UTILIZATION OF CATHODE RAY TUBES (CRT) CULLET IN THE FORMULATION OF CERAMIC BODY

Akinruli I. J, Lamidi Yinusa Daniel

Department of Glass and ceramic Technology, Federal Polytechnic Ado-Ekiti

Email: dayoakinruli@gmail.com; 08035781643

ABSTRACT

In this study, the rate of accumulation, method of disposal, and risk involved in the CRT glut were accessed. Cullet of TV and PC cathode ray tubes additions were used in substitution for feldspar to formulate stoneware body and simulating standard tile -making process at Royal ceramics Limited (RCL) Suleja. The technological and mechanical properties of the CRT-body system were evaluated against the extant requirements for tiles. Results show that bodies containing between 10 to 50 percent by weight CRT complied with the requirements for standard tiles without violating the rule of firing above volatilization temperature of 1150^{o}C for lead. The sintering pattern shows modifications according to amount (wt %) of cullet addition. There is a lowering of the maximum densification temperature and of the activation energy. Establishment of collection centres is recommended in addition to legislation about the disposal of garbage CRT by Environmental Protection Agencies at all levels in Nigeria.

INTRODUCTION

In early March 2008, people living in Kipevu, near Mombasa (Kenya), complained of feeling ill because of chemicals leaking from the containers of nitric acid that were dumped in the area. Today, Nigeria has become a dumping yard for obsolete gadgets containing Cathode Ray Tubes (CRT) as it could be observed on the streets of major cities where the 'tokunbo' electronic hardware are sold. CRTs are the video display components of televisions and computer monitors.The rate at which the CRT in the form of used television and computers are being shipped to Nigeria in large quantities is of great concern, because of the toxic components they contain. The United States Environmental Protection Agency - USEPA (2002) remarked that the glass in CRTs typically contains enough lead (Pb) to require managing it as hazardous waste under certain circumstances. The situation at Kenya was still better because the source of the pollutant was recognised early enough. In the Nigerian case it may be hard to discover because the effect would manifest long after the dumping of the toxic bearing material had been forgotten.

LITERATURE REVIEW

Exporting Reuse and Abuse to Africa

The advancement in the flat screen of Liquid Crystal Display (LCD) and Plasma Display Panel (PDP) technologies is causing rapid displacement of the bulky cathode ray tubes as components of computers and the television sets. This displacement accounts for the large number of used CRT bearing gadgets being exported from Developed Countries (DC) to Less Developed Countries (LDCs). Particularly in Nigeria, Secondhand computers find application in business centers, printing houses, computer institutes / training schools, cyber cafes and home use. The American Retroworks Inc. / Good Point Recycling - ARI/GPR, (2003) pointed out that due to the economic incentives for foreign dumping, wholesale exporters accept damaged CRTs at low prices and all goes on the shipping container as Toxics Along for the Ride (TAR). Poon (2008) confirms the suspicious shipments of discarded computer monitors and TV sets from developed countries in Europe and North America to the less developed countries. It further expresses that E-waste disposal, especially of CRT has become a global environmental problem.

In late June 2005, government ministers from about 170 countries attended a five-day meeting in Bali on waste management. The meeting of signatories to the Basel Convention focused on the impacts of the large-scale exportation—primarily to LDCs—of hazardous waste, particularly in discarded mobile telephones, computer components, and other forms of “e-waste.” The study conducted by Basel Action Network -BAN (2005) in Nigeria, revealed the alarming level of trans-boundary movement of secondhand and scrap E-waste into Nigeria. The study observed that an average of 500 containers enter Nigeria through the Lagos ports monthly with each containing about 800 monitors or CPUs. This indicates that an average of 400,000 secondhand or scrap PCs or monitors enter the country monthly through the Lagos ports. About 25 – 75% of the imported secondhand computer wares are unusable junk that are non-functional or irreparable (BAN, 2005). This figure amounts to 15,000 – 45,000 tons of scrap recyclable electronic components, which may contain as much as 1000-3,600 tons of lead. Estimated quantities of about 45% of the imports are from EU, 45% from the US, and the remaining 10% from other locations such as Japan, Belgium, Finland, Isreal, Germany, Italy, Korea, Netherlands, Norway, and Singapore

