Journal of Civil Engineering Research 2013, 3(2): 81-87
DOI: 10.5923/j.jce.20130302.03

Performance of Concrete Paving Blocks Reinforced with Bamboo and Rice Husk Ash as Partial Replacement for Cement

Omoniyi T. E*, Akinyemi B. A, Akinosun T. A.

Department of Agricultural and Environmental Engineering,University of Ibadan, Oyo State, Nigeria

Abstract This research involved the production and evaluation of concrete paving blocks (CPBs) by partially replacing the cement content by rice husk ash (RHA) and addition of bamboos. One of the problems usually experienced during the service life of concrete paving blocks include occasional failure due to excessive surface wear. This has led to the preference of other materials of construction. CPB samples with 100% cement content plus 0%, 1%, 2%, and 3% bamboo by weight of cement were produced. Others were 0%, 10%, 20%, and 30% cement replacement with RHA plus 3% in each were produced. Mechanical tests including compressive, flexural and abrasive strength tests were performed on the samples and the results gotten were analyzed. It was observed that cement replacement up to 20% by RHA with 3% is appropriate in strength. Also, the presence of in the blocks had a positive effect on their strength properties. Surface wear in all the CPB samples were also observed to have drastically reduced far below the 1% allowable limit.

Keywords Rice Husk Ash (RHA), Bamboo s, CPB

1. Introduction

The use of CBP for roads began in the Netherlands after the Second World War. Brick paving was the traditional surface material in the Netherlands before the Second World War[1]. Concrete paving blocks (CPB) are precast solid products made out of cement concrete. The product is made in various sizes such as rectangular, square and round blocks of different dimensions with designs for interlocking of adjacent tiles blocks. Concrete paving blocks are utilized in a variety of commercial, municipal and industrial applications. The primary reasons for selecting CPB over other paving surfaces are low maintenance, ease of placement and removal, reusage of original blocks, aesthetics appeal, and immediate usage after installation or repair[2]. The raw materials required for manufacture of the product are portland cement and aggregates which are available locally in every part of the country. Rice husk ash (RHA) is a by-product from the burning of rice husk. Rice husk is an important crop grown in the South Western part of Nigeria wherever swamps are located. The rich land and tropical climate make for perfect conditions to cultivate rice and is taken advantage by the peasant farmers in such areas. The husk of the rice is removed in the farming process before it is sold and consumed. It has been found beneficial to burn this rice husk in open fire places to make various things. The rice husk ash is then used as a substitute or admixture in cement. It is generally recognized that incorporation of pozzolanic materials as a partial replacement to Portland cement in concrete is an effective means for improving the properties of concrete[3]. This is due to the fact that calcium hydroxide produced by cement hydration reacts with pozzolan and produces additional calcium silicate hydrate (CSH) gel, blocking existing pores and altering the pore structure. By-products from agricultural process have also been used as pozzolan to improve the properties of cement paste and mortar; these include rice husk ash (RHA) and palm oil fuel ash.[4] and[5] worked on the effect of rice husk ash on cement mortar and concrete, the results showed that compressive strength of concrete samples showed maximum increase 3.08% between RHA 7.50% to 10.00% which decreased further for higher percentage of RHA. Also they observed that 12.5% of rice husk ash by mass of cement is the optimum dose to be added in concrete production particularly when the husk is burnt under field condition. Their final assertion was that the best applicable percentage of rice husk ash as per field condition is 10.00% for optimal strength and durability.[6] worked extensively on rice husk ash and their conclusion was that it is important to use rice husk ash substitution for ordinary Portland cement up to 30% so as to decrease the weight of the finished project, decrease the cost and dispose of the rice husk ash waste product.[7] stated that the flexural strength tended to be reduced as the

* Corresponding author:
temidayoomoniyi@gmail.com (Omoniyi T. E)
Published online at http://journal.sapub.org/jce

fly ash replacement ratio increased. This tendency was stronger in the 7-day specimen than in the 28-day one. This reduction in strength was as the result of substantially increased water-cement ratio caused by the largely increased unit water content due to the increase in the fly ash replacement ratio, while the increase in the filling rate was at a minimal level. As the result of the visual inspection, no honeycombs, cracks or outstanding deformation were found on hardened paving dry cast concrete blocks in every mix tested.[8] studied the use of waste mud from ceramic tile production in paving blocks and determined compressive strengths of these blocks. They reporteded that the blocks containing cement of 20 wt.% gave satisfactory strength values .

