Sustainable Civil Infrastructures

Anand Tapase
Jeffrey Lee
Lei Zhang *Editors*

Infrastructure Sustainability Through New Developments in Material, Design, Construction, Maintenance, and Testing of Pavements

Proceedings of the 6th GeoChina International Conference on Civil & Transportation Infrastructures: From Engineering to Smart & Green Life Cycle Solutions – Nanchang, China, 2021

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Sustainable Civil Infrastructures

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Introduction

This volume contains 14 papers that were accepted and presented at the 6th GeoChina 2021 International Conference on Civil & Transportation Infrastructures: From Engineering to Smart & Green Life Cycle Solutions in September 18–19, 2021, Nanchang, China. It contains research data, discussions, and conclusions focusing on a number of pavement materials and related geotechnical aspects of infrastructure. Topics include issues related to civil infrastructure such as use of construction waste, recycled aggregates, service life prediction of pavements, mechanical behavior of SMA, control measures of ready mixed concrete, determination of landslide high-risk areas, simulation of rock hydraulics in rock joint, and sustainable planning for provision of basic infrastructural facilities in rural areas of India. This information should lead to more resilient and sustainable infrastructure design, maintenance, and management. Various types of research were used in the various studies, including field measurements, numerical analyses, and laboratory measurements. It is anticipated that this volume will support decisions regarding the optimal management and maintenance of civil infrastructures to support a more resilient environment for infrastructure users.

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About the Editors

Dr. Anand Tapase Assistant Professor at the Department of Civil Engineering of Rayat Shikshan Sanstha's Karmaveer Bhaurao Patil College of Engineering, Satara, is renowned Indian Civil Engineer with a research interest in pavement engineering, pavement materials, and sustainable constructions. He completed his Bachelor's degree in Civil Engineering from Rayat Shikshan Sanstha's, Karmaveer Bhaurao Patil College of Engineering, Satara of Shivaji University, Kolhapur, and both M. Tech and Ph.D. degrees from the College of Engineering, Pune (C.O.E.P.) of Savitribai Phule Pune University Maharashtra, India. He is working as Associate on an International Cooperative Research Project carried by Texas Transportation Institute, Texas A&M University, in collaboration with the Texas Department of Transportation, United States of America (USA).

He has two patents by his name. He is Editorial Board Member of International Journal, "Innovative Infrastructure Solutions, Springer Nature Switzerland AG". He is Associate Member of the American Society of Civil Engineers (ASCE) and Transportation and Development Institute (TDI). He is working as Consultant on various government projects. He has authored, co-authored, and edited refereed research 11 journal papers, 19 chapters (author/co-author/editor), and 36 conference papers. He is working as Reviewer for renowned international publications including International Journal of Pavement Research & Technology (IJPRT), Journal of Cleaner Production both published by Elsevier/Science Direct, Journal of Testing and Evaluation of ASTM International, Journal of Performance of Constructed Facilities of ASCE. He is been recognized as '*Outstanding Reviewer*' by the Journal of Cleaner Production published by *Elsevier/Science Direct*. Also, he has worked as Editor of a book volume for Springer Publication at GeoChina 2018. He was invited to serve as Session Chair/Moderator at the GeoChina 2018 International Conference in China. Presently, he is working as Member of the Technical Committee of International Conference GeoChina 2021 which will be held in Nanchang, China, in the year 2021, and working as Lead Editor for the Sustainable Civil Infrastructure Book Series, Springer.

Dr. Jeffrey Lee is Principal Pavement Engineer at the Australian Road Research Board (ARRB) responsible for the management and delivery of research projects for the Department of Transport and Main Roads and other members of the Australian Road Authorities. He has been providing advisory services to road authorities in the areas of asphalt pavement designs, non-destructive evaluation, and increase use of recycled material for pavement construction.

Jeffrey has been Peer Reviewer for different journals published by the American Society of Civil Engineers (ASCE) and American Society for Testing and Materials (ASTM). More recently, he is Chief Editor for an ASCE Geotechnical Special Publication (GSP) and Co-Chair of the Technical Organizing Committee for the upcoming GeoChina 2018 International Conference. He is current Queensland Branch President of the Australian Society for Concrete Pavements, Fellow of the Institute of Engineers Australia, Adjunct Professor at the Queensland University of Technology, and Adjunct Fellow at the University of Technology Sydney.

Prof. Lei Zhang is Professor of Intelligent Transportation System Research Center and Transportation School at Southeast University, China. He had worked earlier at California University, San Diego, as postdoc. His research interest covers non-destructive detection technology and pavement structure and material for transportation infrastructures including highway, steel deck bridge, airfield, and high-speed railway. He completed both his undergraduate and graduate studies at Southeast University. He has authored, co-authored, and edited more than 50 technical papers, 2 books, and 2 standards. He is Associate Editor of the International Journal of Pavement Research and Technology, and he is International Member of ASTM, Member of TRB (AFB65), and Co-Chair of WTC subcommittee. He was awarded as Outstanding Youth Teacher of Southeast University and was also included in Six Talent Peaks Project of Jiangsu Province.

