Study of reconditioning of the Eucalyptus ***camaldulensis dehn*** from Algeria (Arboretum Bainem)

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Abstract

This purpose of this study is based on the qualification in terms of physical properties (density, retractibility) of an Algerian wood (*Eucalyptus camaldulensis Dehn*) in order to use it as timber. The specie Eucalyptus is particularly sensitive to the collapse phenomenon which occurs during drying. This latter leads to checking and undesired structural deformations with appareance of cracks. A part of the collapse can be under control by a drying sufficiently well controlled. It is possible to recover an important part of collapse during the drying process by a steam treatment.

In this context, the objectives of this work will focus on the reconditioning of a Algerian wood "the Eucalyptus camaldulensis Dehn" from Bainem Arboretum located at 15 Km west of Algiers-Algeria.

The plant material is constituted with standards samples extracted from a tree at different levels. The comparison of the results before and after reconditioning allows a global valuation of the resulting collapse phenomenon. It is a hard and dense wood affected with collapse.

The anisotropy ratio of shrinkage is about 0.49 (the average is 0.5 for the eucalyptus), so a quite drying behaviour. The measured axial shrinkage al is weak, it constitute a good indicator for the tensionwood

(up to 1%). It moves from 0.11% (before reconditioning) to -0.17% (after reconditioning). The collapse recovery obtained is satifying. It is more important in tangential direction (reconditioning ratio: 1.18) than in radial direction (weak reconditioning ratio: 0.96). The density lost is 4% and constitute also a good indicator of the collapse phenomenon.

The correlation found between the volumetric shrinkage and the infradensity is negative and very significant (r=- 0.488). It indicates that the wood is less subject to the collapse phenomena with the increasing of density.

Eucalyptus camaldulensis Dehn / Valorization/ physical properties / reconditioning/collapse recovery.

1. Introduction

The Australian Eucalyptus is particularly sensitive to the collapse. However, at the present, no data are available concerning the technological characteristics of this wood in the purpose to endorse it. To overcome this lack, we start this preliminary study with view to characterize the physical plan and applying the technology of reconditioning of Algerian wood samples from *Eucalyptus camaldulensis dehn*. It is well known that during drying there are two different phenomena: the collapse and shrinkage. Both cause structural deformities parts and the appearance of fissures during the drying process. The collapse is a phenomenon that occurs when drying above the saturation point, where water in the fibers is evacuated from the empty cell. It is characterized by cell collapse localized. It's the result of the interplay between the distribution of free water content in wood and wood structure of the plan on the one hand, the structure and strength of anatomical elements on the other [1, $2_{a,b,c}$]. The collapse might be restricted by a well-controlled drying. A wide collapses are recovered by processing techniques applying steam during the drying [3]. Studies by Chafe (1985 and 1986) of 69 species of Eucalyptus, Sesbou and Nepveu (1990) on Eucalyptus camaldulensis dehn; have shown that there is a significant negative correlation between shrinkage due to collapse and wood infradensity. The shrinkage study without collapse is a special characteristic of material. It is carried out by using small tubes [4-$6_{a,b,C}$] [7].

2. Materials and methods

2.1 Materials

The raw material was kindly donated by the Arboretum from Bainem (Algeria), station of forested research of INRF (Table 1). A slice of about 80cm in length from the base strain of regeneration (length about 50cm) was used as a sample to carry out the physical properties of wood, in this area the intensity of collapse is the strongest. From this piece 2 planks heart (see Fig.1), were debited in their turn, and normalized to (36 cubes of 20x20 mm) normalized to the standard methods.

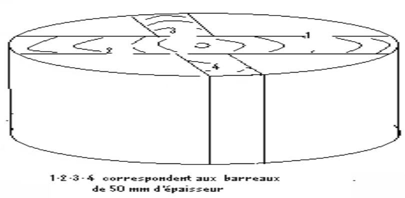

Figure 1. Plan cutting washers

Table 1: Characteristics of the sampling station (Arboretum of INRF Bainem)

Geographic Location	**Forest of Bainem**
Description of settlement	
Plot surface	10.04 ha
From a reforestation	Artificial settlement
Composition	Eucalyptus
Average height	15m

Average diameter	24cm
Spacing between 2 trees	2.5 to 3m
Average age	35 Years (1957 source INRF)
Current treatment	Nil
Description of the station :	
Topography	Very low slope
Exposure	South West
Altitude	165m

2.2 Method

The samples (36 cubics of 20x20mm) were analyzed; the following physical characteristics were carried out: shrinkage with collapse (before reconditioning); shrinkage without collapse (after reconditioning); the infradensity and moistures.

