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Research Article

An Investigation into the Local Production Technology of Burnt Bricks in Nigeria

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Abstract

The acceptability of fundamental features of burnt clay bricks is a control course obtained during the production process. The applied knowledge and skills in production technology of burnt clay bricks were subjectively evaluated and quantified. Multi-method research approaches were adopted which included questionnaire instruments and experimental analysis. Assessing the source of knowledge and skill, the experience of labour and team capacity showed that most of the participants have been in the burnt brick production business for 6-10 years (37.3%) through the tutelage of their friends (72.9%) and participated in the groups of 4-5 people (25.4%). There was a deficiency in knowledge and skills needed for forming and firing stages for standard quality burnt clay brick but only effective in the extraction and preparation stage but deficient in shaping, drying, building the field kiln and firing the field kiln. The independent-sample *t*-test showed that the mean of the measured water absorption value of the locally produced burnt clay brick was statistically higher (mean ± SD = 29.51±0.58) than the minimum allowable standard water absorption value (mean ± SD = 20.00±0.0) significant at p = 0.00. A similar observation was made for compressive strength as the measured mean compressive strength value for the locally produced burnt clay brick was 3.98±0.30 N/mm² which was statistically higher than 3.5 N/mm². However, the dimensions of the burnt clay bricks were with the tolerance of approximately 5% for locally produced bricks. Considering the importance of good quality burnt clay bricks in construction local producers need a training.

Keywords

Burnt clay bricks, Product quality, Local production, Drying and compressive strength

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1. INTRODUCTION

The locally produced burnt clay bricks in Nigeria feature on the knowledge capacity through acquisition, sharing, and application in transforming raw materials (clay) into finished consumer goods (burnt clay brick). According to studies, the craft involved in the local production of burnt bricks making is a time-proven method that has transcended from generations [1-2]. The burnt clay bricks production technology is almost wholly indigenous and requires simple tools, less scientific skill, and little or no organizational input. The operation is basically for household income generation [1, 3]. The mixed production processes, according to studies, varied because of the different customs, civilizations, and availability of raw materials in various regions [3]. Irrespective of production processes and raw material sources, it is expected that the quality of the burnt clay bricks should be consistent with the standards for the proper performance of minima 3.5 N/mm^2 compressive strength and not more than 20% water absorption. Good clay for bricks production is available in abundant qualities and quantities almost everywhere in Nigeria [2-3]. As no raw material has real value except if it is processed, the combination of resources and application technology to produce goods that satisfy people’s needs depend on the ability to do real things expertly [4-5]. Forming and firing the brick are two main stages in the production of bricks. The forming stage is the extraction of the clay, clay preparation, moulding or shaping, and drying. The vital steps in firing the brick are building the field kiln and firing the field kiln. The acceptability of any product is the collection of features such as product performance, reliability, conformance to specification, durability, serviceability, aesthetics, and perceived quality. Technically, all high performance and sustainable buildings superior properties consider certain components of design such as weather resistance, good thermal and acoustic comfort, renewable energy, high compressive strength and durability, water efficiency, excellent fire resistance, safety and security [6-7].

The versatility and durability of brick facilitate its use as part of many sustainable design elements [7]. When the desire properties of these materials are not met, it generates a negative impact, leading to a reduced value and perceived inappropriateness of locally available materials [2]. This necessitates that the controlled properties of burnt clay brick compressive strength, hardness, dimensional stability, thermal expansion, density, abrasion, weight, water absorption, chemical properties, and fire resistance of the finished product be considered at the production process [8-11]. It is therefore becoming important that the standardized characteristics of bricks in terms of form, size, quality, and strength should be considered [12]. Adapting and complying with the standard characteristic of the burnt clay bricks allow for mixed sources from different makers and proper estimation of the number of bricks for a structure.

According to studies preference, and discrimination in using earth-based materials for construction and building projects were observed to cut across the end-users and the builders [10, 13]. Some challenges associated with their use include lack of compressive strength, having low resistance to abrasion and highly susceptible to water ingress [14-15]. Beamish and Donovan [12] highlighted form, size and quality as factors contributing to the preference and discrimination of locally made burnt clay bricks. These attributes culminate in making the walls deficient in satisfying new needs in buildings such as roof structures collapse, difficulty in the supply of water and electricity conduits works [16-17]. Maximizing the potential of burnt clay brick in achieving low construction cost, less rural-urban migration, reduced reliance on foreign and imported building materials noted as defects of over-reliance on imported and foreign materials. The quality must be controlled through an effective production process. The knowledge in locally produced burnt clay brick is based on knowledge acquisition, sharing, and application is important to investigate the local production technology of burnt bricks. Measuring knowledge is discrete facts but measuring skills and the ability to apply knowledge is subjective. As skill can perform a specific task, it can be measured accurately and common and comparable [18-19]. Therefore, this study subjectively evaluated the applied knowledge and skilled on local production technology of burnt bricks and objectively quantified the quality of the burnt clay brick.

2. MATERIALS AND METHOD

The research approach model in this study methodology is shown in Fig. 1. Subjective measurement of skills and ability in the production of burnt clay brick was conducted among local burnt clay brick producers in Benue State, Nigeria. A Multi-method research approach was adopted in this research process. The multi-method research approach involved subjective evaluation of the skill and knowledge of the burnt brick makers. The skill and knowledge of the burnt bricks were assessed using a questionnaire instrument. The development of the questionnaire was based on the established guideline and standard on burnt clay brick making by Beamish and Donovan [12]. The developed questionnaire was tested for reliability and validated. The quality of the burnt clay brick production practices was quantified through the physical characteristics and mechanical property tests of the produced burnt clay bricks. Sixty local burnt clay brick producers were contacted, and their participations were based on their agreements to supply the relevant information needed for this study. Since there is no official document on the registered local burnt clay brick producers in the study area, the sample size was based on individual contact with the researchers. The local burnt clay brick producers were met at the processes involved in the burnt clay bricks production. Fig. 2 exhibited a selected view for forming stage of the bricks by the participants. This included the extraction of the clay, clay preparation, moulding or shaping, and drying.

