Journal of Engineering Innovations and Applications
Volume 1(2), pages 23-31, August 2022
Article Number: 3EF4CAF71
ISSN: 2971-673X
https://doi.org/10.31248/JEIA2022.022
https://integrityresjournals.org/journal/JEIA

Full Length Research

Evaluating the quality of electrical wires used for residential building wiring in Delta State, Nigeria

Odoh, F. E[1], Ebisine E. E.[2] and Okieke U. J.[2]*

[1]Department of Electrical Engineering, Delta State University of Science and Technology, Ozoro, Nigeria.
[2]Department of Electrical/Electronics Engineering, Delta State University, Oleh Campus, Delta State, Nigeria.

*corresponding author. Email: okiekeufuoma@gmail.com

Received 2nd August 2022; Accepted 25th August 2022

ABSTRACT: The utilization of counterfeit and substandard building materials for residential building construction had become a major concern, due to the hazards the occupants of those buildings are being subjected to. This research was carried out to appraise the quality of electrical wires used for residential building wiring in Delta State, Nigeria, and to also investigate the reasons why property developers still use these substandard materials despite the glaring negative consequences. Three commonly used electrical wire sizes (1.5, 2.5 and 4 mm^2) for residential building electrical wiring were randomly selected within the Delta state, and their electrical properties (electrical resistance and electrical resistivity) and mechanical properties (area, tensile strength, and tensile strain) were determined following the Institute of Electrical and Electronics Engineers (IEEE 400), Nigeria Industrial Standard (NIS), and America Standard Testing Material (ASTM) International recommended procedures; also, well-structured questionnaires were administered to four groups of respondents. The findings indicated that the mechanical and electrical properties of most electrical wires, used for residential building wiring in Delta State failed to meet NIS standards. Across the five sampling locations, the mean electrical resistivity of the 1.5 mm^2 wire ranged between $2.04 \pm 0.07 x10^{-7}$ and $2.09 \pm 0.08 x10^{-7}$ Ωmm, while the 2.5 mm^2 wire's mean electrical resistivity varied from $1.90 \pm 0.06 x10^{-7}$ to 1.97 ± 0.13 $x10^{-7}$ Ωmm, and the 4 mm^2 wire's mean electrical resistivity varied from 1.75 ± 0.08 $x10^{-7}$ to 1.87 ± 0.06 $x10^{-7}$ Ωmm. Also, across the five sampling locations, the mean tensile strength of the 1.5 mm^2 wire ranged between 144.1 and 163.3 MPa, while the 2.5 mm^2 wire's mean tensile strength varied from 163.2 to 177.4 MPa, and the 4 mm^2 wire's mean tensile strength varied from 169.4±20.6 to 185.4±17.2 MPa. Furthermore, the analysis of variance indicated that sampling location had no significant effect on the wires' mechanical and electrical properties ($p \le 0.05$); portraying that this fraudulent practice is widespread across the state. The analysis of the questionnaire results confirmed that financial constraints and inappropriate actions of many building contractors were the major contributing factors to the utilization of substandard wires for residential building wiring in Nigeria. Based on this study's findings, it is recommended that standard regulatory agencies should step up their efforts against substandard building materials, to avoid its impending danger in Nigeria.

Keywords: Building materials, electrical wires, electrical resistivity, mechanical properties, substandard materials.

INTRODUCTION

Globally, metals that are commonly used to produce electrical wires and cables include; copper, aluminum, and their high-quality alloys (Knych *et al.,* 2022). Copper has become one of the most widely used metals for the production of small-size electrical wires, due to its excellent mechanical, electrical, and thermal properties (Zhang *et al*., 2021). However, copper metal is now highly counterfeited by wires and cable manufacturers. The Nigerian community is now flooded with fake and substandard electrical and electronic materials. This is partially responsible for the occurrences of electrical fires and electrical power outages (Onyekachi and Nduka, 2019; Uguru and Obukoeroro, 2020; Obukoeroro and Uguru, 2021a; Obukoeroro and Uguru, 2021b). Obukoeroro and

Uguru (2021b) reported that the metallic conductor, and insulating materials used, for the production of most electrical cables and wires sold and utilized in Nigeria, fall short of the NIS: 172 recommended standard; thus making these electrical materials susceptible to problems related to electrical fires and electrocution, once they are overloaded. Steward *et al*. (1998) stated that if the electrical properties of electrical cables and wires failed to meet international standards, the electrical cable neither is unable to endure abnormal (high) voltage nor will be able to foil current leakages in strange directions. This is one of the major causes of electrical fires or localized electrical power outages. Alteration of the electrical plan is another major factor that causes electrical failures in buildings, particularly due to the inability of the electrical wires and cables to withstand the new electrical loads that they may be subjected to (Obukoeroro and Uguru 2021c).

