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EFFECT OF POLE SIZE ON PRESERVATIVE PENETRATION AND RETENTION IN AIR-DRIED UGANDAN GROWN EUCALYPT UTILITY POLES

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ABSTRACT

Treated wooden utility poles, from trees such as eucalypts, are the most commonly used for telephone and electricity transmission lines in Uganda. In the last decade, however, frequent failure of wooden poles in service has been reported, likely due to the preservative chemical, wood used or the treatment process. The objective of this study was to assess the creosote preservative penetration and retention in eucalypt wood. A total of 126 *Eucalyptus grandis* poles i.e. 42 poles for each size category, with an average moisture content of below fibre saturation point (28%) were treated in different charges depending on their size. In length, poles used were 9, 11 and 14m. Every charge consisted of poles within the same size category. The Full Cell pressure method was used to treat the different charges with creosote preservative. For all the charges the same treatment schedule was maintained. Creosote penetration was highest in 14m poles (20,5mm) and lowest in 9m poles (18,4mm), Creosote retention was also highest in 14m poles (193kg.m^{-3}), but lowest in 11m poles (162kg.m^{-3}). Irrespective of differences in level of penetration and retention among the various pole sizes, all the poles acquired more than the required standard minimum level of penetration and retention i.e. 15mm and 115kg.m^{-3} respectively. However, for all the pole sizes, creosote penetration was less than the sapwood depth. The current treatment schedule seems better suited for the larger poles of 14m than the 9 and 11m. For better treatment, it is recommended that smaller poles i.e. 9m and 11m should be treated for a longer period than 14m poles since they tend to have lager sapwood. The minimum basis of 15mm penetration should be increased to at least cover the entire pole sapwood depth.

Keywords: Creosote, *Eucalyptus grandis*, transmission poles, treated wood, wood preservation.

INTRODUCTION

Preservative treatment greatly increases the service life of wood structures (Lebow *et al.* 2004), reducing replacement costs and allowing more efficient use of forest resources. Preservation of utility poles has expanded rapidly in Uganda in the last decade to cater for the demand created by extensive expansion of the electric grid to many rural areas. In addition, treated poles are also exported to South Sudan, Tanzania and other countries in the region. *Eucalyptus* species are the commonly used and these are mainly treated with coal tar creosote although Copper Chrome Arsenate (CCA) preservative is also increasingly used lately. The treatment methods used involve pressure/vacuum processes to ensure good preservative penetration and retention. However, of recent, frequent premature failures of treated poles in service have been reported in different parts of the country leading to financial losses and risking lives in the case of electric transmission lines. This has raised questions regarding the wood material used, suitability of the preservative chemicals, and the methods of treatment.

Previously it was mostly *Eucalyptus grandis* from government forests that was used for utility

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poles, however, of late poles are mainly sourced from private forests located in different agro-ecological zones around the country. One of the most common eucalypts currently grown on these private farms are the fast growing hybrid clones imported from South Africa. Cookson (2000) noted that as the material changes, utilization of faster growing species with lower natural durability and higher proportions of sapwood increases the need for suitable preservation. Eucalypts generally have treatable sapwood but the heartwood mostly cannot be treated easily (Cookson 2000). The different utility pole sizes in Uganda include 9, 10, 11, 12, 14, 15, 16 and 18m in length depending on the intended use. Poles of different sizes are expected to have varying sapwood sizes which should be fully treated.

Currently, the same schedule is used by the main pole treatment company, Uganda Electricity Distribution Company Limited (UEDCL) in treating poles with creosote irrespective of their sizes i.e. varying pole length and diameter. The schedule involves an initial vacuum of 50kPa for 15 minutes, flooding cylinder with chemical for 20 minutes, applying 1260kPa pressure for 2 hours and 40 minutes, emptying cylinder takes 15 minutes, and the final vacuum of 30kPa for 10 minutes. Using the same treatment schedule might lead to either insufficient treatment for poles with larger sapwood or wastage of resources for poles with smaller sapwood. There has been also a general feeling that the creosote being used could be adulterated leading to insufficient treatment of poles.

The objectives of this study were (i) to assess the creosote penetration in eucalyptus poles of sizes 9m, 11m and 14m; (ii) to determine the creosote retention in the poles; and (iii) to investigate the relationship between preservative penetration and retention among the different sizes of poles.

MATERIALS AND METHODS

Timber

A total of 126 poles i.e. 42 poles for each size; 9, 11, and 14m having an average moisture content below 28% were treated in different charges depending on their lengths, using creosote preservative. The moisture content was determined using a moisture meter which was measured at a depth of 25,4mm (1 inch) into the wood. Exactly the same treatment schedule was used for all the charges (see introduction).

Sampling and measurements

Determination of creosote penetration

Three wood borings per pole were extracted 1,5m from the butt end (Theoretical Ground Line), at mid-length and 1,5m from the top end using a wood borer. The borer was drilled 25,4mm (1 inch) deep into the pole. The borings were spread on a graduated plate where the black part covered by creosote oil was observed and its length measured.

