

FAILURE, CAUSES AND IMPACTS OF REINFORCED ELECTRIC CONCRETE POLES IN SOME AREAS OF ADAMAWA STATE, NIGERIA

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ABSTRACT

Many reinforced concrete poles are damaged around the country, Nigeria every year due to the effect of winds, poor workmanships and material qualities. Concrete poles are always affected by heavy winds especially during the raining season. This research is aimed at assessing the causes and impacts of the failure of reinforced electric concrete poles and to articulate the standard requirement for fabricating and installing of poles in Adamawa State. The methodology applied during the study involved field observation/investigation of affected poles and visitations of the three manufacturing factories in the state. Samples of concrete cubes from the three factories were collected and taken to the laboratory for crushing and compressive strength tests. Also tested were the tensile strength of the steel bars and interviews were conducted on the method of design and production. Findings were made based on field investigations and laboratory tests. The findings are: No standard specifications used, poor workmanships, no technical supervision and monitoring. The impacts include: loss of revenues and high cost of over head on operation and maintenance (Economic Impact); Loss of lives and valuables (Human social Impact); and unsafe environment and waste of materials (Environmental Impact). The study recommended the following: Geotechnical investigations and testings, proper supervision of workmanships, sustainable and durable materials should be used, while poles should be properly installed at least one meter depth with concrete encasement erected above ground level. This study also recommended a minimum mix ratio of 1:2:4, Y8mm steel iron and minimum concrete grade of 20.

Key Words: Pole failure, Reinforced Concrete Electric Poles, Wind effects and poor workmanships.

1.0 INTRODUCTION

Many reinforced concrete electric poles were damaged around the country, Nigeria, every year due to the effect of winds, poor workmanships and material quality. These concrete poles were always affected by heavy winds especially during the raining seasons. The damage can have a devastating economic, human/social and environmental consequences.

According to the study conducted by [1], it was observed that the use of poor quality materials especially concrete, affected the production of these rainforced concrete poles.

Concrete is a material with a wide range of strength and stress-strain curves. A typical curve for concrete in compression is shown in figure I, as the load is applied, the relationship between stress and strain is approximately linear at first and the concrete behaves also like elastic materials with virtually a full recovery of displacement if the load is removed [2]. Eventually the curve no longer linear and the concrete behaves more and as a plastic material, the recovery would no longer be completed and a permanent deformation would remain. The ultimate strain for most structural concrete tends to be a constant value of approximately 0.0035 irrespective of the strength of the concrete which depends on the load application.

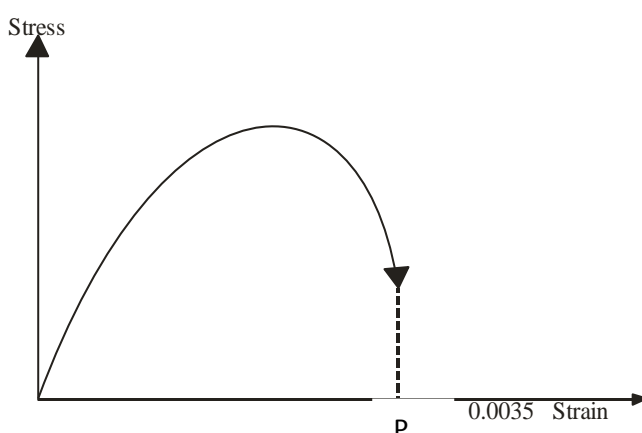


Figure I: Stress-Strain curve for concrete in compression [3]

The strength of these electric concrete poles and the loads which are applied to that pole are critical and must be assessed. Before a concrete pole is made free-standing, it must be inspected in accordance with NS146 safe inspection procedure for working on poles.

British standard institution [4], further explained that “If an authorised person was de-satisfied with the pole condition, or the pole was shown by the inspection to be unsound, or if the pole was not properly fixed or condemned, the pole must not be clined and stripped unless it is stayed or supported in accordance with section 12 of the design code.”

According to [5], in describing the specification for concrete poles, explained that “Light standards (poles) are designed to accommodate certain specific environmental load and aesthetic requirements”. Various standards, guide lines and codes that govern their use like, American Association of State Highway and Transportation officials (AASHTO), American National Standards Institute (ANSI) and many local design codes. These standards and codes are based on theoretical analysis, research and current industry practices. The standards and codes take into account of direct wind pressures on the pole and luminaire (bending moment, shear, axial and torsional stresses; secondary moment effects deflects the pole(s) and the effect of heat on the base material in the area adjacent. Pole design required consideration of field condition and all variables must be taken into consideration with or when selecting the pole.

Typically, poles are designed or selected based on the 50 years mean wind map found in AASHTO, ANSI or local building codes. These indicate a minimum wind load of 70 mph, but do not take into account certain wind conditions that can create damaging variation. Vibration can be caused by steady relatively low speed wind (10-30 mph), or the topography where the pole is mounted, can also have impact. Studies indicated that the natural turbulence of the airstream at higher wind velocities above 30 mph, inhibit vibration, which can in turn, affect the concrete electric poles. Destructive vibration is not indication of substandard material, workmanship or design of the pole.

