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Quality assessment of locally produced nails in Nigeria

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Abstract

The increased demand of nails in building and construction sector results in a need for better understanding of nails. An assessment of the quality of mild steel plain wire nails manufactured in Nigeria was carried out using a method known as statistical process control and corrosion film thickness test. Samples of nails (101mm and 76mm) were obtained from five producing nail industries. Nails imported from the people's republic of China, Nigeria largest source of imported nails were analyzed for physical characteristics and mechanical properties. Also, corrosion film thickness was determined for the roofing nails. The results showed that the local nails satisfy the requirements of Nigerian Institute for Standards NIS: 118:1981.

Keywords: Quality Assessment, local Products; Nails; Nail Quality

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1. Introduction

The building and construction industries are fast growing especially in the Africa largest economy like Nigeria. The market demand for nail in Nigeria is on the increase daily. As a result of inadequate importation of nail, the local industry is growing bigger in the production of nail, hence, there are various type of nails in the market, the quality of some of the product are low. Nail is an important element of Nigeria's building business sector. Most nails made today are wire nails, machine made from mild steel wire and more or less round from specific gauges. Previously, 'cut nails' were more common; cut nails which are still made, are from steel or iron plate and so have a rectangular section and have holding power of about 1.5 times greater than that of wire nails of the same length, but are more expensive to manufacture (Vable, 2012). Nails are increasingly important as a means of fastening wood, and other composite materials. Some product couldn't function as expected, this may be due to the fact that they are new and are still undergoing testing or their design is not well studied. In addition, some product couldn't function as expected because they aged quickly or lose value. Moreso, the material they are made of may be of low quality and quantity, this therefore reduce their performance. Furthermore, the failing in the product may be due to lack of modern equipment for the processing and manufacturing. These had prompted the use of laboratory tests to standardize nails and testing procedure in this research effort.

1.1. Aim of the research

The aim of study is to understand how to come up with quality nails that can compete with nails imported into Nigeria and to understand what it takes to manufacture wire nails. The assessment of quality is a necessary ingredient in the evaluation of facet of market performance of a product.

In order to better understand quality assessment at it relates to mild steel wire nails, the general objective and specific objectives were presented. The general objective is to understand how to come up with quality nails in Nigeria that can compete with nails imported into the country and to understand what it takes to manufacture wire nails.

Specific test were carried out to determine which producer meets the Nigerian Industrial Standards (NIS) and possibly the American Society for Testing and Materials (ASTM) standards; a comparison of the products from the five manufacturers and imported nails were examined.

The specific objectives of this work are:

1- To verify if wire nails manufactured locally meet the requirements of Nigerian Industrial Standards (NIS), Article 18: 1981, UDC: 669, 426, 672: 886.2 i.e.

   Minimum ultimate strength of 540N/mm^2 for most sizes and types of wire nails.

   Minimum average thickness of zinc coating of 0.0125mm when galvanized.

2- To verify if the dimensions of sizes under study (76-101mm) satisfies the requirements.

3- To carry out the same type of tests on nails imported from the Peoples Republic of China – which remain the largest exporters of wire nails into Nigeria (MAN, 2006).

4- To verify from the local producers, their testing procedure and compare with international test procedures and standards.

5- The research work would be very useful to regulating bodies such as Manufacturer Association of Nigeria (MAN) Nigeria

Institute of Standard, Consumer Protection Council and some organizations involved in construction, particularly ship repairers, light and heavy duty construction companies, packaging industries, marketing and export promotion council as a stimulant to boost the local economy and individuals that may be in need of nail.

1.2. Statement of the problem

The number of nails that will fail to hold a joint or penetrate a wooden or composite material without deformation or fracture increases as the amount of nails used increases. This is against the background of the efforts of Nigerian Institute of Standards (NIS) to come up with requirements for local and imported nails. The 1981 NIS: 118 (Revised 1988) standards placed emphasis on dimensions and materials rather than quality which may affect users directly such as in bending (deformation), during use, which results in nail losses as well as loss of earnings for the manufacturer with their products not being able to compete for market shares in other countries where the enforcement of quality standard might be more stringent; than those obtainable in Nigeria.

There are, however, no official figures to indicate the demand of imported nails in Nigeria, however, there is the likelihood that two nails out of ten may bend during a nail process (FCDA, 2000), gives credit to the need for this kind of research, as the end result will enable local manufacturers of nails to have a feedback from the consumers which should give the Nigerian Institute of Standard (NIS) the impetus when necessary to revise Article NIS 118: 1988 as well as the Manufacturers Association of Nigeria (MAN) to take a closer look towards the activities of the local nail manufacturing companies. There is also the preference of improved nails over locally manufactured nails by local Artisans and builders (Ryzewski and Gordon, 2008).

1.3. Significance of the research

The significance of the research will be to ascertain the followings:

(i) To determine if nails manufacturing companies have specific testing standards and to which extent they comply with the standard.

(ii) To identify the need for another revision of NIS Article 118:1981 to include testing procedure and determine dimensions as stated in Article NIS 118: 1981, UDC: 669,426,672:886.2

(iii) To determine how American Society for Testing and Materials (ASTM) International Standards can be incorporated in Article NIS 118: 1981.

(iv) To determine if nails manufactured locally have desired ‘finish’ and corrosion resistance attributes.

(v) To see how the research findings can be of benefit to the local producers in particular and the Manufacturers Association of Nigeria (MAN).

1.4. Research questions

Many questions may be asked to enhance our understanding of wire nails, such as;

- What classify one size of nail from one manufacturer better than the other?
- Does high nailing force required from artisan as to enable it penetrate and hold a joint?
- If a nail bends easily during a nailing process. What does it connote?

1.5. Researchers tests

This researchers tested samples from local manufacturer hereby labelled A – E for sizes 76 – 101mm (3” – 4”) mild steel wire nails and sample G – H 64mm (2½ inches) roofing nail (zinc coated) for dimensions such as shank length, shank diameter, head diameter and tip length also tested are yield stress, ultimate stress, compressive stress for comparison with (Revised 1988) Article NIS 118:1981 (Revised 1988) of the Nigerian Institute of Standards.

Some of the tests were carried out at both the Civil Engineering Laboratory (Material Laboratory) and Mechanical Engineering Department of Kaduna Polytechnic, Kaduna, Nigeria. While corrosion film thickness tests perform at the Air force Institute of Technology, Kaduna.

1.6. Scope of the research

The topic of quality assessment of nails includes many diverse areas. Quality is affected by several factors of raw materials, processing techniques, machinery and expertise labour. Those issues of raw material, chemical composition, processing techniques and machinery are beyond the scope of this project. Areas of focus for this project include the laboratory testing of finished mild steel wire nails of sizes 76 – 101mm (3” – 4”) for six different local producers as well as analysis of laboratory findings to determine yield stress, ultimate compressive stress, dimension, and see how they differ from nails imported into the country, especially those from the Peoples Republic of China and compare same with the ASTM standards.

Film thickness on corrosion resistance roofing nails on two local nails will also be determined. Efforts will also be made to determine which other qualities make imported nails more popular and marketable than locally produced nails.

