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Improved Performance of Electric Transmission Concrete Poles for National Integrated Power Project (NIPP) in Nigeria

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Abstract
This paper deals with the testing of electric transmission concrete poles. The Dillon (precision Electronic Dynamometer family) used was inspected and was certified to be in perfect condition before testing commenced. 1000 concrete poles were tested arranged in batches of 400 and 300poles. These poles were arranged in such a manner that the markings, serial numbers e.t.c., with pole positions are easily seen. Also the poles were stacked in such a manner that any pole selected for testing was easily drawn out. All poles tested satisfied the standard acceptance criteria to withstand any concrete pole failure for the National Integrated Power Project (NIPP) electrification purpose based on the experimental validations carried out for different actual applied loads plotted again the pole deflection.
Keywords: NIPP, Concrete pole, testing, acceptance criteria, On-site assessment

1. Introduction
Generally, a pole acts as a cantilevered structure, which is designed and analyzed as a tapered member with combined axial and bending loads. Concrete poles are specified in special situations where poles of unusually high strength are required, beyond the range of wood poles, and where guying may be difficult or unobtainable. Stresses imposed on concrete pole are calculated, as if they were cantilever beam fixed at one end. The selection of poles for a particular project may be based on the values obtained from the calculation with proper factors of safety applied. The forces acting on a pole are from: the vertical loading (comprising of dead weight of conductors, cross arms, insulators an associated hardware) and the Horizontal loading (due to wind pressure on conductors and pole) (Oritola S.F., 2006).

The technology advancements in recent years have propelled the use of concrete poles into an ever increasing, and significant role in the design and construction of high voltage electrical transmission lines. These technologies significantly have occurred in three key aspects namely; the types and quality of the raw materials utilized in the production of high performance concrete have dramatically improved, and in some instances have just recently been developed. Also, scaled up manufacturing methods and equipment to produce high quality, stronger, longer length poles are being realized. Finally, with reasonable Research & Development (R & D) investment in the technology, significant and innovative enhancements to the engineering design technology of concrete poles are being utilized (Oliphant Wesley J., and Jerry Wong C., 2002). However, due to shear forces been small compared to bending moments, concrete poles are very resilient. Axial loads are small, too, and are generally ignored except when the structure is guyed. Stresses induced by handling, transportation and erection should always be considered in the design of electric transmission. Besides, weight of cross arms and other attachments should be put into proper consideration in calculating the center of gravity of the electric transmission pole (Thomas E. Rodgers, Jr., 1984).

In Nigeria, the electricity industry is in the process of deregulation and it is proposed that the old National Electric Power Authority (NEPA) now Power Holding Company of Nigeria (PHCN) which had a whole responsibility of generation, transmission and distribution of electricity, would be unbundled into six generating companies, eleven distribution companies and just one transmission company (PHCN annual report, 2009-2012). These companies need to be result driven and profitable to the investors. Thus, each of them must be able to account for the amount of energy it draws or supplies to its clients. Also, the introduction of the National Integrated Power Project (NIPP) in several parts of the country has gone a long way to boast electricity supply in the country by increasing the megawatts available in the grid system. In additional to earlier commissioned NIPP, the federal government recently commissioned the Geregu (Kogi state) and the Omotosho (Ondo state) NIPP projects (Annual NIPP Report, 2013), while others are still under construction. This paper presents a detailed testing procedure of an electric transmission concrete pole manufactured for NIPP, as part of the solution to curb the erratic power system in the Nigerian Electricity Industry. A detailed testing procedure was carried out for several actual applied loads on the pole against the deflection of the pole. The experimental results show that there was improved performance of the pole system designed.

2. Merits of Concrete Poles over Wooden Poles
Concrete poles are used widely 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 result. Concrete poles are also encouraged in environment of chemical pollution that may cause rapid deterioration in case of wood poles (Anthony, 1986).

Wood poles are composed of a naturally grown, biological material, which exhibits inconsistent material properties throughout the length of the pole. Thus, in wooden poles, there are direct impact on strength, leading to knots, checks, shakes and splits. Also, they are possibilities of rot and decay over the design life of the structure of a wood. The wood pole has less strength at the end of its service life than when it was originally placed in service. Wood poles are susceptible to insect and animal attack. The effects of termite and woodpecker attack can significantly decrease the load carrying capacity of the wood pole well before the end of the anticipated service life (Lonestar Prestress Mfg Inc., 2010). Some of the key merits of concrete poles over wooden poles are;