Bioaccumulation of Toxins from Environmental Pollution

Toxic wastes are poisons, even in very small or trace amounts. They may have acute effects, causing death or violent illness, or they may have chronic effects, slowly causing irreparable harm. Some are carcinogenic, causing cancer after many years of exposure. Others are mutagenic, causing major biological changes in the offspring of exposed humans and wildlife. CRT glasses are nondegradable pollutants and the particles of lead compounds leached from it can reach dangerous levels of accumulation as they are passed up the food chain into the bodies of progressively larger animals. For example, molecules of toxic compounds may collect on the surface of aquatic plants without doing much damage to the plants. A small fish that grazes on these plants accumulates a high concentration of the toxin. Larger fish or other carnivores that eat the small fish will accumulate even greater, and possibly life-threatening, concentrations of the compound. This process is known as bioaccumulation

Disposal and legislation

The CRT forms about 80% of the electronics waste. Being of glass, the CTR constitute a kind of solid waste which is not biodegradable and is incombustible. Non-degradable pollutants are materials that either do not decompose or decompose slowly in the natural environment. Once contamination occurs, it is difficult or impossible to remove these pollutants from the environment. There are relatively few glass furnaces or lead smelters recycling post-consumer CRT glass, and this makes solution to its disposal somewhat intractable.

In Nigeria, there is virtually no capacity for material recovery operations for electronic waste, as a result of which these items become discarded in local dumps. There is neither a well – established system for separation, storage, collection, transportation, and disposal of waste nor an effective enforcement of regulations relating to hazardous waste management. USEPA provided a leading example by streamlining the management of cathode ray tubes (CRTs).

Vitification of CRT with kaolin

In previous work by Raimondo et al.(2006) the CRT was introduced in 5 wt. % and 10 wt. %, in partial replacement of the soda feldspar. It was shown that the presence of glass allows preserving good technological and mechanical properties, without significant detrimental effect. However, the temperature of 1200°C at which the samples were fired was beyond the volatilization temperature of 1150°C for lead as pointed out by Taylor and Bull (1986). Consequently it negates the USEPA regulation. This work therefore seeks to evolve a body using CRT in such a way that the maximum temperature for lead volatilization is not exceeded, while keeping the technological and mechanical properties of the tiles within acceptable range.

The required technical performance of conventional ceramic tiles is normally associated with their dimensional parameters, mechanical strength, water absorption, chemical stability and wears resistance. The NIS standard and that of Royal Ceramics limited is as shown in table 1

Table 1. Standard water Absorption and Scratch Hardness for Tiles

Physical Properties	NIS wall	NIS floor	RCL wall	RCL floor
Water Absorption	>10	3-6%	>6	3-4%
Scratch Hardness (Mohr's)	3Min	5 Min	4	7

Source: Royal Ceramics (2011)

Materials and Methods

Body Composition

Ceramic tile bodies are normally composed of two groups of materials: plastic and non-plastic. The plastic material is predominantly based on clays and sometimes kaolin, which are essential to the development of plasticity as well as to impart satisfactory green and dry mechanical strength. The non-plastic part is associated with inert (silica and alumina), fluxes (Soda or Potash in Feldspar) and flux-inducing materials (calcite). The correct mixture of these materials makes the products able to present the desired technological properties and allows them to be easily processed with the lowest possible cost.

In this work Abia Clay, Yankari Kaolin, limestone from Obajana and CRT glasses were used in place of Feldspar to compose the bodies.