1.7. The research motivation

The most nails in our markets are sub-standard in quality such as roofing nails, when used it does not hold or fix firmly into the wood or iron thereby causing roof to be remove during storm. Therefore, this study will assist the nail manufacturing companies on quality production of nails for both domestic and industrial uses. This is necessary because the rate of nails consumption is on the increase as building and construction works are multiplying. The study is to provide a good, novel approach and method for multi-objective decision-making based on six dissimilar objectives attributes: quality, quantity of raw materials, efficient processing systems, efficiency and effectiveness of use and evolving technology. Morealso, the study is to help nails production in Nigeria meet with international standard for market competitiveness and price relativity. Furthermore, to improve on the local ideas on nail production as well as filling the gap between local production of nail and industrial nail manufacturer.

2. Nail production in Nigeria

A nail is a headed pin or spike of metal, commonly of iron. The principal use of nails is in fixing members in wooden construction, but nail are also employed in shoemaking, upholstery and saddlery work. The locally produced nails in Nigeria are been manufacture from the gathering of metal wire which are been hand pick from waste composite at home and industrial waste metals. The metal wires are put into a locally produced nail-making machine which can produce between 500 -700 nails per minute. The nails are then twisted to formed nail shape, which are cleaned, finished, and packaged. Figure 1 presented samples of locally produced pile of nails in Nigeria.

Figure 1. Locally produced pile of Nails

2.1. Production Process

Manufacturing of nails passes through the following steps.

(a) Feeding of wire coil to nail making machine

(b) Forming the bottom and top portion of nail and cutting on the nail making

(c) Machine manufacturing of flat head nails ends here

(d) Manufacturing of the nail head on a washer making machine

(e) Polishing of head part

(f) Feeding the head to the nail making machine

(g) Punching of the head to the nail and pressing to umbrella shape

(h) Galvanizing - is the process of applying a protective zinc coating to steel or iron, to prevent rusting.

2.2. Nail composition

Nails is formerly made of bronze or wrought iron, today's nails are typically made of steel, which is an alloy of iron and carbon, often dipped or coated to prevent corrosion in harsh conditions or improve adhesion. It can be classified as low carbon or mild steel nail when the percentage of carbon is between 0.15% - 0.45% (Deming and Edwards, 1982).

Other alloying elements such as Nickel, Chromium, Tungsten Molybdenum, cobalt when added will produce an improvement in the properties either by increasing wear resistance or corrosion resistance. Most nail composition are iron, zinc, silver, monel steel, alluminium, copper, brass, bronze, stainless steel and nickel. Generally, wooden nails are soft which makes it easy for penetration into the wood, the composition are low- cabon or mild steel, iron, silicon or manganese. Concrete nails are harder as it does not bend easily when nailed to wall or material, it has more percentage of carbon composition between 0.5 – 0.8% when compared to wooden nail which has less percentage of carbon composition between 0.1 – 0.3%.

2.3. Type/kind of nails

There are several kinds of nails, examples are: (1) Common wire nails (2) Common spikes (3) Finishing nails (4) Casing nails (5) Smooth box nails (6) Brads nails (7) Wire nails (8) Escutcheon pins (9) Rail road spikes (10) Apple box nails (11) Berry box nails (12) Cigar box nails (13) Egg case nails (14) Fruit box nails (15) Beer case nails (16) Cleat nails (17) Hoop fasteners (18) Hook head, metal lath nail (19) Orange box nails (20) Veneer box nails (21) Spiral shank nails, (22) Roofing nail (23) Concrete nail (24) Annular nail. Figure 2 explained sample of types of nails.

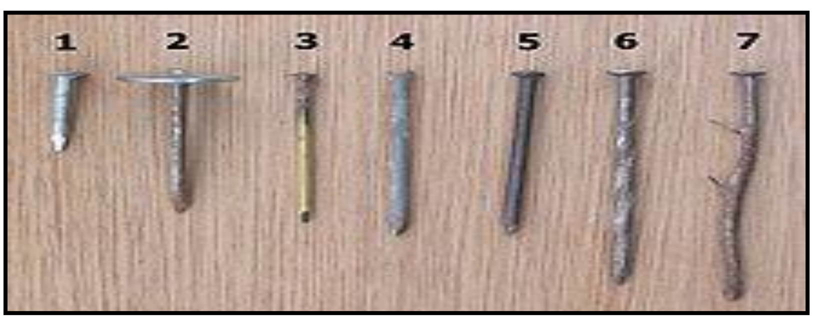

Figure 2. Different types of Nails

From Figure 2, Nail number “1” stand for Roofing nail, while nail “2” represent Umbrella head roofing nail, nail “3” stand for Brass escutcheon pin, nail “4” represent Finish nail, nail “5” stand for Concrete nail. Also, nail “6” represent Spiral-shank nail, and nail “7” represent Ring-shank nail (the barbs are a leftover component of the feed system of a nail gun).

2.4. The concept of quality

The concept of quality varies from one user to another with a company producing goods of different degrees of quality. Quality was defined as the fitness for a purpose, whereas assessment has to do with the appraisal of the value of an object or testing its value. Quality was defined as the fitness for a purpose (Olarewaju, 1985).

In most parts of the world, nails are described by their dimensions in millimeters, a "150 x 4" is a nail 150mm long and 4mm in diameter and mainly varies in length between 13mm (½in) – 150mm (6in); a description of the 'head' and 'finish' may be typically added. Some nails have no 'finish' and are mostly used for rough carpentry work where appearance is not important, but strength is essential. When inclined they can be used to split a piece wood and can be rusty when used on surfaces in contact with water. A common way of making nails corrosion resistant is to coat them with zinc; Hot-dipped (H.D.) nails can be galvanized by dipping them in molten zinc while electro – galvanized nails are plated with zinc and are not as corrosion – resistant as hot dipped nails (Serope, 2001). A third process, 'peening' is the process of applying zinc onto the nails by roughening the nail surface, all these treatments – especially hot dipping also increase the holding power of the nail.

2.4.1. Background information on quality control

The idea that quality must be designed and built into a product rather than detect defective is one of the major objectives of total quality control. Certain experts in quality control have put into larger perspective many of the quality control concepts and methods; notable among experts on quality philosophy are (Deming, Juran and Taguchi, Serope, 2002).

The method of statistical control arose from the recognition that there were variations in the performance of machines, people and quality of dimensions of raw materials. Their efforts involved not only statistical method of analysis, but also a new way of looking at manufacturing operation from the perspective of improving quality and lowering costs.

Edwards Deming offered 14 key principles for management to follow for significantly improving the effectiveness of a business or organization. Many of the principles are philosophical. Others are more programmatic. All are transformative in nature. The points were first presented in his book *Out of the Crisis* (Deming, 1986). The condensation of the 14 Points for Management as they appeared in the book are as follow:

1- Create constancy of purpose towards improvement of product and service
2- Adopt the new philosophy
3- Cease dependence on mass inspection to achieve quality
4- End the practice of awarding business on the basis of price tag
5- Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease cost
6- Institute training on the job

7- Institute leadership (as opposed to supervision)
8- Drive out fear so that everyone can work effectively
9- Break down banners between departments
10- Eliminate slogans, exhortations and targets for zero defect and new level of productivity
11- Eliminate quotas and management by number numerical goals
12- Remove banners that nib the hourly worker of pride of workmanship
13- Institute a vigorous programme of education and self-improvement
14- Put everybody in the company to work to accompanish the transformation.