Potential of Fired Clay Brick for Use as Short Beams and Columns

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Abstract. A clay soil, collected from Paggo village, along Minna-Paiko road on Niger state, Nigeria was, molded into clay bricks and fired at temperature of 600 °C. The molds were formed specially with grooves and protrusions of varied depths and thicknesses on both sides. The molds with groves and protrusions were separately used to cast the various bricks. The bricks with protrusions were then fitted into those with grooves using cement slurry of 0.7 water-cement ratio to form short beams. These arrangements categorized the interlocking bricks into three groups (A, B and C), based on depth and thickness of the protrusions and grooves. The results indicated elements formed, interlocking clay bricks of category B, which has higher space between the grooves and protrusions, for cement slurry binder, gave highest compressive strength of 3.7 N/mm^2, which satisfy the strength for load bearing walls according to Nigerian Industrial Standard. Also, elements formed, interlocking clay bricks of category A, which has longer and deeper protrusions and grooves respectively, gave the highest flexural strength of 0.48 N/mm^2, which is far above the near zero flexural strength attributed to masonry clay bricks. This study showed that incorporating relatively longer and deeper protrusions and grooves respectively, as interlocks of fired clay bricks will make withstand reasonable flexural strength that can make the elements serve as short beams.

1 Introduction

The binding properties of cement, which increase in the presence of moisture, makes it took center stage in building and construction industries, since its discovery in 19th century. The setbacks associated with its production, such as emission of carbon dioxide into the atmosphere, high cost of energy, coupled with its relative high cost later became issues of concern, thereby making its use in low cost buildings economically unwise. The cost of cement, which accounts for major cost of development of basic infrastructural, such as roads, water supply, hospitals, schools, houses and ports have tremendously escalated due to hike in cost of energy, required in its production. The carbon dioxide emitted during its production is also hazardous to environment and is therefore needed to be minimized. This has led to various researches on comparative cost analysis of various ways of using cement in building construction industry. Ogunbiyi *et al.* [1] carried out study to compare clay brick and sandcrete blocks as building components.

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The result showed that cost of sandcrete blocks ranges between 120 to 150 naira, while the stabilized clay brick ranges between 45 to 60 Naira. The hike in the price of cement is a major concern to Nigerian government especially to its target of *housing for all by the year 2020* [2].

The developments in construction industry are based on innovative ideas. Addition of other materials to reduce the use of cement is one of the initiatives [3]. A recent research used clay soil as partial replacement for cement as a binder for concrete and mortar production. Bentonite clay was added in order to reduce the percentage of cement in concrete without changing its properties. The mixture was made with different proportions and the highest strength was achieved at 5% addition of Bentonite clay. The use of clay as building material has been considered with upmost importance because of its availability and cost effectiveness [4].

Unfired clay bricks without any form of stabilizer have been used successfully to produce clay bricks for building constructions. Kiptum *et al.* [5] work on effect of depth of clay sample on its suitability for clay brick production. The amount of clay brick lost per annum was also evaluated using peoples' opinion. The author concluded that clay soil samples below the depth of 0.5 m was observed to be suitable for clay brick production and was recommended to avoid loss of brick during processing and handling. Incorporation of natural fibers in production of unfired compressed clay bricks was studied by Njau and Park [6]. Compressive strength of both the fiber reinforced and unreinforced clay bricks were observed to range from 1.74 to 6.85 N/mm^2. Field tests required to evaluate suitability of clay soils for use in production of clay bricks was studied by Suryakanta [7], using smearing test, ball test, wet ball test, dry ball test, sedimentation test, soil shape test and lime tests. The author highlighted the range of parameters that are required to be satisfied by clay before it can be suitably used for clay brick production. Some of these parameters are liquid limit to range from 25 to 38%; plasticity index to range from 7 to 16%; volumetric shrinkage to range from 15 to 25%; composition of sand to range from 20 to 45%; composition of silt to range from 25 to 45% and composition of clay to range from 20 to 35%. According to Murali *et al.* [8], it is essential to identify the characteristics of a clay soil before any construction activities are carryout with it.

Clay materials are sometimes modified or stabilized to manufacture clay bricks so as to enhance their strength and durability. Alumina filler waste and coal ash has been used along with some proportion of clay to produce unfired clay bricks [9]. Unconfined Compressive Strength (UCS) was observed to increase from minimum of about 5 N/mm^2 to over 28 N/mm^2, depending on composition of the admixtures. However, the strength was found to decrease with increase in clay content. Venkatesan [10] studied bricks made of clay, mixed with wood ash and charcoal and observed that at 15% charcoal ash, the bricks have compressive strength of 11.07 N/mm^2, while the maximum strength for those with 15% wood ash was 7.9 N/mm^2. Comparative study on the performance of normal clay bricks and those made using fly ash stabilized clay was carried out by Kumar and Hooda [11]. It was observed that the weight of fly ash clay stabilized bricks reduced by 29% compared to the normal clay bricks and the strength is higher than the best carrying capacity of normal clays by 25%. Chokshi *et al.* [12] carry out a similar study to compare normal clay bricks and fly ash stabilized clay bricks in Gujarat region of India.