Loads play an important role in how a concrete pole is designed and what materials and methods are used in its construction [6]. The identification of how these loads are transferred during structural alterations and construction is even more important. These concrete poles must be strong enough to deal with three main types of loads, static, dynamic and hidden loads.

Dynamic loads are described in [7, 6], as loads acting suddenly, such as those due to high wind and earth quakes. It stipulated that the electric concrete poles must be well installed, to avoid felling and causing damage [8].

The aim of this study is to investigate the causes and impacts of failure of reinforced electric concrete poles and to articulate the standard requirement for fabricating and installing of poles used in Adamawa State.

2.1 Investigation of Failure of Reinforced Concrete Poles.

Investigation on the failure of these reinforced concrete poles reported that more than 80% are all weather related line failures are caused by High Intensity Winds (HIWS), ranging from fully mature tornadoes to various forms of gusts and micro bursts that are associated with the occurrence of thunderstorms [9].

There are many examples of failure of these poles due to high wind induced oscillations which indicate a lack of know-how on the part of engineer/Technician installing these poles with regards to effect of wind.

In [10], explained that during the design of these poles there should be consideration on the effect of wind. The force is always calculated when the installation is assumed to be completed, but there may be a critical stage during the erection due to the impact of the wind load on the reinforced concrete poles. If these poles are not properly secured at the base, it may also lead to failure.

The loads used in most codes of practice, standards and design recommendations are based almost entirely on large-scale wind storms as well known as amenable to analytical treatment [10].

In their studies [11], stated that the gust wind velocity is converted to loads acting on a concrete pole using appropriate load factors and that the resulting loadings on the reinforced concrete poles are determined using loading coefficients presently taken from design codes of practices. Wind effects on reinforced concrete poles under the buffeting action of wind gust have traditionally been treated by the "Gust loading Factor (GLF) method in most major codes and standards around the world". In this scheme, the equivalent static wind loading used for design is equal to the mean wind force multiplied by the GLF. Although the traditional GLF method ensures an accurate estimation of the displacement responses, it may fall short in providing a reliable estimate of other response components [12].

According to study by [12], force is always calculated when the reinforced concrete pole is assumed to be complete, but there may be a critical stage during the construction due to the impact of high wind on the reinforced concrete poles. This study predicted the effect of wind load on these concrete poles during construction to prove that there is a critical stage, and that this stage should be taken into consideration during the design.

In reference [13], the maximum values of the base moments at both critical and after completing stages due to wind effect, will be obtained. The natural frequencies of the mast at two stages have been obtained by using exact solution and 3-D finite Element Method.

This study proved that there is a critical stage in design of reinforced concrete poles during construction under effect of Wind load that should be taken into account. There is also difference(s) in the natural frequency of poles at critical stage and after completing the construction work. Some of the factors that affect the installations of the reinforced electric concrete poles includes the following; Wind Loads, High Intensity Winds (HIW), Equivalent Static Wind Loads (ESWLs), Gust Loading Factor (GLF), Free Vibration (FV) and the Foundational Work (FW).

2.2 Wind Effect

One of the major if not the greatest difficulty in developing a wind loading code is to take the load fluctuation due to gustiness (Strong rush of wind), their non-simultaneous occurrence and their effect on man is not suitable. The most convenient way is to include these in an equivalent static load [13]

Division of the American Society of Civil Engineers (ASCE) in 1987, introduced the wind directionality factor for calculating the design wind speed for each individual wind direction, thus enabling rational design considering the reinforced concrete orientation with respect to wind direction. Moreover, the topographic factor for turbulence intensity is newly added to take into account the increase of fluctuating wind speed.

The effect of winds are stipulated in ASCE (1989). For most reinforced concrete poles, wind load can be treated as a static load and is computed with the aid of reference velocity pressures, gust factors, exposure factors and shape factors. These reinforced concrete poles and their components are to be designed to withstand the code-specified wind loads. Calculating wind force resisting system [13], as also reported by [10], that the following methods also be put into consideration during the design of concrete poles.

- (i) Method 1: Simplified procedure;
- (ii) Method 2: Analytical procedure; and
- (iii) Method 3: Wind tunnel procedure

In agreement with [14], which “advised that in constructing areinforced concrete poles, the simplified procedure can be used to calculate, or using the analytical procedure provided that it is regular in shape, and also that the connections and the direction of the wind should also be put into consideration”.

Reinforced concrete pole should be treated as a kind of grounding lead conductor and a grounding electrode for lighting over voltage.

Making use of sustainable quality raw materials are also very important when manufacturing the concrete poles. These concrete poles are widely used in various communities and industries [15].