The standard organization of Nigeria (SON) in their official gazette stated that substandard electrical cables and other electrical accessories utilized in Nigeria are one of the leading causes of electrical fires in Nigeria (Agbakwuru, 2019; Obukoeroro and Uguru 2021c). According to SON, most of the substandard electrical materials used in Nigeria, are brought into the country from the Asia continent (Schneider Electric, 2015; Obukoeroro and Uguru, 2021a). Schneider Electric (2015), in this research, observed that China and India are the leading exporters of fake electrical materials to Africa; though substantial quantities of fake electrical materials utilized in Nigeria are also produced within Nigeria. Although the Nigerian government has adopted various policies to combat this menace, the problem persists. The high influx of counterfeit materials into Nigeria is encouraged by the endemic corruption in the country and exacerbated by the very porous border. These factors make proper quality control and monitoring of materials sold and used within the country practically impossible (Agbi *et al*., 2020; Akpokodje *et al.,* 2021).

The utilization of substandard construction materials has led to the death of thousands of people, and the destruction of properties worth billions of dollars, through buildings collapses, electrocution, and electrical fires. Ugochukwu *et al*. (2014) reported that the utilization of substandard materials during building construction jeopardized not only the safety of human beings residing in the building but also the safety of the properties and the economy of the people. Calebella (2021) reported the quality of building materials is a vital factor that contributes to the integrity of buildings, and the safety of the occupants. Faremi *et al*. (2020) and Calebella (2021) further linked the persistent building failures in Nigeria to the poor quality of construction materials, such as; reinforcement rods, bricks, sand, concrete blocks, coarse aggregates, wooden planks, and cement. The materials used in any building construction are dependent on the intended use of the buildings; hence, appropriate materials selection is of great significance, regardless of the materials cost. According to Akinyemi *et al*. (2016), approximately 60% of the cases of building collapses in Nigeria can be linked to the use of substandard materials; though poor workmanship, non-adherence to the proposed building plans, and inadequate soil tests, also contribute immensely to building collapses in Nigeria.

Though several researchers (Ezeagu et al., 2015; Akinyemi *et al*., 2016; Agbi *et al*., 2020; Akpokodje *et al.,* 2021) have embarked on appraising the qualities of building materials utilized in Nigeria; not much is recorded in literatures, on the qualities of electrical wires used in Delta State, Nigeria, and the possible reasons people still patronized these substandard electrical wires. Therefore, this study is aimed at appraising the standards of electrical wires used for buildings wiring in Delta state, evaluating if they meet international standards, and if not, why property developers still use them for electrical wiring.

MATERIAL AND METHODS

Study area

This study was embarked upon in Delta State, Nigeria. Delta State is currently one of the 36 states of Nigeria, located in the southern region of the country, and consists of upland and lowland areas. Asaba, Ughelli, Agbor, Abraka, Ozoro, Warri, and Sapele are some important upland regions in the state, while Burutu, Ogbe-Ijaw, and Bormadi are some of the lowland regions in the state. The state has several medium and small scales industries, located both in the urban and rural areas of the state. Conurbation exists among several towns in the states, mostly in the Asaba, Warri, and Ughelli regions. Delta State is chosen as the study area because it is a rapidly developing state due to the presence of several industries, and educational and financial institutions. This has led to an increase in the human population, which in turn has given rise to a surge in residential building construction.

Electrical materials sampling

Three commonly use electrical wires (1.5, 2.5, and 4 mm^2) employed for residential building electrical wiring and installations in Nigeria were selected for this study. To have robust data set on the status of electrical wires used in Delta State, five popular towns/regions (Asaba, Ughelli, Warri, Agbor, and Ozoro) within the state were chosen as the sampling locations. This is to give a fair representation of the quality of wires used for electrical wiring and installations in Delta State. At each sampling location, the wires were randomly sampled from four electrical stores, at the rate of three samples per wire size.

Field survey

A comprehensive field survey was carried out to determine why many still used substandard materials for residential building wiring, despite their purported serious consequences. Two hundred (200) well-structured questionnaires were distributed to the residents in the region. The responses from the questionnaires were designed to be able to provide an appropriate answer to the following question:

Why do people still use substandard electrical materials, despite their negative socio-economic consequences?