2.2.1 Shrinkage measurement with collapse (before reconditioning)

2.2.1.1 The shrinkage

The shrinkage was determined for every cube, according to three orthotropic directions (R, T, and L): axial, radial and tangential and between the both successive states:

- The saturated state: by immersion of samples in the water
- The dry condition in air: corresponding to a 12% moisture carried out by drying the samples in a climatic surrounding wall conditioned to 72% of moistures of air (dry temperature =50°C; wet temperature =44°C) during 48 hours.
- Anhydrous state: by drying out the test tubes, in the oven at l30°C±2°C, (oven dry base).

The analyses of this shrinkage are measured from the average dimensions of six points of measure by type of shrinkage with a specific comparator in 1/100 (see Figure2).

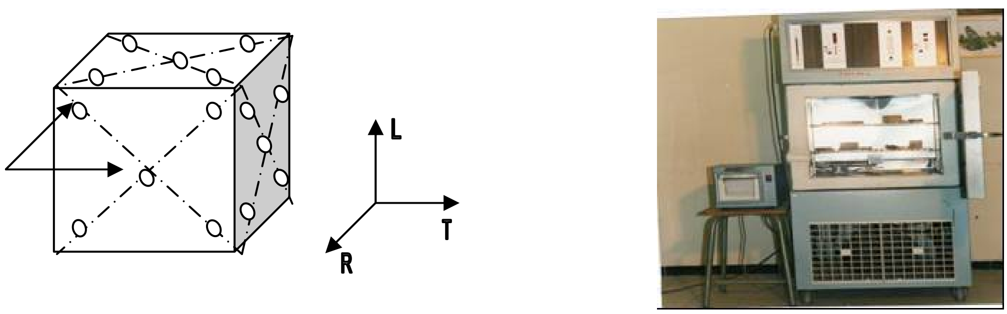

Figure 2: Achievement of measurement points shrinkage on 3 shots (TR, TL and RS)

Experimental device for shrinkage measuring

Autoclave for reconditioning of specimens

The shrinkage in percent (%) is calculated by the following expression:

$$R = (L_s - L_{12}) / L_{12} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: L_s: the average measures in the saturated state. L_{12}: the dry state in air.

2.2.1.2 Volumetric shrinkage in the dry air

It is calculated by the following expression:

$$RVS=1-(1-RTS)\ (1-RRS)\ (1-RLS)\ldots\ldots\ldots\ldots (2)$$

Where: RTS: tangential shrinkage. RRS: radial shrinkage. RLS: longitudinal shrinkage. CRTS: Coefficient of tangential shrinkage. CRRS: Coefficient of radial shrinkage.CRLS: Coefficient of axial shrinkage. CRVS: Coefficient of volumetric shrinkage

2.2.1.3 Complete volumetric shrinkage

It is calculated by the following expression:

$$RVT=1-(1-RTT)\ (1-RRT)\ (1-RLT)\ldots\ldots\ldots (3)$$

Where: RTT: tangential shrinkage. RRT: radial shrinkage. RLT: longitudinal shrinkage. CRTT: Coefficient of tangential shrinkage. CRRT: Coefficient of radial shrinkage.CRLT: Coefficient of axial shrinkage. CRVT: Coefficient of volumique shrinkage

2.2.2 Shrinkage measurement of wood without collapse (after reconditioning)

It is calculated by the expression:

$$RVC=1-(1-RTC)\ (1-RRC)\ (1-RLC)\ldots\ldots\ldots\ldots (4)$$

Where: RTC: tangential shrinkage. RRC: radial shrinkage. RLC: longitudinal shrinkage. RVC: volumetric shrinkage

Having been re-conditioned under vaporization at 110°C during 20 minutes in autoclave, the test tubes were oven dry base, what allows making the comparison of the shrinkage before and after reconditionnement. Measures in the dry stage in air in 3 directions and for the same length measured before reconditionnement were done again; the same expressions were applied to calculate the tangential, longitudinal, radial and volumetric shrinkages as well as the transverse anisotropy.

