Covenant Journal of Engineering Technology (CJET) Vol.1 No. 2, Dec. 2017

An Open Access Journal Available Online

Assessment of Pre-Stressed Concrete Electric Poles for Rural Electrification Projects

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Abstract: Rural electrification is the process of bringing electrical power to rural and remote areas in a country in order to improve the living conditions of the people. In accordance with the extant electricity regulation act chapter 106 Laws of the Federal Republic of Nigeria (1990) Part VI No 47 (i), every support carrying electric lines shall be made of treated wood, steel or reinforced concrete or any combination of such materials or other approved materials. Regulation No 47, (2)(1990), further stipulates that every support shall be so constructed to withstand the transverse, horizontal and vertical loads. Hence, in order to confirm that any pre-stressed concrete electric pole is acceptable and fit with adequate strength for rural electrification projects, a test or assessment was carried out. After the test, a safety factor of above 2.0 units was obtained and the cube test result satisfied the minimum strength of 40N/mm2 for the pre-stressed concrete pole.
Keywords: Pre-stressed concrete electric poles, factor of safety, tensile strength, concrete cube, concrete mix, rural electrification.

1. Introduction

Electricity plays a very important role in the socio-economic and technological development of every nation. Significantly, rural electrification is the backbone of rural economy and basic input for rapid rural development. Rural electrification is the process of bringing electrical power to rural and remote areas in a country in order to improve the living conditions of the people. As a result of this gesture, electricity would be available for lighting and household purposes and would also assist in agriculture mechanization practice. Hence, rural electrification is the main infrastructure for ensuring speedy growth of the agricultural sector and agro -based industrial structure in rural areas.

Furthermore, in order to control population drift from rural areas to urban areas, the Nigerian Federal Government set up Rural Electrification Agency (REA) with statutory function to electrify the rural areas and the border towns in the country.

The Rural Electrification Programme was initiated in 1981 by the Federal Ministry of Power and Steel. A major strategy of the programme was to extend electricity to all 774 local government headquarters in the country and border towns. The Rural Electrification Agency is established to carry out the following functions:

i. Promote rural electrification in the country;

ii. Co-ordinate federal and state rural electrification activities; and

iii. Establish and manage the Rural Electrification Fund (REF).

The objectives of Rural Electrification are to: (a) promote agriculture, industrial, commercial, economic and social activities in rural areas through provision of good quality and affordable electricity; and (b) raise the living standards of the rural population through provision of adequate pipe borne water supply, available uninterrupted electricity supply and ensure adequate security for the populace, in order to assist in reducing rural-urban migration.

2. Rural Electrification Distribution System

The distribution system is one of the three components of an electric power system, that is, generation, transmission and distribution. Ewesor (2010) expressed the fact that the distribution involves primary and secondary transformation of high voltage to the standard medium of low voltage by the appropriate transforming equipment. A distribution network connects all loads in a particular area to the transmission line or network. The distribution network design, planning and operations are of great importance in the quest towards the provision of continuous stable electric power. Desphande (2006) states that the network distribution system is applicable in large loads and where the system has to be made more reliable for continuity of power supply. He stated further that to start designing the rural distribution system, the first requirement is to predict or know the load in the area.

According to Pabla (2008), the distribution system is part of the system between transmission and the consumer service point.

It contains:

(i) Sub-transmission circuits in voltage ratings usually between 33kV and 220kV which deliver energy to distribution substation;

(ii) Primary circuits of feeders operating in the range of 11kV to 33kV and supplying the load in a well-defined geographical area; and

(iii) Distribution transformer are installed on poles or on plinth or near the consumer’s sites which transforms the primary voltage to secondary voltage usually 240/415V.

In addition, Garg and Uppal (2011) expressed the fact that all the equipment in the distribution substation, overhead lines, and underground cable radiating from the distribution substation combined together are known as distribution system.

The empirical formula (Gupta, 1998) for calculating the optimum voltage of primary distribution system is given as:

$$V_L = 5.5\sqrt{\frac{L}{1.6} + \frac{P_L}{100}} \qquad (1)$$

where VL is the line voltage in kV, L is the length of the line in km and PL is the power in kW.

According to popular saying by cable manufacturers, "Electricity has no legs but has to be carried by conductors". Conductors carry electric power from the sending-end station to the receiving-end station. The common conductors used for overhead lines are copper, aluminium, steel-cored aluminium, galvanized steel and cadmium copper. In this country, aluminium conductors are used for low voltage distribution lines with varying sizes from 35mm2, 50mm2, 70mm2, 100mm2 and 150mm2.

For 11- kV and 33-kV distributions, the conductor used is the steel-cored aluminium, and it is also known as aluminium conductor steel reinforced (ACSR) of various sizes of 70mm2, 100mm2 and 150mm2.