This research study will verify the following null hypothesis:

H_{01}: Financial constraint has no significant effect on the qualities of materials used for buildings constructed in Nigeria,
H_{02}: Fraudulent actions of the building contractors have no significant effect on the quality of materials used for buildings constructed in Nigeria.

Laboratory tests

All the laboratory tests were carried out following the procedures approved by the Institute of Electric and Electronics Engineers (IEEE 400), Nigeria Industrial Standard (NIS), and America Standard Testing Material (ASTM) International.

Electrical wire size determination

The size (cross-sectional area) of each wire strand was calculated by using the expression presented in Equation 1.

$$\text{Area} = \frac{\pi d^2}{4} \quad (1)$$

Where: d = diameter

The diameter of each wire strand was measured by using the digital caliper, as shown in Figure 1.

Electrical resistance and resistivity determination

The electrical resistance of each wire was determined following the procedures approved by the Institute of Electric and Electronics Engineers (IEEE 400). The wire strand's resistively was calculated using the expression provided in Equation 2 (Obukoeroro and Uguru, 2021b).

$$\text{Resistively } (\rho) = \frac{RA}{l} \quad (2)$$

Where: R = the resistance of the electrical wire strand, d = the diameter of the electrical wire strand, and l = the length of the electrical wire strand.

Figure 1. Measurement of the diameter of a wire.

Testing the tensile properties of the wire strand

The tensile properties of the wire strands were determined using Universal Testing Machine (UTM), following ASTM International procedures. For each test, the wire strand was fastened in the clamping jaws of the UTM, and pulled slowly, at a speed of 2 mm/min, until breakage point (Figure 2). As the test progresses, the UTM calculates the corresponding tensile strain, tensile stress, tensile energy, and tensile strength of the metallic conductor.

The wire's tensile strength and elongation (strain) were calculated by the machine based on Equations 3 and 4. For each sampled wire, the tensile test was repeated three times and the average value was recorded.

$$\text{Tensile strength } (\sigma) = \frac{F_{Max}}{Area} \quad (3)$$

$$\text{Tensile Elongation } (\%) = \frac{\Delta L}{L} \quad (4)$$

Where: ΔL = extension of the wire, L = the initial wire length, and F_{max} = maximum applied load on the wire.

Data analysis

The laboratory results obtained were statistically analyzed using the SPSS (version 2.0); while Microsoft Excel (version 2015) was used to plot the results summary. Additionally, the chi-square was used to analyze the results obtained through the questionnaires. The Chi-square equation is given in Equation 5.

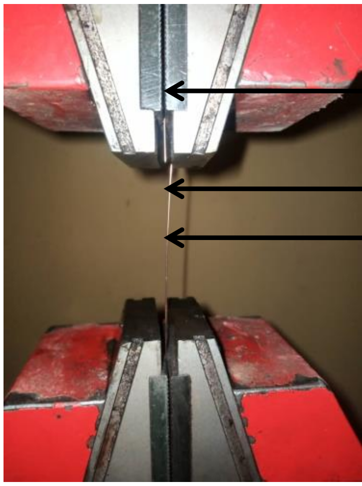

Figure 2. Determining the tensile properties of the wire strand.

$$X^2 = \frac{\sum(O-E)^2}{E} \quad (5)$$

Where: X^2 = Chi-square, O = Observed Frequency, and E = Expected frequency

The expected frequency was calculated by using Equation 6 (Obukoeroro and Uguru, 2021d).

$$E = \frac{\text{ith row total} \times \text{jth column total}}{\text{grand total}} \quad (6)$$

If the X^2 calculated is greater than the value in X^2 table; then the H_o will be rejected.

RESULTS AND DISCUSSION

Wire sizes

The ANOVA result of the effect of sampling location and wire size on the wire diameter is presented in Table 1. As shown in Table 1, sampling location does not have a significant effect on the wire diameter ($p \leq 0.05$); but the wire size had a significant effect on the wire diameter ($p \leq 0.05$). Furthermore, Table 2 presents the descriptive results of the wire sizes collected from the studied area. Generally, the results presented in Table 1 revealed that the wire sizes generally (mean result) failed to meet the met NIS:172 recommendations for electrical wires, required to be used for electrical wiring and installations. NIS:172 states that wire strand diameters for 1.5, 2.5, and 4 mm^2 wires must not be lower than 1.38, 1.78, and 2.23 mm respectively.

