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Quality characteristics of concrete poles manufactured in the Ibadan metropolis, southwest Nigeria

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Abstract

In Nigeria, power is transmitted by overhead transmission lines fixed on wooden or concrete poles. Often times these poles collapse under excessive loads occasioned by storm and accidents. This project work is to determine the quality characteristics of concrete electric poles used to carry overhead conductors in the Ibadan metropolis of Nigeria. Samples of broken concrete poles were collected from various sites within Ibadan metropolis. Core, permeability, cube and tensile tests were carried out on samples of stumbled poles and fresh concrete mix collected from companies producing poles. This was to check the conformance of the poles to the standard set by the regulatory authority. The test results showed that all the samples on which the core and permeability tests were carried out fell short of the required standard of 37,000KN/m. For the core test, only one sample had the average values of 46,200KN/m and 50,400KN/m^2 at 7days and 28days respectively which exceeded the standard minimum value. The results showed that the manufacturers did not use the right ratio of materials, the mode of mixing of the aggregates was not adequate and casting allowed voids/air space which made the poles permeable and the period of curing (the number of days) of the poles was not adequate. Almost all the poles were found to be below standard

***Key words**: aggregate, crushing strength, crushing load, concrete curing, overhead conductors*

1. Introduction

In recent times, efforts have been geared towards the production of electric poles that meet the international quality standards. With the level of development in Nigeria, the use of electric poles has been on the increase as a result of the rural electrification programme. In effect, efforts have been made to provide quality facilities and amenities for the production of poles in the rural and urban areas.

Reinforced concrete is a strong and durable building material that can be formed into various shapes and sizes. It's utility and versatility are achieved by combining the best features of concrete and other materials. In Nigeria, electricity is transmitted by conductors carried overhead by concrete and wooden poles. Concrete Pole design is dependent on the power and voltage that is to be transmitted. In Nigeria, 33/11/0.415kv is usually transmitted generally by overhead conductors; hence the wooden and concrete pole types are suitable for use (Ilochi et al 1996). The design of poles is mainly based on the principle of conductor loading. However, sag-tension calculation is quite involved due to the varying loading effect on conductors and the nature of conductor materials. The calculations would be simpler if the conductor could be regarded as being subjected to a fixed loading. This however, is not the case since the conductors may be subjected to a gale or may only be acted upon by their own weight in still air. As a result of varying conditions, the overhead line design engineer must be able to design the support to carry the conductor under different conditions. The stumbling/falling and cracking of the poles have constituted a great nuisance in the environment and also endangered the lives of people residing in the vicinity.

The objective of this paper is to examine the quality characteristics of poles produced locally in the Ibadan metropolis in Nigeria with an aim to establishing causes of failure and conformance or otherwise of the poles to infrastructure quality standards. Only one of the outfits studied in Ibadan was owned by government and this had since gone out of production.

2. Theoretical background

The tensile strength of concrete is only about 10% of the compressive strength. As a result of this, nearly all reinforced concrete are designed on the assumption that concrete does not resist any tensile force. Reinforcement is designed to carry these tensile forces, which are transferred by bonds between the interface of the two materials (i.e. concrete and the reinforcing steel bar). If this bond is not adequate, the reinforcing bars will slip within the concrete and there will not be a composite action. Thus, the members should be detailed, so that the concrete can be well compacted around the reinforcement during construction. This is further facilitated by the use of bars that are ribbed or twisted to produce an extra mechanical grip.

In the analysis and design of the composite reinforced concrete section, it is assumed that there is a perfect bond so that the strain in the reinforcement is identical to the strain in the adjacent concrete. This ensures that there is what is known as "compatibility of strains'' across the cross-section of the member. The coefficients of thermal expansion for steel and for concrete were of the order of 10 x 10^{-6} per ^{0}C and 7– 12x10^{-6} per ^{0}C respectively. (Mosley et al 1990).

The span length, height of support and the strength of support required are functions of the conductor Sags and tension. (Ilochi et al 1996).

Whenever tension occurs, it is likely that cracking will take place. This cracking, however, does not detract from the safety of the structure provided there is good reinforcement bond to ensure that the cracks are restrained from opening so that the embedded steel continues to be protected from corrosion. In determining the strength of a pole, the pole is considered as a cantilever beam anchored at one end i.e. the pole is designed for bending strength (Akala.. 2002). When the compressive or shearing forces exceed the strength of the concrete, steel reinforcement must again be provided to supplement the load carrying capacity of the concrete. To prevent these bars from buckling, steel binders are used to assist the restraint provided by the surrounding concrete.

Total bending moment on pole at ground level,

$$BM = (P.h.W.H/2)\ kg.m \quad \ldots\ldots\ldots\ldots 1$$

Where

H = the height of pole above the ground level

h = height of centre of gravity of conductor loading in meter above ground level

P = total horizontal conductor loading in Newton acting at height h meters above the ground level

Assuming a maximum fiber stress of $8000 kg/mm^2$ on the pole;

Max. allowable fibre stress

$$F = \frac{8000}{S}\ kg/mm^2 \quad \ldots\ldots\ldots\ldots 2$$

Where S = factor of safety.