Electricity is carried by wires supported by reinforced concrete poles. These poles have become very popular as line supports for township distribution and for rural electrification schemes. They have greater mechanical strength, longer life span, and permit longer spans than wooden poles. They give good outlook and require little maintenance. They have good insulating properties. The holes in these poles facilitate climbing of the poles and at the same time reduce the weight of the line supports.

The overhead power line is designed by keeping in view the electrical and mechanical requirements. Wind pressure on poles and conductors are calculated as per the basic wind speeds given in International Standard: 802 (Part I, Section 1 of 1995). This is given as

$$P = 0.6V_d^2 \qquad (2)$$

where P is design wind pressure in N/m2 and Vd is design wind speed in m/s.

During the construction of rural electrification line, it was observed that when 100-mm2aluminium conductor steel reinforced (ACSR) is shrunk on cross-arms supported by reinforced concrete poles, these poles got cut-off from the top thus making them useless. The cutting off action of the poles results in delay in rural electrification projects due to cutting corners by the electrical contractors. Hence, investigation and test were carried out on reinforced concrete poles used for rural electrification projects.

The rural electrification scheme demands careful supervision, monitoring, valuation and testing to ensure that the requirements and specifications for quality assurance are strictly adhered to during construction stage.

3. Reinforced Concrete Pole Production and Testing

According to Chandra and Gehlot (2004), cement is a cementitious material which has the adhesive and cohesive properties necessary to bond inert aggregates into a solid mass of adequate strength and durability. Cement is the most important constituent of concrete.

Chandra and Gehlot (2004) stated further that a carefully proportioned mixture of cement (used as binder), fine aggregate (sand),coarse aggregate (gravel) and water. This mixture which hardens to a stone-like mass, is called concrete. They emphasized that the steel bars are used to reinforce the concrete. The steel barswhich are completely surrounded by hardened concrete form internal part of the structural member. Hence, in such a manner, the steel bars and concrete act together in resisting forces. The concrete reinforced with the steel bars is known as reinforced concrete.

The pole is designed for bending strength. If W denotes the load in kg applied at 0.30m from the top of pole, then; we have

$M = fz$ ………………………..(3)

where M is sum of the bending moments of the loads on the pole at ground level, z is modulus of the section of pole; and f is the fibre stress maximum.

Concrete poles of ratio 1:1.5:3 with 15mm size well-graded shingle are used for construction of the lines.

Casting of the poles is carried out by arranging a network of 8mm2 high tensile reinforcement steel wires in moulds with the help of 6mm2 link, pouring in a well-mixed concrete into the mould to cover the arranged reinforcing iron rods. The moulded reinforced pole would be fabricated by compacting the concrete with vibrators. The resulting moulded reinforced poles would then be placed into the curing bath (tank) which is full of water.

The poles are normally left in the bath (tank) for 5 to 12 days, after which they are taken out of the bath (tank) and subjected to another 4 to 16 days of wetting with water by sprinkler in the open air after which they are ready for use.

The re-inforcement of the 10.40-m pole is produced in the factory with 8 in number reinforcing irons embedded in it while the reinforcement of the 8.5-m pole is produced in the factory with 6 in numbers reinforcing iron rods embedded into it.

The tensile strength and Young modulus of elasticity of the reinforcement rods were determined by Avery Testing Machine. The tensile strength of iron rods was above 160kg/cm2.

The poles that have been cured for more than 21 days were tested. The reinforced concrete poles were fixed horizontally and were rigidly supported up to a length of about 1.46m for 8.5m pole from the butt end. The load was applied at right angles to the axis of the pole at a point 0.6m from the top end of the pole. The free part of the pole was laid on smooth surfaced wooden planks to reduce the induced bending moment due to the weight of the pole. The applied loads were read on a dynamometer scale. The pole was subjected to the following types of test:

(a) The elastic phase test: the appropriate loads in graduated steps of 0%, 20%, 40%, 60%, 80% and 100% of the working load were applied. The deflection was measured at the point of application of the load; the numbers and locations of hair cracks were noted. The load was then reduced to zero and the deflection at that instance was noted.

(b) The breaking phase test: the loading was graduated in steps until the pole was destroyed. The hair cracks and deflection at each loading step and the length from the butt to the breaking point were noted.

Table 1: Pole Types under Test

Parameter	**Pole A**	**Pole B**
Pole length (m)	10.40	8.5
Weight (kg)	900	700
Butt dimension (mm)	250 x 380	240 x 350
Top dimension (mm)	150 x 150	150 x 150
Number of reinforcing iron rods	8	6
Rigid support from butt end (m)	1.96	1.46
Point of load application from top (m)	0.6	0.6
Working load (kg)	300	240

4. Results and Discussion

The test results for type A pole is shown in table 2 while that of type B pole is shown in table 3.