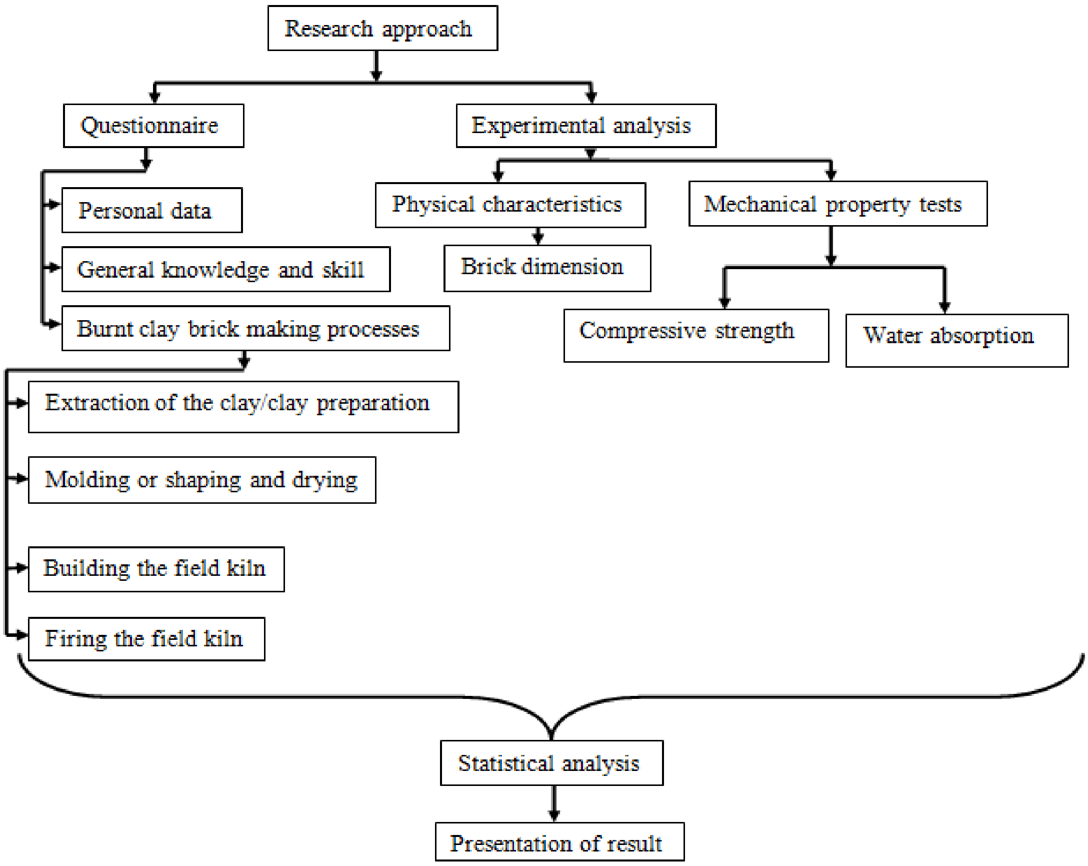

Figure 1. Methodology flowchart

Figure 2. The forming stage of the bricks (field work).

Firing stages in the production of bricks which included building the field kiln and firing the field kiln as shown in Fig. 3.

Stacked bricks in the kiln — Firewood arrangement in the tunnels — Closed kiln with clay for burning

Firing of the bricks in the kiln — Burnt clay brick

Figure 3. Firing stages in the production of bricks (field work).

Five burnt clay bricks were randomly picked from the kiln of the 55 burnt clay brick producers making a total of 275 burnt clay bricks. Product quality is a standardized assessment of the superiority of a product was carried out in terms of sizes of the burnt clay brick dimension regarding. The standard dimension used for the comparison was 230x115x73 for length, breadth and height respectively. 275 burnt clay bricks were used for the mechanical property assessment of the bricks produced. These bricks were also measured for compliance with the standard dimension. The values obtained were compared with the standard dimension.

The statistical analyses carried out on the data obtained include descriptive statistics and an independent sample t-test. The descriptive statistics helped in summarizing the data information. The comparative analysis of the established mechanical property produced by the local burnt clay brick producers was through an independent sample *t*-test. All the analyses were carried out on the SPSS package (20.0). The output significance was ascertained at a confidence level of less than 0.05.

3. RESULT and DISCUSSIONS

3.1. Demographic Characteristics of the Participants

The participants in this study operate in 26 communities within Benue State. All of which were male (100%). Most of the participants had secondary education (45.5%), married (65.5%) and within the age groups of 26-30 (21.8%) years as shown in Figs. 4-6. The preponderance of males in this study may be attributed to male dominance in outdoor activities/occupation as found in other construction-related fields. They are traditionally breadwinners of their homes. The domination age ranges of 26-30 (21.8%) followed by 21-25 (20.0%) and 31-35 (18.2%)

years were of the early adulthood (20-39 years) when male adults' superior physiologically and physical ability performance is at its peak [20-21] need for the strenuous activities of stages of burnt clay brick making.

