Eucalyptus urophylla STANDS WOOD UTILIZATION AT TWO DIFFERENT AGES FOR PRODUCTION OF PARTICLEBOARD PANELS

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ABSTRACT: This work aimed to assess the quality of wood particle panels manufactured with wood from *Eucalyptus urophylla* stands at age 7 and at age 12 years. To that end, particleboard, oriented strand board (OSB) and cement-bonded panels were produced in a laboratory and then analyzed for the following physical and mechanical properties: water absorption and thickness swell 2 and 24 hours after immersion, internal bond, compression parallel, as well as MOE and MOR from static bending. The obtained results demonstrate that tree age had little influence on the physical and mechanical properties of particleboard, OSB and cement-bonded panels. After evaluating the physical and mechanical properties of these three panel types, all manufactured with wood from *Eucalyptus urophylla* stands at age 7 and at age 12, we can argue that our results are satisfactory in comparison to existing literature results.

Key words: *Eucalyptus urophylla* stands, particleboard, OSB, cement-bonded panels.

UTILIZAÇÃO DA MADEIRA DE UM CLONE DE *Eucalyptus urophylla* EM DUAS DIFERENTES IDADES, NA PRODUÇAO DE PAINÉIS PARTICULADOS

RESUMO: *Neste trabalho foi avaliada a qualidade dos painéis particulados de madeira produzidos com madeiras de um clone de Eucalyptus urophylla com 7 e 12 anos de idade. Foram produzidos em laboratório painéis aglomerados, painéis de partículas orientadas – OSB e painéis cimento-madeira. Foram avaliadas as seguintes propriedades físicas e mecânicas dos painéis: absorção de água e inchamento em espessura 2 e 24 horas, ligação interna, compressão paralela, MOE e MOR em flexão estática. Os resultados obtidos demonstraram que a idade das árvores dos clones de Eucalyptus urophylla teve pouca influência sobre as propriedades físicas e mecânicas dos painéis aglomerados, OSB e cimento-madeira. Na avaliação geral das propriedades físicas e mecânicas dos três tipos de painéis particulados, produzidos com madeiras de clones de Eucalyptus urophylla com idades de 7 e 12 anos, pode-se afirmar que os resultados obtidos nesta pesquisa foram satisfatórios em comparação aos apresentados na literatura.*

Palavras-chave: Clones de Eucalyptus urophylla, aglomerados, OSB, painéis cimento-madeira.

1 INTRODUCTION

In Brazil, cultivated forests extend over almost 5.6 million ha and account for nearly 1% of the country's total forest cover. Out of this total, approximately 93% correspond to eucalyptus and pine plantations, particularly in the southeast, south and northeast regions. Eucalyptus plantations are concentrated in Minas Gerais, São Paulo and Bahia states and extend over nearly 2.4 million ha (ABIMCI, 2006). Eucalyptus wood is mainly used for coal, cellulose and paper production as well as particleboard and fiberboard panels, though more recently it has been used as sawn wood. Eucalyptus not only is a major source of raw material for the manufacturing industry but also helps reduce environmental pressure on the exploration of the Amazon Rainforest.

The main species of eucalyptus commercially used in Brazil are *Eucalyptus grandis, Eucalyptus saligna, Eucalyptus urophylla* and, to a lesser degree, *Eucalyptus viminalis* and *Eucalyptus dunnii* (SOCIEDADE BRASILEIRA DE SILVICULTURA, 2006). Studies have been performed in the field of genetic improvement of eucalyptus species in an attempt to increase forest productivity and enhance the characteristics of its wood. Yet, the use of new genetic material of *Eucalyptus spp* for industrial purposes requires more in-depth evaluations

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regarding timber yield, wood quality and its behavior when subjected to industrial processes (FERREIRA et al. 2004).