Table 2: Pole Type A Test Result

Percentage Loading (%)	Applied Load (kg)
0	0
20	60
40	120
60	180
100	240
110	300
120	360
140	420
160	480
180	540
200	600
220	660
240	680

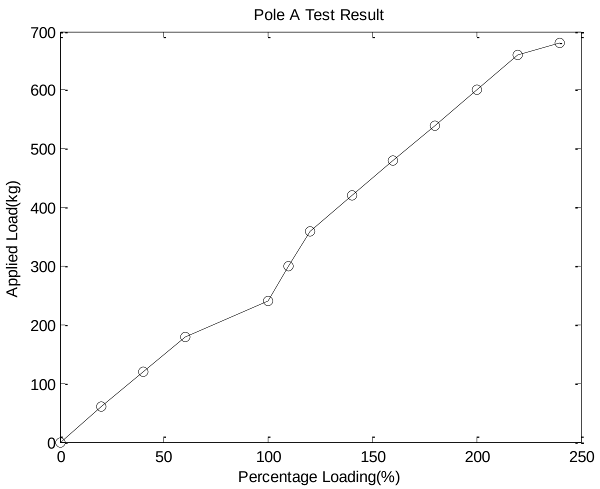

Figure 1: Pole 'A' Test Result

The pole broke when applying the last load of 680kg at 1.6m from the butt end. By definition,

$$safety\ factor = \frac{ultimate\ load}{working\ load} = \frac{680}{300} = 2.3 \ldots\ldots (4)$$

Table 3: Type B Pole Test Result

Percentage Load (%)	Applied Load (kg)	Deflection (mm)
0	0	0
20	48	0
40	96	2.5
60	144	2.5
80	192	6.7
100	240	12.8
120	288	18
140	336	27
160	384	35
180	432	110
200	480	Pole broke

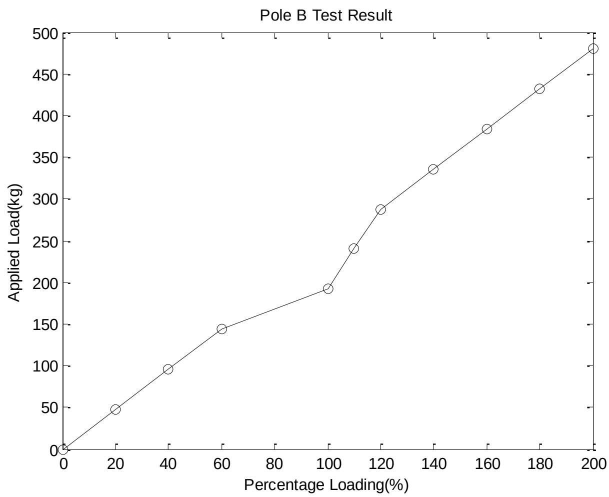

Figure 2: Pole 'B' Test Result

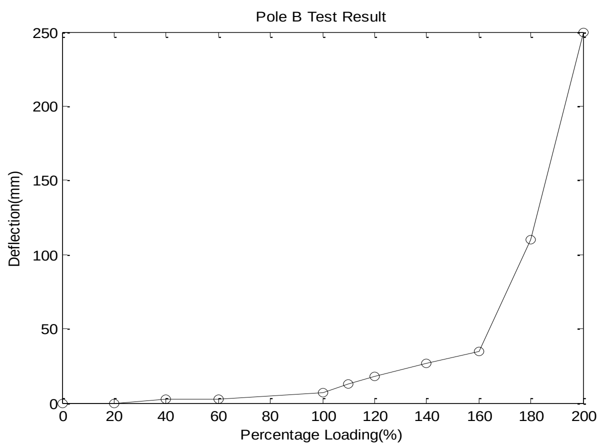

Figure 3: Pole 'B' Test Result for Deflection

The pole broke when applying the load of 480kg at 1.7m from the butt end.

By definition

$$safety\ factor = \frac{ultimate\ load}{working\ load} = \frac{480}{240} = 2.0 \quad \ldots\ldots(5)$$

Variation in the number of iron rods used for reinforcement could give rise to varying tensile strength of the concrete poles. From the graph of fig. 1 and the result of the tested concrete poles and the observation made from the broken poles, it could be concluded that the broken poles were not constructed according to the standard specifications due to sub-standard materials which resulted in structural failure.

Conclusion

(i) The straight through reinforcement iron rods should not be jointed en-route to prevent breaking of the poles at the point of joints.

(ii) The reinforcement network for moulds should not be reduced under the disguise of economics in material use.

(iii) The poles manufacturing procedure should be subjected to occasional random test and inspection.

(iv) All poles should incorporate built-in earthing wire to enable overhead earthing points to be connected to earth rods at the base of the pole.

(v) Concrete electric poles should be purchased by electrical contractors from government approved manufacturers, hence concrete reinforced electric poles that satisfied the conditions stipulated by Electricity Supply Regulation 133 of chapter 57 of the Laws of of the Federal Republic of Nigeria, Part VI No 53 Electricity Act CAP 106 Laws of the Federal Republic of Nigeria (1990) and the relevant British Standard and International Standards should be used for Rural Electrification Projects.

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