Table 2: Table of composition

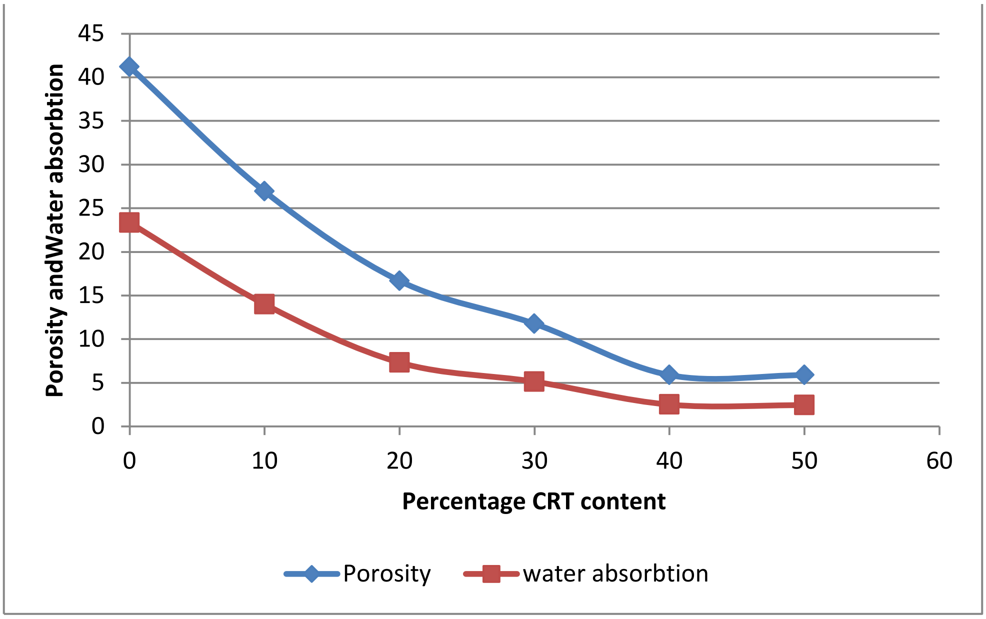
Samples	Abia	CRT	Kaolin	Lime
A1	87.50	12.50	0.00	0.00
A2	79.07	13.95	6.98	0.00
A3	80.00	20.00	0.00	0.00
B1	40.98	54.10	4.92	0.00
B2	39.68	52.38	4.76	3.17

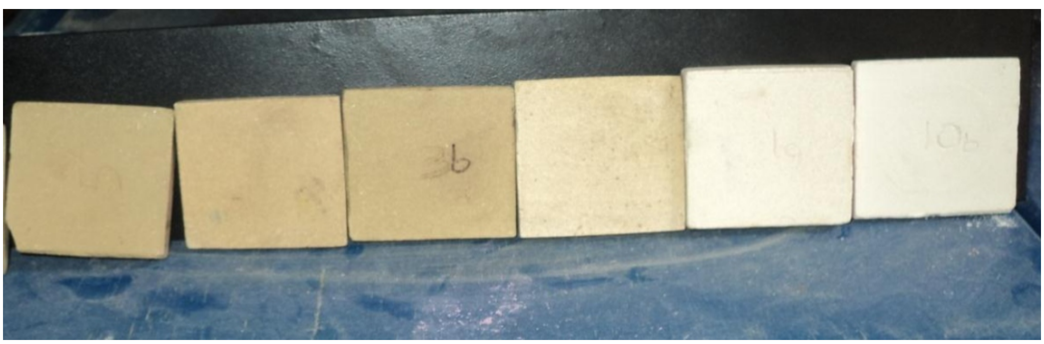
Body preparation, Shaping and Firing

The procedure used follows the schedule of production employedat Royal Ceramics Limited (RCL) Suleja, except that firing was done in an electric test kiln at maximum temperature ranging from 1000°C to 1160 °C with a thermal cycle of 4 hours cold-to-cold.