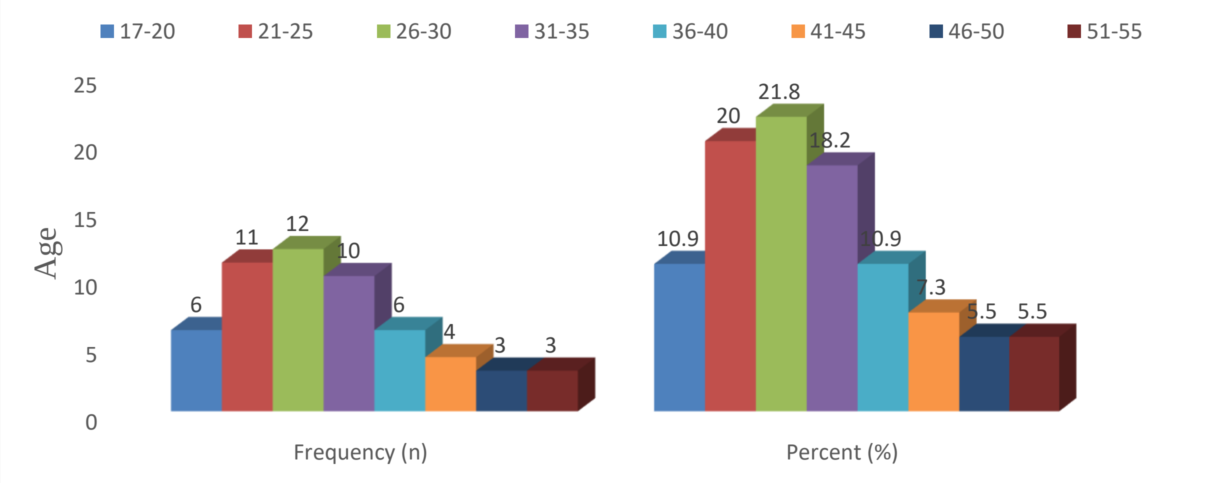

Figure 4. Demographic characteristics of the participants by age

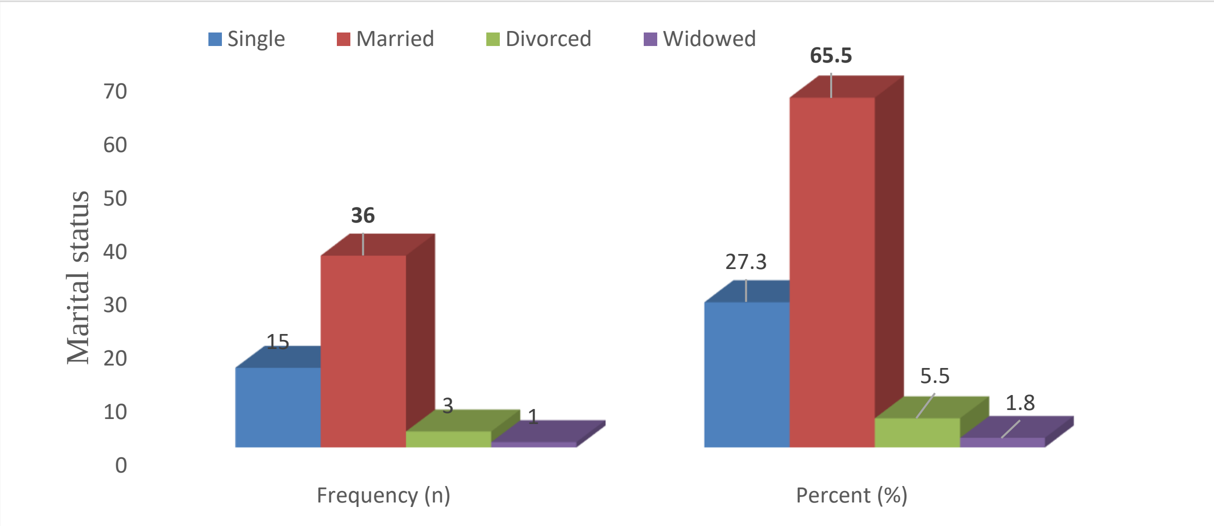

Figure 5. Demographic characteristics of the participants by marital status

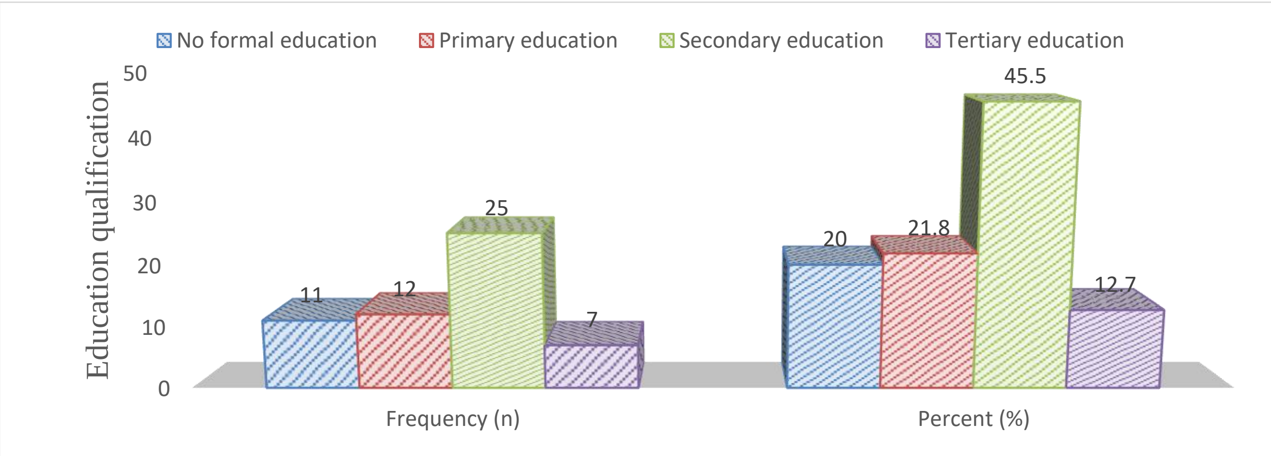

Figure 6. Demographic characteristics of the participants by education qualification

3.2. General Knowledge and Expertise on Burnt Clay Brick Making

The processes at the stages involved in brickmaking are neither technically sophisticated nor complicated. However, the approaches to it might be classified as correct or incorrect as it affects the produced bricks. This is traceable to the producers' knowledge, skill, and experience to produce good quality bricks [12]. The quality of burnt clay bricks is measured by the minimum basic quality standards [22]. The factors affecting the burnt clay brick quality assessed include production technology used, skill set, tools, labour experience, and availability of needed raw materials. Assessing these factors in this study showed that most of the participants have been in the burnt brick production business for 6-10 years (37.3%) through the tutelage of their friends (72.9%) and participated in the groups of 4-5 people (25.4%) as exhibited in Figs. 7-11. The view of product quality in this study was from the producer's perspective covering the experience, raw materials, and production process involved. The responses to some of the factors enumerated were whole. These included the use of water and clay as the brick forming materials, the form burnt clay brick produced (solid) being produced only during the dry season of every year using simple tools. The predominant knowledge acquisition, sharing, and application in the local production technology of burnt bricks from friends (72.9%) showed that the technology for the burnt clay bricks production is wholly indigenous through simple tools, less scientific skill, and little or no organizational input. The mode of craft and skills in the local production of burnt bricks in this study agreed with research in the literature that it is a time-proven method that has transcended and circulated over the years [1-2]. To allow for a considerable time for the forming and firing stages in the burnt clay brick making, the participant adopts different locations for the making, with 1-5 locations being used by most of the participants (91.0%) (Fig. 10). Analysis of the quantity of burnt clay brick production following Beamish and Donovan [12] showed that most of the participants (34.5%) produced 3000-5000 per time.