• Maintenance free
• Aesthetically pleasing and environmentally friendly
• Resistant to vandalism and theft because they have: no scrap or resale value and no value as wood or building struts for houses
• Resistant to fire
• Resistant to termites
• Standard in dimensions
• Made to client's specifications with preformed holes
• No drilling necessary thus assembly of fittings is easy
• Amenable to being stored and stockpiled even in remote areas, because: weight of poles discourages theft, poles will not corrode or rot and rectangular profile is easy to stack.
• Capable of an extra long service life from the high density concrete
• Non-absorbent. Traffic and any other markings can be painted on without the need for special primers
• Constant in taper and dimension. Handling and installation equipment can be standardized

3. Class of Poles

Concrete transmission poles are generally single pore or H-Frame structures. H-Frame poles are usually selected by strength class (Tip Load Computation) and since concrete poles are generally replacing damaged wood poles, the concrete class can be determined or investigated by the earlier work done with wood poles. Table 1 shows the various classes of concrete poles with their weight and transverse load in KN. Based on the experimental results in subsequent sections presented in this paper, the poles under investigation could be tagged class E.

4. Test Apparatus and Selection of Samples

The Dillon (precision Electronic Dynamometer family) used was inspected and was certified to be in perfect condition before testing commenced.

Inspection of batches of pole:

The 1000 concrete poles were arranged in batches of 400 & 300 poles. These poles were arranged in such a manner that the markings, serial numbers e.t.c with pole positions are easily seen. They were also stacked in such a manner that any pole selected for testing was easily drawn out. The following visual inspections on the selected concrete poles were carried out.

a) Random overall dimensions, hole position, hole size and straightness were checked and found to be of NIPP standard (e.g length for HT Pole-10.36m, and hole mark 1.8m from base etc)
b) Reinforcement bars and stirrups were not exposed.
c) The poles were of fair finish without honey combings.
d) The poles were properly marked, also with NIPP acronym as per contract stipulation

5. Markings and Testing Procedure

The following marking in accordance to NIPP specifications were observed.

1) Pole Size – *10.36*
2) Date of Casting - 0*3/04/2012& 20/04/2012*
3) Serial No: *1 - 1000*
4) NIPP embossment: *ok*
5) Name/identification No. of manufacturer – *Transpole*

The precast concrete pole was properly fixed in horizontal position in such a way that there is absolutely no movement during the process of loading, in the bottom part of pole between the butt-end and the line of testing (level of fixity i.e. 1.80m).The balance length of the pole was free to move in the lateral direction and the end loading was applied in a transverse direction of the pole.

The loading of the pole was effected by applying suitable calibrated weight and the instrument (dynamometer) Dillon (ED) was connected to the loading system just before the point of loading of the pole in order to read the exact value of the load transfer to the pole through a hook chain not more than 50mm width, going round the pole exactly at 0.6m below the top end of the pole.

Loading was increased by increments of 10% of the ultimate load and measurements of deflections of the top end of the pole were recorded as shown in Tables 3 to 5, of experimental readings. These measurements were taken with the help of a pointer and measuring tape, observation at every 10% load increment is made and information of hair cracks were carefully recorded.

On application of 40% of the ultimate load, the loading was reduced to zero and the permanent set of the top of the pole measured and recorded. Increasing the loading again starting from zero in 10% increments and hair cracks carefully observed and recorded on the surface of the pole until 60% of the ultimate load was applied and again loading reduced to zero and the permanent set measured and recorded.

It was observed that all the hair cracks formed during loading were completely closed for the concrete pole tested. Loading increased again from zero in steps of 10% of the ultimate load and measurements of deflection after each load increments were taken, maintaining each load above 60% of ultimate load for at least 3 minutes until failure, revising hair cracks were observed and recorded as shown also on experimental Tables 3-5 and displayed in Figures 1 to 3 below. A second pole randomly selected was subjected to the above procedure and result recorded as shown earlier.

6. Acceptance Criteria and Observation

All poles tested satisfied the following acceptance criteria following Tables 2-5 and Figures 1-3.

1) At release of applied load of 40% of the ultimate load, the tested pole did not develop any hair cracks.
2) The permanent set after removal of test load of 60% of the Ultimate Load as shown on all the tables of experimental reading, did not exceed 10% of the deflection recorded for same test load.
3) At the release of applied load of 60% of the Ultimate Load, the pole under test developed no hair cracks, and a deflection all through was negligible.
4) The test load at failure exceeded the ultimate load (6.8KN) in each case.
5) On breaking the concrete after failure, it was established that reinforcement specifications/parameters were in accordance with NIPP standard.

It was observed that the mark at 1.8m indicating the normal depth of planting was not visible enough in some of the poles. This was pointed out to the manufacturer and he promised to make them visible before they move them for erection.