According to Deming, these points are not to be seen as a check list or menu of tasks, they are the characteristics that 'Deming' recognized in companies that produce high quality goods; Deming suggestion on direct involvement of company workers in the production of goods with adequate information and communication as well as education with right manufacturing technology has gained popularity and acceptance in country like Japan.(Serope 2002). Since the end of World War II, only recently have some segments of the U.S manufacturing communities begun to implement them. A contemporary of (Deming, and Juran, 1904) emphasizes the following ideas that:

(a) Recognizing quality at all levels of an organization, including upper management.

(b) Fostering a responsive corporate culture.

(c) Training all personnel on how to plan, control and improve quality.

In 1924, G. Taguchi in his book introduction to quality engineering introduced his high quality, low cost method by combining engineering and statistics to optimize product design and manufacturing processes, His work may be summarized as follows;

- Poor quality leads to customer's dissatisfaction.
- Manufacturer's credibility diminishes in the market place.
- The manufacturer eventually losses its share of the market

Taguchi's method of quality engineering emphasizes the importance of enhancing cross functional team interaction between design engineers and process or manufacturing engineers and enable process or manufacturing engineers to communicate with each other in a common language. He discussed the effects of controllable and uncontrollable variables on the product, with the idea of minimizing variations in product dimension and properties and ultimately bring the mean to the desired level.

There are complexity in the design methods used as these were not simplifying as it involves a whole number and disorderly arrangement that limit the number of test required, which does not help even in identifying environmental problem.

Another aspect of quality is a concept also suggested by Taguchi, which has continuously grown in importance and is referred to as robustness. A robust design, process or system is one that continues to function within acceptable parameters despite variabilities. Robustness refers to a product or machine performance being insensitive to tolerance change and the performance should not deteriorate significantly over its intended life (Ross, 1992).

Taguchi, also gave a loss function calculation where he ascertained that the lack of quality of a particular product is a loss to the company. Mathematically, the loss cost can be written as**:**

$$\text{Loss cost} = K(CY - T)^2 + S^2 \quad \text{equation (1)}$$

where,

Y = Mean value from manufacturing

T = Target value from design

S = Standard deviation of parts from manufacturing

K = Constant, defined as

K = Replacement Cost

$$(LSL - T)^2 \quad \text{equation (2)}$$

The lower specification limit LSL and (USL), upper specification limit are the same (that is, the tolerance are balanced), either of the limits can be used in this equation.

2.4.2. Quality control

Quality control is a way of enforcing or maintaining of product standard by testing samples in the laboratory or otherwise to ascertain consumption certification. The raw materials for nail production need require chemical composition to balance corrosion resistance, hardness, properties and yield strength for best performance to be achieved in the industry. Also, the manufacturing of nail require specification of properties and dimensions, this is done through a control series of stages and a detailed examination of elements and structure alongside with determination of constituent parts of mixture.

2.4.3. The uses of quality

An acceptable, empirically measurable concept of quality should have four major uses:

1- to provide value for money with regards to desirable result and satisfaction
2- provide information for market competitiveness
3- as a valuable exchange for materials desire
4- to facilitate market development in terms of demand and supply of products in the economy

2.5. Materials for nails

Production of nails require the following raw materials

- Chemical like carbon steel (low)
- (ii) Rolled steel (cold) sheet

Apart from mild steel, there are two major types of nails that are common, these are 304 and 316 stainless steel, but stainless steel nails are not as stronger as ordinary steel nails and also stainless steel nails are three times expensive as galvanized nails and are more resistant to rust. Aluminum nails are not so strong for most structural framing, but majorly used to fasten aluminum siding or screening, unlike copper nails that are used in roofing and in marine application.

2.6. Locally produced nails

The Nails produced in Nigeria are from mild steel wire and are required to satisfy (NIS) standards (NIS 118: 1981). There are about half a dozen functioning manufacturers of nails in Nigeria and about another half a dozen companies closed (MAN newsletter July – August 2007). Table 1 is the list of some major producers of nails in Nigeria.

Table 1. List of Some Major Producers of Nails in Nigeria

S/No	Name/Address	Volume of Annual Production	Year Established	Remarks
1	Highland steel & allied Industries limited	3607	1988	Closed
2	Ifena coy Limited Enugu, Enugu state	35T	1974	Closed
3	LSN metal industries Nigeria Limited Hadeija Road Kano	5060	1977	Closed
4	Lekwas metal works limited Aba, Abia state	15	1979	Closed
5	Liman industries Limited Nasarawa Road Kaduna	3000	1980	Closed
6	Mikko Nails limited Aba	Not stated	1980	Closed
5	Moore Nails & steel industry Aba	Not stated	1980	Closed
6	Nails and General steel products Aba	Not stated	1980	Closed
7	Kamwire Nigeria Limited	Not stated	2007	Functional
8	Light metal industries	Not stated	2006	Functional
9	Lowil Nigeria Limited, Ilorin Kwara state	Not stated	2007	Functional
10	Tulip Group (Mazari) Nigeria Limited Zaria, Kaduna state	Not stated	2007	Functional

Samples collected for test are from the following manufacturers:

1. Brand Name - United Wire
   Manufacturer - United Wires Nigeria Limited, Kaduna
   Sizes produced - 12.7, 25, 76, 101mm (1", 1/2 ", 3"- 4")
2. Brand Name - Kamwil
   Manufacturer - Kamwire Nigeria Limited, Ilorin, Kwara State
   Sizes produced - 25 – 127mm (1" – 5"), Roofing nail 64mm (2½")
3. Brand Name - Light Metal
   Manufacturer - Light Metal Nigeria Limited Onitsha, Anambra State
   Sizes produced - 25 – 127mm (1" – 5")
4. Brand Name - Eureka
   Manufacturer - Eureka metal Limited, Lagos
   Sizes produced - 25 – 127mm (1" – 5")
5. Brand Name - Lowil
   Manufacturer - Lowil Nigeria Limited, Ilorin, Kwara State
   Sizes produced - 25 – 127mm (1" – 5")
6. Brand Name - Mazari nails
   Manufacturer - (Tulip Group), Mazari Nigeria Limited Zaria, Kaduna State
   Sizes produced - 25 – 127mm (1" – 5"),
   Roofing nail - (64mm, 2½")

2.7. Corrosion and corrosion protection of roofing nail

Corrosion is the removal of metal beginning at the surface as a result of electrochemical reactions with components in the environment. Metal atoms are oxidized and form non-metallic compounds. The process can be either by the metal being oxidized as a result of potential difference reacting with the metallic constituents which attacks the medium (Eugene, 1997)

2.7.1. Types of corrosion

There are several types of corrosion, a frequent type of corrosions in which the thickness of removed material can be calculated per unit of time on the basis of corrosion current are:

Pitting Corrosion: This is a localized attack by the corrosive medium which forms holes, or pits, in the material whose depth is almost always greater than their diameter. Practically no material is removed from the outside the pitted areas, pitting corrosion is frequently caused by halogenide ions.

Crevice Corrosion: Corrosive attack which primarily takes place in the narrow crevices, and is caused by concentration differences in the corrosive medium.

Stress Corrosion: Corrosion which occurs as a result of the simultaneous effect of a corrosive medium and mechanical tensile stress which can also take the form of internal stress in the work piece.

Vibration Corrosion: Corrosion caused by the simultaneous effect of a corrosive medium and mechanical fatigue stress, fpr example as caused by vibration.