Examples of such concrete poles are: mass concrete poles, reinforced concrete poles and prestressed concrete poles, but the research study is focused mainly on reinforced concrete poles. Reinforced concrete cement (RCC) compound poles are utilized for transmission and distribution of electricity. These poles are made with advanced technology and machinery and are highly durable and sustainable in nature. They are resistant against corrosion and tolerant to wind, rain and sun [15]. These poles offer excellent safety standards, thereby facilitating easy climbing, thus enabling regular maintenance.

2.3 Specification

In agreement with [16], which stipulated that concrete poles are also specified in areas of chemical contamination and pollution that may cause rapid deterioration especially wood poles. According to [5], in special situations where poles of unusually high strengths are required, stresses imposed on concrete pole will be calculated, as if they were cantilever beams fixed at one end. These values, with proper factors of safety applied, was used in the selection of the pole. The forces acting on a pole are from; the vertical loading (comprising of Dead weight of conductors).

The horizontal loading (due to wind pressure on conductors and pole), usually overshadowed that of the vertical to the extent that it may not be given further attention. For the horizontal loading, the pole can be considered as a cantilever beam anchored at one end [16]. The bending moment produces stresses in the concrete with the maximum fibre stress occurring at the edge of the cross section far from the neutral axis; the stresses are compressive on the side on which the load is pulling and tensile on the opposite side. BS 607 part 2, gave the minimum ultimate transverse load for different class of poles as shown in Table 1.

Table 1: Rural Utilities Service Construction Standard (RUS)

Class of Pole	1	2	3	4	5	6
Minimum Ultimate Transverse Loads at 0.6m from top (KN)	2.8	3.9	5.6	7.8	11.1	15.6

Source: [16]

Table 1 showed Minimum Ultimate Transverse Loads (MUTLS).

2.4 Dynamic Characteristic of Poles

[16], opined that prior to response spectrum analysis, modal analysis were performed in order to determine the elastic modal properties of the poles. Several seismic codes provided guidance on how concrete poles construction should be calculated. Reinforced concrete poles are a vital component used in the community and therefore their management needs assessment of the reliability, safety and sustainability to minimize the risk of destruction in service, especially during severe winds and earth quakes.

2.5 Concrete Pole Inspection and Treatment

[5] explained that all concrete poles should be inspected to ensure it is free from any defects such as transport damage or surface cracks. More also, they further explained that drilling, cutting or grinding of a concrete pole will not be permitted unless specifications approved by a designated Ausgrid representative who is in attendance during the procedure.

[5], stated that appropriate lifting slings will be used when handling a concrete pole such as pole strop slings or synthetic slings so as not to damage the concrete surface and reduce the concrete coverage of the reinforcing steel.

2.6 Wind Scale

Between year 1774-1857, Beaufort defined wind as air in motion. It is produced by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of various land and water formations, it absorbs the sun's radiation unevenly. Two factors are necessary to specify wind; Speed and direction.

Beaufort between 1774-1857 in [17], further explained what causes the wind to blow. As the sun warms the earth's surface, the atmosphere warms too, some parts of the earth receive direct rays from the sun all year and as result earth always warm.

Wind is the fastest growing source of electricity in the world. Its often one of the least expensive forms of renewable energy available. Some experts say it can sometimes be the cheapest form of power.

Generating power from the wind leaves no dangerous waste product behind, best of all, its supply is unlimited, but the major problems are the collapse and failure of our electric concrete poles, especially in raining season. See standardized type/sizes of reinforced concrete poles in Table2.

Table 2: Standardized Types/Sizes of Reinforced Concrete Poles.

Standardized Types/Sizes of reinforced concrete poles Height of Poles Meter(m)	Buried length Mete(m)	Working Load (Kg)	Purpose
6.0	1.40	50	Insulated wire service connection
8.3	1.40	100	LV lines (without street lamp wire)
9.0	1.5	115	LV lines (Self supporting pole)
10.0	1.7	300	(i) Only MV line (ii) Combined run (iii) MV and LV on same pole.

Source: [17]

LV= Low Voltage ,MV= Medium Voltage

2.6 Types of Wind

The types of wind that causes damage is called the monsoon wind. This monsoon wind is a seasonal wind, found especially in Asia that reverses direction between summer and winter and this often brings heavy rains, while winterstorm is a storm with high winds with little or no rain.

Table 3: Beaufort Wind Scale.

Beaufort Numbers	Wind Speed (MPH)	Wind Speed (Knots)	Land Description
0	<1	<1	Calm
1	1-3	1-3	Wind motion
2	4-7	4-6	Leaves rustle
3	8-12	7-10	Smaller twigs
4	13-18	11-16	Small branches begin to move
5	19-24	17-21	Smaller trees Sway
6	25-31	22-27	Large branches on motion
7	32-38	28-33	Whole trees in motion
8	39-46	34 -40	Twigs broken from trees
9	47-54	41-47	Light Structure damage
10	55-63	48-55	Considerable structure damage
11	64-72	56-63	Wind spread structural damage
12	73-82	64-71	Massive and wide spread damage and breaking of reinforced concrete electrical poles.