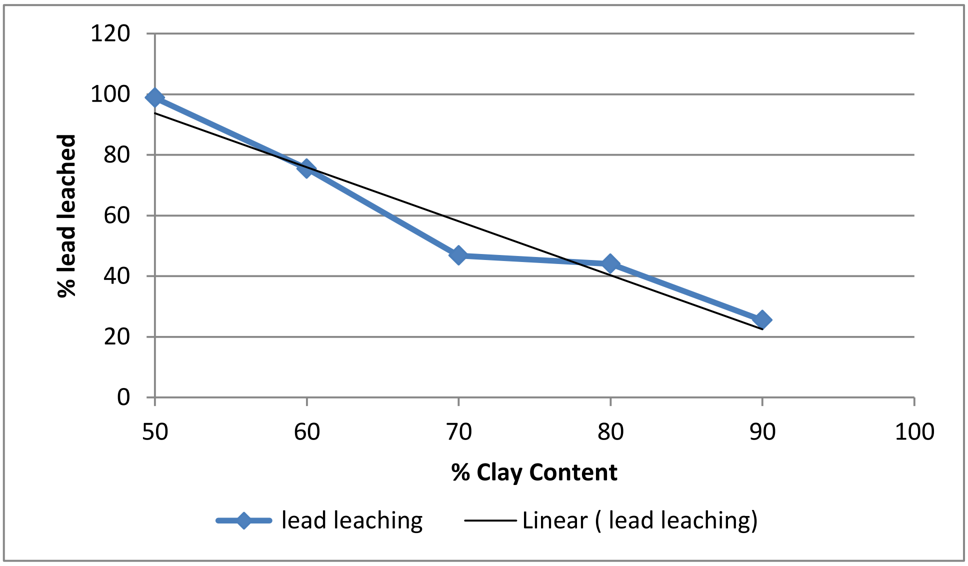
Samples Evaluation

After firing, the shrinkage rate was measured using a steel rule used to measure the final length and the total shrinkage percentage was calculated based on the mould dimension. The percentage water absorption was obtained using the method described by ASTM C20-00.The hardness was tested using reference stones of the Mohr's Scale of hardness. Quartz (scale 7), Feldspar (scale 6) and Apatite (scale 5) were used as the scratching medium. Cotton wool was used to apply blue die over scratches in order to make the mark more visible. Scratched pieces were observed under a magnifying lens.





Lead Leaching from Vitrified Clay -Cullet Sy stem



The workability of a clay is closely related to its plasticity and this plasticity depends on particle size and shape, and the cat-ion present (Worral, 1989). The clay is so plastic as to remain workable up to the point at which the cullet addition is 70%. Hence workability of the clay was not significantly affected by the of cullet.

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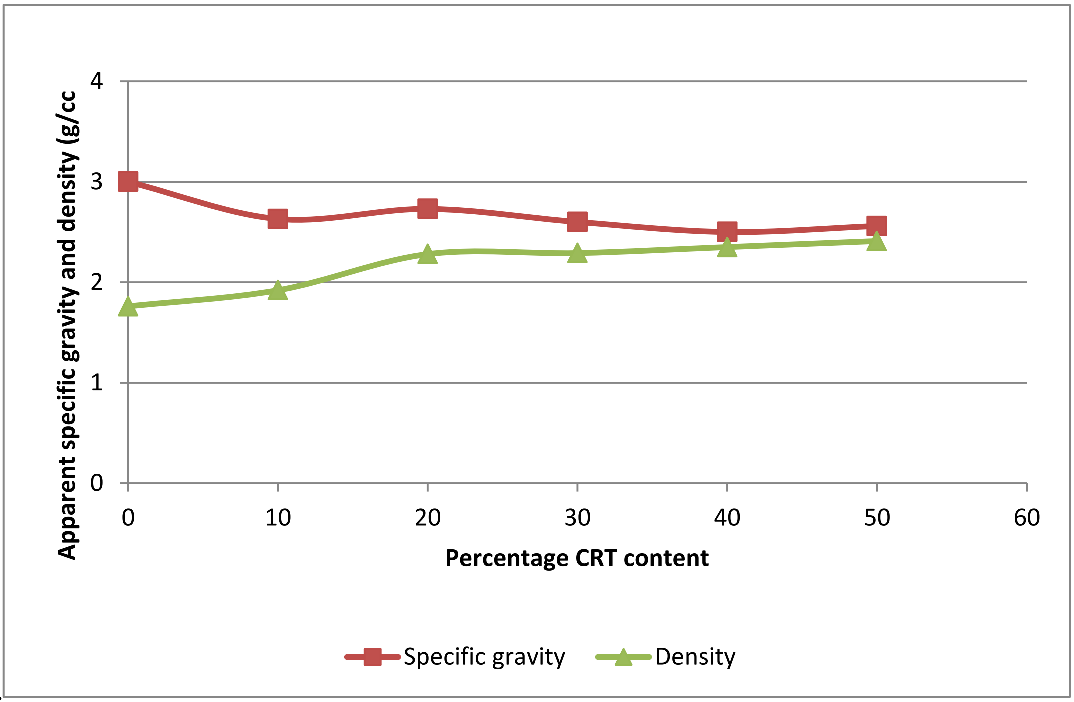
Table 16 shows the behaviour of the samples when fired to 1000°C. As it could be observed on plate 14, some samples maintain their respective shapes while some were distorted, some melted and began to flow.

Effect of cullet on Porosity and the Water of Absorption

The effect of cullet on porosity and the water of absorption on the bodies are closely related. As shown in figure 7, the values for both properties fall with increasing cullet content. The curve of water absorption which is below that of porosity might be indicating the existence of closed pores that are not accessible to water. The values show that compositions between 30 and 50 percent cullet can be used as a body for vitrified tiles and consequently tesserea. The values fall within the limit suggested by DFRD for vitrified tiles, NIS specification for floor and wall tiles, and Royal Ceramics value for floor and wall tiles.