Though the mean results of the wire sizes failed to meet the international standard; further statistical analysis of the results presented in Figure 3 depicted that, some percentage of the wire was able to meet NIS size requirements. The findings presented in Figure 3 show that 20% of the wires sampled from Ozoro region, 34% of the wires sampled from Ughelli region, 37% of the wires sampled from Asaba region, 25% of the wires sampled from Warri region and 21% of the wires sampled from Agbor region, were able to meet NIS requirements. These findings are quite similar to results previously obtained by Onyekachi and Nduka (2019) and Obukoeroro and Uguru (2021b), which stated that the majority of the electrical wires and cables sold in Rivers, Abia, and Bayelsa States of Nigeria, were unable to meet NIS size requirements for wires and cables.

Electrical wire resistivity

The univariate analysis of the effect of sampling location and wire size on the wire resistivity is presented in Table 3. As presented in Table 3, sampling location had no significant effect on the wire resistivity ($p \leq 0.05$), while the wire size had a significant effect on the wire resistivity ($p \leq 0.05$). Table 4 presents the descriptive statistics of the wire resistivity. The mean electrical resistivity of the 1.5 mm^2 wire ranged between 2.04±0.07 x 10^{-7} and 2.09±0.08 x 10^{-7} Ωmm, the 2.5 mm^2 wire's mean electrical resistivity varied from 1.90±0.06 x 10^{-7} to 1.97±0.13 x10^{-7} Ωmm, while the 4 mm^2 wire's mean electrical resistivity varied from 1.75±0.08 x10^{-7} to 1.87±0.06 x10^{-7} Ωmm; across the five sampled locations. It was observed (from Table 4) that mean wire resistivity failed to meet the NIS standard, although the high standard deviation values are an indication that some wires' resistivity was able to meet the NIS recommendation. According to NIS recommendations, the electrical resistivity of 1.5, 2.5, and 4 mm^2 wires should be below 2.0 X 10^{-7}, 1.85 X 10^{-7}, and 1.70 X 10^{-7} Ωmm, respectively (Adetoro, 2012).

The general high resistivity of the wires can be linked to the high resistance to electricity flow developed by the wires, despite their small sizes and the low ambient temperature (24±3^{o}C) under which the resistance of the wires were tested. Subjecting wires with high electrical resistivity to high electrical loads can result in electrical fires since they can be easily heated up due to their high resistance and small surface areas (Adekoya, 2019). Electrical Engineering (2020) stated that wires with high resistivity can create voltage drops across the circuit; thus, leading to malfunctioning of the electrical items connected to the circuit.

Tensile strength of the electrical wire

The univariate analysis of the effect of sampling location and wire size on the wire's tensile strength is presented in Table 5. As presented in Table 5, sampling location had no significant effect on the wire's tensile strength ($p \leq 0.05$), while wire size had a significant effect on the tensile strength ($p \leq 0.05$). The descriptive results of the tensile strength of the electrical wires, evaluated in this study are

Table 1. ANOVA results of the effect of sampling location and wire size on the strand diameter.

Source	Df	Mean Square	F	p-value
location	4	0.01	0.35	0.8405[ns]
Size	2	5.02	293.72	1.02E-31*
location x size	8	0.01	0.55	0.8128[ns]

ns = not significant; * = significant at 0l05 according to DMRT.

Table 2. The electrical wire diameter.

Location	Wire diameter (mm)		
	1.5 mm²	2.5 mm²	4 mm²
Warri	1.30[a]±0.09	1.70[b]±0.09	2.16[c]±0.20
Ozoro	1.24[a]±0.13	1.67[b]±0.12	2.27[c]±0.19
Asaba	1.35[a]±0.07	1.73[b]±0.14	2.19[c]±0.03
Ughelli	1.29[a]±0.11	1.69[b]±0.17	2.20[c]±0.15
Agbor	1.29[a]±0.12	1.70[b]±0.12	2.11[c]±0.09
NIS	1.38 mm	1.78 mm	2.23 mm