Source: Sir Francis Beaufort wind scale 1774-1857 in [17]

2.6 Vibration

There are two types or common types of vibration observed in reinforced concrete electrical poles[18]. The first mode of vibration sometimes referred to as sway in which the maximum deflection occurs at the top of the pole. The deflection off center is not equal from side and it occurs at a low frequency, approximately once cycle per second. This form of vibration usually not harmful to the pole.

Second mode of vibration can be the most damaging form of failure and occurs approximately at the mid-point of the pole with deflection off centre equal from side to side. This is known as resonance. As steady low level wind moves past the pole, vortices are shed alternately from either side of the structural shaft causing displacement oscillations in a direction perpendicular to that of the wind. Vortices are a swirling motion of pattern of the wind. The most serious situation arises when the vortex shedding frequency synchronizes with the natural period of vibration in the pole, which can ultimately fatigue the pole to structural failure [18]

2.7 Installation Procedures

According to[19], Design considerations, service Benefits and Economic Reward, explained that poles are designed to carry a load. These reinforced concrete poles are never installed with out the intended luminaire being installed. In furtherence to research work by [20],who explained that if a pole is installed deeper than it was designed, the circumference will be less than it was designed for.

Thus, the pole will not be as strong as the designer intended. One can usually tell when a pole is buried too deep because the bench mark of the pole is low to the ground. The bench mark is a descriptive marking of the pole class and material [20].

2.8 Petrographic Analysis

[4], gave the analysis on how we can determine the physical irregularities in concrete by observation. This type of analysis was used to determines strength, mixture proportion estimate (Such as water cementt ratio), corrosion potential of embedded steel.This type of information can aid to provide, the root cause of failure and extent of cracking, dusting scaling or coating in a reinforced concrete poles.

[16], stated that prior to installation of poles, check for damage, such as cracking and spalling, are all put in place. And if any is discovered, it should be replaced.It was further explained that sections deep enough to expose reinforcing steel, should also be replaced.

2.9 Initial Design Consideration

The design of reinforced concrete poles require consideration of many aspects including loading, fabrication techniques, method of shipment, construction and maintenance, methods, types of foundations load restriction and code [21].

2.9.1 Determination of Performance Requirements.

Poles are designed by the ultimate strength method, to resist the largest factored load, or if it means to resist the loads without failure (Collapse) recognising that it required a stronger pole to resist damage than to resist collapse[21]. In the case of a damaged pole, the steel might have been stretched beyond its elastic limit and or some concrete would have spalled off the pole. The pole will be permanently deformed and will no longer perform as it was designed but will need to be replaced. A pole which has collapsed is one which has reached such a state that the line can no longer carry power.

2.9.2 Limit State Design

Reinforced concrete is a composite material where load bearing and determination properties are determined by the behaviour between the elements (steel and concrete) as well as the individual constituents of these elements, particularly those of the concrete at all ages, have a low tensile strength compared to the compressive strength [22]. Concrete tends to brittle breaking easily under sudden stress and crumbling under the influence of time and weather, so for this reason, reinforcement bars must be introduced. Steel has poor corrosion resistance and concrete has excellent anti-corrosion properties.

Current practices for the design of reinforced concrete poles components is to use a limit state design approach as set out in (b) 1-1999 Guide lines for design and maintenance of cover head distribution and Transmission lines. This approach allow components strength to be more reachly matched and optimised by economic comparism. Conductor tension loads will increase in response to the higher design wind pressures by a factor depending on conductor every day [23]

2.9.3 Why Do Concrete Poles Fail

Fresh concrete is a transient material with continuously changing properties. Its been discovered that concrete is a plastic material and not elastic, so reinforced concrete poles failure is almost always caused by the corrosion of the steel reinforcing bars. In most cases, reinforcing bars are used without any protective coating and relies on the passivation of its surface by the highly alkaline cement. So when the steel and the concrete are used together, they exhibit the same behaviour [24].

Reinforced concrete poles uses extra materials like steel bars, wooden beams or fibres, along with a wire frame to help mold the concrete, The reinforcement interacts with the concrete, strengthening it and providing enough support for it. The concrete provides enough shielding for the steel so that it doesn't corrode as quickly and together they are a common component in modern construction [25]. Conductor weight loads will increase due to the effect of increased tension on poles with a height profile above the average of neighbouring poles, however in general this factor is fairly minimal in relatively flat terrain. Note that wind effect on pole, stands to be environmental load on the poles[25].

The wind load on the conductor will increase the apparent weight of the conductor resulting in an increase in tension. Thus, increase in resultant load will result in an effective sag in an inclined direction with both horizontal and vertical concrete poles (Manis and Jones, 2008).

2.9.4 Pole Movement

[23] opined that "butress of any movement of pole top due to stay relaxation will have the effect in introducing additional length into the span.

L_r = ruling span

L_i = horizontal span/length of span

n = number of spans between strain of poles.

