INVESTIGATION INTO THE CREEP BEHAVIOUR OF INITIALLY GREEN SMALL DIAMETER TIMBER POLES DRYING OUT UNDER LOAD

by

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Abstract

This paper describes a study that was carried out to determine the long term creep deflections of initially green timber poles which are to be used as roof timber.

The long term creep deflection that occurs in initially green timber subject to bending, as they dry out under load is often as much or more than the instantaneous deflection that occurs on application of load. Limiting of deflection is often the controlling design criteria in the sizing of dry timber beams. Thus the magnitude of creep deflection becomes more significant in the sizing of initially green timber poles in bending and drying out under load.

Pairs of poles were subject to different loading conditions for a period of six months and their deflection measured on a weekly basis. It was observed that the long term deflection is about double the instantaneous deflection.

1.0 Introduction

It is now necessary to encourage the use of small diameter timber poles (plantation thinnings) as building timber particularly in roof construction, as the supply of better known indigenous species can no longer meet the increasing demand for construction timber.

Eucalyptus and Pinus species were introduced to Sri Lanka some years ago and at present there exists a vast area under their plantation. While the larger diameter trees are used in pole form for transmission poles or are processed for furniture, the thinnings have had little use. Preliminary studies were carried out to assess the feasibility of using the thinnings as roof timber subject to bending (2,3). The bending strength and modulus of elasticity were found to be adequate. Both these species however, need to be preservative treated to increase their durability. Boron diffusion was considered a cost effective method of preservative treatment provided the poles are used while still in the green condition. A previous study (3) indicated that the poles removed from a Boron preservative tank took 3 to 4 months to reach equilibrium moisture content. Thus the poles must be loaded while still in the green condition and then allowed to dry out under load.

The limiting of bending stress, shear stress, bearing stress and deflection control the design or sizing of beams. For typical span to depth ratios, it is often the limiting deflection that controls the design of a seasoned timber beam. It is thus expected that limiting deflection will be even more the controlling design requirement for the green poles in bending and drying out under load.

2.0 Creep Behaviour

Creep is the increase of deformation with time, under a constant applied action. The parameters that influence creep of timber are the duration of load, the moisture content, the stress level and temperature. Under a given load, creep of timber may increase from two to four times for load duration ranging from six months to twenty years. Creep is more pronounced in wet timber than dry timber. The change in moisture content is a significant contributory factor to creep behaviour. It is the change in moisture content rather than the actual level of moisture content, that contributes to the long term deflection of timber. The higher the stress, the higher the rate of creep and the shorter the time before fracture. The higher the temperature, the greater the amplitude of creep

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deflection. However, when the temperature does not exceed 50°c, its influence on creep is negligible and is masked by the effects of moisture content.

The creep of poles is often defined by a term relating the deflection after a given period of time to the initial elastic deflection. This term is generally referred to as relative creep.

In this paper, relative creep is defined as:

$$K_{cr} \text{ at time } T = \frac{d_T \text{ at time } T}{d_i}$$

Where

d_T is the total mid-span deflection of pole at a period of time T after application of load

and

d_i is the total elastic mid-span deflection immediately after application of load.

Some of the relative creep factors recommended in different codes of practice are given in Annexe 1.