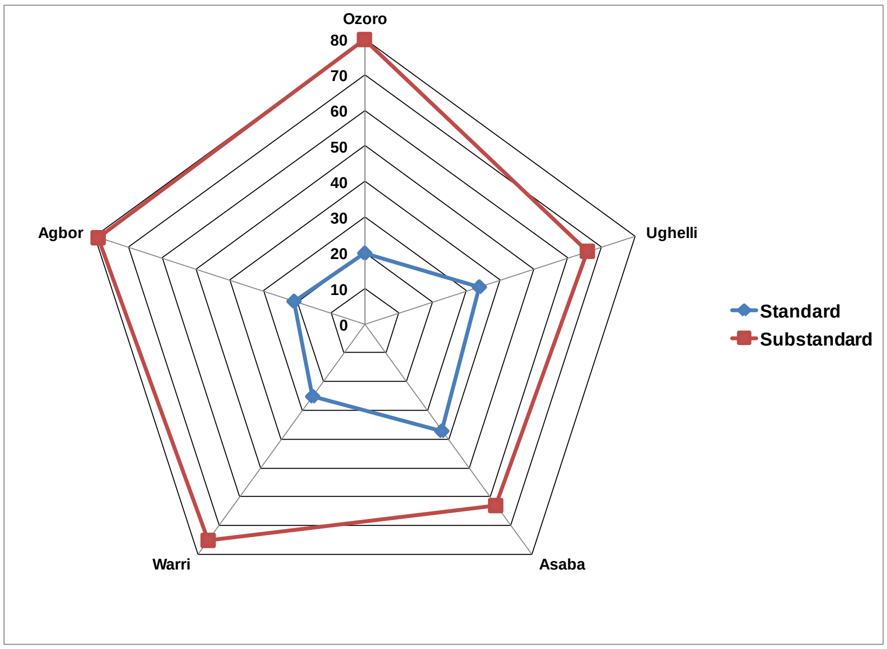

Figure 3. Proportion of the standard electrical wire sizes.

presented in Table 6. Generally, the study's findings revealed that electrical wires commonly used for residential building wiring in Delta State failed to meet the international standards for tensile strength for electrical wires and cables. The high standard deviation values obtained in this study signaled that the tensile strength of some of the electrical wires could meet the minimum allowable tensile strength requirement of 196 MPa, as approved by NIS for insulated small size copper conductors.

Similar results were obtained by Obukoeroro and Uguru (2021a) for electrical wires and cables sold in Anambra State, Eastern Nigeria. According to Obukoeroro and Uguru (2021a), most of the small sizes electrical wires used for electrical installations in Anambra state failed to meet SON recommendations for electrical wires and cables. Furthermore, Lewachi (2022) reported that the tensile strength of electrical wires sampled from Lagos and Rivers State varied between 12.5 and 25 MPa. The International Electrotechnical Commission (IEC) stated

Table 3. The ANOVA of the sampled electrical wires.

Source	df	Mean Square	F	p-value
Location	4	0.002	0.21	0.9326
Size	2	0.420	56.60	1.54E-14*
Location x Size	8	0.009	1.22	0.3052

Table 4. The resistivity of the sampled electrical wires.

Location	Electrical resistivity (x10^{-7} Ωmm)		
	1.5 mm^2	2.5 mm^2	4 mm^2
Warri	2.06^a±0.05	1.94^b±0.08	1.81^c±0.09
Ozoro	2.04^a±0.07	1.92^b±0.09	1.87^c±0.06
Asaba	2.04^a±0.07	1.97^b±0.13	1.75^c±0.11
Ughelli	2.07a±0.09	1.90^b±0.06	1.81^c±0.11
Agbor	2.09^a±0.08	1.96^b±0.07	1.75^c±0.08
NIS	**2.0 X 10^{-7}**	**1.85 X 10^{-7}**	**1.70 X 10^{-7}**

± means plus standard deviation; Means with the same common letter (subscript) in the column mean that they are significantly different (p ≤0.05).

Table 5. Univariate analysis of the sampled electrical wire.

Source	df	Mean Square	F	p-value
Location	4	57.997	0.121	0.974
Size	2	2437.976	5.104	0.009
location * size	8	365.615	0.765	0.634

Table 6. Electrical wire tensile strength.

Location	Tensile strength (MPa)		
	1.5 mm^2	2.5 mm^2	4 mm^2
Warri	144.1^a±18.6	168.0^b±18.9	185.4^b±17.2
Asaba	163.3^a±23.1	163.2^b±29.0	185.4S^b±22.1
Ozoro	160.0^a±17.1	173.0^b±19.1	176.5^b±23.4
Ughelli	161.1^a±23.7	170.8^b±23.3	169.4^b±20.6
Agbor	159.1^a±19.6	177.4^b±23.0	167.8^b±25.5

± means plus standard deviation; Means with the same common letter (subscript) in the column mean that they are significantly different (p ≤0.05).

that all electrical conductors meant for electrical installations must have tensile properties that meet its standards or the standards of other internationally recognized regulatory bodies (NERC, 2014).