Determination of creosote retention

Using the same borings that were used to determine creosote penetration 6,45mm (0,25 inch) part of the boring was cut and discarded. The remaining 19mm (0,75 inch) of the boring was weighed and recorded. The weighed borings were placed in a syphon-type extraction cup held in the neck of a flask in which toluene was boiled. The vapors of toluene and water passed into an offset condenser that was fitted at the bottom with a calibrated water trap. The condensed water settled to the bottom of the trap and the lighter toluene formed a layer above it. The condensed toluene flowed back over the borings in the flask and gradually extracted the oil. Extraction continued until the solvent was colorless and no water dropped into the trap. The volume of water was read, and the borings were removed and placed in an oven to evaporate the toluene. The borings were then weighed. The difference between the initial and final weights of the borings was corrected for the water collected, to determine the amount of oil removed. It was assumed that 1mm of water weighed 1g (Baechler 1959).

Data analysis

Data analyses were carried out using SPSS version 17 and Minitab14. Since data were normally distributed, parametric tests were used. To compare differences in creosote penetration and retention with pole sizes, one-way analysis of variance (ANOVA) was used. Univariate analysis was used to show the variation of creosote along the pole length.

RESULTS

General

The average pole diameter, sapwood depth and moisture content for the poles studied are shown in Table 1. Nine meter (9m) poles had the largest sapwood (butt and top) and highest mid length moisture content while 14m poles had the smallest sapwood (top).

Table 1. Average pole diameter, sapwood depth and moisture content for the poles**.**

Pole Length (m)	Butt end Diameter (mm)	Butt end sapwood depth (mm)	Top diameter (mm)	Top sapwood depth (mm)	Mid length moisture content (%)
9	196	28,8	120	25,6	25,4
11	261	27,4	180	24,6	23,7
14	323	27,8	236	20,8	24,2

Creosote penetration and retention

The mean creosote penetration and retention in the various sizes of poles is shown in Table 2. Creosote penetration was highest in 14m and lowest in 9m (Table 2) while retention was highest in size 14m and lowest in 11m poles (Table 2). It can be observed from Table 1 and Table 2 that the sapwood of all the pole sizes was not fully treated.

Table 2. Mean creosote penetration and retention.

Pole length (m)	Creosote penetration (mm)		Creosote retention ($kg.m^{-3}$)	
	Mean	Standard Deviation	Mean	Standard Deviation
9m	18,4*a*	2,73	174,6*a*	43,98
11m	18,5*a*	1,77	161,9*a*	22,65
14m	20,5*b*	2,19	193,0*b*	41,89

Same letter = No significant difference, Different letters = There is a significant difference.

One-way ANOVA showed significant differences ($p < 0,05$) in penetration among the pole sizes. Significant differences ($p < 0,05$) in creosote retention were also observed among the different pole sizes. Post Hoc tests confirmed retention being significantly ($p < 0,05$) higher in 14m than both 9 and 11m poles (Table 2). However, differences in creosote penetration and retention in the 9 and 11m poles were not significant ($p > 0,05$).

Variation of preservative penetration along the pole length

Univariate Analysis showed that the bottom part had a significantly ($p < 0,05$) higher creosote penetration compared to mid length and top parts. Post hoc LSD test confirmed that creosote penetration at the bottom was higher compared to the midpoint and the top positions (Figure 1).

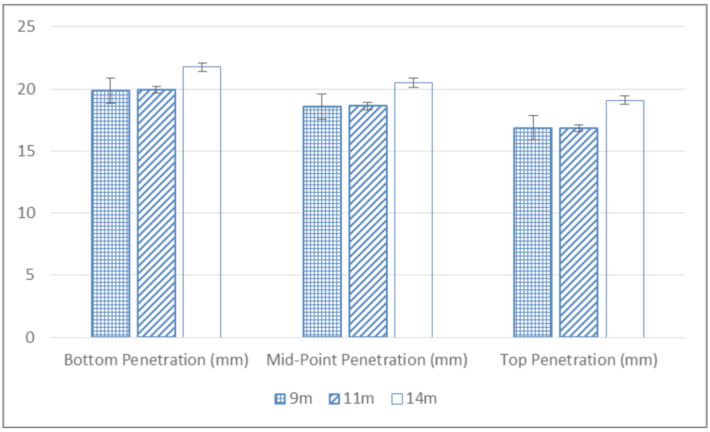

Figure 1. Creosote penetration along the pole length.

Relationship between Creosote Penetration and Retention

A strong, positive correlation was observed between creosote penetration and retention (r = 0,66; p <0,05) as showed in Figure 2.