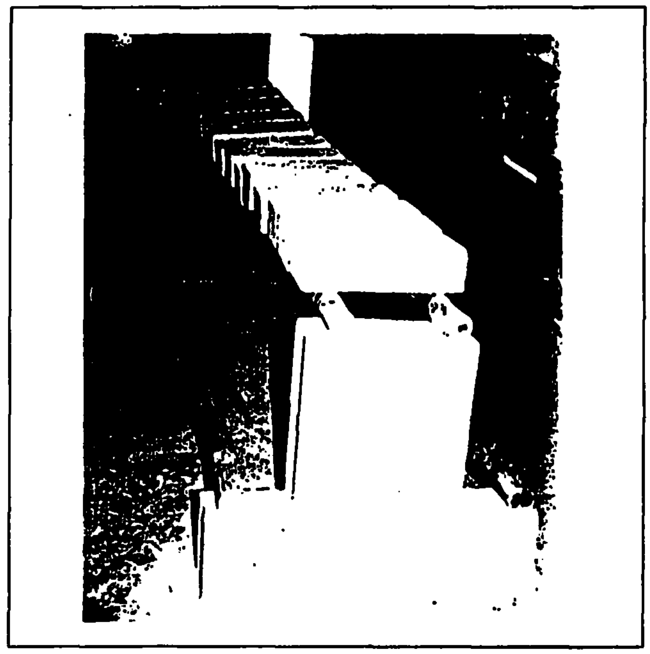
3.0 Objective

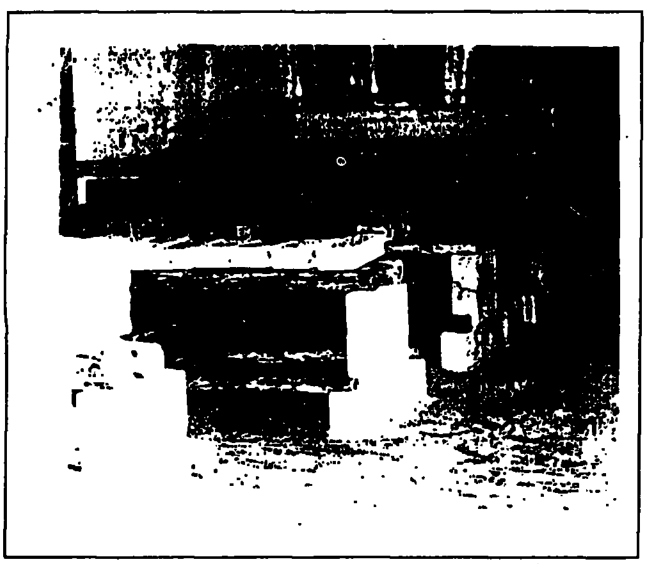
The objective of this study was to determine the magnitude of relative creep; ie. the factor (K_{cr}) that can be applied to instantaneous elastic deformations (d_i) calculated using beam theory to evaluate long term deformations (d_{lt}) (elastic and creep deflections) for initially green small diameter timber poles drying out under bending stress.

4.0 Experimental Programme

The poles were tested in modules. Each module consisted of a pair of simply supported poles at a lower level loaded by steel rails and a pair of simply supported poles at a higher level loaded by cement-sand blocks. The poles were selected in pairs matched for size (see Fig: 1). A total of 16 Eucalyptus Grandis and 12 Pinus Carribaea poles were tested. Details of the poles tested are given in **Table 1**. The nominal mid span diameter of the poles ranged from 75 mm to 130 mm. The loading on the poles was such that the nominal bending stress at mid-span of the poles was in the range of 3.5 N/mm², 5.0 N/mm² or 10 N/mm².

Deflection measurements were taken at mid-span of the poles initially at more frequent intervals and then every week over a period of 28 weeks. The vertical deflection was measured with the aid of a graduated spirit level held vertically beside a nail inserted horizontally at mid-span in the outerside (with respect to test module) of the pole (see Figs: 2 & 3).