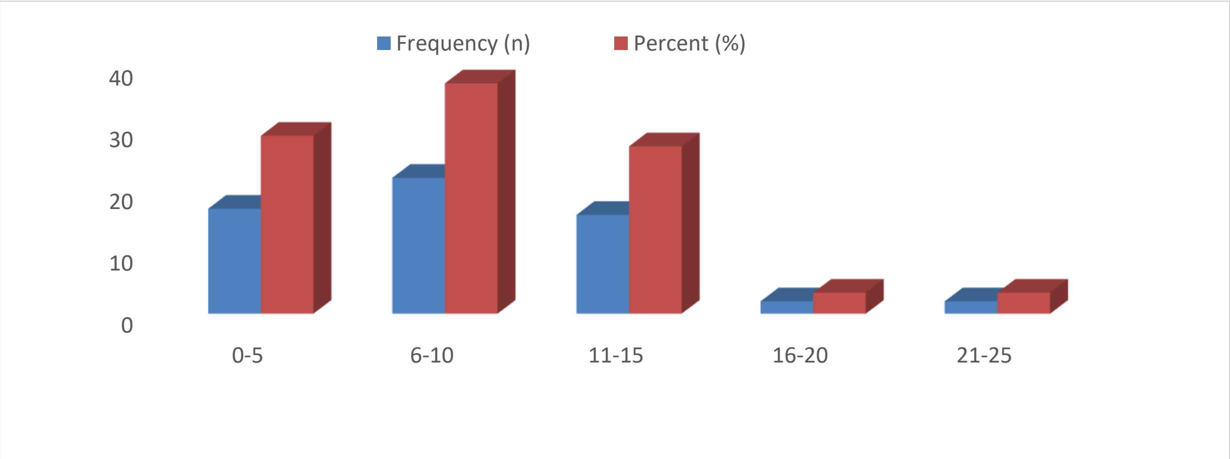

Figure 7. Years of burnt clay brick making experience

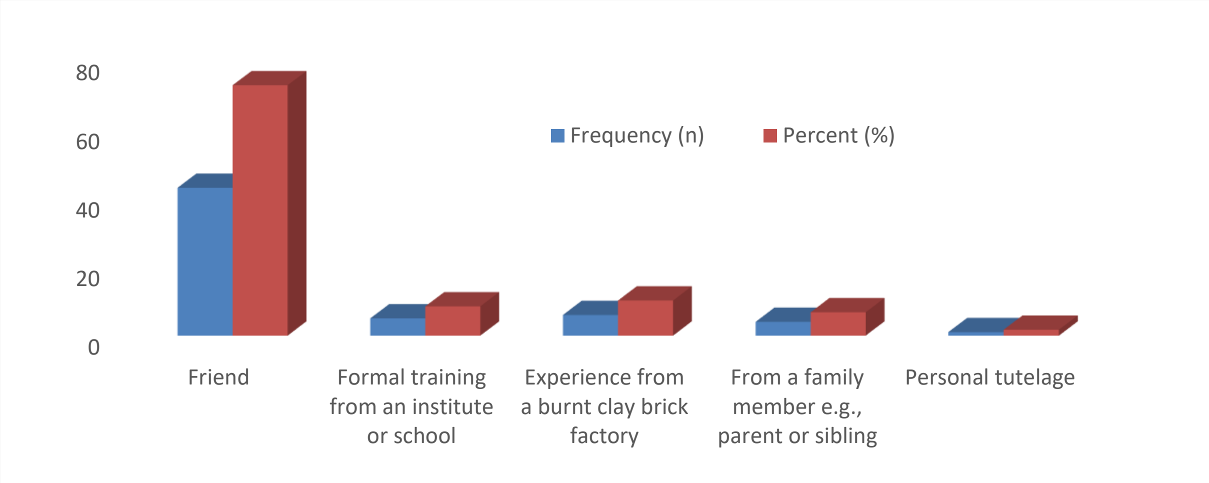

Figure 8. The source of knowledge and skill concerning burnt clay bricks

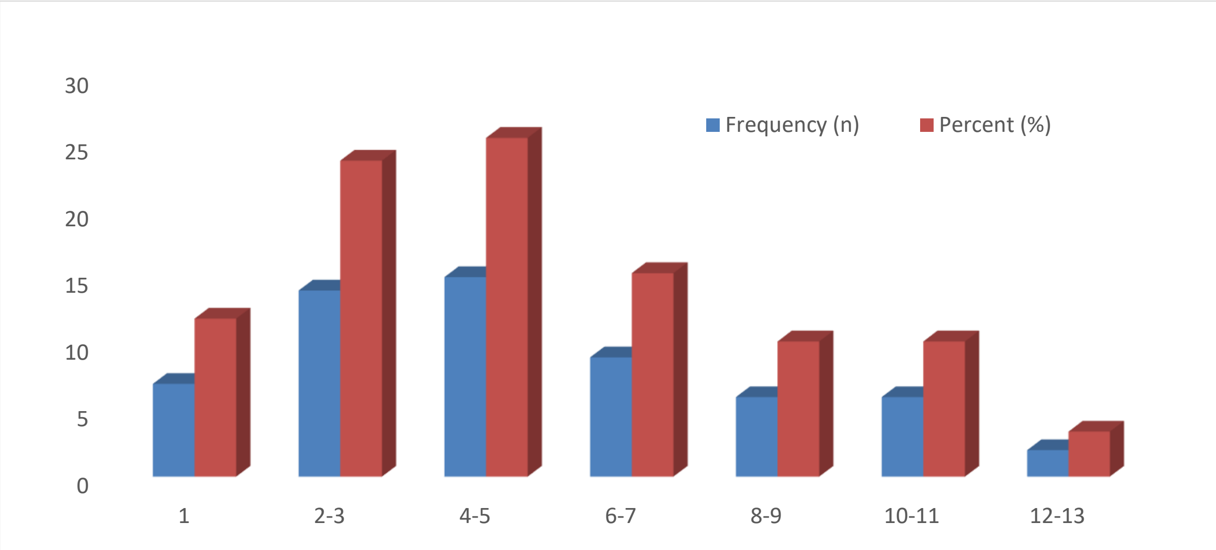

Figure 9. Burnt clay brick production team population

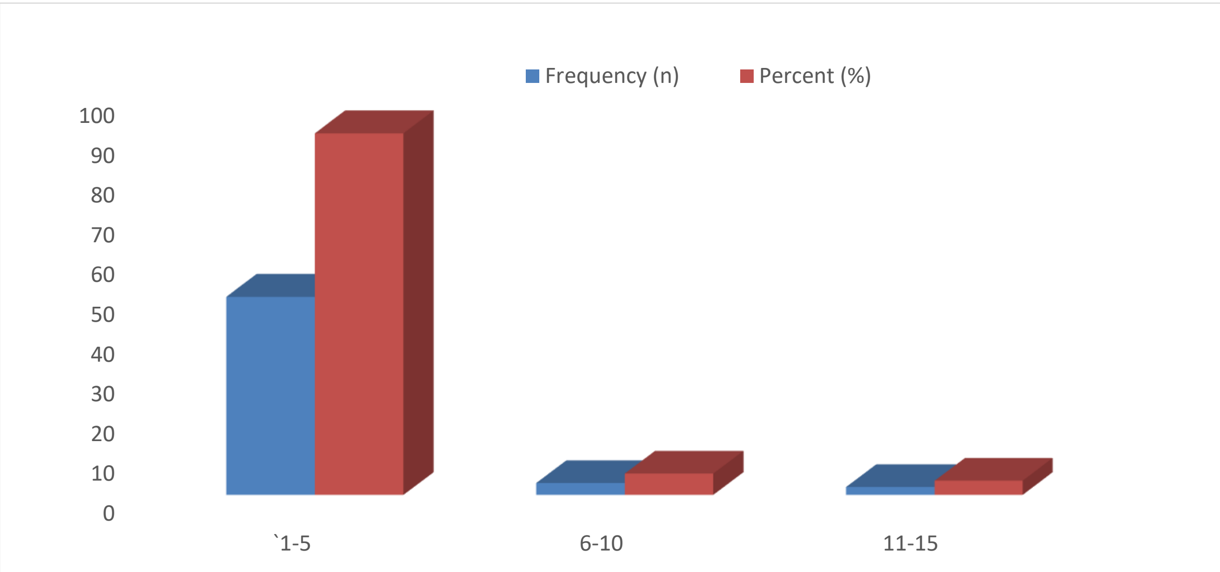

Figure 10. Number burnt clay brick making locations

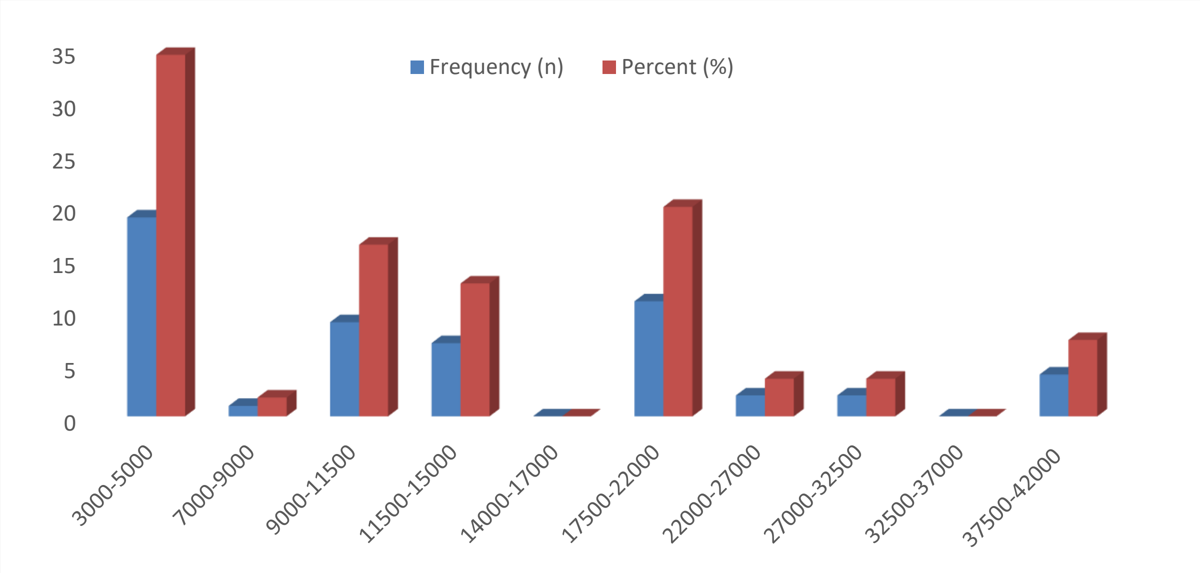

Figure 11. Maximum number of bricks produced

The clay bricks production unit needs good quality clay to produce a strong brick used in construction. However, not just any type of clay is good for making burnt clay bricks; in a situation like this, analysing the soil, especially in an area where there is no tradition of making bricks. Ibanga and Ahmed [22] added that although the raw materials may be abundant, they may not meet basic standards for proper performance. Eighty percent (80.0%) of the participants that sourced clay materials to produce bricks got the materials from traditional used places and hence, never solicited for the assistance of the local public office for soil assessment and analysis (Figs. 12-15). The various processes and techniques that have led to the burnt brick in this study showed that 58.2% of the study population use the sand moulding method. Generally, a hard, well burnt, uniform throughout, sound in texture and colour, and sharp shape and dimension is considered a good brick. A dimension of quality of any product (burnt brick clay), according to studies, follows the performance, conformance to requirements, fitness for use, and freedom from defect [23-25]. The quality of the bricks should be consistent with the basic standards for proper performance, e.g. compressive strength minima of 3.5N/mm² and water absorption of not more than 20%. However, without machine testing, there exists a simple test for strength for burnt clay brick. Studies enumerated the simple strength tests (non-destructive test) of burnt clay bricks as drop a brick from a height of 1.2 metres (shoulder height) without breaking, a repeat of test height drop test after with a wet brick (a brick soaked in water for one week) [12, 26]. If the soaked brick does not dissolve or fall apart underwater nor break when dropped, the quality is good enough for construction work. The categories of simple strength tests by the local burnt brick producer in this study are presented in Fig. 15, showing that only 27.3 and 7.3% of the participants have the basic knowledge of the simple strength test of the burnt clay bricks through dropping the brick at the shoulder height and soaking in the brick in water, respectively.