The author also reported that fly ash bricks are far lighter than the normal clay bricks and possesses higher strength. Bricks made of clay, replaced with varied composition of materials ranging from cement, sawdust, lime and sand was considered by Smeu *et al.* [13]. The compressive strength was observed to be higher for mixtures containing lime compared to the mixtures containing cement alone. The mixtures with lower water value of 15% gave higher strength compared to those with 25% water content. The flexural strength ranges from 0.4 to 2.6 N/mm^2, while the compressive strength ranges from 2.75 to 6.2 N/mm^2.

Treatment of soil with cement reduces the volume change, but this type of treatment becomes unsuitable for soils with high plasticity index [14]. Soil can be stabilized by addition of cement or lime. Such stabilization processes improve various engineering properties of the soil resulting to improved construction materials. Increase in soil strength, durability, stiffness and reduction in plasticity and swelling/shrinkage potential are some of the benefits of soil stabilization [15]. Limestone powder, class C fly ash, silica fume and water were used to manufacture bricks without cement [16]. The strength was observed to increase with increase in silica fume. At 20% silica fume, the strength was maximum at early curing days and increased from 23 to 26.5 N/mm^2 after 28 and 90 days of curing respectively. The cost of producing these bricks reduces by 6.5% when compared to those made from normal clay.

Another important way of increasing the strength of clay bricks is by firing them at a high temperature of between 500 and 1500 °C. Karaman *et al.* [17] observed that the time taken for firing and the firing temperature significantly affect mechanical properties of the bricks. The authors concluded that high temperature resulted in higher compressive and bending strengths as well as higher densities and lower water absorption. However, the duration of firing has relatively minimal effect on the mechanical properties of fired bricks. The compressive strength was observed to increase from 9.12 N/mm^2 at 700 °C to 31.4 N/mm^2 at 1100 °C. Laboratory study of clay bricks, prepared admixing cocoanut shell ash was carried out by Fernando [18], to determine the influence of the ash on strength of the bricks. The optimal Unconfined Compressive Strength (UCS) of 19.5 N/mm^2 was obtained at 2% cocoanut shell ash. AbdulKadir *et al.* [19] work on effect of coffee waste ash on the strength of fired clay bricks, and observed the compressive strength to decrease from 21.75 N/mm^2 for the normal burnt clay bricks to minimum of 10.24 N/mm^2 when mixed with 5% the ash. Tse [20] evaluated the suitability of clay deposits on the plain of Benue State for bricks production. The results showed that water absorption was between 3–4%, while the compressive strength ranges between 38 and 111 N/mm^2. The use of sawdust in production of light-weight clay bricks was also studied by Chemani and Chemani [21]. These bricks were fired to between 800 and 950 °C. The authors observed 9% optimum sawdust to give characteristics for clay bricks that are suitable for technological purposes.

There has been increase in the usage of clay bricks for construct of bungalows and other low-rise buildings for low to medium income earners in Nigeria, in the recent times. This has tremendously reduced the cost of buildings. However, cement is still used for construction of some elements of these buildings, such as reinforced concrete columns, slabs and beams. The use of clay pots in construction of slabs has reduced the use of cement in that regard. But columns and beams require materials with high flexural strength which is relatively minimal in normal clay bricks masonry. Although, even some traditional clay bricks making molds are made in such a way that the resulting bricks [22] have some kind of grooves and protrusions, the amount of flexural stresses building elements, made with them resist is very minimal. Attempt has also been made, although with little success, to produce unfired clay bricks incorporating some additives [23] that will add to their resistance to flexural stress. This study therefore, investigated the response of building elements constructed with fired clay bricks, made with special grooves and protrusions, which aided their assemblage in formation of the elements, to flexural stresses. This study indicated the possibility of using these bricks for short beams and columns in low rise buildings.

2 Materials and Methods

The materials used in this study are included specialized fabricated clay brick molds, whose assemblage consisted of protrusion and grooves (depression) with dimensions as shown on Table 1. Three categories of the molds, A, B and C were used, each with different dimensions as shown in Fig. 1.

Table 1. Brick dimensions

Brick no.	Groove (depression) size (mm)	Protrusion size (mm)
A1	100 × 55 × 110	100 × 53 × 108
A2	100 × 55 × 110	100 × 50 × 105
A3	100 × 55 × 110	100 × 47 × 102
B1	75 × 45 × 90	75 × 43 × 88
B2	75 × 45 × 90	75 × 40 × 85
B3	75 × 45 × 90	75 × 37 × 82
C1	60 × 35 × 70	60 × 33 × 68
C2	60 × 35 × 70	60 × 30 × 65
C3	60 × 35 × 70	60 × 27 × 62

The second major material used in the study was a clay soil, collected at Paggo village, along Minna-Paiko road in Niger state, Nigeria. The clay soil was transported to Civil Engineering Laboratory, Federal University of Technology, Minna, Nigeria, and prepared using the methods highlighted in BS 1377-1 [24].

The methods adopted in the study involved carrying out index properties, X-ray Fluorescence (XRF) test and X-ray Diffraction (XRD) tests, to classify the clay and obtain its mineralogical and oxide compositions. 15% water by dry weight the clay was then added and mixed properly and allowed for some time to give a good and uniform consistency. The mixture was then placed into the protruded and depressed molds and allowed to dry before removing them from the molds. The freshly demolded air-dried clay bricks are shown in Fig. 2.