Lead Leaching from Vitrified Clay -Cullet System

Vitrifying clay with cullet reduces its problem of lead leaching. Figure 9 shows progressive increase in the percentage of lead trapped in the clay-culletsystem as the clay content increases. It reaches a peak at 80% clay-20% cullet. It is suggestive that when the clay content is low there would be excess lead ions, once equilibrium is reached with the just enough cullet–clay stoichiometry to form strongly bonded lead-aluminosilicate. The implication is that the system does not contain enough free silica to bring about the formation of lead bi-silicates which Singer and German (1978) observed to be the least soluble. In order to achieve zero lead solubility, a higher percentage of clay, between 70 to 80% must be used. In the alternative, addition of silica and calcium oxide as demonstrated by Harkot Sprechsaal and presented by Singer and German (1978). The body composition of 40 cullet : 60 clay is safe for manufacture of tesserea since BS 4860 part 2 stipulates limits for even cooking ware to be 7.0 mg l^{-1} (Taylor & Bull, 1986) while a body with CRT cullet content as high as 50% has 0.5 mg l^{-1}


Apparent specific gravity and density (g/cc
4
3
2
1
0
0
10
20
30
40
50
60
Percentage CRT content
Specific gravity
Density

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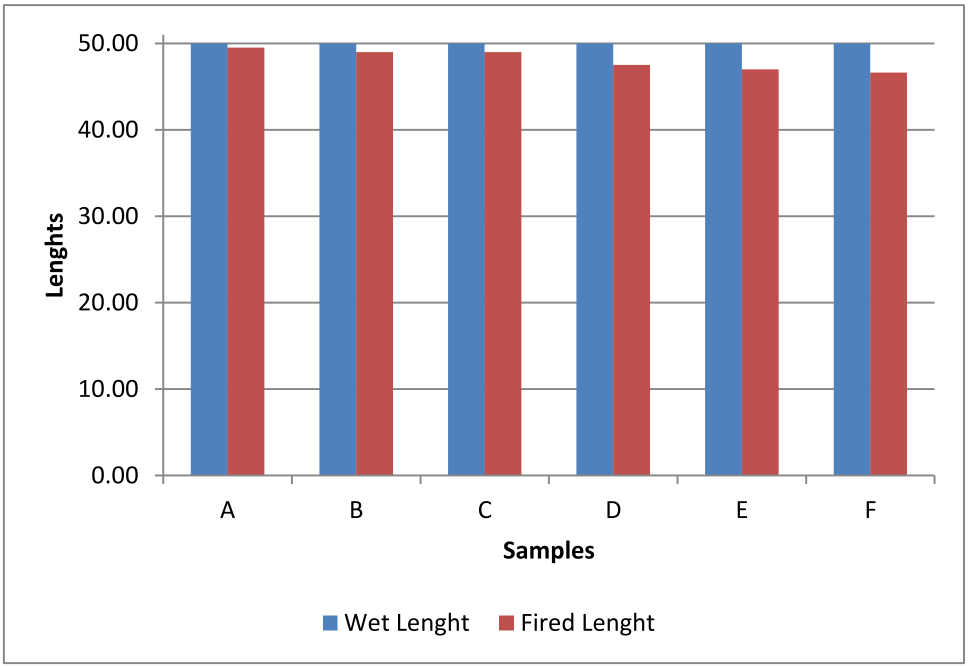
50.00
40.00
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Lenghts
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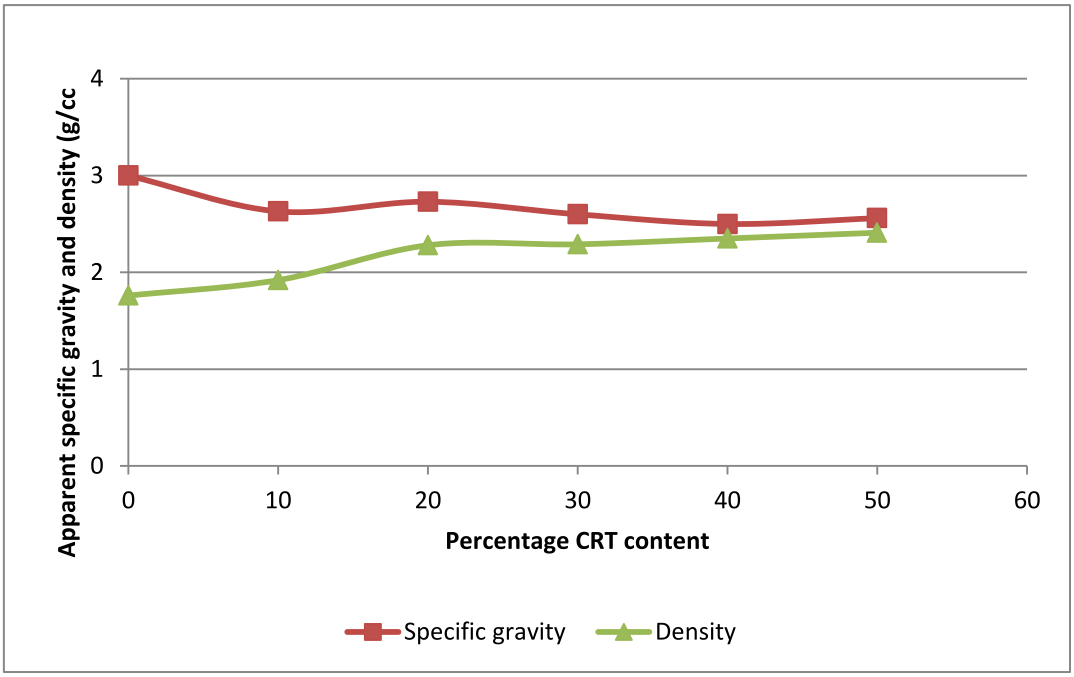