2.9.5 Wind Span

The wind span in reinforced concrete poles is the length of span that determines the transverse load on the poles due to wind action on the conductor and is defined as:

L_w = one and half of the sum of the adjacent span[27]

In designing concrete poles, the following factors should be put into considerations: First is Short Duration Limit state loads example wind loads and Secondly Long Duration Loads example conductor weight of pole structures, particularly single member pole supports were used to carry both high and low voltage conductors[28]. The researcher further, explained that good pole supports properly chosen with regards to local conditions and requirements, are a decisive factor in ensuring high continuity of service long life of equipment and low maintenance costs.

2.9.6: Pole Design Loads

According to Electrical contractor under Ontario Regulation 570/05 made under part VIII of Electricity Act (1998), Stated that under stayed poles may be subjected during services to the following horizontal loads.

- Horizontal load due to wind acting on pole;

- Horizontal load due to conductor wind span; and
- Horizontal load due to conductor tension on angle.

Unstayed termination and unbalanced strain poles due to differential conductor tension in adjacent spans.

A vertical load is only imposed on unstayed poles by the conductor weight span, weight of fittings seldom becomes an important consideration, however, for stayed poles, a vertical load imposed by the stayed as the weight and fittings and this becomes a major consideration stayed poles are also subjected to a bending moment, which is generally greatest at the stay foundation.

2.9.7 Pole Foundation

[29], explained that the design of support foundations are more difficult than the design of other overhead line components, as the properties of soil are not as definite as those for other materials (Such as steel, aluminum, copper etc). Consequently for design purposes, soil properties are selected with very widely varying limits.

2.9.8 Foundation Strength

[30], which gave the assertion that the allowable pole tip, due to foundation strength is estimated by the by the following equation:

$$\text{Tip Load} = K_{\max} DJ^3 (12(h+3/4j)) \dots\dots\dots 1$$

Where K_{\max} = Passive soil reaction (K_{Pa}/m)

d = Average diameter of pole below ground (m)

j = Pole setting depth (m)

h = Height of pole above ground (m)

2.9.9 Essential Consideration During Design of Poles.

According to [31], who Opined that the following characteristics/consideration have to be put into check when designing a pole

How long the poles will need to be and their spacing?

What will be the correct height of all poles?

How far down will the pole need to penetrate in to the ground?.

The concrete mixture quality also should be put into consideration,

What will be the diameter of the pole?

What type of reinforcement needed to be used?.

2.10.0 Factors to be Considered When Designing the Concrete Poles Against Wind

[32], illustrated that the following factors should also be put into consideration when designing reinforced concrete poles. Poles shall be designed so that the cracking strength of the pole exceeds 40 percent of required ultimate strength; Poles shall be designed to withstand a one point (tilting) pickup during erection; and Pole design shall include allowances for loads from handling, transportation and erection without failure.

2.10.1 Failure of Reinforced Concrete Poles.

[33], explained that the reason for using reinforced concrete as a construction material is to take advantage of the best attributes of both concrete and steel. The most common loading conditions for poles to resist is bending moments. When the bending moments are large enough, the concrete on the outside curvature of the pole will go into tension, and perhaps crack and the steel resist the crack due to tension.

When very low overload factors are used (such as are common in the 1.0-1.1 range for high wind), the poles will crack under the unfactored loads.

According to [34] "for a successful implementation, the design of concrete pole and making provision for testing of its strength will ensure an all-time reliable working systems".

For an electric overhead system, the supports for the conductors and equipments must withstand the forces imposed on them, while the conductors themselves must be sufficiently strong to support their own weight and the forces imposed on them. The forces acting on a pole stem from the vertical loading occasioned by the weight has to carry it and from the horizontal loadings applied near the top of the pole. These latter forces are exerted by the conductors as a result of uneven spans, or offsets and bends in the lines, and of the pressure of wind blowing against them.

In general, concrete poles are used in those areas, such as swampy and persistently wet areas where the soils greatly shorten the life expectancy of wood poles. Moreover, in such instance, the rate of decay may be as erratic and uncertain, as to permit unsafe condition to arise and may not be discovered before accidents results.

Concrete poles are also recommended in areas with chemical contamination and pollution that may cause rapid deterioration in case of wood pole [20]

In agreement with [35], who stated that concrete poles are specified in special situations where poles of unusually high strength are required. Beyond the range of wooden poles where guy cable or rope may be difficult, unobtainable stresses imposed on concrete pole will be calculated as if they were cantilever beam fixed at one end. These values, will be used in the selection of the poles.

3.1 RESEARCH METHODOLOGY

The data used was collected through observation/visitation, laboratory testing and previous literature reviews.

3.2 Method of Data On Materials Collection

Materials used for the research, include the following: Cubes samples from each of the pole manufacturing factories visited and reinforcement bars used by the companies.

3.3 Method of Data Analysis

Weighing and determining the crushing compressive strengths of concrete cubes and testing of tensile strength of the reinforcement bars.