1.2.2.1 Calculation of the reconditioning fraction:

The analysis report of reconditioning, in a sample is defined as the report of shrinkage with collapse on the extraction without collapse. It is always superior to 1; hence, the recovery is the most important.

2.2.3 Transverse Anisotropy

$$\textit{Anisotropy ratio: } RR / RT \text{ ……… } (5)$$

2.2.4 Measurement of the infradensity

$$Y = M_0/V_s \text{……………… } (6)$$

Where: M_0: the anhydrous mass in kg. Vs: volume of the wood saturated in water (m^3).

$$Y = M_0/V_s = 1/\,(M_{max} / M_0 - 0{,}347) \text{ (calculated from Keylwerth)…………}(7)$$

where: M_{max}: maximum weight (saturation). M_0: anhydrous weight.

2.2.5 Moisture measurement

$$H\,(\%) = (m_H - m_0)\ 100/m_0) \text{ ………… } (8)$$

Where:

m_H: the mass, in gramme of the test tube before drying out. m_0: the mass in gramme of the anhydrous test tube is.

2. Results and discussions

To summarize the operation of drying the samples, we have represented the kinetics of these samples: D13 *, D12 *, D21 *, D31 *, D11 *, D32 *, D22*. These samples are regularly weighed to know at definite instants the evolution of the moisture of wood in the climatic surrounding wall (figure3).

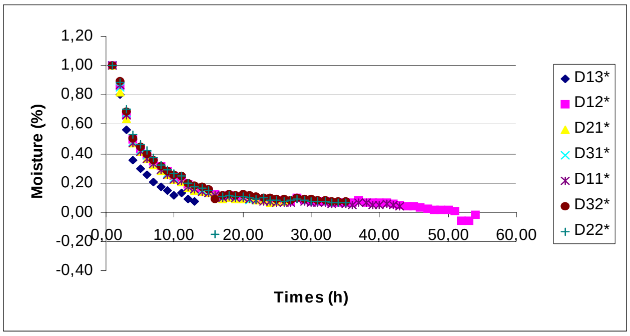

Figure 3. Kinetics drying test witnesses

On macroscopic plan, the collapse manifests by visible distortions to the naked eye of the test tube. Indeed, the form of the initially prismatic test tube with right angles, once collapse it taken is shown in figure 4. The faces curves (with an inside convexity) occurs by the subsidence of fibres. The later is much more pronounced in tangential direction than in radial direction. In axial direction, the subsidence of fibres is not observable for the reason that the big rigidity of the wood in this direction. Besides, we can see that the appearance of radial slits, which highlight the collapse of the woody rays. Hence, our results indicate in terms the weakness of woody plan. The reasons of deformations and longitudinal swelling between the saturated positions and the dry status in air: There is longitudinal swelling between saturated and dry forms in air. This characterizes a not free shrinkage. The mechanical behavior during the drying is the predominant factor of this swelling. Between dryness in air and anhydrous stages, we noticed a weak longitudinal shrinkage. From literature review this phenomenon is called "effect Coquille", (Kelsey, 1957): the wooden cube act during drying as the rigid box, which oppose to the shrinkage and go through a deformation comparable to affect of Poisson. The complete shrinkage of distortion can be considered to be the combination of two types of distortion:

Elastic deformation is reversible for affect of Poisson's were noticed above. Whereas, non-reversible plastic deformation, were noticed when subjected to wood hydration-dehydration cycles, furthermore, appears the collapse during drying process.