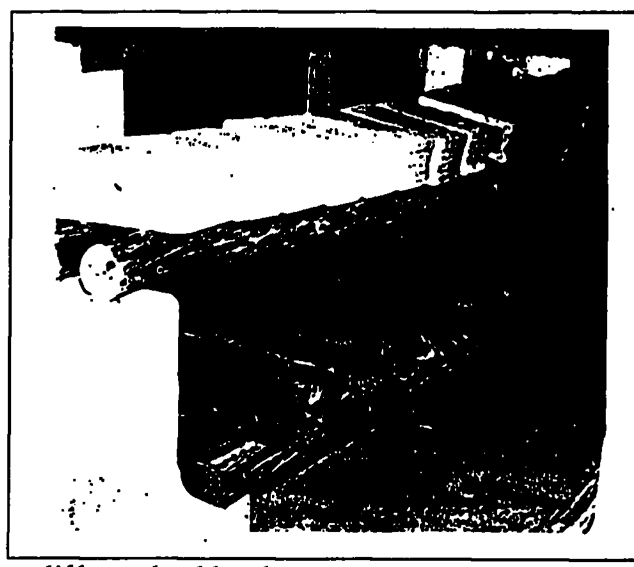


Fig: 1 - Pairs of poles subject to different load levels

Table 1: Details of poles tested (span of pole is 3.6m)

Species	Nominal mid-span diameter (mm)	Nominal bending stress at mid-span (N/mm^2)	No. of poles tested	Type of load	Description of load applied	Pole Refs.
	115	3.5	2	Pt.L.	4 No. steel rails	E17, E3
		5.0	2	u.d.l.	32 No. 100 thick blocks	E12, E7
Eucalyptus Grandis		3.5	2	Pt.L.	2 No. steel rails	E19, E16
	100	5.0	2	Pt.L.	4 No. steel rails	E1, E2
		10.0	2	u.d.l.	16 No. 150 thick blocks+ 16 No. 100 thick blocks	E11, E14
		3.5	2	u.d.l.	4 No. 100 thick blocks	E13, E15
	75	5.0	2	u.d.l	2 No. steel rails	E4, E5
		10.0	2	u.d.l.	16 No. 100 thick blocks	E8, E9
	130	5.0	2	u.d.l	32 No. 150 thick blocks	P2, P16
Pinus Caribaea		3.5	2	u.d.l	16 No. 100 thick blocks	P9, P11
	115	5.0	2	u.d.l	16 No. 150 thick blocks	P13, P14
		10.0	2	u.d.l	16 No. steel rails	P3, P6
	100	3.5	2	Pt.L.	2 No. steel rails	P4, P5
		10.0	2	Pt.L.	6 No. steel rails	P7, P10

The self-weight, density and moisture content of the poles were determined at the beginning and at the end of the test programme. The variation of moisture content of similar unloaded poles during the test period was also determined using a moisture meter.

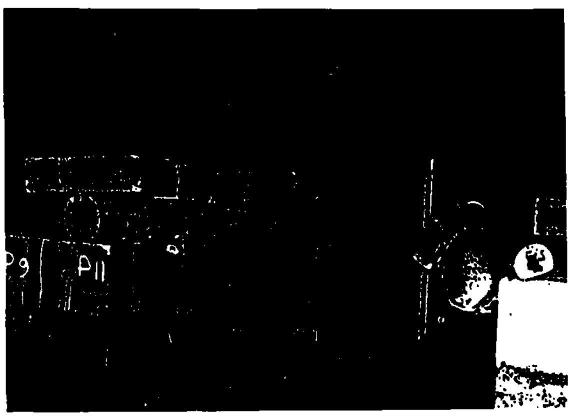


Fig 2: Deflection measurements in progress

5.0 Results

5.1 Physical properties

The average values of density and moisture content of the poles just prior to loading and on unloading are given in Table 2.

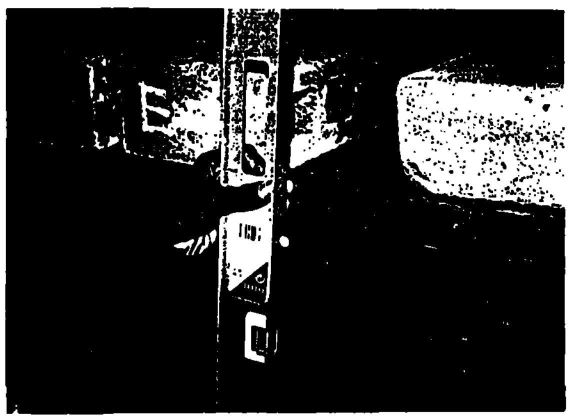


Fig: 3 Close-up of deflection measurement

Table 2 - Salient physical properties of poles tested

Property	Density (kg/m3)		Moisture Content (%)	
Species	Prior to test	on unloading	Prior to test	on unloading
Eucalyptus Grandis	870	510	100	21
Pinus Caribaea	910	410	175	21