The bricks were then transferred to Urban Shelter Company at Poggo village along Minna-Paiko road, where they were fired at 600 °C using industrial furnace, after which the bricks were brought out from their furnace. After firing, the color of the bricks changed to reddish (Fig. 3).

The fired bricks were then joined such that the protruded parts were fixed into the groves by cement slurry of 0.7 water-cement ratio. This fixture resulted to a clay bricks of between 0.60 to 0.66 m lengths as shown in Fig. 4.

The interlocked bricks were then transported to National Center for Agricultural Mechanization (NCAM) in Ilorin, Kwara State, Nigeria for compressive and flexural tests as shown in Figs. 5 and 6 respectively. Three samples each for the three categories were tested for both flexural and compressive strengths.

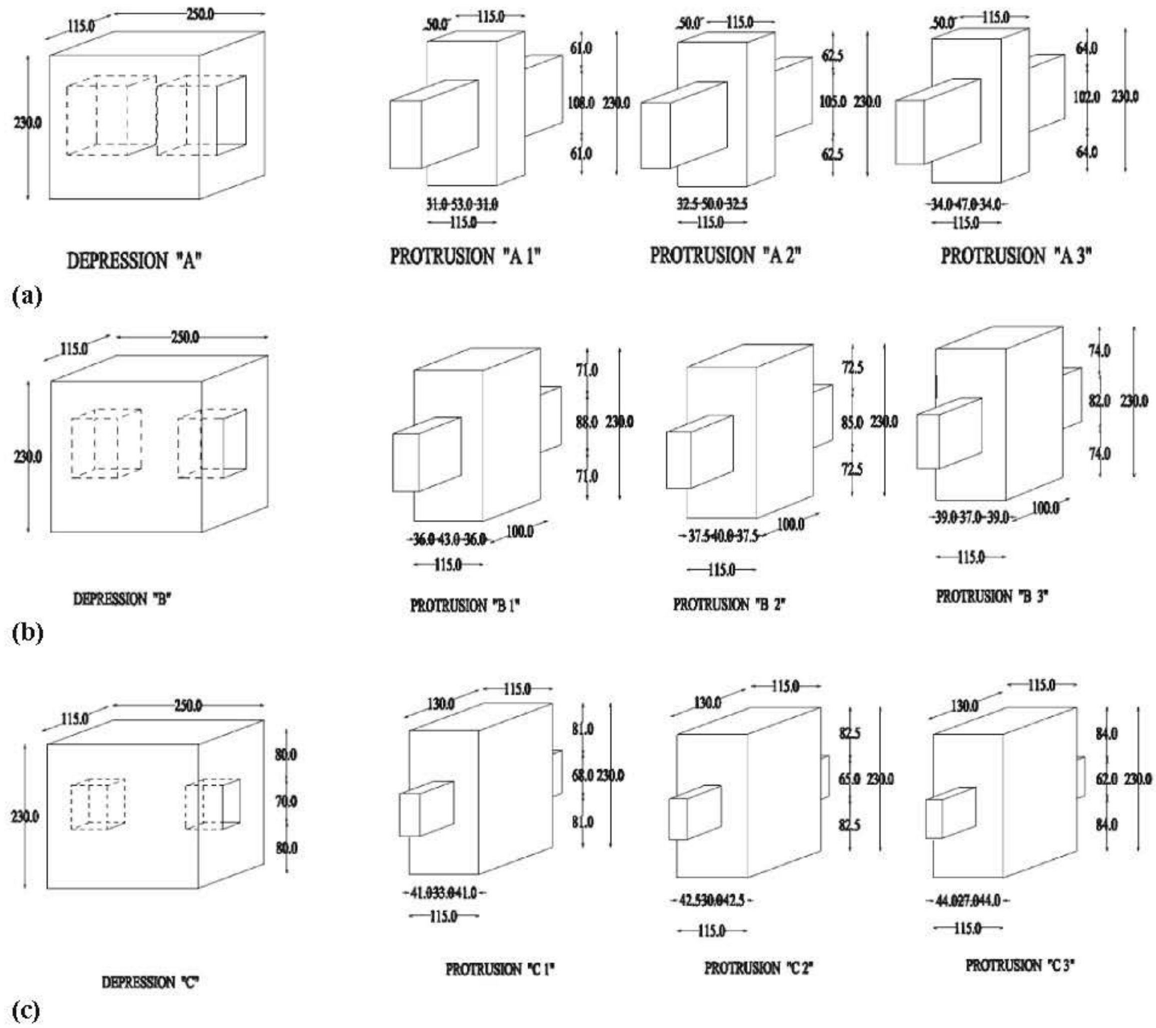

Fig. 1. Shapes and dimensions of the molds for the a: A category, b: B category and c: C category