This research was conducted to determine the partial replacement of cement by RHA as a pozzolan material to increase the strength properties of CPBs so as to make it withstand various uses to which it would be subjected in practice particularly its use in residential and commercial buildings in Nigeria.

2. Materials and Methods

2.1. MATERIALS

2.1.1. Fine Aggregates

This was packed along the Nnamdi Azikiwe river course, University of Ibadan. It conforms with the requirements of[9] which includes ensuring that the sand is clean, free of salts and other organic impurities.

2.1.2. Coarse Aggregate

The granite gotten from tipper loads delivered from the quarry as this is better to use compared to river gravel. The sizes of coarse aggregate used vary but the maximum nominal size used was 13.2mm as recommended in[10].

2.1.3. Cement

Cement used was gotten from a nearby market within Ibadan. The brand bought conforms to required properties of cement such as fineness and high strength.

2.1.4. Water

The public water supply in the Department of Agricultural and Environmental Engineering, University of Ibadan was used in the mixing of the concrete tiles. The water is relatively free of acids, alkalis, salt, organic matter and other impurities. It is also potable.

2.1.5. Bamboo

The cut bamboo sticks were dried and then hammer-milled into of length 5mm and below. Dust and small particles passing through 6μm sieve were however sieved out. The was kept in a polythene bag given a prolonged storage of over 5 months in a cool, dry place to serve as a pre-treatment method to reduce the amount of hydrolyzed sugar and tannins thereby aiding its compatibility with cement.

2.1.6. Rice Husk

This was obtained from a nearby farm settlement in Ibadan, Oyo State.

2.2. Methods

2.2.1. Rice Husk Ash Production

The rice husk was burnt in open air in a cylindrical container, as shown in Figure 1which was cut longitudinally into two halves, under normal temperature and other environmental conditions for over nine (9) hours. Waste woods were ignited to serve as source of heat for burning. The color of the rice husk was observed to change from brown to black and then to dark ash at the end of this period. The set up was then well covered while it was left to cool until the next day. The product passing through a 0.3μm sieve was kept and transferred carefully into an air-tight polythene bag, while those retained were thrown away.

Figure 1. Burning of the Rice Husk

2.2.2. Batching and Mixing of Materials

The batching of materials was done in percentage by weight. This is to avoid any error that may occur due to variation in the proportion of void spaces contained in a volume of the product. The mix ratio used was 1:2:4 (cement: sand: granite). 7 different concrete tiles were cast as follows:

- Control (0% and 0% RHA)
- 1% by weight of cement in the mix
- 2% by weight of cement in the mix
- 3% by weight of cement in the mix
- 10% RHA by weight of cement + 3%
- 20% RHA by weight of cement + 3%
- 30% RHA by weight of cement + 3%

The control sample was produced so as to compare it with the other mixes. Mixing of the cement, sand, and RHA was thoroughly done in a head pan using a hand trowel before the coarse aggregate was added for mixing. Water (0.55- water to cement ratio) was then added and mixed thoroughly until a slurry mixture was gotten.

2.2.3. The Slump Test

This test was conducted to check the consistency of the concrete mix in the slurry state and carried out according to ASTM standards. The materials used for the slump test are: cone, tampering rod and base Figure. The concrete containing cement, sand, coarse aggregate (1:2:4) and bamboo (3% by weight of cement); was mixed in a head pan using a water-cement ratio of 0.55.

$$\text{Water cement ratio} = \frac{\textit{weight of water}}{\textit{weight of cement}}$$

2.2.4. Production of the Concrete Paving Blocks

The moulding of the CPBs was done by ensuring that the concrete mixture was well distributed in the mould. When filled up, the loaded mould was transferred onto the vibrating table for vibration to ensure that there are no void spaces within the mould and to remove air bubbles present within the mix. The loaded plastic mould was then transferred to a flat horizontal surface where it is well covered using polythene material in order to protect it from external environmental conditions but with the addition of RHA, de-moulding was extended to 48 hours. The de-moulded pavers were sprayed with water daily to ensure that the hydration reaction occurring within cement continues until the concrete is well cured. The covering and wetting of the CPBs continued for the next 28 days.