Dezincification: This is a selective removal of zinc from metal leaving behind a porous metal structure, dezincification and de-aluminification are analogous processes; which results in rust formation, and this is the type corrosion that is common on roofing nails.

2.7.2. Corrosion testing

The following corrosion tests are available.

2.7.2.1. Electrochemical Corrosion Testing Procedure (DIN 50918)

In this testing the corrosion currents are determined in addition to the potentials of the corroding materials during the corrosion reaction. These corrosion currents can be used to precisely calculate the loss of weight and thickness per unit of time in the case of uniform general corrosion. The Table 2 showing loss the loss of mass and thickness due to general corrosion of various metals with a corrosion current density of 1μA/Cm^2.

Table 2. Loss of Mass and Thickness of Corrosion of Various Metals

etal	Atomic weight	Density g/cm^2	Loss of mass mg/cm^2 year	Loss of thickness μm/year
F_e	55.9	7.87	9.13	11.6
C_u	63.5	8.93	10.4	11.6
C_d	112.4	8.64	18.4	21.0
N_1	58.7	8.90	9.59	10.8
Z_n	65.4	7.14	10.7	15.0
A_1	26.9	2.70	2.94	10.9
S_n	118.7	7.28	19.4	26.6
B_6	207.2	11.3	33.9	30.0

Source: Bosch 1986

Electrochemical processes are thus a valuable supplement to non-electrochemical methods. The degree of corrosion is measured by the polarization resistance method which is the slope of the current/voltage curve in measuring free corrosion. In measuring contact corrosion, the current which flow between the two metals concerned is measured when both are immersed in the same corrosive medium. Metal removal rates are determined through electrochemical measurements. These processes are not obtainable.

2.7.2.2. Non-electrochemical corrosion testing procedures

In non-electrochemical test procedures, either the weight loss is measure by weighing or the rust degree is determined DIN 53210 defines fine different rust degrees indicated by rust covered or rusted through surfaces. ASTU Standardized Corrosion Testing Procedures have become established in practice which all specifically adapted to specific requirements.

The following are some ASTM selected standardized Non- Electrochemical Corrosion Testing Procedures.

(i) ASTM B-380 - Corrodcote test for chrome plated motor vehicle parts

(ii) ASTM B-185 - Continuous immersion tests in artificial seawater

(iii) ASTM B-192 - Alternate immersion test

(iv) ASTM B-117 - Salt spray test

(v) ASTM B-287 - Acetic acid salt spray test

2.8. Zinc and zinc alloy coating

Zinc which is used mainly as coating of roofing nails is an inexpensive non-ferrous metal produced from sulfide, silicate or carbonate ores by a process involving concentration and roasting followed either by thermal reduction in a zinc – lead blast furnance.

2.9. Coating of roofing nails

Roofing nails can be coated using one of the following processes:

- Tumbler/Hot Galvanized **–** Nails are galvanized by putting zinc chips into a hot rotating barrel with the nails; with the zinc then "washing" off unto the nails
- Mechanical Galvanizing **–** This is a cold process which hammers zinc powder onto the nail to give then galvanized coating.
- Electro Galvanizing **–** This method uses electricity and zinc anodes to put on a beautiful. Shiny coating, but also very thin, the thin coating soon oxides away allowing rust to quickly set in. This is the type of zinc coating carried out on the only local company producing roofing nail.
- The Double Hot Dipped Galvanizing **–** as a method of improving thickness, it is for optimum performance. This is as specified in ASTM A – 153.

2.10. The ISO and QS Standards

With increasing international trade, global manufacturing and price sensitive competition have come a wide choice of industrial and individual consumers. Customers are increasingly demanding high – quality products and services at low price and are looking for suppliers that can respond to this demand consistently and reliably.

This trend has in turn creates the need for international conformity and consensus regarding the establishment of methods for quality control, reliability and safety of a product. In addition to these considerations, equally important concerns regarding the environment and quality of life are now being addressed with new international standards.

2.10.1. The ISO 9000 Standard

First issued in 1987 and revised in 1994 (Rothey, 1995) the ISO 9000 standard (Quality Management and Quality Assurance Standard) is a deliberately generic standard series of quality system management. The ISO 9000 standard has permanently influenced the way manufacturing companies conduct business in world trade and has become the world standard for quality.

The ISO series includes the following standards:

(1) ISO 9001 – Quality systems: model for quality assurance in design / development production, installation and servicing.

(2) ISO 9002 – Quality systems: model for quality assurance in production and installation.

(3) ISO 9003 – Quality systems: model for quality assurance in final inspection and test.

(4) ISO 9004 – Quality management and quality system element: Guidelines.

Companies voluntarily register for these standards and are issued certificates ISO 9000 standard is not a product certification. It is a quality process certification; the QS 9000 standard, ISO 14000 standard are rapidly being employed by manufacturers in the automobile industries.

2.11. Mechanical properties of metals

Mechanical properties of metals are those which are associated with the ability of the material to resist mechanical forces and load. These properties include strength, stiffness, elasticity, plasticity, ductility, brittleness, malleability, toughness, resilience, creep and hardness. The detailed study of all the properties of a metal provides a sound basis for predicting its behaviour in the manufacturing shop and also in actual usage.

2.12. Strength of materials

Strength is the ability of a material to resist externally applied force without breaking or yielding.

2.12.1. Stress

The stress is defined as the internal resistance set up by the molecules of a material to resist deformation, due to the application of external forces; this internal force per unit area at any section of the body is known as unit stress or simply a stress. It is usually denoted by sigma (σ), mathematically,

$$\text{Stress, } \sigma = P/A \quad \text{equation (3)}$$

where, P = Force (N) or load acting on a body and A = Cross – sectional area of the body (m^2).

2.12.2. Strain

The strain is defined as the deformation or change in length per unit length under the action of the external force. It is also called axial strain, linear strain or longitudinal strain, It is usually denoted by the letter epsilon (ε), mathematically.

Strain (ε) = dl/l or dl = ε.l .... equation (4)

where, dl = change in length of the body, and l = original length of the body.

Furthermore, strain can be explained as the ratio of extension to original length, strain has no units as it is a ratio of two lengths measured in metres. The ratio of the increase in length to the original length is known as tensile strain. Mathematically, strain can be represented as;

Strain = *extention / Length* .... equation (5)

Strain = *Extention in Length(EL) / Length(L)* .... equation (6)

where, EL = extension in Length measured in metres and L = original length measured in metres

2.12.3. Tensile stress and strain

In this context tensile means been likely to stretched that is a material that is subject to expand or increase in length. While *stress* is the pressure or force that can be observe on material like tensile, the pressure or force on the material can be measure per unit area. The *strain* is the total expansion that occurs when a material is under pressure (stress) per unit area.

The Figure 2 showed the the plot of stress against strain.