7. Conclusions and Recommendations

In the light of the above, it is confirmed that the poles manufactured by Messrs Transoceanic Industrial Services Ltd are tested for deflection to meet the specification of NIPP projects in Nigerian. The above test confirms that this company who has been manufacturing concrete poles for other NIPP EPC contractors is still maintaining NIPP standards. In view of the above, it is recommended that the 1000 concrete poles manufactured by Transoceanic Industrial Services Ltd for Sermatech Nigeria Ltd (Lot D-EPC-EK1/9 and Lot D-EK2/24) and for which this FAT was conducted be accepted for the NIPP projects.

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Table 1 Class of Concrete Poles (StressCrete Canada, 2008)

Class	Minimum Ultimate Transverse Load (KN)	Class	Minimum Ultimate Transverse Load (KN)
C	5.3	J	20
D	6.7	K	24
E	8.5	L	28.5
F	10.7	M	33.4
G	13.3	N	38.7
H	16.5	O	44.5

Table 2 Test Pole S/No 1& 2 CEB Standard 044-3:1996

Date of Manufacture :03-04-2012 &20-04-2012

Pole 1					Pole 2		
10% of load applied	Value of 10% load (Kgf)	Actual load applied (Kgf)	Deflection(mm)	Hair cracks	Actual load applied (Kgf)	Deflection (mm)	Hair cracks
0	0						
10	69.36	80	-	-	65	20	-
20	138.72	130	30	-	140	40	-
30	208.08	205	180	3	205	180	4
40	277.44	275	270	3	270	230	8
p set	0	0	130	0	0	150	closed
10	69.36	65	130	0	65	150	-
20	138.72	135	140	0	135	170	-
30	208.08	205	220	2	205	195	-
40	277.44	270	270	5	275	245	6
50	346.8	345	360	8	360	410	6
60	416.16	425	420	2	420	495	4
p set	0	0	130	closed	0	250	closed
10	69.36	60	140	0	65	255	-
20	138.72	130	170	0	140	260	-
30	208.08	205	230	0	215	300	-
40	277.44	275	320	3	270	340	-
50	346.8	350	390	1	340	385	2
60	416.16	420	430	3	430	500	1
70	485.52	480	530	3	480	570	8
80	554.88	555	1120	3	555	890	6
90	624.24	625	2165	0	635	1740	6
100	698.6	705	2243	8	725	1800	4
110	708	720	failure		729	failure	
120	763.4						

Table 3 Experimental Readings for 0 to 40% of ultimate load

10% of load applied	Value of 10% load (kgf)	Actual Load applied (kgf)	Deflection (mm)	No of Hair cracks
0%	0	0	0	0
10%	69.4	65	20	-
20%	138.8	140	40	-
30%	208.2	205	180	4
40%	277.6	270	230	8
0%	0	0	150	closed

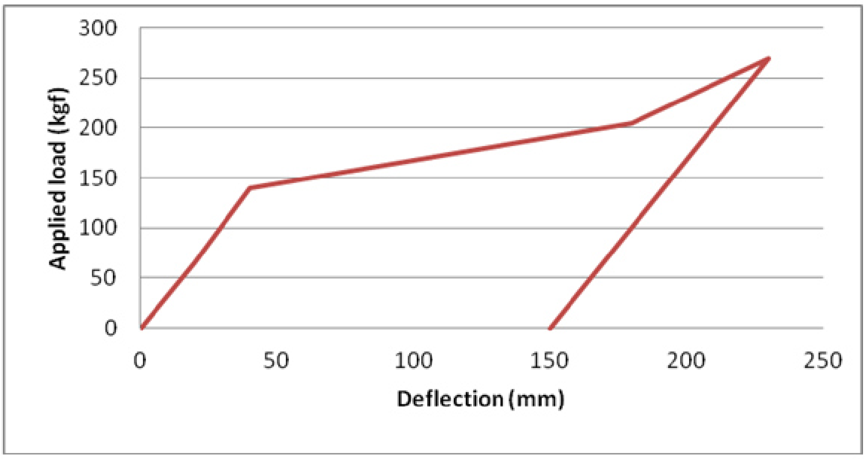

Figure 1 Graph of actual applied load (0 to 40% of ultimate load) versus deflection

Table 4 Experimental Readings 0 to 60% of ultimate load

10% of load applied	Value of 10% load (kgf)	Actual Load applied (kgf)	Deflection (mm)	No of Hair cracks
0	0	0	130	0
10%	69.4	65	150	-
20%	138.84	135	170	-
30%	208.2	205	195	-
40%	277.6	275	245	6
50%	347	360	410	6
60%	416.4	420	495	4
0%	0	0	250	closed