Fig. 2. Freshly demolded clay brick components

Fig. 3. Clay bricks after firing from the furnace

Fig. 4. Interlocked clay bricks

Fig. 5. Compressive test on clay brick

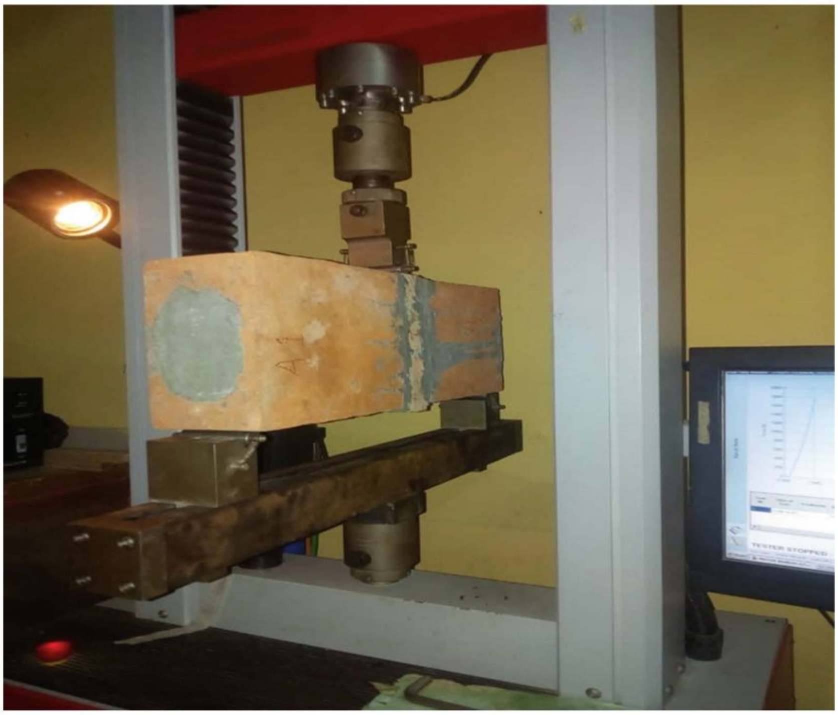

Fig. 6. Flexural test on clay brick

3 Results and Discussions

3.1 Index Properties

Results of index properties of the clay soil are shown on Table 2. From the results, the clay soil classified as clay of low plasticity (CL) according to Unified Soil Classification System (USCS) and A-6 according to AASHTO soil classification system. The liquid limit of 40.4% is slightly above the range of 25–38% recommended for clays to be used for clay bricks manufacturing. However, the sand, silt and clay compositions of 41.2, 39.4 and 19.4% respectively, are within the ranges of 20–45, 25–45 and 20–35% for sand, silt and clay respectively. The plasticity index of 10.3%, obtained for the clay is within the range of 7–16% recommended by Suryakanta [7].

3.2 Mineralogical and Oxide Composition of the Clay

The result of x-ray diffraction test conducted on the clay is shown on Fig. 7. From the figure, the clay has predominantly quartz, albite, montmorillonite and potassium mica. The presence of montmorillonite is probably responsible for the high liquid limit observed. Result of the x-ray fluorescence conducted on the clay is shown on Table 3. The clay contained substantial amount of silica and alumina with minimal traces of heavy metals.

Table 2. Index properties of clay soil

Description	Value
Natural moisture content	11.5%
Liquid limit	40.4%
Plastic limit	30.1%
Plasticity index	10.3%
Sand	41.2%
Silt	38.4%
Clay	20.4%
Specific gravity	2.73
USCS classification	CL
AASHTO classification	A–6

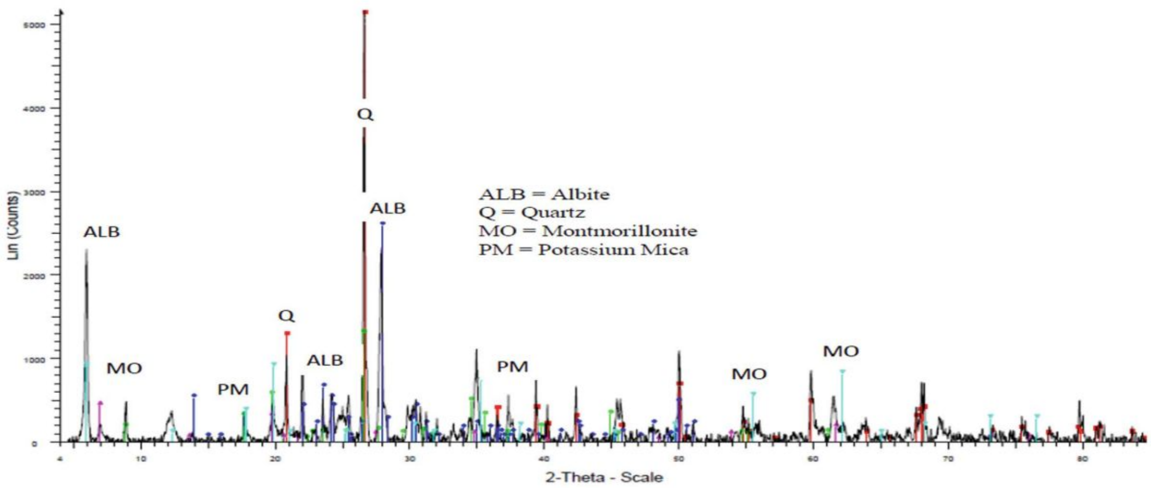

Fig. 7. X-ray diffraction graph of the clay soil

Table 3. Oxide composition of the clay soil

Oxide	Fe_2O_3	MnO	Cr_2O_3	V_2O_5	TiO_2	CaO	K_2O	P_2O_5	SiO_2	Al_2O_3	MgO	Na_2O	LOI	Total
Amount (%)	6.74	0.12	0.01	0.02	0.80	2.79	1.63	0.12	59.70	18.26	1.66	1.88	5.49	99.2

3.3 Compressive Strength of the Interlocking Clay Bricks

A typical result of the compressive strength of the interlocking clay bricks for category A is given on Tables 4 and 5 and Fig. 8.