Moment of inertia for circular pole

$$I = \frac{\pi D_g^4}{64} mm^4 \ldots\ldots\ldots\ldots 3$$

Section modulus $Z = \frac{I}{D_g/2} = \frac{\pi D_g^3}{32} mm^3 \ldots\ldots\ldots 4$

Allowable Stress $= F = \frac{BM(10)}{Z} = \frac{BM(10)(32)}{\pi D_g^3} \ldots\ldots 5$

Pole Diameter at ground level = D_g

$$\therefore D_g = \sqrt[3]{\frac{BM(102)}{F}}\ mm \quad \ldots\ldots\ldots\ldots 6$$

Poles are not designed to withstand such impact strength that might occur when a moving vehicle hits a pole. Poles should, if at all possible, be sited to minimize this possibility (NZE: 3115:1980).

The minimum requirement for reinforced concrete pole should be high grade with a specified strength of 30mpa, and in prestressed concrete poles the specified strength is 40mpa. The deflection of the top of the pole under specified working load should not exceed the distance from the ground line to the top of the pole divided by 50. The cover to all steel reinforcement including stirrups and prestressed tendons should not be less than 20mm except for spun poles. Thus minimum cover may be reduced to 12mm. The position and size of holes are to be specified by the purchaser. Holes should be within 5mm of the specified position and should be 4mm larger in diameter than the intended bolt size. Provision for earthing should be made only when specified by the purchaser. Prestressed steel must not be used for earthing purpose. All poles must be clearly and indelibly marked with the following:

(a) Date of manufacture at approximately 3m from the butt end.

(b) The specified working load, in kilo Newton and at approximately 3m from the butt end.

(c) A warning notice, when requested by the purchaser.

(d) A horizontal mark to show the designated ground line position

(e) The design lifting points.

Where it is not obvious in which direction a pole is to be placed on site, the pole should be marked to give an indication of the required orientations.

Cubes were made from samples of concrete mix collected from water absorption. The bars in the concrete were also tested to determine the tensile stress.

The sample of concrete from broken poles used in this study were collected from various parts of the Ibadan metropolis (see plates 1 – 6).

3. Methodology

Plate 1: Fracture at 1,200 mm

Plate 2 Clean fracture at 900mm

Plate 3 A fracture and a tear

Plate 4 Multiple fracture

The core and permeability tests were carried out on them. The tests were carried out to determine the crushing strength and the rate of water absorption of the concrete.

Avery Universal testing machine 600KN capacity, Diamond Cutting machine, meter rule and the specimens (concrete) were used for the test.

Plate 5: Stumbled Pole wires unbroken   Plate 6: Stumbled Pole

3.1 Procedure

The samples were cut into equal sizes using a diamond cutting machine. The cube length was 0.150m; the breadth was 0.2m and the cross sectional area calculated was $0.03m^2$. The core and permeability tests were carried out on the cubes on different days ranging from 4 to 20 days.

3.2 Core test

The concrete was placed flat down in the compressive side of the machine. The machine was switched on and was gradually loaded until the specimen was crushed. The core test was carried out on the hardened concrete poles and the result was recorded as follows

TABLE 1 Core Sample

Sample	Crushing Load KN/m^2	Cross sectional area (m^2)	Crushing strength (KN/m^2)
A	392	0.03	13,067
B	438	0.03	14,600
C	680	0.03	22,667

3.3 Permeability test

The samples were weighed before being submerged in water and were tested on different days after removal from the water and reweighed; the weight and the crushing load values were recorded. This was done in order to determine the rate of water absorption.

Some of the identified problems that led to the collapse of some of the remnants of broken poles picked up in the Ibadan metropolis included permeability to continuous rainfall, poor compaction/consolidation and inadequate curing.

The results showed that the samples tested were not up to the required standard of $37{,}000kN/m^2$ set by the regulatory body; therefore. Hence they did no show conformity to the standard set for poles manufactured in Nigeria.