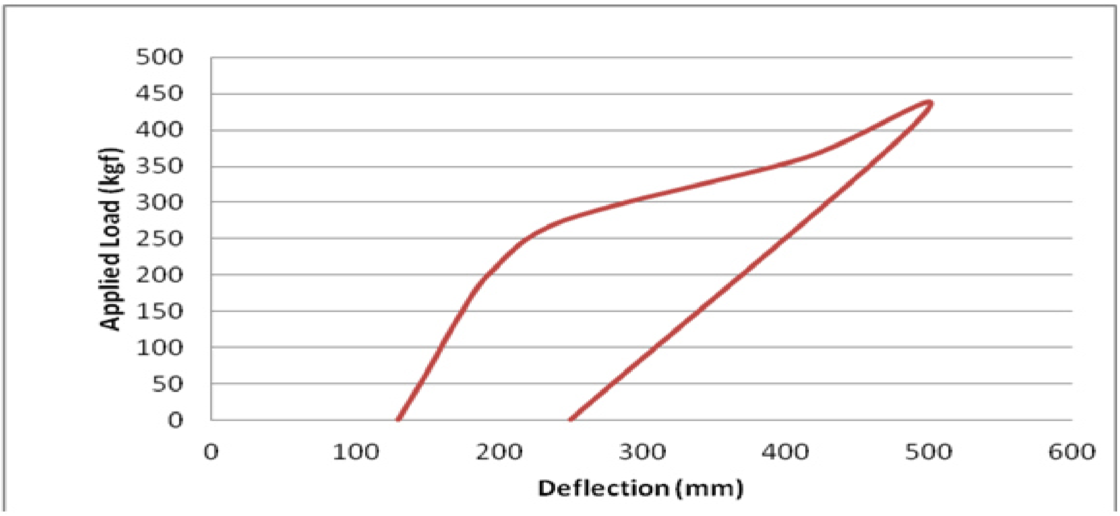

Figure 2 Graph of actual applied load (0 to 60% of ultimate load) versus deflection

Table 5 Experimental Readings 0 to 100% and above ultimate load

10% of load applied	Value of 10% load (kgf)	Actual Load applied (kgf)	Deflection (mm)	No of Hair cracks
0%	0	0	250	0
10%	69.4	65	255	0
20%	138.8	140	260	0
30%	208.2	215	300	0
40%	277.6	270	340	0
50%	347	340	385	2
60%	416.4	430	500	1
70%	485.8	480	570	8
80%	555.5	555	890	6
90%	624.6	635	1740	6
100%	694	725	1800	4
		729	failure	

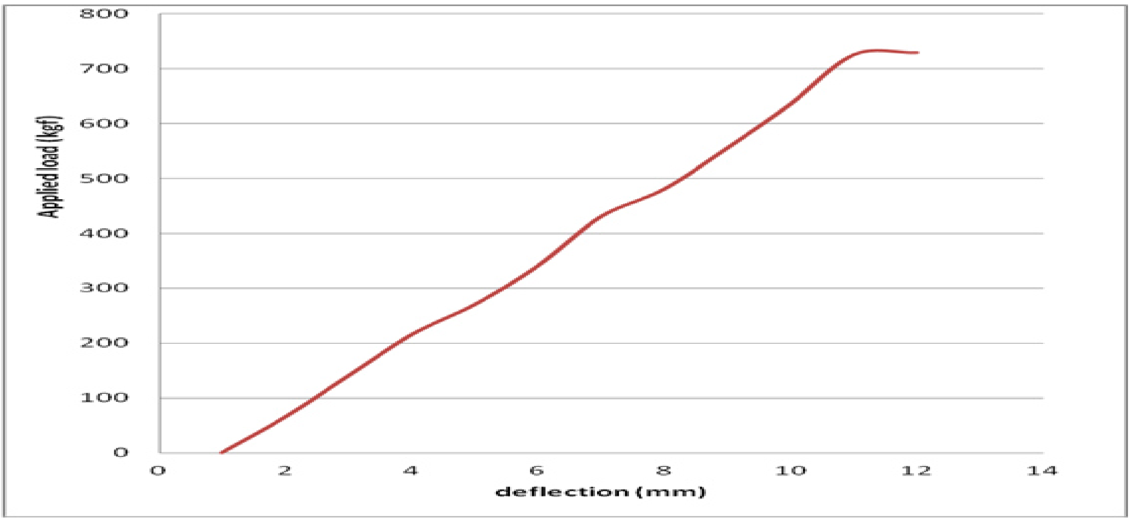

Figure 3 Graph of actual applied load (0 to 100% and above ultimate load) versus deflection

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