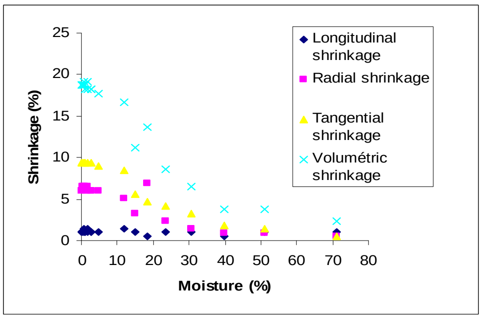

Figure 4: Variation of the different collections of sample of *eucalyptus camaldulensis dehn*

Tableau 2: Measurement of Physical Characteristics: infradensity and shrinkage of eucalyptus camaldulensis dehn wood with collapse at dry ambient air (H = 12%) (Before reconditioning)

Samples: 36	RLS (%)	RRS (%)	RTS (%)	RVS (%)	RRS/RTS	CRLS (%)	CRRS (%)	CRTS (%)	CRVS (%)	Y (g/dm^3)
Average	0,11	3.93	8.26	11.98	0.49	0.01	0.20	0.42	0.60	638.50
Standard deviation	0.16	1.93	3.71	5.08	0.17	0.01	0.10	0.23	0.31	43.51

Coefficient of variation (%)	141.74	49.12	44.96	42.45	34.24	141.28	51.85	54.70	50.63	6.81

Tableau 3: Measurement of Physical Characteristics: infradensity and complete shrinkage of eucalyptus camaldulensis dehn wood with collapse (Before reconditioning)

Samples: 36	RLT (%)	RRT (%)	RTT (%)	RVT (%)	RRT/RTT	CRLT (%)	CRRT (%)	CRTT (%)	CRVT (%)	Y (g/dm^3)
Average	0.33	6.03	10.43	16.10	0.59	0.01	0.20	0.35	0.54	638.50
Standard deviation	0.12	1.34	1.93	2.67	0.12	0.00	0.04	0.06	0.09	43.51
Coefficient variation (%)	37.59	22.19	18.49	16.56	20.39	37.59	22.19	18.49	16.56	6.81

Tableau 4: Measurement of Physical Characteristics: infradensity and shrinkage of eucalyptus camaldulensis dehn wood without collapse at dry ambient air (H = 12%) (after reconditioning)

Samples: 36	RLC (%)	RRC (%)	RTC (%)	RVC (%)	RRC/RTC	Y (g/dm^3)
Average	-0.17	4.11	7.01	10.35	0.66	666
Standard deviation	0.27	1.77	3.40	4.29	0.38	34.72
Coefficient of variation (%)	-157.10	43.06	48.52	41.40	57.73	5.21

3.1 Shrinkage with and without collapse

The results of the shrinkage stocks are summarized in tables 2, 3, 4 at dry ambient air (H = 12%). In the case of the shrinkage with collapse: we noticed an axial extraction of 0.1 %; a radial extraction of 3.9 %; tangential extraction of 8.3 % and a volumetric extraction of 12 %. After reconditioning, we clear see a drop in the extraction: An axial shrinkage about -0, 17 %; a radial shrinkage about 4, 11 %; tangential extraction about 7, 01 % and a volumetric extraction is about 10, 35 %, as was expected. Kingston and Risdon (1961) found on Australian samples a tangential shrinkage of 8, 9 % with collapse and 4, 8 % after reconditioning; a radial extraction of 4, 4 % with collapse and 2, 7 % without collapse. Wright [15] richer similar values for eucalyptus in Australia. The shrinkage without collapse is about 4, 6 % in tangential direction and 3 % in radial direction with a volumetric shrinkage of 7, 7 %. These results concern rejections from 18 to 20 years old. Although, in the case of the Australian samples, there were older grown-up trees. In Brazil, in the Institute of Sao-Paulo (1961), the experience shows 15.5 % to the tangential shrinkage, 6.8 % in the radial shrinkage, the volumetric shrinkage being 25.9 %. In Australia, among the commercialized eucalyptus trees, *E.Wandoo* is 2 % the weakest shrinkage without collapse and *E. Diversicolor*, mainly significant with 12.5 %. For the shrinkage axial found: 0.1% negligible compared to other shrinkages, with a high variability (141.7%). This may be a good indicator for the tension wood and juvenile (very important axial shrinkage exceeding 1%). In our case, this indicator of tension wood is lower. The infradensity is negatively associated with the axial shrinkage. The correlation is not found significant, but the trend is similar to that determined by Sesbou [16] on Moroccan and Italian eucalyptus aged 9 years old.