RESULTS AND DISCUSSI ON

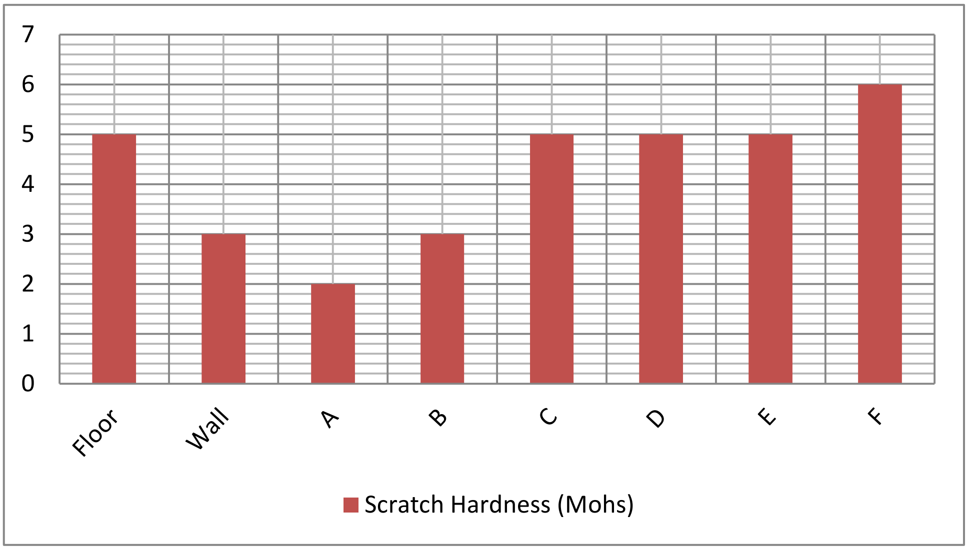

Figure 3: Effect of temperature of firing on Shrinkage

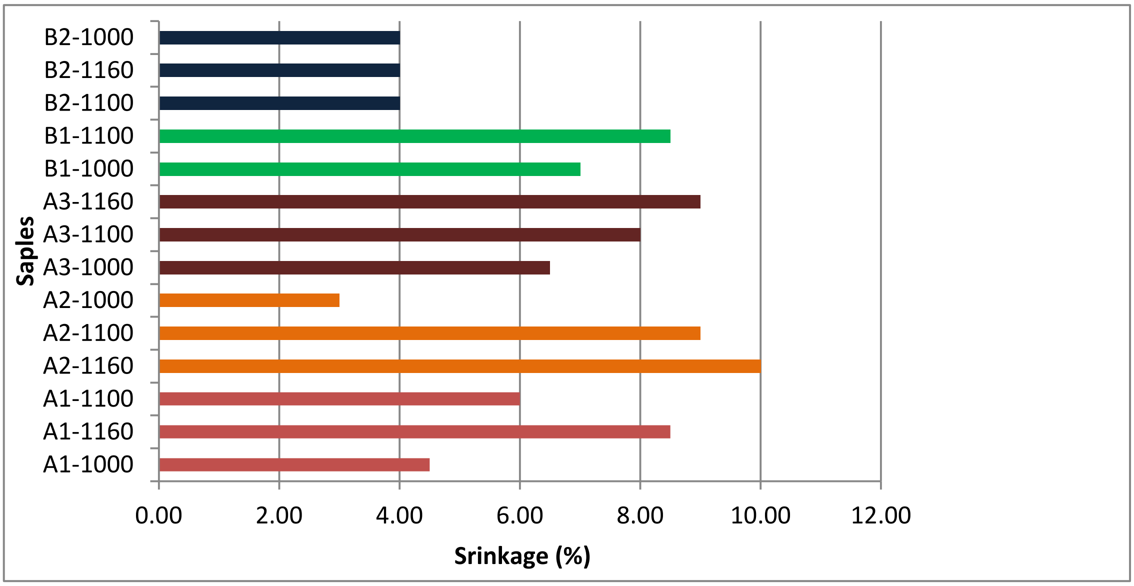

Table 3 shows contraction pattern for the samples. Samples with high content of secondary clay have the highest shrinkage percent. Samples that contain lime show constant contraction for all temperatures between 1000 and 1160. This might be due to the possible formation of wollastonite crystals in the system.