Table 4. Compressive strength test result for category A clay bricks

Test no.	Date of test	Code	refz	Energy to peak (N/mm^2)	Energy to yield (N/mm^2)	Force at peak (N/mm^2)	Def. at peak (N/mm^2)	Force at yield (mm)	Def. at yield (mm)
1	06/11/2019	A1		111.5	111.5	65266.0	4.04	65260.0	4.04
2	06/11/2019	A2		174.0	131.0	79730.0	5.19	74460.0	4.64
3	06/11/2019	A3		103.7	103.7	64730.0	7.89	64730.0	7.89
Min.				103.9	103.9	84730.0	4.04	84730.0	4.04
Mean				129.7	115.6	89906.0	5.71	88150.0	5.52
Max.				173.9	151.0	79730.0	7.89	74460.0	7.89
SD				38.5	14.1	8511.4	1.97	5471.0	2.07
C of V				29.7	12.2	12.2	34.81	8.03	37.51
ICI				34.0	80.4	48763.0	0.80	54559.0	0.38
UGL				225.5	150.4	91050.3	10.61	81741.0	10.66

Table 5. Continuation of compressive strength test result for category A clay bricks

Test no.	Force at break	Deformation at break	Strain at peak	Strain at yield	Strain at break (N/mm^2)	Stress at yield (N/mm^2)	Stress at break (N/mm^2)	Stress at peak (N/mm^2)	Young's modulus (mm)
1	42250.0	4.60	0.734	0.734	0.837	2.47	1.60	2.47	363.5
2	67440.0	5.66	0.944	0.842	1.034	2.82	2.65	3.01	399.9
3	64260.0	7.91	1.434	1.434	1.437	2.45	2.43	2.45	235.3
Min.	42250.0	4.60	0.734	0.734	0.837	2.45	1.60	2.45	235.3
Mean	57983.3	6.07	1.037	1.004	1.103	2.58	2.55	2.64	333.0
Max.	67440.0	7.91	1.434	1.434	1.437	2.82	2.19	3.01	399.9
SD	13717.9	1.68	0.359	0.376	0.306	0.21	0.52	0.32	86.5
C of V	23.66	27.75	34.608	37.507	27.748	8.03	23.66	12.18	26.0
ICI	23905.7	1.58	0.148	0.059	0.343	2.06	0.90	1.84	118.1
UGL	92060.9	10.24	1.929	1.939	1.863	3.09	3.48	3.44	547.8

The graph of stress-strain curves shows that the stiffness of the bricks is low with gentle increase to a yield point and then finally to a braking point. This is a representation of the brittle nature of the fired clay bricks. The compressive strength of the three categories of the interlocking clay bricks is shown on Fig. 9.

The highest compressive strength of 3.7 and 3.4 N/mm^2 were recorded in category B for specimen B2 and B3 respectively. The size of protrution and depression in category A bricks are close, thus leaving little space to be filled with cement slury. In category C bricks, the thickness of the protrusions are relatively small which can easily give way under compression. Category B bricks however, posses medium thickness of protrusion