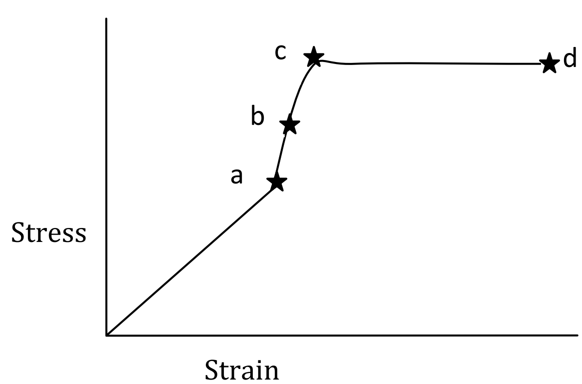

Figure 2. Stress against strain

(1) “a” represent the extent of expansion of the material

(2) “b” is the expansion limit point of the material

(3) “c” is the point at which an infinitesimal increase in expansion cause larger expansion in the material

(4) “d” represent the point at which expansion of the material can no longer be tolerated, otherwise damage will occur.

2.12.4. Compressive stress and strain

The ratio of the decrease in length to the original length is known as compressive strain. Mathematically, strain can be represented as;

Compressive Strain = Decrease in Lenght / *Original Length* ………equation (7)

Strain = *Decrease in length(DL) / Length(L)* ………equation (8)

where, DL = Decrease in Length measured in metres and L = original length measured in metres

2.12.5. Shear stress

It is a stress that is parallel to the surface of the material, as opposed to normal **stress** when the **stress** is vertical to the surface. That is the stress or the body is subjected to two equal and opposite direction acting perpendicularly or tangentially across the resisting sections, this makes the body to shear off the section. Therefore, the stress induced is called stress.

The corresponding strain is known as shear strain and it is measured by the angular deformation accompanying the shear stress and strain are denoted by the letters tau (τ) and phi (ϕ) respectively, mathematically,

Shear stress = *Tangential force / Area resisting the force* ………equation (9)

Consider a body consisting of two pieces of wood connected by a nail. The tangential force P tends to shear nail at one cross section as shown in b. It will be noted that when the tangential force is resisted by one cross section of the nail (or when shearing takes place at one cross section of the nail), then the nail is said to be in single shear. In such a case, the area resisting the shear of the nail will be:

A = πd / 4 ………equation (10)

and the shear stress on the nail cross – section

$$= P/A = \frac{4P}{xd^2}$$ ………equation (11)

where, p = Applied force, A = nail cross- section area, d = diameter of the nail, x = Projected area of the nail

2.12.6. Bearing stress

It is a restricted reduction in tension on top of contact between two material that are proportionally at rest.

If one considers the bearing or stress or crushing stress (stress at the surface or contact between the nail and the wooden material).

$$\sigma_b(_{or}\sigma_e) = \frac{P}{d.t.n} \quad \text{equation (12)}$$

where

d = diameter of the nail,

t = Thickness of the wood,

$d.t$ = Projected area of the nail,

n = Number of nails per pitch length in bearing or crushing and p = Applied force

2.13. Related work

Related study include "Profile on the production of wire nail"(Profile on the Production of Wire Nail, 2015),"The Rise and Decline of the American Cut Nail Industry"(Amos, 1993), "This Old House Guide to Building and Remodeling Materials"(Vila, 1986). Others are "Nails Get a Better Grip" (Johnson, 1994), "Fastenings" (Soltis, 2010) and **"**Determination of Screw and Nail Withdrawal Resistance of Some Important Wood Species**"** (Alper, 2008).

3. Research methodology

The mechanical properties of materials used in engineering are determined by tests performed on specimens of the material. Nail specimens were prepared by standard laboratory techniques of sectioning, polishing and etching for examination with optical or electron microscopes. As samples of round wire mild steel nails from six local manufacturers were collected randomly for lengths between 76 – 101mm and shank diameters between 220 – 420mm and the diameters of the head between 80 – 110mm, which are mainly used for rough carpentry work where appearance is not as important as strength. The purpose is to determine mechanical properties such as shear stress, bending strength, yield, and ultimate stresses.

Also zinc coating thickness which prevents rust or corrosion on roofing nails was similarly tested. More tests were carried out on nails imported from the People's Republic of China which has been the largest exporter of nails to Nigeria (MAN 2005). The tests was conducted in the material laboratory of Kaduna Polytechnic which is equipped with the appropriate testing machines.

The machine used for Tensile and compressive stress test at the material laboratory of Civil Engineering Department of Kaduna Polytechnic is the Maekawa Universal Testing Machine method. The Maekawa Universal Testing Machine method is one of the most widely used and is also a known ASTM testing machine.
It is specifically used for evaluating proportional limit, elastic limit, yield point, ultimate stress, breaking stress, and percentage reduction in area, percentage elongation, from which parameters of, other parameters can be determined.

The machine used for impact test is the Charpy V-notch (CVN) impact tester (pendulum type), while the electron microscope was used to determine corrosion film thickness.

3.1. Testing – tensile and compressive

The test was performed as follow:

- One end of the specimen is gripped in the jaws provided in the adjustable cross head and then after lifting the cross head to the appropriate height (depending upon the length of the specimen). The other end of the specimen is fixed in jaws in the top cross head.
- The tensile load is then applied hydraulically by turning the hand wheel towards the right provided in the control unit. The load –measuring gauge incorporated in the control unit shows the magnitude of the applied load.
- The load is gradually increased until the specimen breaks and the corresponding extensions are recorded.

3.2. Impact test

In the Charpy V-notch (CVN) impact test conducted, a notched bar specimen was used which is loaded in bending. The energy absorbed from a swinging pendulum in fracturing the specimen is measured. The pendulum strikes the specimen at 4.86 - 5.80 m/s so that the specimen deformation allocated with fracture occurs at a rapid rate. This ensures a conservative measure of toughness.

3.3. Preparation of sample

The dimensions and forms of the specimen vary according to the size of the nails to be tested and the main objectives in view. The test specimen is having uniform cross section throughout the gauge length.

4. Data presentation and analysis inferences

During the testing of nails, readings of physical properties such as shank length, nail head diameter, shank diameter and tip (point) length were obtained, the idea was to compare readings obtained with the specifications of NIS 118:1981 as well as to establish their variance with nails imported into the country especially with the more common brands from the People Republic of China.

4.1. Results of physical analysis

Readings are presented in Tables and the symbols used in the tables are defined as follows:

A_1 – A_6 – samples of nails or specimen from location A (Imported) nails

B_1 – B_6 – samples from location or manufacturer B (imported)

$C_1 – C_6$ – samples from location or manufacturer C (local)

$D_1 – D_6$ – samples from location or manufacturer D

$E_1 – E_6$ – samples from location or manufacturer (Local)

L – Shank length of nails (mm)

S_D – Shank diameter of nail (mm)

H_D – Diameter of nail head (mm)

T_L – Tip Length of nail (mm)

The Table 3 showed the data obtained during measurement of plain nail samples of 101 mm(4^{in}) Size

Table 3. Summary of Reading obtained during Measurement of Plain Nail Samples of 101 mm(4^{in}) Size