The tensile strain of the wire strand

The results of the tensile strain of the electrical wires are presented in Table 7. Largely, the study's findings depicted that the tensile strain of the wires sampled for this investigation fell below the IEC and SON recommendations. NIS IEC 60227 recommended a minimum allowable tensile strain of 30% for 1.5, 2.5 and 4 mm^2 copper wires. Electrical wires with low tensile strain are brittle and tend to break easily; thus, exposing the system to short-circuiting, and other electrical hazards. Obukoeroro and Uguru (2021a) reported similar results for electrical wires and cables sampled in Anambra State, Nigeria. The poor tensile strain of the all the wires investigated confirmed the

Table 7. Electrical wire tensile strain.

Location	Tensile strain (%)		
	1.5 mm²	2.5 mm²	4 mm²
Ozoro	12.53±1.59	16.80±4.32	18.91±2.55
Ughelli	14.57±2.54	19.37±2.92	18.04±2.60
Warri	15.04±3.46	16.24±2.39	16.64±3.41
Asaba	17.83±3.40	16.35±1.99	17.60±3.28
Agbor	15.62±3.26	14.97±2.17	17.12±4.49

± means plus standard deviation; Means with the same common letter (subscript) in the column mean that they are significantly different ($p \leq 0.05$).

assentation by Obukoeroro and Uguru (2021a) that low-quality copper metal is utilized for some cables and wires production in Nigeria.

According to He *et al*. (2020), tensile strain and strength of wires are some of the most predominant mechanical indicators, used by regulatory bodies to determine the quality of electrical wires and cables. Knych *et al*. (2022) reported that impurities have serious negative consequences on the electrical and mechanical properties of copper wires. In the field, the mechanical properties of wires are greatly affected by environmental conditions, electrical load and ageing. Therefore, materials which are used for wire production must be able to withstand these extrinsic factors, to prevent power failure or electrical hazards (Li *et al*., 2013).

The study had shown that the 1.5 and 2.5 mm² wires were the most counterfeited electrical wires, in Delta State; this can be linked to their high demand for residential building wiring purpose. This poses a serious threat to electrical installations within the region because low tensile strength wires tend to fail easily during field applications, leading to power failure (Haddad, 2009). Additionally, it was observed that for the large diameter wires, despite their large sizes, their resistivity and tensile properties were very poor (low). This observation could be a tactic employed by the wire counterfeiting syndicates to deceive the unknowing public and regulatory agencies, as wire and cable sizing is usually the first confirmatory test carried out for wire accreditation and acceptance.

Determining why substandard materials are still used in residential building wiring

Table 8 presents the profile of the respondents. Out of the 200 questionnaires administered, 191 were retrieved and analyzed. Table 8 depicted that; 51.83% of the respondents were tertiary institution graduates, 43.46% of the respondents had secondary school certificates, 4.19% of the respondents had primary school certificates, and 0.52% of the respondents had informal education. According to Akpokodje *et al*. (2021), respondents with an average level of formal education and experience can provide reliable answers, which can be used to determine the quality of building materials used for building construction.

Table 8. Respondents' profile.

Education level	Number	Percentage
Tertiary	99	51.83
Secondary	83	43.46
Primary	8	4.19
Non-Formal	1	0.52
Total	**191**	**100**

Testing the hypotheses

Hypothesis H_{01}: Financial constraint has no significant effect on the qualities of materials used for buildings constructed in Nigeria

Table 9 presents the X^2 summary table of hypothesis one. Since X^2_{cal} is greater than $X^2_{critical}$; H_{01} is rejected. Therefore, financial constraint is one of the major factors that contributed to the utilization of substandard wires in residential building wiring. According to Agbi *et al*. (2020) and Faremi *et al*. (2020), due to the high cost of high-quality building materials, many people tend to use cheaper and lower-quality materials for the construction of their buildings.

Hypothesis H_{02}: Fraudulent actions of many building contractors have no significant effect on the quality of materials used for buildings constructed in Nigeria

Table 10 presents the X^2 summary table of hypothesis two. Since X^2_{cal} is greater than $X^2_{critical}$; H_{02} is rejected. Therefore fraudulent actions of many building contractors are contributing to the utilization of substandard wires in residential building wiring. This affirmed the earlier report of Faremi *et al*. (2020) which stated that sharp practices, on part of the building contractors, are one of the major causes for the utilization of substandard materials in

Table 9. The X^2 table for hypothesis H_{01}.