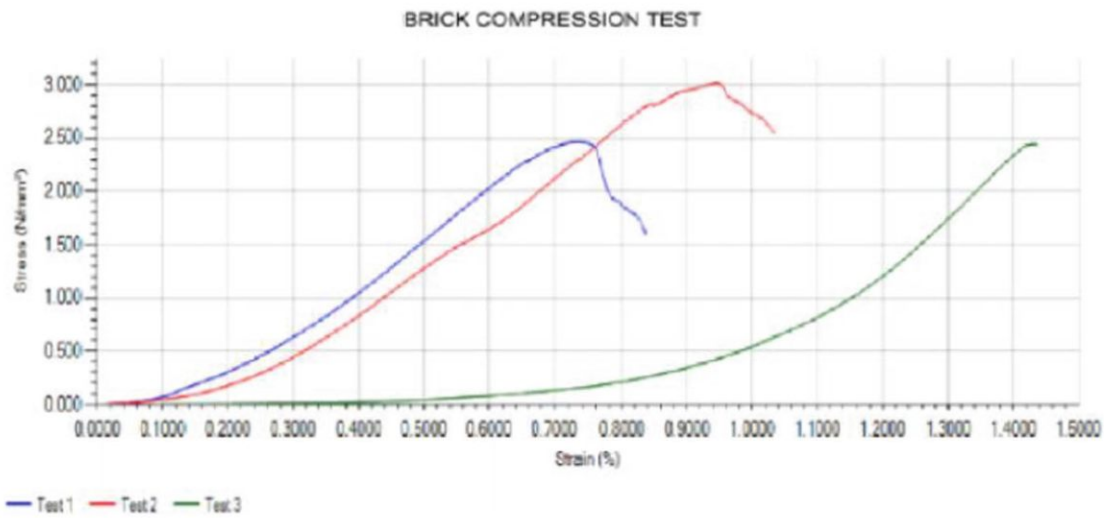

Fig. 8. Result of compression test for category A clay bricks

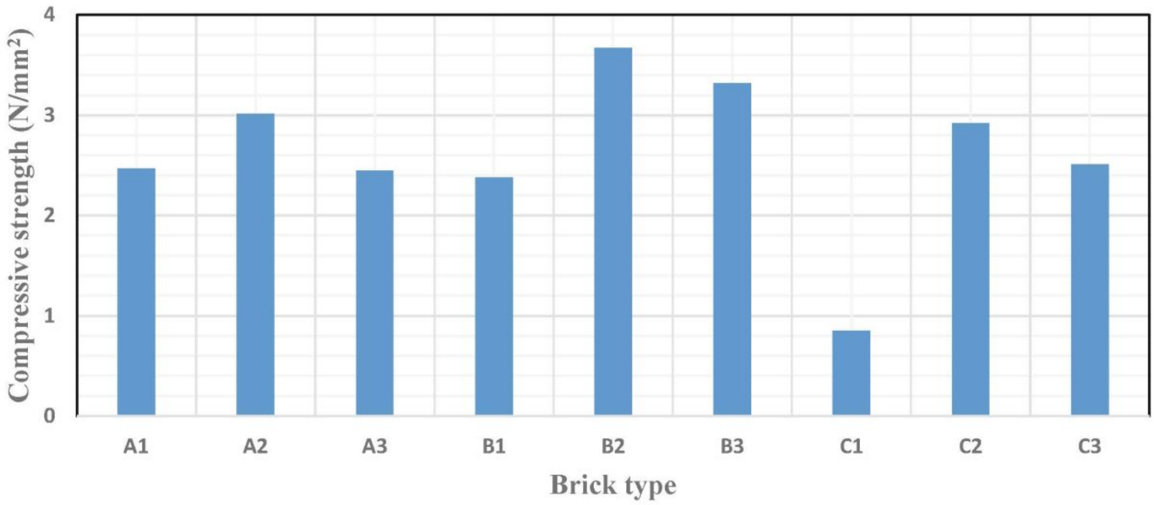

Fig. 9. Compressive strength of fired interlocking bricks

with B2 and B3 having higher spaces to be filled with cement slurry on interlocking. This is probably responsible for the higher compressive strength values recorded.

3.4 Flexural Strength of the Interlocking Clay Bricks

Result of flexural strength of the three categories of the interlocking clay bricks is shown in Fig. 10, while typical result as obtained from the compression machine is shown on Tables 5 and 6 and Fig. 11 for category A.

The result showed that flexural strength depends mainly on depth of the protrusions and to a large extent, on the space to be filled with cement slurry. The highest depth of protrusion (102 to 108 mm) exists in category A bricks, which is probably responsible for the higher flexural strength recorded for this category. Also, the higher spaces available to be filled with cement slurry occurs in A2 and A3 of this category which must have contributed to the higher strength (0.36 and 0.48 N/mm^2) recorded. The lowest flexural

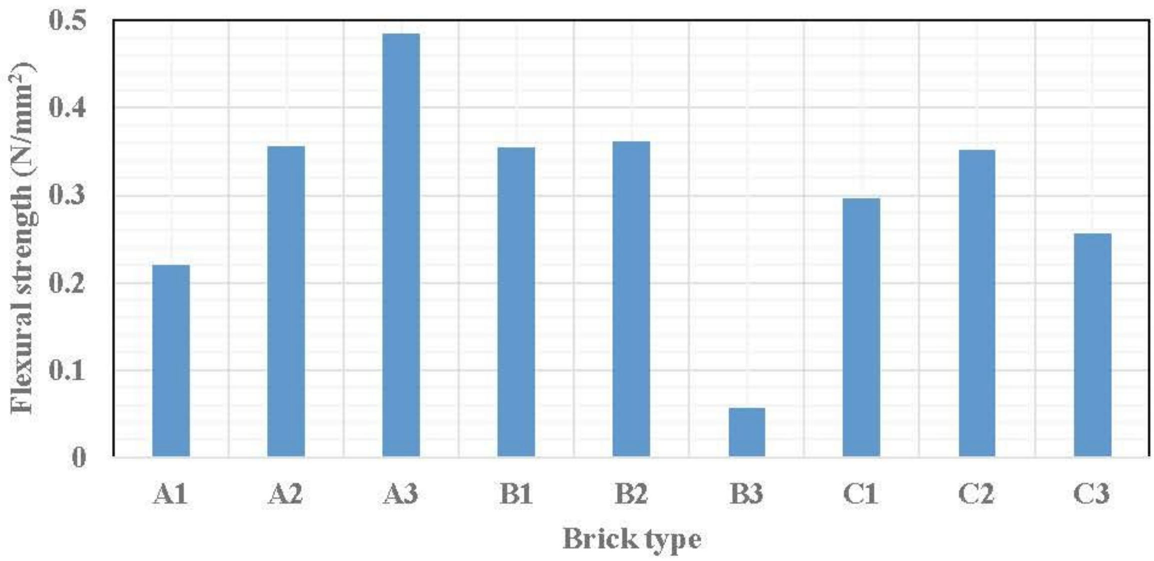

Fig. 10. Flexural strength for the three categories of the interlocking bricks

strength of 0.06 N/mm^2, observed with specimen B3 must have resulted from a defect on the brick (Table 7).