A topic widely discussed and researched concerning species of genus *Eucalyptus* is growth stress. Growth stresses become noticeable soon after trees are felled and cut into logs, with occurrence of splits on the log ends, which significantly reduces the final yield of processed wood (ROCHA, 2000). Technical solutions to eliminate or at least to minimize these defects include genetic improvement and different stages of the actual industrial process. The use of methods to release growth stress, log cutting procedures, log heating prior to veneering, or the use of reconstituted wood products technology, are only some examples of how the use of eucalyptus wood on an industrial scale can be made possible in Brazil.

Reconstituted wood products result from transformation of solid wood into small fragments and subsequent reconstitution into a new product by addition of adhesive binders. The resulting product will provide not only greater dimensional stability but also better distribution of tensile strength, besides many other technical, economical and environmental advantages (MALONEY, 1993). Reconstituted wood products such as particleboard, OSB and cement-bonded wood panels are some examples of materials that fit into this technological concept.

Particleboard panels are constituted by small wood particles that are hot-pressed and reassembled using a urea-formaldehyde resin (MALONEY, 1993; MOSLEMI, 1974). The technological advantages of particleboard panels are mainly attributed to their homogeneous structure and unrestricted use of raw material as to shape and size. Here, the bonding process is based on urea-formaldehyde resin and so particleboard panels are mainly used for production of furniture and room dividers (MOSLEMI, 1974). OSB panels are manufactured with wood strands which are bonded together by waterproof adhesive and wax and then subjected to intense heat and pressure to form an oriented strand mat. The geometry of the strand-shaped particles and their orientation in three cross-directional layers confer greater mechanical strength and dimensional stability on these boards (IWAKIRI et al. 2003). OSB panels are largely used in structural applications such as wall and roof sheathing and floor decking, I-joists, wooden packaging etc., on account of their good mechanical strength and dimensional stability (CANADIAN STANDARDS ASSOCIATION, 1993).

The production of cement-bonded wood panels uses a blend of wood particles, cement, water and chemical additives. While widely accepted and used by demanding markets such as Europe and Asia, this type of panel is yet to be introduced commercially into the Brazilian market (MOSLEMI, 1998).

According to Lopes et al. (2004), the above panels have some advantages over other types of panel, including high durability, good response to nail and screw use, similar workability to other wood products, high resistance to moisture as well as to fungi and insects, resistance to drastic temperature changes, not to mention that they are virtually fireproof, they provide thermal and acoustic insulation and are formaldehyde-free.

This work aimed to evaluate the influence of tree age on the quality of particleboard, OSB and cement-bonded panels manufactured with wood from a *Eucalyptus urophylla* stand.

2 MATERIALS AND METHODS

The wood used in this work came from a *Eucalyptus urophylla* stand from a plantation located in Curvelo region, Minas Gerais state, with trees at age 7 and at age 12.

The particles used for manufacturing the particleboard and cement-bonded panels were obtained using a disk flaker and then a hammer mill to reduce them to final size. The strand-shaped fragments used for manufacturing the OSB panels were obtained using a disk flaker, each being approximately 85mm long, 0.7mm thick and 25 mm wide.

2.1 Production of particleboard panels

The particleboard panels followed a nominal density of 0.70 g/cm³ and measured 480 x 480 x 15 mm. After drying them to an average moisture content of 3%, according to dry particle weight, it was applied 1% of wax emulsion and 8% of urea-formaldehyde resin, both in percentage of solids. The panels then were pressed at a temperature of 160ºC and specific pressure of 40 kgf/cm², for 8 minutes. After placing them in an environmental chamber at a temperature of 20$\pm$1ºC and relative humidity of 65$\pm$3%, test specimens were removed to perform the following physico-mechanical tests: water absorption and thickness swell 2 and 24 hours after immersion in water, internal bond, compression parallel and static bending. Tests followed procedures described in the D-1037-93 standard (AMERICAN SOCIETY FOR TESTING AND MATERIAL

- ASTM, 1996). Results were statistically analyzed using analysis of variance and the Tukey test at the 95% probability level.