3.4: Observation/Visitation

In order to determine the real cause impacts of reinforced concrete poles failure visits were made within the State especially areas where there are critical failures/issues for example; Jabbi Lamba, Girei, Song, and Jimeta shopping complex, Jimeta and the three manufacturing factories located in the study area. See plates 1,2,3,4 showing failed reinforced electric poles.



Plate I: Failure of Reinforced Concrete Pole with 12mm bars at Jimeta Shopping Complex

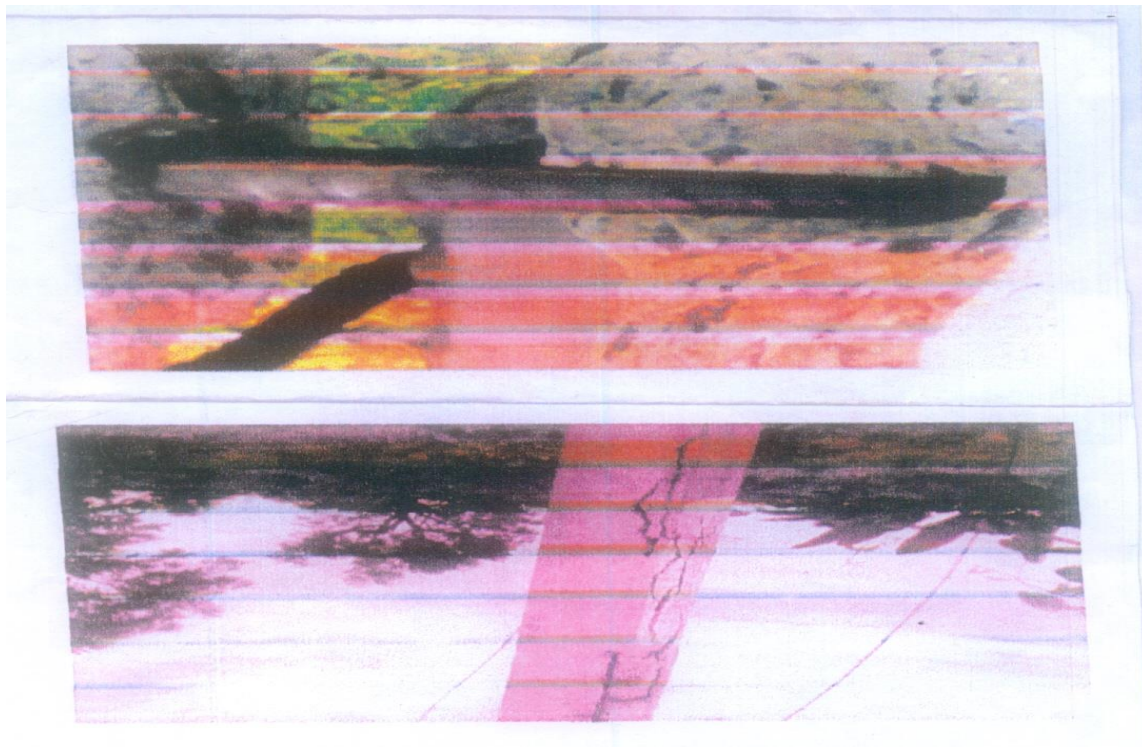


Plate II: Physical Crack on reinforced concrete pole, in Girei L.G.A, Yola.



Plate III: Failure of (circular) reinforced concrete poles with 12mm bars (Jabbi Lamba, Girei L.G.A)

4.1 VISITATION REPORTS/RESULT FROM THE STUDY AREAS

During the visitation/observation, it was found that there were some observations and it was discovered that 30m long concrete poles were used for primary distribution line, while 26m long concrete poles were used for the secondary distribution line.

It was also discovered that some of the poles have failed and others showing sign of failure as a result of wide visible cracks: Other observations included the following:

Poor mix of concrete, i.e use resulted to the collapse of the poles

Substandard reinforcement bars, i.e iron bars used have broken into pieces

Poor workmanship

4.2: Visitation To Three Concrete Poles Manufacturing Factories

Factory A:

Method of production

Materials and procedures

Bending of the links;

Tying the reinforcing bars Y10mm;

Mixing of concrete at a ratio of 1:2.4;

Concrete poles were lifted with electric chain machine after 24 hours into the reservoir;

Concrete poles were allowed for 21 days in the reservoir for proper curing;

Each one was tested for bending strength by the use of hydraulic pressure; and

Ten workers were used in the production and produces ten poles per day.

Types of pole produced by factory A.

- High tension poles with 10.5m height
- Low tension poles with 8.5m height

Cement used:

B U A Products

Factory B.

Materials and procedures (round pole)

Reinforcement bars were bent into sizes (Y8mm) and placed into circular mould formworks

Concrete mix ratio used: 3:5:7

Concrete placed in the mould was transferred to spinning machine which spined the entire nuxtures to required shape .

Concrete poles were steamed for twelve hours for the purpose of making it very strong.