Table 6. Flexural strength test result for category A clay bricks

Test no.	Date of test	Treatment	Specimen	Bending strength at yield (N/mm^2)	Bending strength at peak (N/mm^2)	Bending strength at break (N/mm^2)	Bending modulus (N/mm^2)	Def. at yield (mm)	Def. at peak (mm)
1	06/11/2019		A1	0.220	0.220	0.220	41.3	0.973	0.973
2	06/11/2019		A2	0.184	0.184	0.097	44.0	0.869	0.869
Min.				0.184	0.184	0.097	41.3	0.869	0.869
Mean				0.202	0.202	0.158	42.7	0.921	0.921
Max.				0.220	0.220	0.220	44.0	0.973	0.973
SD				0.025	0.025	0.087	1.93	0.074	0.074
C of V				12.006	12.606	65.071	4.52	7.989	7.989
IGL				−0.027	−0.027	−0.625	25.4	0.260	0.260
UCL				0.431	0.431	0.942	60.0	1.582	1.582

From Fig. 11, specimen A1 and A2 showed similarity in slope, strain at failure and mode of failure. Specimen A3 however, showed lower slope with higher flexural strength and strain at failure. The higher strain at failure and higher magnitude of flexural strength is attributed to size of the protrusion and higher space available to be filled by cement slurry.

Table 7. Continuation of flexural strength test result for category A clay bricks

Test no.	Def. at break (mm)	Force at yield (N)	Force at peak (N)	Force at break (N)	Plastic strain at break (%)	Strain at yield (%)	Strain at break (%)	Strain at peak (%)	Transvers rupture strength (N/mm^2)
1	0.973	1784.0	1784.0	1784.0	0.005	0.537	0.537	0.537	0.220
2	1.238	1492.0	1492.0	784.0	0.464	0.480	0.683	0.480	0.184
Min.	0.973	1492.0	1492.0	784.0	0.665	0.480	0.537	0.480	0.184
Mean	1.105	1638.0	1638.0	1284.0	0.234	0.508	0.610	0.508	0.202
Max.	1.238	1784.0	1784.0	1784.0	0.464	0.537	0.683	0.537	0.220
SD	0.187	206.5	206.5	707.1	0.325	0.041	0.103	0.041	0.025
C of V	16.050	12.8	12.8	55.1	138.6	7.969	16.950	7.989	12.605
IGL	−6.578	−217.1	−217.1	−5069.0	−2.683	0.143	−0.319	0.143	−0.027
UCL	2.789	3493.1	3493.1	7637.1	3.151	0.879	1.539	0.873	0.431

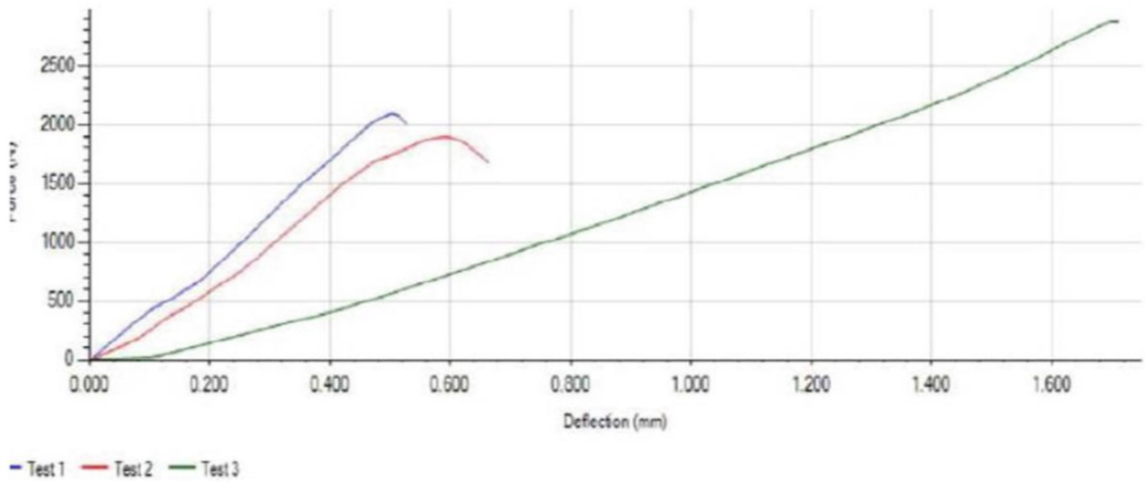

Fig. 11. Typical result of Flexural strength for category A interlocking Brick

4 Conclusion

The following conclusion is drawn from the study:

Elements formed, interlocking clay bricks of category B, which has higher space between the grooves and protrusions, for cement slurry binder, gave highest compressive strength of 3.7 N/mm^2, which satisfy the strength for load bearing walls according to Nigerian Industrial Standard.

Elements formed, interlocking clay bricks of category A, which has longer and deeper protrusions and grooves respectively, gave the highest flexural strength of 0.48 N/mm^2, which is far above the near zero flexural strength attributed to masonry clay bricks.

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