Sample	L(mm)	SD(mm)	HD(mm)	T_L(mm)
B_1	105.0	42.2	90.5	7.0
B_2	105.0	42.3	101.0	5.0
B_3	95.0	42.6	82.6	8.0
B_4	108.0	42.9	92.2	6.0
B_5	110.0	43.2	100.4	5.0
B_6	106.0	42.4	81.5	8.0
C_1	104.0	43.2	102.5	8.0
C_2	110,0	43.0	104.0	5.0
C_3	104.0	42.9	102.5	7.0
C_4	11.0	43.3	100.5	6.0
C_5	103.0	43.2	102.2	5.5
C_6	95.0	43.3	104.6	6.0
D_1	111.0	43.0	84.8	7.0
D_2	106.0	42.9	82.2	7.0
D_3	94.0	42.6	93.9	7.0
D_4	113.0	43.0	93.2	6.5
D_5	103.0	42.8	100.3	7.0
D_6	108.0	43.9	92.9	7.0
E_1	106.0	42.5	100.7	7.0
E_2	106.0	42.8	104.5	5.0
E_3	95.0	42.8	100.0	7.5
E_4	111.0	42.9	100.0	3.0
E_5	105.0	43.3	104.5	6.0
E_6	109.0	42.5	102.7	7.5

The Table 4 presented the data obtained during measurement of plain nails samples for the 76mm (3^{in}) size

Table 4. Summary of Readings obtained during Measurement of Plain Nails Samples for the 76mm (3^{in}) Size

Sample	L(mm)	SD(mm)	HD(mm)	T_L(mm)	Remarks
A_1	76.0	32.5	81.2	5.0	Imported nail A_1 – A_6 are only available in size 76mm (3^{in}) size
A_2	79.0	33.0	83.0	5.0	
A_3	80.0	32.4	81.9	6.0	
A_4	80.0	32.7	81.2	5.0	
A_5	80.0	33.2	80.6	4.0	
A_6	79.0	32.4	80.2	5.0	
B_1	81.0	31.8	74.5	6.0	
B_2	81.0	32.8	72.4	4.0	
B_3	80.0	32.4	74.6	5.0	
B_4	81.0	32.1	74.4	6.0	
B_5	80.0	32.0	64.3	5.0	
B_6	80.0	32.7	71.4	5.0	
C_1	83.0	32.8	70.7	5.0	
C_2	87.0	32.8	82.5	5.5	
C_3	80.0	33.0	71.9	6.0	
C_4	79.0	3.27	71.6	6.0	
C_5	80.0	32.5	81.1	6.5	
C_6	81.0	33.0	81.0	7.0	
D_1	90.0	33.0	72.4	5.0	
D_2	77.0	33.0	61.5	5.5	
D_3	84.0	33.2	70.4	5.0	
D_4	73.0	33.2	52.0	4.8	
D_5	85.0	33.0	72.4	5.0	
D_6	83.0	31.6	72.5	5.0	
E_1	74.0	32.8	70.7	4.0	
E_2	75.0	32.7	73.2	5.0	
E_3	79.0	32.9	72.6	5.1	
E_4	80.0	32.7	83.0	4.0	
E_5	74.0	32.9	73.6	3.8	
E_6	74.0	33.1	73.5	3.8	

The Table 5 highlights the data summary of mechanical analysis.

Table 5. Summary of Mechanical Analysis

SAMPLES	DIAMETER (mm)	AREA (mm2)	LOAD (KN)	Ultimate STRESS (N/mm2)	Compressive Load stress (KN) N/mm2	Remarks
A (76mm)	3.77	11.17	5.0	448	10 895.2	IMPORTED
B	3.69	10.70	4.0	374	10 934.5	LOCAL
C	3.79	11.29	4.0	354.3	8 708.6	LOCAL
D	3.69	10.70	5.0	467	7 654.2	LOCAL
E	3.27	8.39	4.0	476.7	8 9553.5	LOCAL

F	3.50	9.62	4.0	415.8	7 727.6	LOCAL
101mm						
A	4.72	17.51	7.0	399.8	12 685.3	IMPORTE
B	4.84	18.40	7.0	380.4	9.5 516.3	LOCAL
C	4.75	17.72	7.0	395.0	9 507.9	LOCAL
D	4.84	188.40	6.5	353.2	9.5 516.0	LOCAL
E	4.70	17.35	6.5	374.6	10 576.3	LOCAL

4.2. The data obtained for zinc corrosion thickness on roofing nails for locally produced and imported zinc coated roofing nails

The results shows the thickness of the zinc coating corrosion resistant plating, as 0.0010mm samples 6 x H and 0.0012mm the test was carried out using for the imported samples at the Air force Institute of Technology (air force base) Kaduna.

4.2.1. Data analysis and inference on physical analysis of the 101mm (4in) samples

From the data presented in Tables 6, the result of physical analysis that are of major significance they are:

- The shank length of the nails (mm)
- The shank diameter of the nails (mm)
- The head diameter (mm)

Table 6 showing averages of shank lengths of tested 101mm (4^{in}) nails (locally produced) samples average shank lengths

Table 6. Averages of Shank Lengths of Tested 101mm (4^{in}) Nails

B_1	105.0
B_2	105.0
B_3	95.0
B_4	108.0
B_5	110.0
B_6	106.0

Average shank length of entire sample = $\frac{\sum SL}{n} = \frac{629}{6} = 104.83mm$ = 104.80mm

From the data above, the average shank length for locally produced nails 101mm (4^{in}) size is 104.83mm. when compared with the shank length of the imported nail sample 'A' which is 79.00mm. it can therefore be concluded that the imported nail samples (A) falls short the conditions of NIS: 18:1981 of min length for the 101mm size being 98.5mm and maximum length being 101.5mm.

For samples (B_1 – B_4) for the 101mm, locally produced nails, it was observed that the average shank length was 105.40mm.

4.2.2. Data analysis and inference from the physical analysis of the 76mm (3^{in}) samples

From the data presented in table 4.0 to 4.3 it was observed that the averages of the physical analysis on the nails are as follows:

- Average shank length = 79.00mm
- Average shank diameter = 32.70mm
- Average head diameter = 81.36mm
- Average tip length = 5.0mm

When compared to the figures issued by NIS:118:1981, which specifies the lengths as minimum 78.5mm and max. 81.5mm while shank diameter is minimum 3.49mm and maximum 3.61mm diameter of head is minimum 7.73mm and 8.23mm maximum. It therefore follows that figures obtained from locally produced 76mm nails are in conformity with the Nigerian Institute for Standards. The Table 7 presents data on Physical Analysis of 76mm (3^{in}) nail Size of the Imported Nail.

Table 7. Data Analysis and Inference (Physical Analysis) for the 76mm (3^{in}) Size of the Imported Nail

SAMPLE A	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
A_1	76.00	32.50	81.20	5.00
A_2	79.00	33.00	83.00	5.00
A_3	80.00	32.40	81.90	6.00
A_4	80.00	32.70	81.20	5.00
A_5	80.00	33.20	80.60	4.00
A_6	79.00	32.40	80.20	5.00

Average shank length $= \frac{\sum SL}{n} = \frac{474}{6} = 79mm$

Average shank diameter $= \frac{\sum SD}{n} = \frac{196.2}{6} = 32.7mm$

Average Head diameter $= \frac{\sum HD}{n} = \frac{488.2}{6} = 8.36mm$

Average Tip length $= \frac{\sum T_L}{n} = \frac{30}{6} = 5mm$

The Table 8 shows the data Analysis and Inference for the 76mm (3in) for Locally Produced Nails

Table 8. Data Analysis and Inference for the 76mm (3in) for Locally Produced Nails

SAMPLE B	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
B_1	82.00	31.80	74.50	6.0

B_2	82.00	32.80	72.40	4.00
B_3	81.00	32.40	74.60	5.00
B_4	82.00	32.10	74.40	6.00
B_5	81.00	32.00	64.30	5.00
B_6	79.00	32.40	80.20	5.00

Average shank length $= \frac{\sum SL}{n} = \frac{489}{6} = 81.5mm$

Average shank diameter $= \frac{\sum SD}{n} = \frac{193.8}{6} = 32.3mm$

Average Head diameter $= \frac{\sum HD}{n} = \frac{431.6}{6} = 71.9mm$

Average Tip length $= \frac{\sum T_L}{n} = \frac{31}{6} = 5.16mm$

The Table 9 shows the data sample C on (76mm – 3^{in}) nail.