After steaming period, the poles were transferred to the reservoir with hydraulic crane, and remain there for 21 days for proper curing

A physical test was conducted with the aid of cement hammer, using it to tap the concrete for the purpose of checking or confirming its readiness to be used

They were also confirmed by the authorities or experts from power holding companies (PHCN) and National integrated power project (NIPP)

Pole type : round (i.e circular high tension poles with 10.3m height).

Cement type: BUA

Factory C

Materials and Procedures;

Preparation for reinforcing bars and fixing the links.

Reinforcement bars used were Y10mm and Y8mm for high tension poles, while R6mm bars were used for low tension poles.

Concrete mix ratio: 1:2:3 with enough vibration

After 24 hours, poles were removed from mould and dipped inside a reservoir with the aid of a crane for 21 days. At the expiration of 21 days, the poles turned to white and the water was drained out before poles are dip again.

They were tested to confirm the strength of the concrete

Type of pole: four sided poles at a height of 10.2m for high tension and 8.5m high for low tension.

While BUA cements were used.

The method of production in all the three factories visited were similar, although with some differences especially in the production of circular poles.

5.1 DISCUSSION AND RESULTS

The result of the analysis for the three manufacturing factories are tabulated in Table 4, while design calculations are shown in appendix I.

5.2 Summary of Weights, Densities and Compressive Strengths of the above samples design calculations

Table 4: Summary of weights, densities and compressive strengths for factories A, B and C

Factory A				Factory B				Factory C				
Sample	Weight	Length	Depth	Strength	Weight	Length	Depth	Strength	Weight	Length	Depth	Strength
	ht	gth		ht	ht	ght		h	ht	ht	h	h
Summary	Kg	m	Kg/m ³	N/mm ²	Kg	m	Kg/m ³	N/mm ²	Kg	m	Kg/m ³	N/mm ²
1	5.005	130	14895	15.48	6.662	320	2309	11.11	4.411	160	2553	11.11
2	0.500	120	1488	14.28	7.11	445	2470	15.15	6.189	260	3582	18.05
3	6.006	190	17875	22.62	5.989	430	2062	14.93	5.160	220	2986	15.28
Total	11.51	440	34,258	52.38	19.71	1195	6,841	41.49	15.76	640	9121	44.44
Average	3.84	147	11.419	17.46	6.57	398	2,280	13.83	5.25	213	3040	14.81

Factory Strengths A: Approximately 18N/mm², Factory B: 14N/mm² and Factory C: Approximately 15N/mm²

Source: Laboratory Result,(2015)

5.3 Results

In accordance to the procedure in BS code 5328 part 4 and BS code 1881 which gave the minimum and maximum compressive strengths of a cube for 21 days at 15N/mm²-35N/mm², while the minimum compressive strength at age of 28 days was 41N/mm².

Therefore, factory A and factory C were within the minimum standard, while factory B was below standard compressive strength.

Using the universal testing machine, the tensile strength of the reinforcement bars (Y10mm) was 1199mpa = 1199 x10⁶ N/mm²= 1199X10⁶N/mm²

5.3.1 Field Observations

The field observations for investigations was noticed that the bending and brittle failure of reinforced concrete was caused by the following factors:

Corrosion of steel reinforcing bars which were exposed and led to the buckling of the poles (by weakening their strengths through long time exposure)

Sagging effect of the cables, also had effect on the poles

The bendings were large as it exceeded the normal limit, thereby causing the concrete to go into tension and then crack occurred;

Monsoon wind which come with heavy rainfall caused serious damages to poles; and

Vibration above 30MPH caused serious damage to poles.

5.3.2 Material and laboratory observations.

Some of the materials used in the manufacturing/ production process had issues:

The reinforcement bars used by the three factories differed, thereby effecting their product's qualities;

Each of the factories differed in concrete Mix Ratio;

The use of BUA cement for the production, resulted to a better quality concrete pole

Each company produced different grade of concrete (with different compressive strengths)

5.4 Impacts

The impacts observed were in three folds Economic, Human/Social and Environmental impacts;

Economic impact: Loss of revenues and high cost of overheads (maintenance and operation);

Human/Social Impact: Loss of lives and valuables; and

Environmental Impact: Unsafe environment and waste of materials used for the construction or manufacturing of the poles.

6.1 CONCLUSION

The manufacturing industries always ignore design specification in the sizing of construction and engineering elements such as reinforcement or steel bars, cables etc, which clearly violated limit state design standard specification and best practices.

During the field investigations, it was noticed that poor workmanships, apparent absence of technical supervision/know-how contributed to the failure of electric concrete poles. Also observed were shallow foundation of the poles, wind actions and poor installation system.

Again, laboratory tests also showed that BUA cement have more binding effect than other cements. It improved the compressive strength of the concrete poles.

6.2 RECOMMENDATIONS

Based on the discussions and result above the following recommendations were made in order to reduce the re-occurrent of failures of reinforced electric concrete poles, not only in the study area, but also in other States of Nigeria.