2.2 Production of oriented strand board panels (OSB)

The OSB panels followed a nominal density of 0.65 g/cm³ and measured 480 x 480 x 15 mm. After they were dried to an average moisture content of 3%, it was applied, according to dry particle weight, 1% of wax emulsion and 8% of phenol-formaldehyde resin, both in percentage of solids. The particleboard mat was formed using a forming line where cross-directional layers of strands are deposited. The face-to-core ratio was set at 25:50:25. The panels then were pressed at a temperature of 180ºC and specific pressure of 40 kgf/cm², for 8 minutes. After the panels were placed in an environmental chamber at a temperature of 20±1ºC and relative humidity of 65±3%, test specimens were removed to perform the following physico-mechanical tests: water absorption and thickness swell 2 and 24 hours after immersion in water, internal bond, compression parallel and static bending. Tests followed procedures described in the ASTM D 1037 standard (ASTM, 1996). Results were analyzed statistically using analysis of variance and the Tukey test at the 95%. probability level.

2.3 Production of cement-bonded wood panels

The cement-bonded wood panels followed a nominal density of 1.1 g/cm³ and measured 480 x 480 x 15 mm. First the particles were immersed in cold water for 24 hours to remove substances known to inhibit cement curing. After the water was drained, the particles were rinsed and dried to an average moisture content of 12%. To form the cement-bonded composite, wood particles and cement were placed in a concrete mixer at a ratio of 1:2.75, then it was added water at a ratio of 0.25 to cement weight and 3% calcium chloride based on cement weight. After the material was blended into a homogeneous mix, the amount corresponding to one panel was weighted and spread over a mat forming box, each panel being pressed at room temperature and specific pressure of 40 kgf/cm² and kept clamped by a special device for 24 hours until completely hardened. The panels then were stacked and kept for 28 days in an environmental chamber at a temperature of 20±1ºC and relative humidity of 65±3% to finalize the cement curing process, after which time test specimens were taken to perform the following physico-mechanical tests: water absorption and thickness swell 2 and 24 hours after immersion in water, internal bond, compression parallel and static bending. Tests followed procedures described in the ASTM D 1037 standard (ASMT, 1996). Results were statistically analyzed using analysis of variance and the Tukey test at the 95% probability level.

3 RESULTS AND DISCUSSIONS

3.1 Particleboard panels

Table 1 illustrates mean values of water absorption and thickness swell 2 and 24 hours after immersion in water.

As regards water absorption 2 hours after immersion, the mean value obtained for panels manufactured with wood at age 12 was statistically higher than that for panels manufactured with wood at age 7. And as regards water absorption 24 hours after immersion, the difference between the mean values for each age was not statistically significant.

As regards thickness swell, no statistical differences were detected between the mean values for panels made from wood at age 7 and at age 12. Overall, results demonstrate that age difference in the *Eucalyptus urophylla* stand " more precisely age 7 and age 12 – do not significantly affect water absorption and thickness swell 24 hours after immersion in water. The mean values obtained for thickness swell after 24 hours – 42.33% and 46.00% – fall within the 34.33% to 45.45% range obtained by Iwakiri et al. (2000) for particleboard panels made from *Eucalyptus urophylla* wood.

Table 2 illustrates mean values of internal bond, compression parallel, modulus of elasticity and modulus of rupture from static bending.

Table 1 – Physical properties of particleboard panels.

Tabela 1 – *Propriedades físicas dos painéis aglomerados.*

Age	WA 2h (%)	WA 24h (%)	TS 2h (%)	TS 24h (%)
7	55.44 A	95.78 A	26.22 A	42.33 A
12	80.56 B	104.56 A	28.44 A	46.00 A

Means followed by the same letter are statistically similar at the 95% probability level.
WA: water absorption; TS: thickness swell.