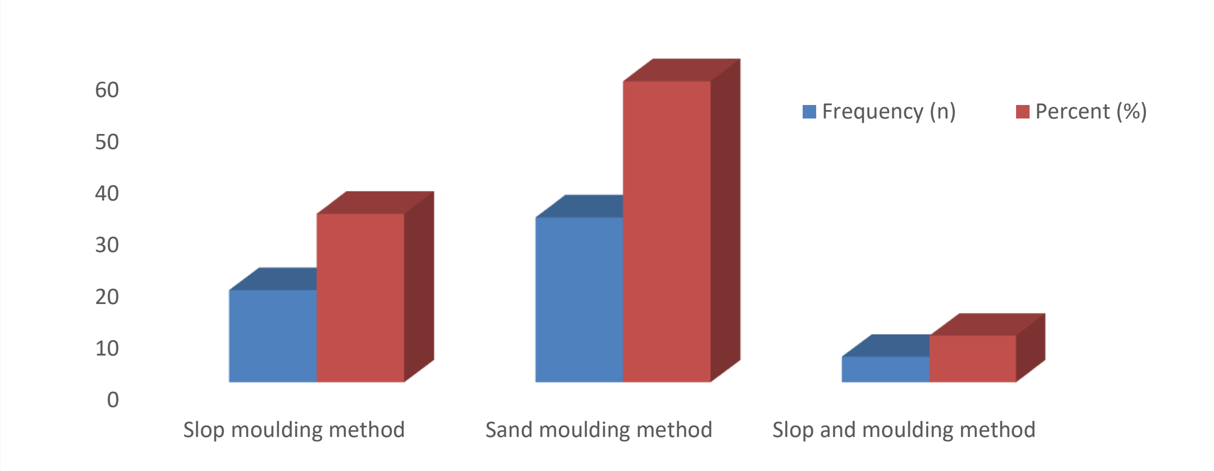

Figure 12. Methods of brick moulding/shaping used

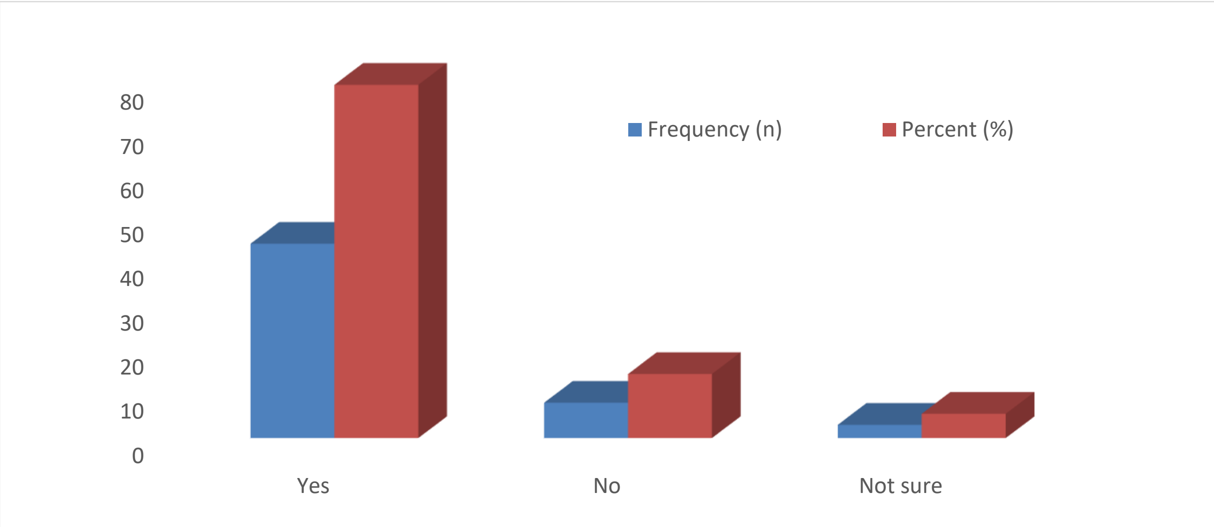

Figure 13. The raw material source location for the making burnt clay bricks is the tradition area in the locality

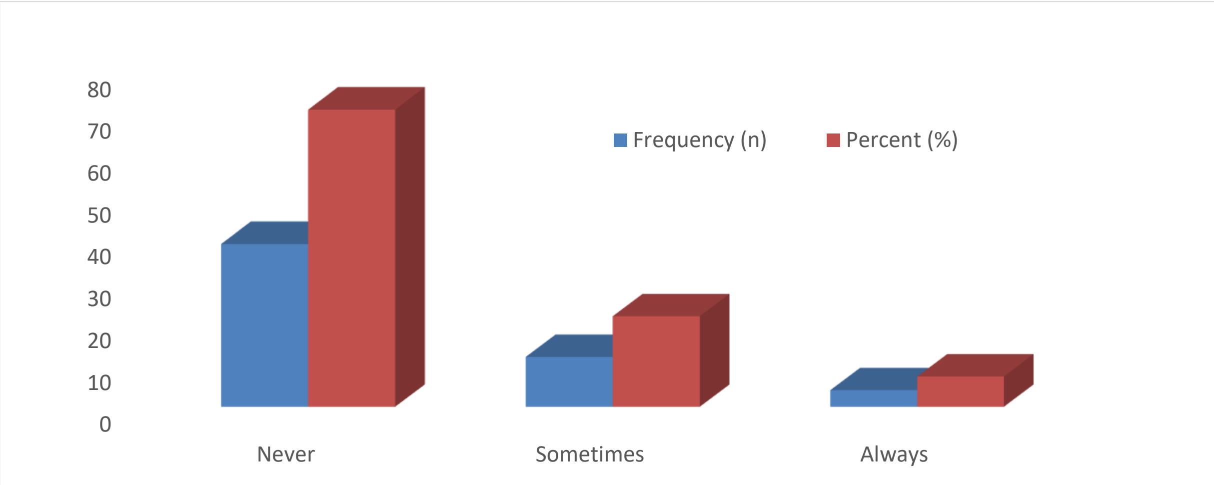

Figure 14. Contact with local public works office and ask for assistance in analyzing the soil

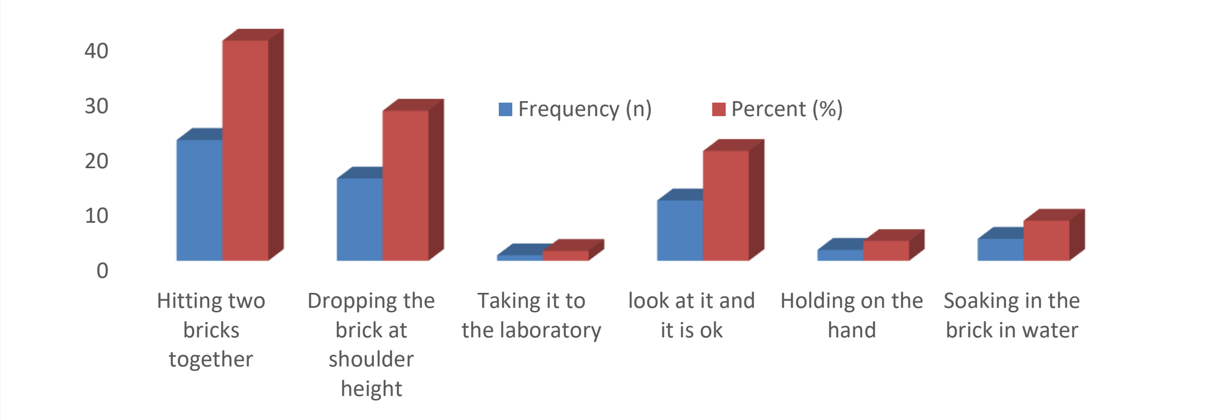

Figure 15. Simple strength tests of the burnt clay bricks by the participants

3.3. Measurement of the knowledge and skills on forming and firing stages for standard quality burnt clay brick making

Pointing out knowledge is an alternative to equipment, capital, materials, and labour to become the most important element in production, Drucker [27] predicted that competitive advantage in future is determined by knowledge resources or workers knowledge. Knowledge has an inherent value to be managed, applied, developed, and exploited [28]. Owing to the properties of knowledge, however, knowledge assets require special attention. Knowledge is often embedded in worker has features for product quality which is good for the public [29-30]. Purcell et al. [31] identified that among the basic requirement for optimal performance among workers is requisite knowledge and skills. However, the knowledge must be trendy with development and technology.