2.2.5. Determination of Paving Block Density

The density of the concrete paving blocks were determined analytically by weighing all the CPB samples on an industrial weighing scale and then dividing their masses by their volumes (the product of their thickness and approximate surface area). That is:

$$\textbf{Density of CPB} = \frac{mass\ \ of\ CPB\ sample\ (kg)}{Volume\ \ of\ CPB\ sample\ (m3)}$$

2.2.6. Compressive Strength Test

Figure 2. Specimen of CPB loaded under compression

This test was carried out in accordance with[11]. All the different samples were subjected to this strength test using a compressive strength machine of capacity 3000kN as seen in Figure 2 and at a loading rate of 2mm/min. The maximum load the samples could carry until there is failure by cracking was recorded.

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{maximum applied load (N)}}{\textit{area of top surface (mm2)}}$$

2.2.7. The Flexural Strength Test

The flexural test was performed to study the bending strength of the different samples of CPBs. The size and shape of the specimen used is the full-size block and the test was carried out after 28 days of curing. The rate of loading of the triple gauge flexural transverse machine is 0.5 ~ 0.02 N/mm2 per second. The machine is shown in Figure 3.

Flexural strength (N/mm2) =

$$\frac{\text{maximum applied load (N) x 150 (mm)}}{modulus\ of\ section\ (mm3)}$$

Figure 3. The flexural strength testing machine showing sample under test

2.2.8. The Abrasion Resistance Test

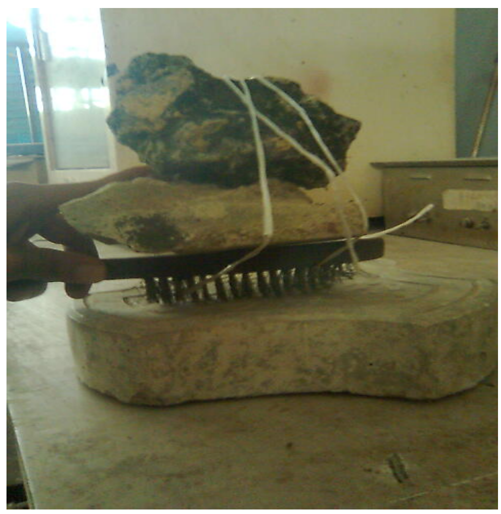

Figure 4. CPB sample under Abrasion resistance testing

An improvised method was employed in the determination of the abrasion resistance of the CPB which involved the subjection of the block to mechanical erosion by brushing with a loaded (3kg) metal brush at a constant pressure over a given number of cycles as displayed in Figure 4. The brushing was done on the side of the block that will be seen in service. The initial and final weight were read and recorded to give the abrasion coefficient. This was carried out in accordance with standards[12] which give the abrasive strength values in percentage mass. The mass of detached matter, i.e. m_1 - m_2, was recorded. The brushed surface area S = L x w (in mm) was also calculated. where:

w = width of the brush (in principle 25mm) and L = length of the brush.

The Abrasion Coefficient, Ca (cm^2/g) = $\frac{S}{m_1 - m_2}$.

2.2.9. Thickness Swelling Test

After curing the concrete paving blocks for 14 days the thickness swelling test was carried out on the different samples to determine the change in dimension of their thickness after being immersed in water for 2 hours and then, 24 hours. The initial and final thickness after 2 and 24 hours were recorded.

3. Results and Discussion

The seven (7) different mixes have been represented as samples A-G:

- Sample A Control (0% and 0% RHA)
- Sample B 1% by weight of cement in the mix
- Sample C 2% by weight of cement in the mix
- Sample D 3% by weight of cement in the mix
- Sample E 10% RHA by weight of cement + 3%
- Sample F 20% RHA by weight of cement + 3%
- Sample G 30% RHA by weight of cement + 3%

3.1. Slump Test

The slump taken at different points on the top surface of the conical concrete slurry were: 7.3, 6.5, 6.2, and 6.7 cm. the arithmetic mean (average) of these figures is:

$$\text{Average} = \frac{(7.3+6.5+6.2+6.7)}{4} cm$$
$$= 6.7cm$$

The slump gotten is a true slump as there was no shearing within the concrete slurry or collapsing of the whole slurry after the cone was removed. This indicates that the water-cement ratio used (0.5) is appropriate and the constituents of the concrete were mixed in the right proportion.

3.2. Density

From the Table 1 and Figure 5, it was observed that the density of the samples with 100% cement content and with 2% shows little difference in density. This may be due to the fact that the presence of does not have effect on the density of the blocks. But with increase in and some cement replacement with RHA, it is observed that there is marked decrease in density as the amount of RHA percentage increases from 0% to 30%.