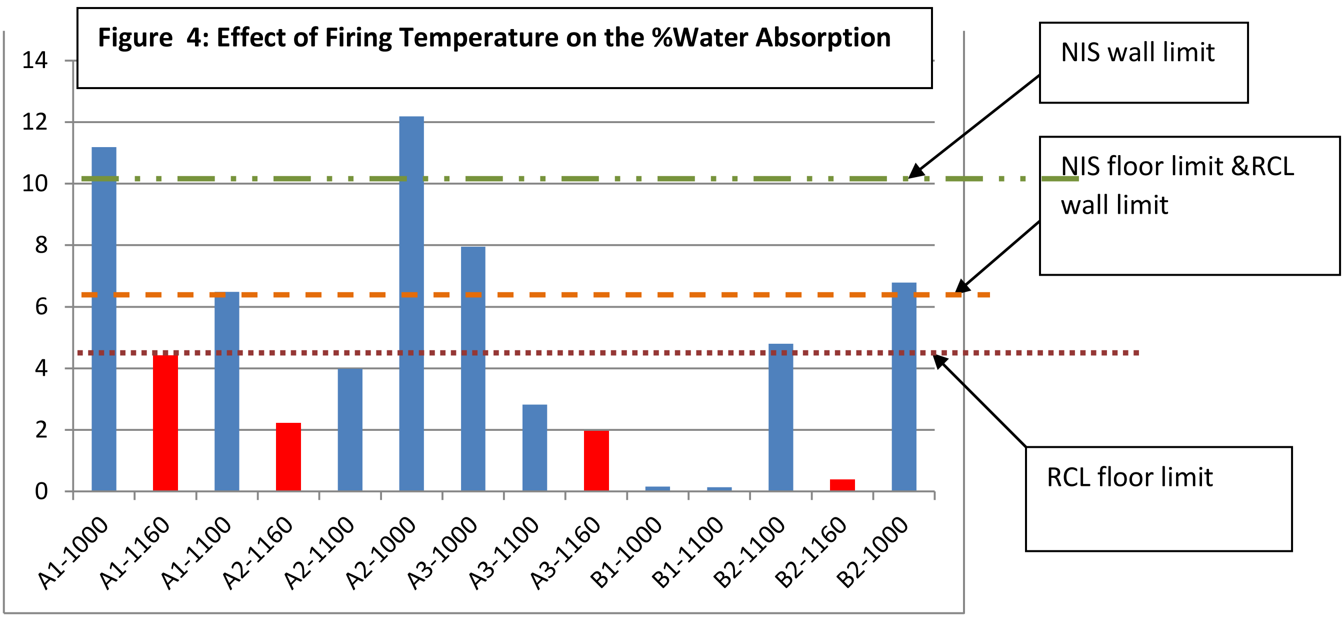

Figure 4 shows the percentage water absorption of the samples as it is affected by the firing temperature. All samples except A1-1000 and A2-1000 have the water absorption that qualifies them for making wall tiles. They all have water absorptions lower than NIS standard. Sample B2-1100 is fit for making floor tiles by NIS standard but not up to the standard required by RCL. Samples A2-1100, A3-1000, A3-1100, B1-1000 and B1-1100 are fit for making floor tiles.