Over the years, the art and science of building have taken many reforms in its usability, acceptability, and comfortability [2]. Although the structural design in African has no historical record on the scientific approach to its design and construction, it, however, satisfies thermal comfort, aesthetics, and sustainability reformation conditions [2]. The qualitative and quantitative forms of Nigeria housing question are primarily a crisis in the local production technology for acceptability, cost, durability, aesthetics, and security. The good clay for bricks production available in abundant qualities and quantities almost everywhere in Nigeria [3] serving as raw material for local production of burnt clay bricks are a non-standardized alternative to the factory produced standardized clay bricks [3] if the stages of the production process are handled appropriately. Local production of burnt clay bricks is non-standardized because the production processes and mix productions vary across different producers [3]. The measurement of the knowledge and skills in the forming and firing stages for standard quality burnt clay brick making in this study covers the extraction of the clay, clay preparation, moulding or shaping, drying, building the field kiln and firing the field kiln. Good brick production management is the actual brick for planning, organizing, and controlling the production of the bricks for adequate supplies of raw materials, equipment, and regularly quality checked of the product. This is because the quality of bricks is consistent because of the different production methods employed and the properties of the constituent materials used. The poor quality and high breakage rate were normally caused by selecting inferior quality clays or/and faulty production techniques during the clay preparation, moulding, drying, and firing stages [12]. The frequency and percentage analysis of the responses to each of the forming and firing stages assessed for each of the participants among the fifty-five (55) local burnt clay brick producers. The investigated burnt clay bricks knowledge and skills for the extraction of the clay and clay preparation, moulding or shaping and drying, building the field kiln, and firing the field kiln stages were calculated for each burnt clay bricks producer that participated in the study. The participants had high knowledge and skill were extraction of the clay and clay preparation (49.1%), average knowledge and skill on moulding or shaping and drying (54.5%), very low knowledge and skill on building the field kiln (41.8%), and low knowledge and skill on firing the field kiln (49.1%) as exhibited in Table 1.

Table 1. Knowledge and skill on local burnt clay brick production.

Burnt clay brick making stage variables	**Very low n (%)**	**Low n (%)**	**Average n (%)**	**High n (%)**	**Very High n (%)**
Extraction and preparation of the clay	0 (0)	0 (0)	14 (25.5)	27 (49.1)	14 (25.5)
Moulding or shaping and drying	0 (0)	19 (34.5)	30 (54.5)	6 (10.9)	0 (0)
Building the field kiln	23 (41.8)	11 (20.0)	15 (27.3)	6 (10.9)	0 (0)
Firing the field kiln	3 (5.5)	27 (49.1)	24 (43.6)	1 (1.8)	0 (0)

3.4. Validation of the burnt clay brick knowledge and skills through experimental analysis (physical characteristics and mechanical property tests)

Product quality is a standardized assessment of the superiority of a product. It is expected that burnt clay brick producers must achieve a quality product that exceeds customers' expectation or call it customer satisfaction. This quality of the product determines the production success or failure. Specifically, the suitability of a material for use on a building is in its properties [32]. The determinant of burnt clay brick product quality produce good quality bricks is the measured regarding the minimum basic quality standards as some knowledge and skills in production processes and practices are about an application [33]. Beamish and Donovan [12] listed form, size, quality and strength as the important factors considered in determining typical characteristics of bricks. However, the factors assessed in this study through experimental analysis (physical characteristics and mechanical property tests). The physical characteristic standard measured the brick dimension regarding [34]. The result presented in Table 2 showed that the length (mean ± SD = 229.74 ± 3.99) width (mean ± SD = 114.69 ± 3.87) and height (mean ± SD = 72.48 ± 3.85) had percentage errors of length (mean ± SD = -0.2 ± 1.56) width (mean ± SD = -0.61 ± 3.68) and height (mean ± SD = -0.2 ± 5.73). The dimension of the burnt clay bricks in this study was within the tolerance of approximately 5% for locally produced bricks [12].

Table 2. Percentage error estimation between measure and standard values of burnt clay bricks.

Descriptive statistics	**Dimension**			**Percentage error***		
	Length (mm)	**Width (mm)**	**Height (mm)**	**Length (%)**	**Width (%)**	**Height (%)**
Mean	229.54	114.29	72.85	-0.2	-0.61	-0.2
SD	3.58	4.24	4.19	1.56	3.68	5.73
Minimum	223	107	65	-3.04	-6.96	-10.96
Maximum	236	122	80	2.61	6.09	9.59

*Percentage error = $\left(\frac{Measure\ dimension - Standard\ dimension}{Standard\ dimension}\right) \times 100$

The mechanical property tests analyzed for product quality of the burnt clay brick is regarding the minimum compressive strength of bricks of 3.5 N/mm² and the water absorption not exceeding 20%. The independent-sample *t*-test showed that the mean of the measured water absorption value of the locally produced burnt clay brick was statistically higher (mean ± SD = 29.51 ± 0.58) than the minimum allowable standard water absorption value (mean ± SD = 20.00 ± 0.0) significant at p = 0.00 that is, higher significance as shown in Table 3. A similar observation was made for compressive strength as the measured mean compressive strength value for the locally produced burnt clay brick was 3.98 ± 0.30 N/mm² which was statistically higher than 3.5 N/mm² [35]. The means are significantly different between the mean of measure and standard of the compressive strength was less than 0.05 (see Table 3). The variation in measure and standard values for the water absorption and the compressive strength showed that the locally produced burnt clay bricks were below the acceptable standard value. [36], found out that adequate stacking with proximity to the firing source greatly influences brick properties, the local production process often fails to conform to standard brick production. What determines whether a material will be suitable for a building is its properties [32]. Compressive strength and water absorption are some of the most important engineering properties desirable for building units, the burnt clay bricks in this study did not meet these basic standards for construction works.

Table 3. Independent sample t-test for mechanical property tests (water absorption and the compressive strength) between measure and standard values.

Burnt clay brick properties		Descriptive statistics			t-test for equality of means		
		Mean	SD	SEM	T	Df	p-value
Water absorption (%)	MV	29.51	9.60	0.58	16.42	274	0.00
	SV	20.00	0.00	0.00			
Compressive strength (N/mm^2)	MV	3.98	0.30	0.02	27.21	274	0.00
	SV	3.50	0.00	0.00			

*Measure value(MV), Standard value (SV)

Conclusion

Product quality has been the major tool in achieving reliability and competitive advantage of factors involved in a production process. Assessment of product quality as a yardstick for measuring the product knowledge and skill of local burnt clay brick production for size, quality and strength showed a deficiency in the quality and strength of the produced burnt clay bricks. The challenge was found knowledge and skills in the forming and firing stages for standard quality burnt clay brick which was only effective in the extraction and preparation stage but deficient in shaping, drying, building the field kiln and firing the field kiln. It is required that for good brick production that will meet the standard brick quality, adequate and updated knowledge is essential for planning, organizing, and controlling the production of the bricks.

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References

[1] J.A. Abah, G.T. Atondo, J.T. Kwaghwa. The Ethnomathematics of Indigenous Burnt Bricks Production in the Benue Valley. *VillageMath Educational Review*, 1:1 (2020) 11-25.