Geotechnical investigation and test should be compressively carried out by the consultant/constructor

There should be proper monitoring and control by the standard organization, council for the regulation of engineering in Nigeria (COREN) and electricity regulatory commission.

There should be proper supervision of workmanship, while materials (steel bars, guy ropes etc) used for the installation of electric poles should be properly checked.

All poles should be properly installed at least one meter deep (foundation depth), while concrete base or pad foundation should be erected above ground level.-This study recommended a minimum mix ratio of 1:2:4, Y8 or T10mm steel rod and concrete grade of 20.

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Appendix I

Weights, densities and compressive strength calculations

Factory A:

Sample 1:

$$\begin{aligned} \text{Volume} &= \text{Length} \times \text{Breadth} \times \text{Thickness} \dots\dots\dots 2 \\ &= 0.14 \times 0.06 \times 0.04 \\ &= \underline{3.36 \times 10^{-4} \text{ m}^3} \end{aligned}$$

$$\begin{aligned} \text{Area} &= \text{Length} \times \text{Breadth} \dots\dots\dots 3 \\ &= 140\text{mm} \times 60\text{mm} \\ &= \underline{8400\text{mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Compressive strength} &= \frac{\text{Load or force applied} \dots\dots\dots 4}{\text{Area}} \\ &= \frac{130 \times 1000}{8400} = \underline{15.48\text{N/mm}^2} \end{aligned}$$

Factory B:

Sample 1

$$\begin{aligned} \text{Volume} &= \text{Length} \times \text{Breadth} \times \text{Thickness} = 0.18 \times 0.16 \times 0.10 \\ &= \underline{2.88 \times 10^{-3} \text{ m}^3} \end{aligned}$$

$$\begin{aligned} \text{Area} = \text{Length} \times \text{Breadth} &= 180 \times 160 \text{ (mm)} \\ &= \underline{28800\text{mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Compressive strength} &= \frac{\text{Load applied}}{\text{Area}} \\ &= \frac{320 \times 1000}{28800} = \underline{11.11\text{N/mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Density} &= \frac{\text{Mass}}{\text{Vol}} \dots\dots\dots 5 \\ &= \frac{6.652}{2.88 \times 10^{-3}} \\ &= \underline{2309 \text{Kg/m}^3} \end{aligned}$$

Sample 2:

$$\begin{aligned} \text{Compressive Strength} &= \frac{\text{Load applied}}{\text{Area}} \\ &= \frac{445 \times 100}{28800} = \underline{15.45 \text{N/mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Density} &= \frac{\text{Mass}}{\text{Volume}} = \frac{7.115}{2.88 \times 10^{-3}} \\ &= \underline{2470 \text{Kg/m}^3} \end{aligned}$$

Sample 3:

$$\begin{aligned} \text{Compressive strength} &= \frac{\text{Load applied}}{\text{Area}} \\ &= \frac{430 \times 1000}{28800} = \frac{430 \times 1000}{28800} = \underline{14.98 \text{N/mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Density} &= \frac{\text{Mass}}{\text{Volume}} = \frac{5.939}{2.88 \times 10^{-3}} \\ &= 2062.15 \text{kg/m}^3 = \underline{2062.15 \text{kg/m}^3} \end{aligned}$$

Factory C:

$$\begin{aligned} \text{Volume} &= 120 \text{mm} \times 120 \text{mm} \times 120 \text{mm} \\ &= 0.12 \times 0.12 \times 0.12 \\ &= \underline{1.728 \times 10^{-3} \text{m}^3} \end{aligned}$$

$$\begin{aligned} \text{Area} &= 120 \times 120 \text{mm}^2 \\ &= \underline{14.400 \text{mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Compressive Strength} &= \frac{\text{Load applied}}{\text{Area}} \\ &= \frac{160 \times 100}{14400} = \underline{11.1 \text{N/mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Density} &= \frac{\text{Mass}}{\text{Volume}} = \frac{4.411}{1.728} \\ &= \underline{2553 \text{kg/m}^3} \end{aligned}$$

Sample 2:

$$\begin{aligned} \text{Compressive Strength} &= \frac{\text{Load applied}}{\text{Area}} \\ &= \frac{260 \times 1000}{14400} = \underline{18.05 \text{N/mm}^2} \end{aligned}$$

$$\begin{aligned} \text{Density} &= \frac{\text{Mass}}{\text{Volume}} = \frac{6.189}{1.7828 \times 10^{-3}} \\ &= \underline{3582 \text{kg/m}^3} \end{aligned}$$

Sample 3:

$$\begin{aligned}\text{Compressive Strength} &= \frac{\text{Load applied}}{\text{Area}} \\ &= 220 \times \frac{1000}{14400} \\ &= \underline{15.28\text{N/mm}^2}\end{aligned}$$

$$\begin{aligned}\text{Density} &= \frac{\text{Mass}}{\text{Volume}} = \frac{5.160}{1.778 \times 10^{-3}} \\ &= \underline{2986\text{kg/m}^3}\end{aligned}$$