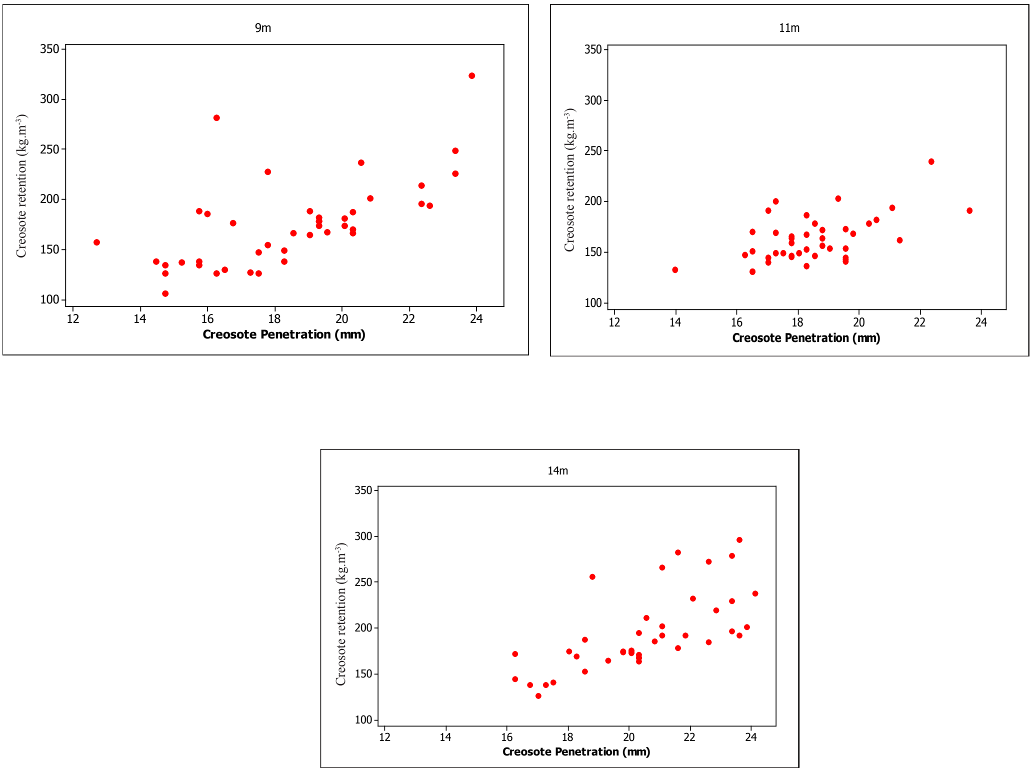

Figure 2. Interactive scatter plots for creosote penetration and retention for the three pole sizes.

DISCUSSION

Differences in creosote penetration

The higher creosote penetration in 14m poles compared to the other sizes could be due to the relatively lower moisture content at the time of treatment (Table 1). Creosote penetration was higher in the bottom parts for all the pole sizes perhaps due to the larger sapwood depth in all poles. Sapwood cells are highly porous compared to heartwood cells hence take in the preservative more easily. Rice and Onofrio (1996) noted the permeability of wood may be influenced by habitat, heart-sapwood sections as well as the chemical constituents. A higher penetration is desired to provide adequate protection against biological agents (Blew and Davidson 1971) especially since the bottom part of the pole is usually inserted in the ground and covered with soil.

Differences in creosote retention

The higher creosote retention observed in 14m poles compared to the other sizes could be due to the relatively lower moisture content at the time of treatment (Table 1). It is possible that since 14m poles had larger diameter compared to the other sizes, they were also older with higher density hence the higher creosote retention. High retention is required for service conditions where the hazard is increased such as ground contact. In any case the average net retention should not be less than 115kg.m^{-3} for proper protection against biological agents (PIESA 1001:2004 and EAS 322:2002).

Relationship between Penetration and Retention

Penetration and retention requirements are equally important in determining the quality of preservative treatment. Penetration levels vary widely, even in pressure-treated material (Blew & Davidson 1971). In most species, heartwood is more difficult to penetrate than sapwood. In addition, species differ greatly in the degree to which their heartwood may be penetrated. In this study, both creosote penetration and retention proportionately increased with a strong positive correlation coefficient. This justifies why eucalyptus is used for heavy duty transmission lines since it requires both higher preservative retention and penetration. It should be noted, however, that all pole sizes in the study met the minimum penetration (15mm) and retention (115kg.m^{-3}) requirements (EAS 322:2002).

CONCLUSIONS AND RECOMMENDATIONS

It was concluded that:

Creosote penetration and retention were highest in 14 m poles (20,5mm and 193kg.m^{-3}) while penetration was lowest in 9m poles (18,4mm) and retention was lowest in 11 m poles (162kg.m^{-3}).

For all the pole sizes, creosote penetration was less than the sapwood depth.

Creosote penetration and retention were strongly and positively correlated, and the relationship was strongest in the 14m poles.

Irrespective of the differences in level of penetration and retention among the various pole sizes, all the poles acquired more than the required minimum standard level of penetration and retention.

The current treatment schedule seems better suited for the larger poles (14m) than the 9 and 11m poles.

It is recommended that:

Treatment schedules be varied with pole size category for better treatment. Smaller poles i.e. 9m and 11m should be treated for a longer period than 14m poles since they tend to have lager sapwood.

Measurements of sapwood/heartwood proportions be ascertained before treatment and related to creosote penetration and retention to ensure critical pole parts are sufficiently treated.

Since the average sapwood for the three pole sizes was approximately 26mm (Table 1), the 15mm minimum penetration basis by the Uganda Electricity Distribution Company Limited (UEDCL) is insufficient and should, therefore, be increased.

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