Table 9. Sample C (76mm – 3^{in})

SAMPLE C	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
C_1	84.00	32.8	70.7	5.0
C_2	82.00	32.8	82.8	5.5
C_3	81.00	33.0	71.9	6.0
C_4	80.00	32.7	71.6	6.0
C_5	81.00	32.5	81.1	6.5
C_6	82.00	33.0	81.0	7.0

Average shank length $= \frac{\sum SL}{n} = \frac{490}{6} = 81.6mm$

Average shank diameter $= \frac{\sum SD}{n} = \frac{196.8}{6} = 32.8mm$

Average Head diameter $= \frac{\sum HD}{n} = \frac{459.6}{6} = 76.5mm$

Average Tip length $= \frac{\sum T_L}{n} = \frac{36}{6} = 6mm$

The Table 10 highlights the data sample D on (76mm – 3^{in}) nail.

Table 10. Sample D (76mm – 3in)

SAMPLE D	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
D_1	90.0	33.0	72.4	5.0
D_2	78.0	33.0	61.5	5.5
D_3	85.0	33.2	70.4	5.0
D_4	74.0	33.2	52.0	4.8
D_5	76.0	33.0	72.0	5.0
D_6	84.0	31.6	72.5	5.0

Average shank length $= \frac{\sum SL}{n} = \frac{487}{6} = 81.2mm$

Average shank diameter $= \frac{\sum SD}{n} = \frac{197}{6} = 32.8mm$

Average Head diameter $= \frac{\sum HD}{n} = \frac{400.8}{6} = 66.8mm$

Average Tip length $= \frac{\sum T_L}{n} = \frac{30.3}{6} = 5.1mm$

The Table 11 presented the data sample E on (76mm – 3in) nail.

Table 11. Sample E (76mm – 3in)

SAMPLE E	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
E_1	74.0	32.8	70.7	4.0
E_2	75.0	32.7	73.2	5.0
E_3	79.0	32.9	72.6	5.1
E_4	80.0	32.7	83.0	4.0
E_5	74.0	32.9	73.6	3.8
E_6	74.0	33.1	73.5	3.8

Average shank length $= \frac{\sum SL}{n} = \frac{456}{6} = 76mm$

Average shank diameter $= \frac{\sum SD}{n} = \frac{197.1}{6} = 32.9mm$

Average Head diameter $= \frac{\sum HD}{n} = \frac{446.6}{6} = 74.4mm$

Average Tip length $= \frac{\sum T_L}{n} = \frac{25.7}{6} = 4.23mm$

The Table 12 showed the data analysis and inference for 101mm (4in) Size for Locally Produced Nails.

Table 12. Data Analysis and Inference for 101mm (4in) Size for Locally Produced Nails

SAMPLE B	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
B_{11}	106	42.2	90.5	7.0
B_{12}	106.0	42.3	101.0	5.0
B_{13}	96.0	42.6	82.6	8.0
B_{14}	109.0	42.9	92.2	6.0
B_{15}	111.0	43.2	100.0	5.0
B_{16}	107.0	42.4	81.5	8.0

Average shank length $= \sum \frac{SL}{n} = \frac{635}{6} = 105mm$

Average shank diameter = $\sum \frac{SD}{n} = \frac{255.6}{6} = 42.6mm$

Average Head diameter $= \sum \frac{HD}{n} = \frac{547.8}{6} = 91.3mm$

Average Tip length $= \sum \frac{T_L}{n} \frac{39}{6} = 6.5mm$

The Table 13 shows the data Sample C on (101mm – 4in).

Table 13. Sample C (101mm – 4in)

SAMPLE C	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
C_{11}	105.0	43.2	102.50	8.0
C_{12}	111.0	43.0	1.4.00	5.0
C_{13}	105.0	42.9	102.5	7.0
C_{14}	111.0	43.3	100.5	6.0
C_{15}	104.0	43.2	102.	5.5
C_{16}	96.0	43.3	104.6	6.0

Average shank length $= \frac{\sum SL}{n} = \frac{632}{6} = 105.3mm$

Average shank diameter = $\frac{\sum SD}{n} = \frac{258.7}{6} = 43.1mm$

Average Head diameter = $\frac{\sum HD}{n} = \frac{615.8}{6} = 102.6mm$

Average Tip length = $\frac{\sum T_L}{n} = \frac{37.5}{6} = 6.25mm$

The Table 14 presents the data Sample D on (101mm – 4^{in}).

Table 14. Samples D (101mm – 4^{in})

SAMPLE D	SHANK LENGTH SL (mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
D_{11}	102.0	43.0	84.8	7.0
D_{12}	107.0	42.9	82.2	7.0
D_{13}	95.0	42.6	93.9	7.0
D_{14}	114.0	43.0	92.2	6.5
D_{15}	104.0	42.8	100.3	7.0
D_{16}	107.0	43.9	92.9	7.0

Average shank length = $\frac{\sum SL}{n} = \frac{631}{6} = 105mm$

Average shank diameter = $\frac{\sum SD}{n} = \frac{258.2}{6} = 43.0mm$

Average Head diameter = $\frac{\sum HD}{n} = \frac{546.3}{6} = 91.1mm$

Average Tip length = $\frac{\sum T_L}{n} = \frac{41.5}{6} = 6.91mm$

The Table 15 presents the data Sample E on (76mm – 3^{in}).

Table 15. Sample E (76mm – 3^{in})

SAMPLE E	SHANK LENGTH SL(mm)	SHANK DIA. SD(mm)	HEAD DIA. HD(mm)	TIP LENGTH T_L(mm)
E_{11}	107.0	42.5	100.7	7.0
E_{12}	107.0	42.8	104.5	5.0
E_{13}	96.0	42.8	100.00	7.5
E_{14}	112.0	42.4	100.00	3.0
E_{15}	106.0	43.3	104.5	6.0

E_{16}	110.0	42.5	102.7	7.5

Average shank length $= \frac{\sum SL}{n} = \frac{638}{6} = 106.3mm$

Average shank diameter $= \frac{\sum SD}{n} = \frac{258}{6} = 42.8mm$

Average Head diameter $= \frac{\sum HD}{n} = \frac{613}{6} = 102.1mm$

Average Tip length $= \frac{\sum T_L}{n} = \frac{36}{6} = 6mm$

The Table 16 presents results of impact test on sample E (76mm – 3^{in}) nail.