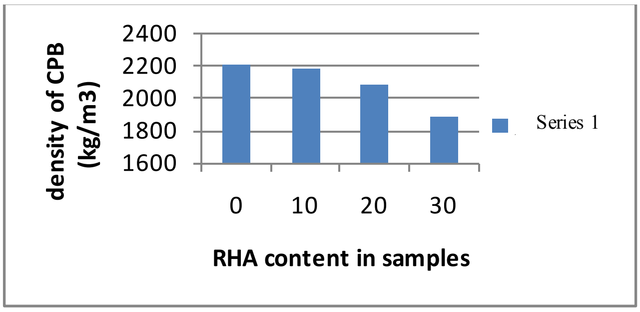

Figure 5. Relationship between density of blocks and RHA content

Table 1. Density of different CPB samples

samples	mass (kg)	area (m2)	Thickness (m)	Volume (m3)	Density (kg/m3)
A	6.13	0.05092	0.054	0.00275	2229
B	6.29	0.05092	0.057	0.002902	2167
C	6.44	0.05092	0.054	0.00275	2342
D	6.31	0.05092	0.056	0.002852	2213
E	6.23	0.05092	0.056	0.002852	2185
F	6.06	0.05092	0.057	0.002902	2088
G	5.68	0.05092	0.059	0.003004	1891

3.3. Compressive Strength

It can be deduced from the compressive strength result in Table 2 and Figure 6 that the samples with bamboo only have higher strength values than those with and RHA. Samples with up to 20% RHA replacement are however appropriate.

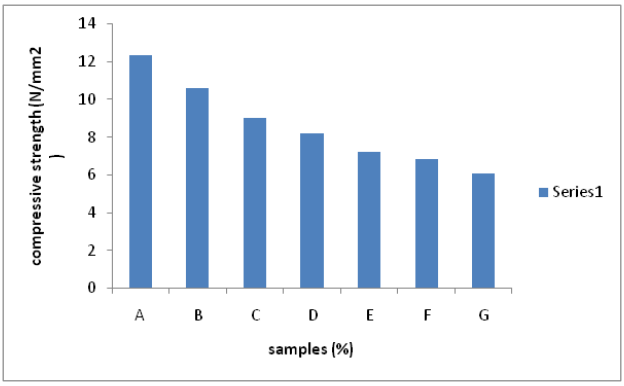

Figure 6. Relationship between CPB samples and Compression strength

Table 2. Compressive strength of the CPB samples

	compression test load (kN)	Area (mm^2)	stress (N/mm^2)
A	630	50920	12.37235
B	540	50920	10.60487
C	460	50920	9.033778
D	420	50920	8.248233
E	370	50920	7.2663
F	350	50920	6.873527
G	310	50920	6.087981

3.4. Flexural Strength

The flexural strength result is as recorded in Table 3, Figures 7 and 8, it was observed from the table that as the percentage of increases, the flexural strength of the blocks increase and as the RHA content increases, the flexural strength decreases. The failure of some CPBs under flexural strength test is shown in Figure 9. There is however high possibility that as the age of the blocks with RHA replacement increases, their flexural strength will also increase.

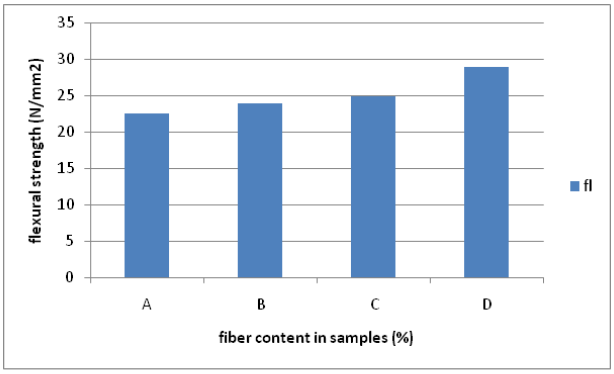

Figure 7. content and flexural strength

Table 3. Flexural strength of CPB's

	load (N)	Area (mm^2)	stress (N/mm^2)
A	22.6	50920	0.44
B	24	50920	0.47
C	25	50920	0.49
D	29	50920	0.57
E	21	50920	0.41
F	18	50920	0.35
G	17.4	50920	0.34