Table 5: Scratch Hardness

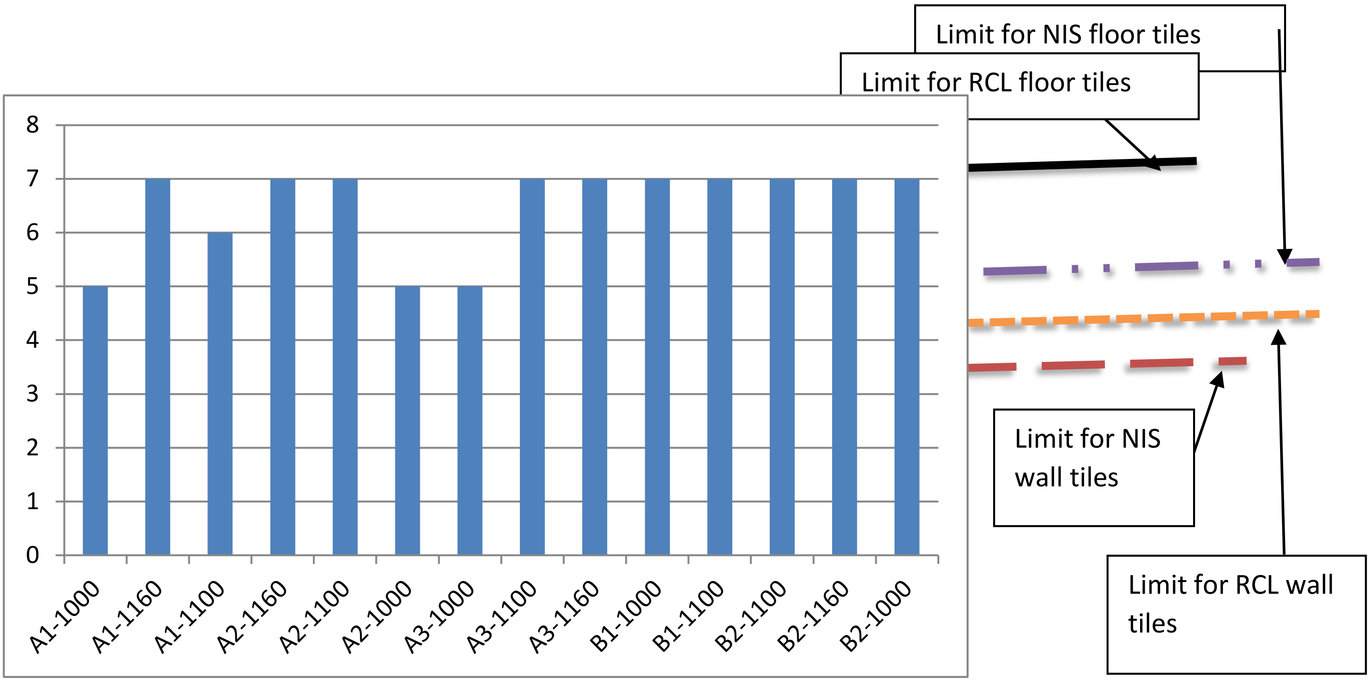

Figure 5 shows the Scratch Hardness of the samples. Sample A_1, A_2, and A_3 have hardness of 5 at 1000°C. Sample A_1 at1100°C has hardness of 6, while other samples have Scratch Hardness of 7, which is the quoted value for RCL floor tiles as shown on table 1. All others meet requirement for either floor or wall tiles by NIS standard.

RECOMMENDATIONS AND CONCLUSION

The result shows that samples B_1 and B_2 maintain dimensional stability as from the temperature of 1000 up to 1160°C. B_1 especially has appreciable hardness and low porosity even at temperature as low as 1000°C. There is an indication that addition of lime to the composition greatly affects the mechanical and technological properties of the body.

In view of the results obtained CRTs are recommended for use as part of material composition in vitrified tiles production.

- The industries in collaboration with government agencies are to establish collection centres where CRT could easily be transported to the industries for reuse.
- Legislations should be put in place about the disposal of garbage CRT by Environmental Protection Agencies at all levels in Nigeria.
- Further research work need to be carried out on the use of CRTs in ceramic body composition especially with limestone addition in various percentages.
- Nigeria needs to put in place a 'cradle- to -grave' monitoring scheme of the imported fairly used electronics so as to prevent indiscriminate dumping of toxic wastes

In conclusion, this goes to say that there is the need for the addition of limestone as a material for ceramic body composition in the recycling of CRT so as to assist the development of the good properties required of tiles.

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