Non-destructive methods to estimate the physical aging of plywood

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Abstract This paper studies the relationship between aging, physical changes and the results of non-destructive testing of plywood. 176 pieces of plywood were tested to analyze their actual and estimated density using non-destructive methods (screw withdrawal force and ultrasound wave velocity) during a laboratory aging test. From the results of statistical analysis it can be concluded that there is a strong relationship between the non-destructive measurements carried out, and the decline in the physical properties of the panels due to aging. The authors propose several models to estimate board density. The best results are obtained with ultrasound. A reliable prediction of the degree of deterioration (aging) of board is presented.

Key words Ultrasound, screw withdrawal, resistance, density, aging, plywood.

1. INTRODUCTION

Several non-destructive methods are currently used to estimate the properties of wooden materials. Screw withdrawal resistance and probing have been successfully used in density estimation of wooden products (Bobadilla et al. 2009). Many references to the use of ultrasound and stress wave vibration methods in different types of board to evaluate different properties have been found (Vun et al. 2003 and Ross et al. 2003). Density, mechanical properties and non-destructive methods during aging have also been studied previously in particle and fibre boards (Bobadilla et al. 2009).

2. MATERIAL TESTED AND METHODOLOGY

176 pieces in 12, 15 and 25 mm thick plywood were tested. Test samples were prepared according to European standards EN 326-1:1995 and EN 325:1994. Conditioning was performed before all of the tests, in a climate chamber at 20±2° C temperature and 65 ± 5% relative humidity. The aging test to evaluate loss of properties was conducted according to EN 321:2002. Non-destructive tests were performed first, after which a quarter of the sample was separated to conduct destructive testing. The remaining sample was subjected to the aging sequence. After each aging cycle, another quarter was separated for testing. Overall density was determined according to EN 323:1994. Non-destructive measurements were obtained using two different sets of equipment: the Screw Withdrawal Force Meter (SWFM) by Fakopp, and the Sylvatest Duo ultrasound device by Concept Bois.

3. RESULTS

Regression models to estimate density using the Sylvatest and SWFM are presented:

$$\delta = A \times V + B \times F + C \times Z_{12} + D \times Z_{15} + E \qquad (7)$$

Where δ = density (kg/m^3), V = ultrasound velocity (m/s), F = screw withdrawal force (kN), Z_{12} and Z_{15} could be 0 or 1 depending on thickness, and the, A, B, C and D constants can be found in table 2.

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Table 1 – Models to estimate density using ultrasound wave velocity and screw withdrawal resistance.

Model	A	B	C	D	E	R^2
US	0.0580	0.0	-25.4001	24.8864	324.11	63
SW	0.0	36.9778	12.2418	43.8542	440.651	61
US and SW	0.0510	31.0996	30.4040	69.0658	262.66	66

Table 2: General results table for density, ultrasonic velocity and screw withdrawal force. The three columns of each variable correspond to board thickness. X (mean values), CoV (Coefficient of variation).

Aging	Density [kg/m³]						Ultrasound velocity [m/s]						Screw withdrawal force [kN]					
	X			CoV %			X			CoV %			X			CoV %		
Cycle	12	15	25	12	15	25	12	15	25	12	15	25	12	15	25	12	15	25
New	498	544	555	3	2	2	3287	3231	3770	3	7	4	0.94	1.30	2.77	17	18	13
1st	475	512	520	2	2	2	3176	2941	3656	3	6	2	0.92	1.15	2.59	23	17	12
2nd	462	510	508	2	2	3	3100	2950	3567	5	8	5	0.88	1.31	2.60	23	18	8
3rd	454	495	502	2	3	2	3138	2966	3527	5	7	3	0.77	1.14	2.41	18	16	10

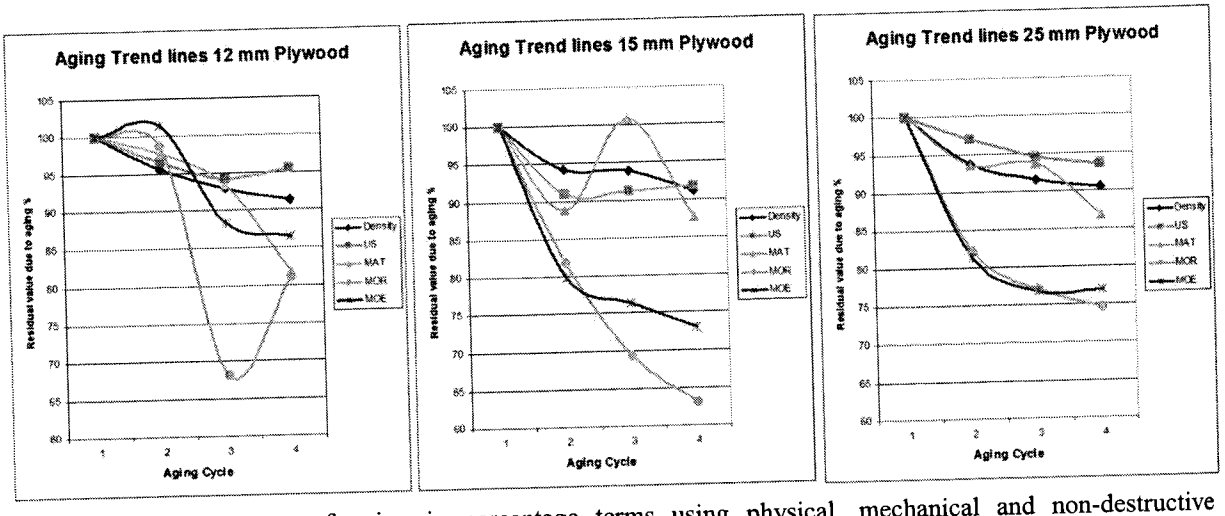

Figure 3 The progress of aging in percentage terms using physical, mechanical and non-destructive measurements in 12, 15 and 18 mm thick boards during the aging cycles. Density (kg/m^3), Ultrasound velocity (m/s) and screw withdrawal Force (kN). A clear parallel between the loss of properties and non-destructive measurements can be observed.

4. CONCLUSIONS

A less pronounced loss of properties than is the case for other boards, such as particle, fibre or OSB, can be observed (Bobadilla et al. 2009). The measurements also vary more during the aging process; this can be explained by the random adhesive fault line areas. A 5% reduction of ultrasound velocity or 15% of screw withdrawal force represents a loss of average density of just under 10%, with 30% loss of mean bending strength. In order to avoid variability, the authors recommend performing several measurements along the piece with the screw withdrawal force meter.

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