Table 2 Permeability test result for sample A

No Of ys	Approximate Cross Sectional Area (m^2)	**Crushing Load KN/m^2**	**Weight in Air (Kg)**	**Weight in Water (Kg)**	**Crushing Strength (KN/m^2)**	**% of Water Absorbed**
4	0.03	**320**	**8.00**	**8.20**	**10,667**	**2.5**
8	0.03	**288**	**8.00**	**8.22**	**9,600**	**6.25**
12	0.03	**273**	**8.02**	**8.70**	**9,100**	**8.48**
16	0.03	**263**	**8.06**	**8.80**	**8,834**	**9.18**
20	0.03	**260**	**8.08**	**9.0**	**8,667**	**12.00**

Table 3 Permeability test result for sample B

No Of Days	Approximate Cross Sectional Area (m^2)	Crushing Load KN/m^2	Weight in Air (Kg)	Weight in Water (Kg)	Crushing Strength (KN/m^2)	% of Water Absorbed
4	**0.03**	**420**	**9.00**	**9.04**	**14,000**	**0.45**
8	**0.03**	**400**	**9.05**	**9.12**	**13,334**	**0.77**
12	**0.03**	**395**	**9.07**	**9.13**	**13,167**	**0.66**
16	**0.03**	**390**	**9.10**	**9.14**	**13,000**	**0.44**
20	**0.03**	**390**	**9.11**	**9.15**	**13,000**	**0.44**

Table 4 Permeability result for sample C

No Of Days	Approximate Cross Sectional Area (m^2)	Crushing Load KN/m^2	Weight in Air (Kg)	Weight in Water (Kg)	Crushing Strength (KN/m^2)	% of Water Absorbed
4	**0.03**	**660**	**8.00**	**8.01**	**22,000**	**0.12**
8	**0.03**	**650**	**8.00**	**8.04**	**21,667**	**0.50**
12	**0.03**	**645**	**8.00**	**8.05**	**21,500**	**0.63**
16	**0.03**	**610**	**8.02**	**8.08**	**20,334**	**0.75**
20	**0.03**	**636**	**8.03**	**8.10**	**20,534**	**0.87**

Sample A: was the most permeable; the concrete absorbed water at a very fast rate when immersed in water for a period ranging from four days to twenty days thereby increasing the weight by the percentage of water absorbed.

Sample B: Though the concrete, absorbed water at a fast rate when it was immersed in water between the fourth day and the eighth day when it was reweighed and tested, the absorption rate became reduced by the twelfth day and finally became constant between the sixteenth and the twentieth day.

Sample C: the absorption rate was not as fast, compared to samples A and B. From the fourth day the absorption was a bit fast but it became reduced between the twelfth and the twentieth day.

The above results revealed that the concrete pole was not produced according to the specification given by the regulatory body. Though the poles have been in use over time they were still found permeable and this was as a result of the void present because the concrete mix was not well compacted.

4. Conclusion

From the test results, only one sample showed full compliance with the specified standard by the regulatory body. Concrete poles that were not cured for the recommended 28 days before use aged fast and were weakened with time and had a shorter useful life. All but one of the samples tested failed to meet the minimum crushing strength of 37,000KN/m^2 specified by the NIS. It was established that the manufacturers only cured the poles for 5 to 7 days instead of the 28 days specified. The poles were not well bonded and as a result weakened in situations where there was continuous rainfall leading to failure regardless of their age due to the voids present. The tensile test showed that all the samples were reinforced with 4mm reinforcing bars, which normally was above the minimum required standard of 0.48KN/mm^2. However, the failed poles showed that the reinforcing bars were inadequate for the excessive load during failure. There is no central testing and licensing authority for concrete pole manufacturers and government does not have any regulatory authority to enforce compliance with laid down standards.

References

Toff consultancy (1982): A feasibility study on manufacturing of prestressed of concrete

Mosley W.H. and Bungey J.H.: Reinforced concrete design 1990

Ilochi E.E., Onoh G.N. and Okafor E.C. (1996): NSE technical Transaction

Akala A. (2002). N.E.P.A.: Technical Training Report NIS: Standard for Steel Bars for the reinforcement of Concrete (reviewed NIS 117-1992)

British Standard: Steel Fabrication for concrete reinforcement B.S. 1221: 1945.

British standard: Specification for reinforced concrete pole. BS 607: 1960.

Adams E.C. Science in building for craft student and technician Volume 3: publish by Anchor press Ltd .1974.

Bernard. H Knight and Rens. G. Knight .Builders material: 3rd edition: publish by Edward Arnold Ltd. 1967.

New Zealand standard: Specification for concrete poles for Electric Transmission and Distribution. NZE 3115: 1980.

Kong. F. K. and Evans. R.H. Reinforced and Prestressed concrete. 3rd edition: 1993.

Charles E Reynolds and James. C. Steedman. Reinforced concrete designer's handbook.9th edition: 1981.

Bassett. C.R. Experimental building craft science, Clearer Hume Press Ltd. 1961

RUS Bulletin 1724E-216: Guide Specification for Standard Class Spun Prestressed Concrete Pole 2000.

Habib Dagher, University of Maine and Ron Randle, EDM International: science of Pole Selection 2003.

Standard Australia: Concrete Structures, AS 3600 -2001, Standards Australia International Sydney. 2001

McDonald S. "Building Pathology" Concrete, Blackwell Science Oxford. 2003

Standard Australia 2003, Concrete Structures, AS 3600 -2001/ Amdt 1-2003, Standards Australia International Sydney. 2003