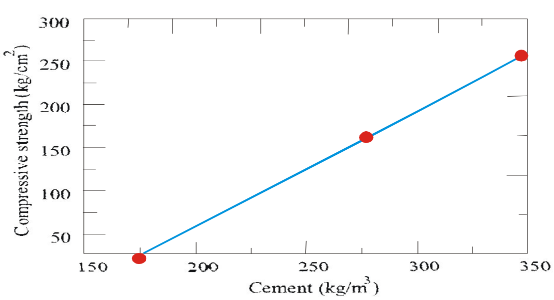

Fig.4 Compressive strength of concrete made with fine crushed brick (coarse sand size) as aggregate

Use of cement stabilized crushed bricks for use as road pavement material.

The ability of the subgrade to sustain traffic loads without excessive deformation is the most important criteria for satisfactory pavement performance (Powel et-al 1984).

As recycled concrete or brick may not readily give satisfactory performance, stabilization with lime, cement or bitumen may be required, as it may lead to large increase in the bearing capacity of the soil (Ingles et al, 1972, Lay 1990).

Unconfined compressive strength (UCS) test is mostly used to evaluate the strength of cement stabilized soils, while the California Bearing Ratio (CBR) is used for the lime stabilized soils (Sherwood 1993).

Masonry bricks and concrete produced from demolition waste were crushed and sieved through 25mm sieve size. The resulting grain size distribution in accordance to AASHTO T27 is shown in Fig 5, for use in sub-base and base construction.

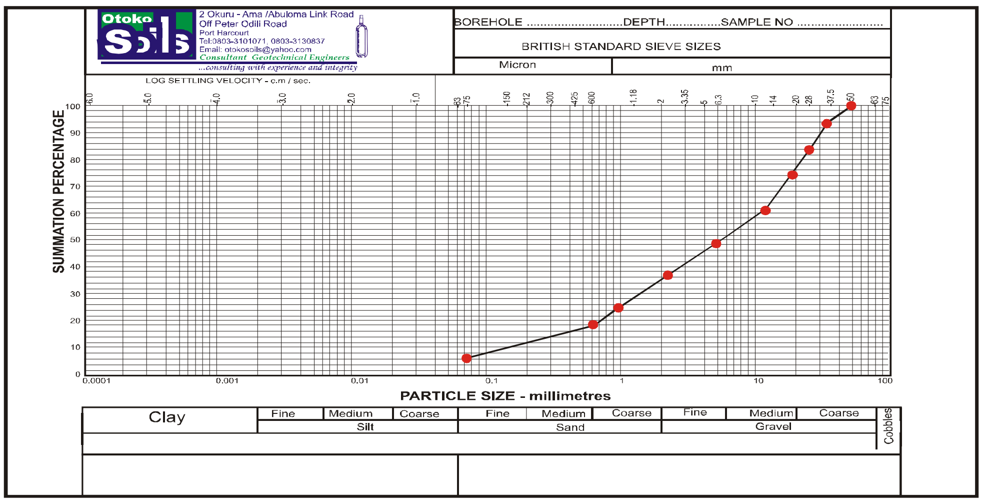

Fig.5 Grain size distribution of brick, cement mortar/concrete for base, and sub-base structure

Brick and cement mortar/concrete were combined as shown in table 8.

Table 8: brick and cement mortar/concrete combination.

Combination No.	Brick	Cement mortar/concrete
B/C-80/20	80%	20%
B/C-65/35	65%	35%
b/c-50/50	50%	50%

Sherwood 1993 Kosmatka & Panarese 1994 have shown that, 2Mpa compressive strength can be achieved after 7days with 3 to 7 percent cement content.

Therefore 3, 5 and 7 percent cement content was used in this investigation. Aggregate and cement were compacted at optimum moisture content and cured for 7days. The resulting unconfined compressive strength for various cement content is shown in table 9.

Table 9: compressive strength of samples containing 80, 65 and 50% brick

Cement content (%)	**Samples containing 80% brick**		**Samples containing 65% brick**		**Samples containing 50% brick**	
Cement content (%)	Compressive strength (Mpa)	Maximum dry unit weight (kN/m^2)	Compressive strength (Mpa)	Maximum dry unit weight (kN/m^2)	Compressive strength (Mpa)	Maximum dry unit weight (kN/m^2)
3	3.2	15.7	3.5	16.7	4.1	17.0
5	4.1	16.5	4.3	16.3	4.7	17.3
7	5.9	15.8	5.0	16.5	6.0	17.2

Table 9 is hereunder plotted as fig 6. It clearly shows that compressive strength increased with increase in the cement content. Bowles 1992 has recommended charts or values corresponding to the UCS or CBR number and thickness of base and sub–grade, while Sherwood 1993 recommended a correlation between CBR number and UCS, which would help in evaluating the performance of cement, lime or bitumen stabilized materials.

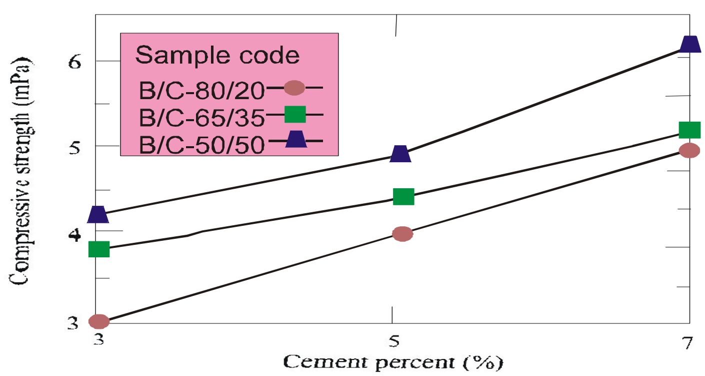

Fig.6 A plot of the variation of compressive strength with different percent cement content

Apart from the correlation between compressive strength and cement, fig 6 also shows that unconfined compressible strength increases with increasing recycled concrete percent (i.e decreasing recycled brick percent). As cement improves the quality of recycled materials, they could be used as base materials, after stabilization with cement.

CONCLUSIONS

Chinwah and Otoko (1988) shown that Nigerian brick plants produce good quality bricks complying with the Nigerian Industrial Standards. This work therefore looks at possibility of recycling such good brick products and use as aggregate in concrete. Inspite of use of the good quality bricks, test results show that the concrete produced from them are still lower quality that the natural rocks, although stronger than ordinary bricks. They could be used in partition walls and other low load bearing areas of new buildings.

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