5.2 Moisture variation

The variation in moisture content over the 28 week period is given in Fig. 4. The equilibrium moisture content is 21% and is reached 12 to 14 weeks from commencement of testing.

5.3 Mid-span deflections

The variation in mid-span deflection during the test period is given in Fig 5, for some of the timber poles. The measured deflection excludes the deflection due to the pole self-weight. However, as the poles were weighed prior to placing on supports the deflection due to self-weight can be evaluated. Since some of the poles are subject to low levels of bending stress the component of deflection due to self-weight is a significant proportion of the full elastic deflection.

It was also observed that very little (if any) increase in mid-span deflection took place in the final ten weeks of the programme. It is interesting to note that the equilibrium moisture content was reached at about this time.

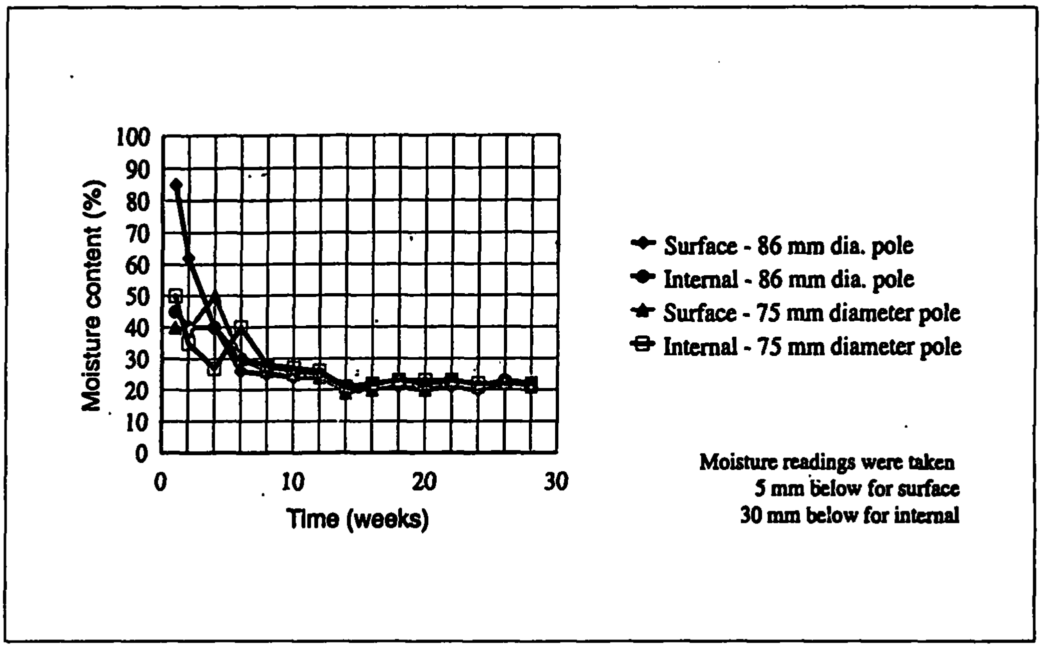


Fig: 4 Variation of moisture content of Eucalyptus Grandis poles

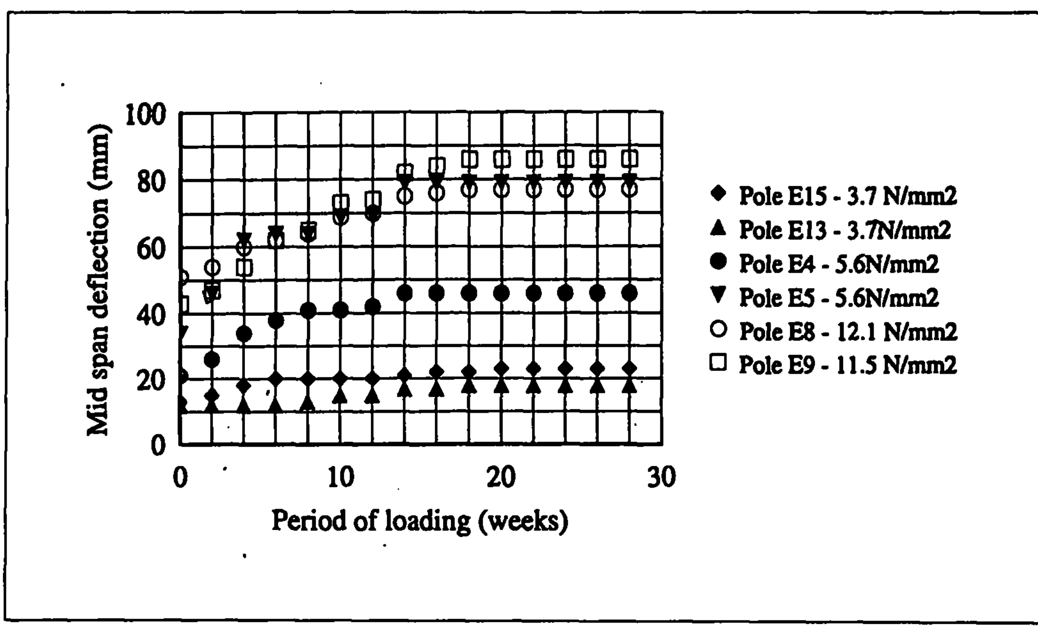


Fig: 5 Mid span defection of 75 mm diameter poles

5.4 Change in load with time

The load acting on the poles at the end of the 28 weeks is less than that at the commencement of the test programme. This is mainly due to the drying out of the poles and to a lesser extent due to the drying of the blocks. The reduction in self-weight of the Eucalyptus poles is about 40% while that of the Pinus poles is about 60%. It is important to note that similar decreases will occur in the poles forming a roof structure. The loss of weight of blocks is only about 4%.

5.5 Shrinkage of poles

Since the poles dry out to below the fibre saturation point (26%) there would occur a shrinkage of the pole cross-section and an overall lowering of the pole would occur. However, with typical values of radial shrinkage of 0.4% per % change in moisture content, the lowering would be about 1mm and this effect is ignored in the measurement of deflection.

Shrinkage also causes splitting (fissuring) of the poles and in some poles distorted the nail inserted to facilitate the measurement of deflection. Such poles were noted and not considered in the analysis.

5.6 Relative creep

The relative creep values for each of the poles is evaluated at a period of 28 weeks from load application. The relative creep values for Eucalyptus grandis poles tested range from 1.13 to 2.63 while for the Pinus poles tested they range from 1.20 to 1.70. It was also observed that there was no indication that relative creep increases with increasing bending stress and there was little variation in relative creep with differing pole diameters (**see Table 3**).

6.0 Recommendations

Instantaneous deflection of the poles under load to be calculated using green values for density and stiffness (see **Tables 2 and 4**).

The experimental data is not sufficient to determine separate values of relative creep for the two different species. Values of relative creep are recommended based on the deflection data of the Eucalyptus Grandis poles. There is more data available for this species and the long term deflection is more pronounced for this species.