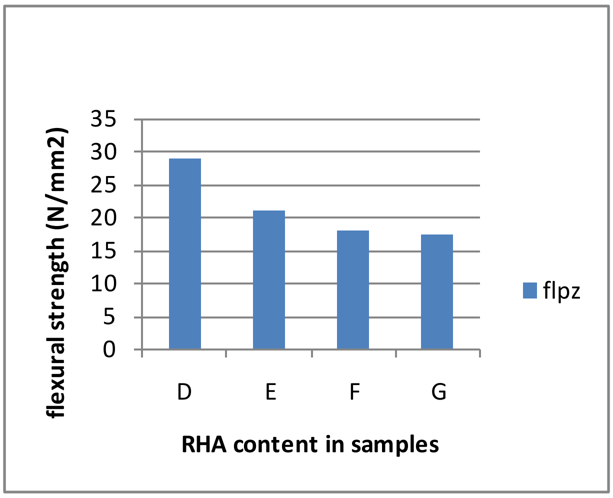

Figure 8. RHA content and flexural strength

Figure 9. Failure of different CPB samples under flexural load

3.5. Abrasion resistance

This test was used to determine the weight loss percentage of a CPB subjected to friction by robbing. It was observed in Table 4, Figures 10 and 11 that as the content increases, the abrasive strength increase and this shows that the presence of s in the CPB have a positive influence on the their abrasive resistance as it increases with increase in content.

After chemical analysis of the used RHA, the total percentage composition of Iron oxide (1.08) Silicon oxide (91.2) and Aluminum oxide (0.76) was found to be 93.53%, so RHA used in this work is an active pozzolan. The bamboo chemical analysis showed that holo-cellulose, cellulose and lignin were present with holo-cellulose having the highest value.

Table 4. Abrasion resistance

	initial mass (kg) m_1	final mass (kg) m_2	Loss of matter (%)
A	6.13	6.1	0.489
B	6.29	6.27	0.318
C	6.44	6.43	0.155
D	6.31	6.3	0.158
E	6.23	6.22	0.161
F	6.06	6.04	0.33
G	5.68	5.66	0.352

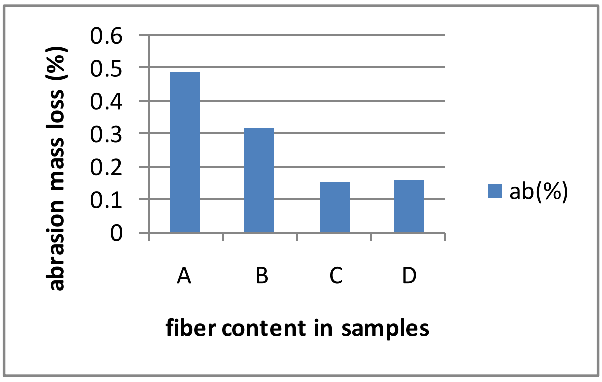

Figure 10. content and abrasion resistance

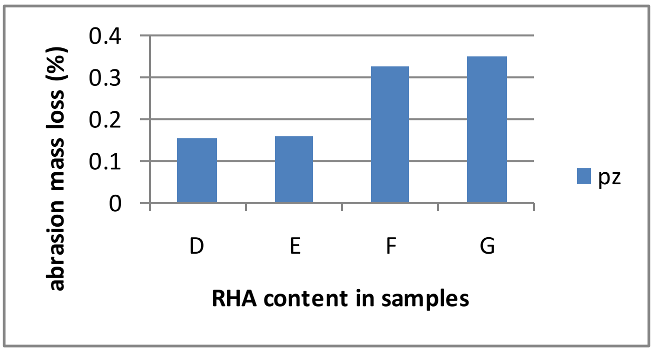

Figure 11. RHA content and Abrasion resistance

3.6. Economics Analysis

3.6.1. Cost Analysis of Concrete paving materials

Considering one unit of concrete paving block; the breakdown is as follows:

(A) Materials

(i) **Cement**: One kilogramme of ordinary Portland cement produces 2 concrete paving blocks

50 kg of cement cost ₦2, 000.00

One concrete paving block cost = $\frac{1}{2}\times\frac{2000}{50}=20$

One concrete paving block cost ₦20 worth of cement.

(ii) **Sand**: 3kg of sand produces 2 concrete paving blocks

5,000kg of sand cost ₦5, 000.00

One concrete paving block cost $\frac{5000}{5000}\times\frac{3}{2}=1.50$

One concrete paving block cost ₦ 1.50 worth of sand.