O	E	O-E	$(O-E)^2$	$(O-E)^2/E$
181	136.5	44.5	1980.25	14.51
10	54.5	-44.5	1980.25	36.33
144	136.5	7.5	56.25	0.41
47	54.5	-7.5	56.25	1.03
130	136.5	-6.5	42.25	0.31
61	54.5	6.5	42.25	0.78
91	136.5	-45.5	2070.25	15.17
100	54.5	45.5	2070.25	37.99
Σ				**106.53**

X^2_{cal} = 106.53; df = 3
Testing at a 5% significant level.
$X^2_{critical}$ at df of 3 = 7.815.

Table 10. The X^2 table for hypothesis H_{02}.

O	E	O-E	$(O-E)^2$	$(O-E)^2/E$
172	123.5	48.5	2352.25	19.05
19	67.5	-48.5	2352.25	34.85
123	123.5	-0.5	0.25	0
68	67.5	0.5	0.25	0
101	123.5	-22.5	506.25	4.1
90	67.5	22.5	506.25	7.5
98	123.5	-25.5	650.25	5.27
93	67.5	25.5	650.25	9.63
Σ				**80.4**

X^2_{cal} = 80.4; df = 3.
Testing at a 5% significant level.
$X^2_{critical}$ at df of 3 = 7.815.

buildings constructed in Nigeria. Similarly, Hawkins *et al*. (2013) reported that corrupt practices of many contractors have long-term disadvantages, as poor quality materials used by the contractors tend to deteriorate fasters and incur higher maintenance costs when compared to higher quality materials.

Conclusion

This research was embarked upon to determine the standard of electrical wires used for residential building wiring in Nigeria. Three commonly used electrical wires (1.5, 2.5, and 4 mm^2) in Nigeria, were randomly sampled from Delta State for laboratory analysis. The wires' electrical and mechanical properties were determined following NIS and ASTM International testing procedures. Results obtained from the research revealed that for most of the wire sizes, electrical resistivity, and tensile properties failed to meet NIS and IEC standards. It was observed that most of the wire strands had a smaller diameters, higher resistivity, and lower tensile strengths and strains. Statistical analysis of questionnaires administered revealed that financial constraints and contractor sharp practices are some reasons, why substandard materials are still widely used for residential building wiring in Delta State. The utilization of small strand diameter wires with high resistivity in residential building wiring is hazardous, as these wires tend to accumulate heat within their bodies, which can later result in electrical fires. Therefore, the Standard Organization of Nigeria should liaise with the Nigerian Institution of Electrical and Electronic Engineers, to weed out substandard electrical materials, and checkmate sharp practices in the system.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Adekoya, F. (2019). SON warns of substandard electric cable in circulation. Retrieved November 2021 from https://guardian.ng/business-services/industry/son-warns-of-substandard-electric-cable-in-circulation/.

Adetoro, A.K. (2012). Assessment of the quality of cables produced in Nigeria. Global Advanced Research Journal of Engineering, Technology and Innovation. 1(4), 97-102.

Agbakwuru, J. (2019). Nigerian markets flooded with counterfeit goods – Buhari. Retrieved November 2020 from https://www.vanguardngr.com/2019/09/nigerian-markets-flooded-with-counterfeit-goods-buhari/.

Agbi, G. G., Akpokodje, O. I., & Uguru, H. (2020). Compressive Strength of Commercially Produced Sandcrete Blocks within Isoko Metropolis of Delta State, Nigeria. *Turkish Journal of Agricultural Engineering Research*, 1(1), 91-103.

Akinyemi, A., Dare, G., Anthony, A., & Dabara, D. I. (2016). Building collapse in Nigeria: issues and challenges. *Conference of the International Journal of Arts & Sciences*, 9(01), 99-108.

Akpokodje, O. I., Agbi, G. G., Uguru, H., & Nyorere, O. (2021). Evaluation of the compressive strength of commercial sandcrete blocks produced in two metropolises of Delta State, Nigeria. *Applied Journal of Physical Science,* 3(2), 61-71.

Calebella, C. (2021). Effect of using substandard materials in construction work. Retrieved from https://www.calebella.com/2021/05/14/effect-of-using-substandard-materials-in-construction-work/

Electrical Engineering (2020). Resistance of wire. Retrieved November 2020 from https://electronics.stackexchange.com/questions/477904/resistance-of-wire.

Ezeagu, C., Udebunu, J., & Obiorah, S. M. (2015). Destructive and non-destructive assessment of collapsed structures in Onitsha, Anambra State, Nigeria. *American Scientific Research Journal for Engineering, Technology, and Sciences*, 12(8), 170-186.