Table 3: Values of relative creep

Pole Ref:	Mid-span diameter (mm)	Mid-span bending-stress (N/mm^2)	Relative creep for each pole	Relative Creep: Variation with stress	Relative Creep: Variation with pole diameter
E15	76	3.7	1.77		
E13	79	3.7	1.50	1.63	
E5	76	5.6	2.32		1.88
E4	76	5.6	2.19	2.26	
E8	73	12.1	1.51		
E9	75	11.5	2.00	1.75	
E19	99	3.5	1.83		
E16	103	3.1	1.73	1.78	
E1	97	6.0	1.53	1.53	1.85
E11	103	10.2	1.54	2.08	
E14	104	9.8	2.63		
E17	114	3.8	2.00		
E3	115	3.7	2.33	2.17	1.72
E12	121	5.6	1.41		
E7	122	5..4	1.13	1.27	
P5	103	3.8	1.20		
P4	108	3.4	1.27	1.23	1.23
P7	91	11.1	1.66		
P10	94	10.4	1.41		
P3	111	11.2	1.43	1.43	1.53
P6	113	10.7	1.22		
P16	131	6.1	1.70	1.55	1.55
P2	134	5.8	1.40		

Table 4 - Modulus of elasticity of green timber poles

Species	Modulus of Elasticity (N/mm2): Mean	Modulus of Elasticity (N/mm2): Minimum
Eucalyptus Grandis	11,000	7,000
Pinus Carribaea	10,500	6,000

It is recommended that the instantaneous deflection should be multiplied by a relative creep value of 2, for load sharing members and 2.5, for isolated members to determine the long term deflection.

The long term deflection to be compared with the appropriate deflection limit. In roof structures a limit of (span/200) seems appropriate.

Since this study was limited to poles subject to bending stress values of less than 10 N/mm2 and equilibrium moisture content of 20%, alternative values of relative creep must be evaluated if either the bending stress exceeds 10 N/mm2 or the poles reach an equilibrium moisture content significantly less than 20%.

7.0 Acknowledgement

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8.0 References

1. Structural utilisation of timber poles in developing countries: An investigation into the creep behaviour of initially green small diameter timber poles which dry out under load. TTL Report No. RREOF 93033/02

2. A testing programme to determine some physical and mechanical properties of small diameter timber poles plantation grown in Sri Lanka. RD 92086 - 2 Structural utilisation of timber poles in developing countries.

3. Structural utilisation of timber poles in developing countries. Seasoning behaviour of small diameter timber poles plantation grown in Sri Lanka.TTL Report No. RD 93006

ANNEXE 1 Design recommendations for determination of long term deflections as given in different codes of practice

New Zealand (from Table 2.5 of NZS 3603: 1993)

Duration of load	Moisture content at time of loading	Relative creep factor for bending
12 months or more	25% or more	3.0
12 months or more	18% or less	2.0
2 weeks or less	Any	1.0

Australia (from Table 2.6 of AS1720.1-1988)

Initial Moisture content (%)	Relative creep factor	
	Load duration ≤ 1 day	Load duration > 1 day
≤ 15	1	2
≥ 25	1	3

Europe (k_{creep} for sawn timber from EC5 - Eurocode recommendations)

$$u_{long\ term} = u_{instantaneous}(1 + k_{creep})$$

	Service classes		
Load duration class	1 <12%	2 12% - 18%	3 18%
Permanent and Long term	0.50	0.50	1.0
Medium term	0.25	0.25	0.50
Short term and instantaneous	0.0	0	0.25

Note: When the moisture content of the timber is near fibre saturation point and the timber dries out under load, it is recommended that the values corresponding to service class 3 are doubled.

USA (from National Design Specifications)

(Total= $\Delta_{Live} + K\,\Delta_{Dead}$
where

K is 1.5 for seasoned timber and
K is 2.0 for unseasoned timber

Canada (CAN/CSA-086.1-M89)

The Canadian code recommends that the maximum instantaneous deflection caused by the full design load does not exceed a limiting value of span/180. No explicit guidance is given for long term deflections. However it further recommends that if the permanent load constitutes more than 50% of the total load, the limit of span/180 be halved to span/360.