(iii) **Water:** 50 liters of potable water cost ₦ 20

0.5litres of water produces one concrete paving block

One concrete paving block = $\frac{20}{50}\times 0.5=.20$

One concrete paving block cost 20 kobo worth of water.

(iv) **Bamboo:** 30 grams (0.03kg) of bamboo produces 2 concrete paving blocks

One concrete paving block is approximately equal to 20 kobo of bamboo.

(v) **Chemical additives** ($CaCl_2$): Container of $CaCl_2$ cost ₦ 600

One concrete paving block cost 0.6 kobo worth of calcium tetrachloride.

3.6.2. Total Material Cost (Unit cost)

Cement	=	₦ 20.00
Sand	=	₦ 1.50
Water	=	₦ 0.20
Bamboo	=	₦ 0.20
$CaCl_2$	=	₦ 0.06
Total		**₦ 21.96**

Total cost of material is ₦ 22.00

(B) Labour: Two workers can produce 200 concrete paving blocks in a day

Daily wage per worker is ₦ 1200.00

One concrete paving blocks $\frac{2400}{200}=12$

Labour cost per sheet = ₦ 12.00

(C) Miscellaneous

This is taken as 10% of total cost

$$\frac{10}{100}\times(22.00+12.00)=3.4=4$$

Total cost of producing one concrete paving block = ₦ 38.00

(D)

(i) **Rice husk**: Batching was by mass;

50 kg of rice husk cost ₦200.00

I kg of rice husk cost ₦ 4

Cost of burning 1kg of rice husk to get ash = matches + wood and labour = ₦ 15

Total cost of producing 50 kg of RHA = ₦ 19

(E) Price Comparison

50 kg of cement cost	₦2, 000.00
50 kg of RHA cost	₦19.00

The Cost of rice husk ash is about 1% of the cost of cement.

4. Conclusions

The results of the research carried out on concrete paving blocks (CPBs), has shown that the production of CPBs with cement replacement with RHA up to 30% and addition of bamboo (3% by weight of cement) is technically possible, this supports the assumption that RHA is a potential partial replacement for cement in the production of CPB.

REFERENCES

[1] Pritchard C., and Dawson S., *Precast Concrete Paving: A Design Handbook*, Interpave, Leicester, England, 60p, 1999.

[2] Ghafoori, N., Mathis, R., "Scaling Resistance of Concrete Paving Block Surface Exposed to Deicing Chemicals", ACI Materials Journal, V 94, No.1, pp 32-38 January-February 1997.

[3] Chindaprasirt, P., Rukzon, S., and Sirivivatnanon, V., 2008 "Resistance to chloride penetration of blended Portland cement mortar containing palm oil fuel ash, rice husk ash and fly ash." *Constr. Build. Mater.*, 22, 932–938.

[4] Chindaprasirt, P., and Rukzon, S. 2007. "Strength, porosity and corrosion resistance of ternary blend Portland cement, rice husk ash and fly ash mortar." *Constr. Build. Mater.*, 22:8, 1601–1606.

[5] Sudisht Mishra and Deodhar S. V., Effect of Rice Husk Ash on Cement Mortar and Concrete NBMCW October 2010. http://www.nbmcw.com/articles/concrete/18708-effect-of-rice-husk-ash-on-cement-mortar-and-concrete.html)

[6] Nick Zemke and Emmet Woods, June 2009, Rice Husk Ash, Published Thesis of California Polytechnic State University.

[7] Karasawa, A., Suda, S., Naito, H. and Fujiwara, H., Application Of Fly Ash To Concrete Paving Block, Proceedings of the 7th International Conference on Concrete Block Paving (Pave Africa 2003).

[8] Wattanasiriwech, D., Saiton, A., Wattanasiriwech, S., 2009. Paving blocks from ceramic tile production waste. *Journal of Cleaner Production* 17, 1663 – 1668).

[9] British Standards 882:1992, *Specification for aggregates from natural sources for concrete.*

[10] South African Bureau of Standards (SABS) 1083:2002, *Aggregates from natural sources - Aggregates for concrete*

[11] ASTM C-39, (2001: Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.

[12] Africa Regional Standards (ARS) 674, 675, 676, 677:1996 -Compressed earth blocks - Technical specifications for ordinary compressed earth blocks and other sundry items.