Table 16. Results of Impact Test

SPECIMEN 76mm-3in) NAIL	**ENERGY ABSORB (J)**	**REMARK**
B1	29.154	Local
B2	28.476	"
C1	28.476	"
C2	31.188	"
D1	28.476	"
D2	28.476	"
E1	28.476	"
E2	25.764	"
A 76mm	12.204	(imported)
(101mm-4in) E1	17.628	Local
E2	17.628	"
Average energy absorb by nail (76mm) Local = 28.561J		"
Average energy absorb by nail (76mm) imported = 12.204J		"
Average Energy absorb by (101mm) Local = 12.628J		"

4.3. Summary of results (1)

- (101mm) LOCALLY PRODUCED NAILS
- Average shank length = 105.40mm
- Average shank diameter = 42.88mm

- Average head diameter = 96.78mm
- Average tip length = 6.42mm
- (101mm) IMPORTED
- Average shank length = 79.00mm
- Average shank diameter = 32.70mm
- Average head diameter = 81.36mm
- Average tip length = 5.00mm
- NIS: 118:1981 – (100 x 50): SL 98 .5min.
- 101.5max; SD 49.4 min. 50.6 max; HD
- 97.5min. 8 102.5 max.

4.4. Summary of results (2)

- (76mm) LOCALLY PRODUCED NAILS
- Average shank length diameter = 32.70mm
- Average head diameter = 72.40mm
- Average head diameter = 72.40mm
- Average tip length = 5.10mm
- (76mm) IMPORTED NAILS
- Average shank length = 76.00mm
- Average shank diameter = 32.70mm
- Average head diameter = 81.36mm
- Average tip length = 5.00mm
- NIS: 118:1981 – (70 x 35.5): SL 68.5.5min
- 71.5max; SD 34.9min 36.1max; HD 77.3min 82.3 max

4.5. Summary of corrosion film

- Average Ultimate Stress (AUS) = 0.001mm = 417.5N/mm^2 (76mm) = 380.6N/mm^2 (101mm)
- Average Load = 4.2KN
- Average compressive Stress (ACS) = 796NM/mm^2 (76mm) = 560N/mm^2 (101mm)
- Average Load = 9.6KN
- NIS: 118: 1981 Requirement (540N/mm^2 A.U.S)
- NIS: 118:1981 Requirement of film thickness = 0.00125mm

5. Conclusion, summary and recommendations

Based on the result obtained and analyzed as shown in the previous chapter, the following conclusion were reached:

- The current physical dimensions as stipulated in N15: 118; 1981, revised 1988 has been meet by most of the sample tested which were all from local manufacturers;
- The results of the stress tests also indicated that Average ultimate stress recorded is 417.5 N/mm^2 (76mm) and 380 N/mm^2 (10/mm), The average compressive stress recorded being 796N/mm2 (76mm) and 560N/mm2) (101mm), the NIS: 118:1981 standard being 540 N/mm2 but without identifying the size or for which specific dimension;
- The test result for the imported nails falls short of the NIS requirements
- Corrosion film thickness for the local roofing nails less than the required thickness for the two locally produced nails
- Locally produced nails can therefore compete with imported nails especially nails imported from peoples Republic of China.
- Nail manufacturing companies do not have standard laboratories to carryout test.
- Most nails manufactured locally do not have the required finish as stipulated in Article NIS 118:1981.

5.1. Summary of mechanical analysis results

The Table 17 presented the summary of mechanical analysis of the study.

Table 17. Summary of Mechanical Analysis

Samples	Diameter	Area (mm2)	Load (KN)	Ultimate stress (N/mm2)	Load (KN)	Ultimate stress (N/mm2)	Remarks
A 76mm-3in	3.77	11.17	5.0	448	10	895.2	Imported
B	3.69	10.70	4.0	474	10	934.5	Local
C	3.79	11.29	4.0	354.3	8	708.6	"
D	3.69	10.70	5.0	467	7	6.54.2	"
E	3.27	8.39	4.0	476.7	8	953.5	"
F	3.50	9.62	4.0	415.8	7	727.6	"
101mm 4in							
A	4.72	17.51	7.0	399.8	12KN	685.3	Imported

B	4.84	18.40	7.0	380.4	9.5KN	516.3	Local
C	4.75	17.72	7.0	395.0	9	507.9	“
D	4.84	18.40	6.5	353.2	9.5	516	“
E.	4.70	17.35	6.5	374.6	10	576.3	“

5.2. Recommendations

From the above conclusion, it is therefore recommended that:

- Four of the five local manufacturers has the capability of installing a well-equipped testing laboratory to enable them carry out test using ASTM standard or similar standard rather than the near scanty laboratory as they “are” at the moment.
- One manufacturer particularly can improve their products especially on tip length, and the required finish”.
- In the next revised NIS standard should include measure of tip length and tests for tensile stress and ultimate stress should go beyond mere harmer blow as currently stated. This is because components requiring to be joined together using nails are far beyond woods only. Composite materials are increasingly becoming popular.
- The (NIS) requirements covers only plain nails, the next revised edition should cover different types of nails.

5.3. Suggestions for further studies

The following are hereby suggested for further studies:

1- Establishing different type of nail for different wood type and moisture contents.

2- Carrying out withdrawal strength for different nails to allow for re-usability of nail after being pulled out.

3- Study the effects of moisture and atmosphere via condition on wood – nail relationship so as to reduce the effects of nails pulling out of wood especially roofing nails can be improved.

4- To study nail withdrawal on cyclone effects.

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References

Alper A. (2008), "Determination of Screw and Nail Withdrawal Resistance of Some Important Wood Species", *Int J Mol Science*, Vol. 9 No. 4, pp. 626–637, available at:http://www.ncbi.nlm.nih.gov/pubmed/19325775 (accessed 24 April 2008).

Amos, L. (1993), *The Rise and Decline of the American Cut Nail Industry*, Greenwood Press, Indiana

Deming, W.E. and Edwards, D.W. (1982), *Quality, productivity, and competitive position (Vol. 183)*, Cambridge, MA: Massachusetts Institute of Technology, Center for advanced engineering study.

Deming, W.E. (1986), *Out of the crisis*, Massachusetts Institute of Technology, Center for advanced engineering study, Cambridge, MA.

FCDA (2000), "FCDA housing bulletin", available at: http://www.fcda.gov.ng (accessed September 2000).

Johnson, D. (1994), "Nails Get a Better Grip", *The Family Handyman,* September 1994, p. 16.

Lawrence, S. (2010), "Wood Handbook Chapter 7 Fastenings – Forest Product", available at:

http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch07.pdf(accessed 2010).

Soltis, L.A. (1999), "Fastenings", in Madison, W.I. (Eds.), *Wood handbook : wood as an engineering material*, USDA Forest Service, Forest Products Laboratory.

Ryzewski, K. and Gordon, R. (2008), "Historical nail-making techniques revealed in metal structure", *Historical metallurgy*, Vol. 42, pp. 50-64.

Olarewaju, A. (1985), *Textile Testing & Quality Control*, Sooji Press Limited, Kaduna, Nigeria.

EIA (2013), "Profile on the Production of Wire Nail", in *Project Profiles on Metal Industry: A study Conducted by Industrial Project Service (IPS) for Addis Ababa Investment Agency*, Ethiopian Investment Agency (EIA), Addis Ababa, Ethiopia.

Kalpakjian, S. and Schmid, S.R. (2002), Manufacturing processes for engineering materials, Prentice Hall, UK.

Gere, J., Gere, J.M. and Goodno, B.J. (2012), *Mechanics of Materials*, Nelson Education.

Vila, B. (1986), *This Old House Guide to Building and Remodeling Materials*, Grand Central Publishing, USA.