3. 2 Anisotropy

The average value found in our samples is 0.49, which is generally observed (0.50) between the two radial and tangential shrinkage. Wright [15] reported for eucalyptus a cross anisotropy of 0.5, the extremes being E.maculata with 0.7 and E.viminalis with 0.26. Clarke (1930) found for 200 samples of 60 species belonging to 21 genera, a report RR / RT ranging from 0.13 to 0.91. On the other hand, Keylwerth (1951) noted the European species for an anisotropy average is 0.61 (Sesbou, 1981). This strong anisotropy in the transverse plane is one of the main causes of distortions caused by the drying of wood.

3.3 Infradensity

The average value found Y= 639g/dm^3, helps to qualify the hard wood. It presents a coefficient of variation accepted for wood (7%). The loss of density is 4% and is also a good indicator of the phenomenon of collapse.

3.3.1 Correlations samples at the tree

The correlation between infradensity and shrinkage longitudinal collapse with the dry air is not significant at the 5%. The shrinkage longitudinal remains low has little variation in the volume of the extraction.

In other radial and tangential directions: The correlation between infradensity and radial shrinkage is not significant at the 5 per cent. However, the correlation (r =- 0582 ***) between infradensity and shrinkage with tangential collapse is highly significant (Fig. 6). The regression equation is as follows:

$$RTS\ (\%) = -0.0497Y + 39.992 \text{ with } R^2 = 0.339 \ldots (9)$$

The infradensity gives a negative link the shrinkage of volumetric collapse (figure7) with r =- 0.488 **: significant correlation. The regression equation is as follows

$$RVS\ (\%) = -0.0571Y + 48.403 \text{ with } R^2 = 0.238 \ldots\ldots (10)$$

The obtained trend curves concored with Sesbou (1981) results: more the density increases, the shrinkage is less important. Confirming that, the phenomenon of collapse is less pronounced for the densest woods. The woods most affected by the collapse are which contains the average density.

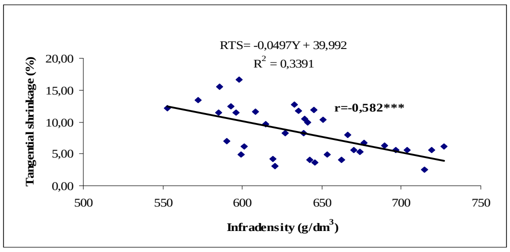

Figure 5. Relationship infradensity-shrinkage tangential to H = 12%

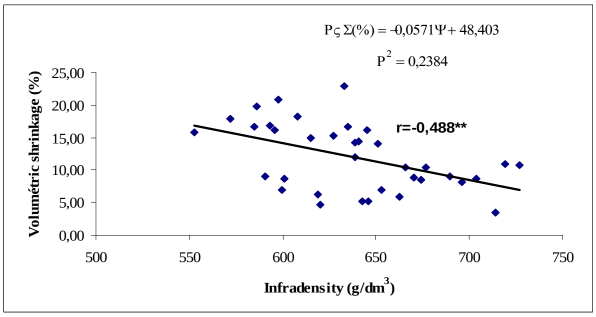

Figure 6. Relationship infradensity-shrinkage volumetric to H = 12%

The binding of infradensity and transverse anisotropy is positive with r = 0.475**. The regression equation is as follows:

$$RRS / RTS = 0.0018Y - 0.6859 \ldots\ldots\ldots\ldots\ldots (11)$$

With R^2 = 0.226

Further increasing of infradensity, more the anisotropy diminishes.

3. **Conclusion**

Based on the results obtained of this preliminary study on Algerian eucalyptus *camaldulensis dehn* we can conclude that:

The wood is hard and dense affected by the collapse.The correlation found is negative and very significant (r =- 0.488 **), indicates that over increases of the density, less the wood is subject to the phenomenon of collapse. Our results are consistent with the literature review. The intensity of collapse varies with the height in the tree; we confirm for all samples from the same tree that is more important from the bottom to summit. The reconditioning done on the specimens has reduced the collapse to a large extent. The first results, including correlation being found between the wood density and recovery are suitable. Demonstrate that the technique of reconditioning used on standard samples at the laboratory scale can be generalized and used on an industrial scale. The technique of reconditioning may be advantageously used for a better valuation of wood products from countries where eucalyptus have been introduced.

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