Faremi, O., Ajayi, O., & Faremi, O. (2020). Factors influencing the use of substandard materials in the construction of residential buildings. *CSID Journal of Infrastructure Development*, 3(1), 40-50. doi:10.32783/csid-jid.v3i1.88

Haddad, A. (2009). Advances in high voltage engineering Ⅱ. Haddad, A., & Warne, D. (eds.). The Institution of Engineering and Technology.

Hawkins, J., Walters, A., Harvey, M., Walshe, M., Matthews, R., Saggers, G., & Nembhard, A. (2013). How to note : Reducing corruption in infrastructure sectors. *In Climate and Environment Infrastructure*. Retrieved April 2022 from http://engineersagainstpoverty.org/wp-content/uploads/2018/07/DFID_HTN_Reducing_Corruption_in_Infrastructure.pdf.

He, D., Zhang, T., Ma, M., Gong, W., Wang, W., & Li, Q. (2020). Research on mechanical, physicochemical and electrical properties of XLPE-insulated cables under electrical-thermal aging. *Journal of Nanomaterials*, Volume 2020, Article ID 3968737, 13 pages

Knych, T., Mamala, A., Kawecki, A., Smyrak, B., Korzeń, K., & Sieja-Smaga, E. (2022). Influence of plastic deformation on the change of electrical and mechanical properties oxygen-free (of) copper and copper alloy wires. *Metalurgija,* 61(3-4), 737-740

Lewachi, A. (2022). Empirical analysis of electromechanical properties of electric distribution cables manufactured in Nigeria. Online Repository, Michael Okpara University of Agriculture, Umudike. Retrieved July 24, 2022 from https://repository.mouau.edu.ng/work/view/empirical-analysis-of-electromechanical-properties-of-electric-distribution-cables-manufactured-in-nigeria-7-2 .

Li, H., Li, J., Li, W., Zhao, X., Wang, G. & Alim, M. A. (2013). Fractal analysis of side channels for breakdown structures in XLPE cable insulation. *Journal of Materials Science: Materials in Electronics,* (24), 1640–1643.

Nigerian Electricity Regulatory Commission - NERC (2014). Nigerian electricity supply and installation standards regulation. Retrieved from http://nipe.org.ng/download/nigerian-electricity-supply-and-installation-standards-nesis-regulations-2015/

Obukoeroro, J., & Uguru, H. (2021a). Analysis of electrical and mechanical properties of electrical cables sold in Anambra State. *International Journal of Innovative Scientific & Engineering Technologies Research*, 9(1), 30-38.

Obukoeroro, J., & Uguru, H. (2021b). A Survey of electrical materials counterfeiting in Bayelsa State: A case study of Yenagoa Local Government Area. *Journal of Physical Science and Environmental Studies*, 7(1), 9-14.

Obukoeroro, J., & Uguru, H. (2021c). Acute epileptic electricity supply in Isoko North Local Government Area of Delta State: Its causes and remediation. *Applied Journal of Physical Science,* 3(1), 13-20.

Obukoeroro, J., & Uguru, H. (2021d). Acute epileptic electricity supply in Isoko North Local Government Area of Delta State: Its causes and remediation. *Applied Journal of Physical Science*, 3(1), 13-20.

Onyekachi, E. M., & Nduka, N. B. (2019). Empirical analysis of core diameter and insulation thickness of house wiring and installation cables in Nigeria. *International Journal of Advanced Research in Science, Engineering and Technology.* 6(9), 10689-10694.

Schneider Electric (2015). Survey on electrical counterfeiting in Africa. Retrieved June 2021 from http://www.apo-mail.org/150322.pdf.

Steward, W. E., Stubbs, T. A., & Williams, F. O. (1998). Modern wiring practice. Oxford University Press. Pp. 268-283.

Ugochukwu, O., & Okechukwu, C. (2014). An appraisal of the sources, quantities and prices of imported building materials in Nigeria. *International Journal of Advanced Research*, 2(9), 871-889.

Uguru, H., & Obukoeroro, J. (2020). Physical characteristics and electrical resistivity of electric cables sold in Delta State. A case study of Isoko Metropolis. *Journal of Engineering and Information Technology*, 7(7), 155-162.

Zhang, W., Xue, X., & Bai, H. (2021). Mechanical and electrical properties of Cu-steel bimetallic porous composite with a double-helix entangled structure. *Composite Structures*, 255, 112886.