[2] I. Onyegiri, I.B. Ugochukwu. Traditional Building Materials as a Sustainable Resource and Material for Low-Cost Housing in Nigeria: Advantages, Challenges and the Way Forward. *International Journal of Research in Chemical, Metallurgical and Civil Engineering,* 3:2 (2016) 247-252.

[3] A.M. Iorakaa. The use of locally produced burnt bricks for low cost housing in Nigeria: the experience in Vandeikya, Benue State. *The Department of Architecture, School of Environmental Sciences, Federal University of Technology,* Yola. (2008).

[4] B.C. Onuoha. Factors militating against the global competitiveness of manufacturing firms in Nigeria. *American international Journal of Contemporary Research,* 3:4 (2013) 54-63.

[5] S.O. Olaitan, C.E. Nwachukwu, G. Igbo, G.A. Onyemachi, AO. Ekong. Curriculum Development and Management Vocational Technical Education (Cape Publishers International Limited, Onitsha, 1999).

[6] S.K. Duggal. Building Materials. (New Age International Publishers, New Delhi, 2012).

[7] Technical notes on brick construction, Brick Industry Association (BIA) http://www.gobrick.com/. (2009).

[8] J.O. Akinyele, O.T. Olateju, O.K. Oikelome. Rice husk as filler in the production of bricks using Gboko clay. *Nigerian Journal of Technology*, 34:4 (2015) 672-678.

[9] T.O. Jegele, A. Adanikin. Assessment of the Strength of Conventionally Produced Sandcrete Blocks and Burnt Bricks. *IOSR Journal of Mechanical and Civil Engineering,* 15:2 (2018) 24-30.

[10] B.K. Baiden, K. Agyekum, J.K. Ofori-Kuragu. Perceptions on barriers to the use of burnt clay bricks for housing construction. *Journal of Construction Engineering,* 502961 (2014).

[11] S. Karaman, H. Gunal, S. Ersahin. Assessment of clay bricks compressive strength using quantitative values of colour components. *Construction and Building Materials*, 20:5 (2006) 348-354.

[12] A. Beamish, W. Donovan. Village-level brickmaking. (Friedr. Vieweg & Sohn., 1989).

[13] D.S. Matawal. Linking academia to industry: a case study of the building and construction industry. Director-General/Chief Executive Officer Nigerian Building and Road Research Institute, NBRRI. http://www.notap.gov.ng, (2011).

[14] F.V. Riza, I.A. Rahman, A.M.A. Zaidi. Preliminary study of compressed stabilized earth brick (CSEB). *Australian Journal of Basic and Applied Sciences*, 5:9 (2011) 6-12.

[15] F. Adogla, P.P.K. Yalley, M. Arkoh. Improving Compressed Laterite Bricks using Powdered Egg shells. *The International Journal of Engineering and Sciences*, 5:4 (2016) 65-70.

[16] W.D. Adzraku, P.P. Yalley, T.J. Akubah,S.O. Bonney. Prospects for sustainable housing in Northern Ghana with the use of local walling materials. *Journal of Economics and Sustainable Development*, 7:20 (2016) 5-13.

[17] Y. Mahgoub. Sustainable architecture in the United Arab Emirates: past and present. In *Proceedings of the CAA-IIA International Conference on Urbanisation and Housing*, (1997) 2-5.

[18] DEST. Employability skills from framework to practice, an introductory guide for trainers and assessors. A report by the Australian Chamber of Commerce and Industry and the Business Council of Australia for the Department of Education, Science and Training, Canberra, (2006).

[19] E. Silva. Measuring skills for 21st-century learning. *Phi Delta Kappan*, 90:9 (2009) 630-634.

[20] P.B. Peele, Y. Xu, A. Colombi. Medical care and lost work day costs in musculoskeletal disorders: older versus younger workers. In *International Congress Series*, 1280 (2005) 214-218.

[21] O. Okunribido, T. Wynn. Ageing and work-related musculoskeletal disorders: A review of the recent literature. Health and Safety Executive Research Report RR799. (Health and Safety Executive, Buxton, 2010).

[22] E.J. Ibanga, A.D. Ahmed. Influence of particle size and firing temperature on burnt properties of rice/clay mix. *Pacific Journal of Science and Technology*, 8:2 (2007) 267-271.

[23] F. Tjiptono, G. Chandra. Service, quality & satisfaction. (Andi, Yogyakarta, 2011).

[24] S.K. Duggal. Building Materials. (New Age International Publishers, New Delhi, 2012).

[25] P.B. Crosby. Quality without Tear: The art of hassle-free management (McGraw-Hill, New York, 1984) pp. 58-86.

[26] J. Brozovsky, J. Zach, Jr.J. Brozovsky. Non-destructive testing of solid brick compression strength in structures. In *IV Conferencia Panamericana de END*, Buenos Aires, Argentina, (2007).

[27] P.F. Drucker. Managing for the future: The 1990s and beyond. (Truman Talley Books/Plume, New York, 1993).

[28] A. Mardani, S. Nikoosokhan, M. Moradi, M. Doustar. The relationship between knowledge management and innovation performance. *The Journal of High Technology Management Research*, 29:1 (2018) 12-26.

[29] A.B. Jaffe. Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value. *American Economic Review*, 76 (1987) 984-1001.

[30] J.P. Liebeskind. Keeping organizational secrets: Protective institutional mechanisms and their costs. *Industrial and Corporate Change*, 6:3 (1997) 623-663.

[31] J. Purcell, N. Kinnie, S. Hutchinson, B. Rayton, J. Swart. Understanding the People and Performance Link: Unlocking the Black Box, CIPD Publishing, (2003).

[32] D.M Tiough. Structural properties of rice husk and sawdust composite bricks. *CARD International Journal of Engineering and Emerging Scientific Discovery*, 2:2 (2017) 118-145.

[33] P. Tamkin. Measuring the Contribution of Skills to Business Performance. Institute for Employment Studies. Mantell Building Falmer Brighton BN19RF UK, (2005).

[34] NIS, Nigeria Industrial Standard. Standard for sandcrete blocks. NIS 87: 2004. Approved by Standards Organization of Nigeria, Abuja, Nigeria, (2004).

[35] P. Foytong, M. Boonpichetvong, N. Areemit, J. Teerawong. Effect of Brick types on Compressive Strength of Masonry Prisms. *International Journal of Technology*, 7:7 (2016) 1171-1178.

[36] F.T. Owoeye, A.P. Azodo, W.K. Joshua. The Effect of Burnt Clay Brick Production Process on the Compressive Strength and Water Absorption Properties. *SNRU Journal of Science and Technology*, 13:2 (2021) 63-70.