Panels made from wood at age 7 presented a statistically higher mean value of internal bond than those made from wood at age 12. The same relationship can be observed for mean values of compression parallel to the surface. Thus the use of older wood contributed to reduce mean values of both internal bond and compression parallel.

The mean values of MOE and MOR for panels made from wood at age 7 and at age 12 did not differ statistically from each other, in fact proving very close in numerical terms. The mechanical properties results proved lower than those obtained by Iwakiri et al. (2000), whose mean values ranged between 7.73 and 10.2 kgf/cm² for internal bond, between 20,783 and 25,591 kgf/cm² for MOE, and between 129.5 and 155.2 kgf/cm² for MOR.

3.2 Oriented strand panels (OSB)

Table 3 illustrates mean values of water absorption and thickness swell 2 and 24 hours after immersion in water. No statistically significant differences were found between OSB panels made from *Eucalyptus urophylla* wood at age 7 and at age 12, with regard to mean values of water absorption and thickness swell 2 and 24 hours after immersion. The mean values of water absorption and thickness swell after 24 hours are compatible with results obtained by Iwakiri et al. (2004) in a study of six eucalyptus species, whose mean values ranged between 28.85% and 70.96% and between 15.71% and 67.05% respectively.

Table 4 illustrates mean values of internal bond, compression parallel to surface, and also MOE and MOR from static bending, parallel and perpendicular.

The mean values of internal bond for panels made from wood at age 7 and at age 12 did not differ statistically from each other, and results were found to be below the minimum requirement of 3.45 kgf/cm² as stipulated by the CSA 0437 standard (CANADIAN STANDARDS ASSOCIATION, 1993). In a study of OSB panels made

Table 2 – Mechanical properties of particleboard panels.

***Tabela 2** – Propriedades mecânicas dos painéis aglomerados.*

Age	IB (kgf/cm^2)	CP (kgf/cm^2)	MOE (kgf/cm^2)	MOR (kgf/cm^2)
7	4.77 B	69.83 B	15,498 A	80.00 A
12	3.00 A	48.96 A	15,486 A	73.25 A

Means followed by the same letter are statistically similar at the 95% probability level.
IB: internal bond; CP: compression parallel; MOE: modulus of elasticity; MOR: modulus of rupture.

Table 3 – Physical properties of OSB panels.

***Tabela 3** – Propriedades físicas dos painéis OSB.*

Age	WA 2h (%)	WA 24h (%)	TS 2h (%)	TS 24h (%)
7	37.30 A	65.26 A	11.65 A	22.43 A
12	42.40 A	69.07 A	12.34 A	23.98 A

Means followed by the same letter are statistically similar at the 95% probability level.
WA: water absorption; TS: thickness swell.

Table 4 – Mechanical properties of OSB panels.

***Tabela 4** – Propriedades mecânicas dos painéis OSB.*

Age	IB (kgf/cm^2)	CP (kgf/cm^2)	MOE par (kgf/cm^2)	MOE per (kgf/cm^2)	MOR par (kgf/cm^2)	MOR per (kgf/cm^2)
7	1.57 A	28.48 B	20,143 A	7,225 A	359 A	159 A
12	1.19 A	19.96 A	15,123 A	7,186 A	291 A	175 A

Means followed by the same letter are statistically similar at the 95% probability level.
IB: internal bond; CP: compression parallel; MOE par: modulus of elasticity parallel; MOE per: modulus of elasticity perpendicular; MOR par: modulus of rupture parallel; MOR per: modulus of rupture perpendicular.

from six species of eucalyptus, the internal bond values obtained by Iwakiri et al. (2004) ranged between 1.10 and 5.83 kgf/cm².

As regards compression parallel to the surface, it was noted that the mean value for panels made from wood at age 7 was statistically higher than for those made from wood at age 12. Statistically speaking, compression parallel was found to be the only mechanical property significantly influenced by tree age.

As regards MOE and MOR, no statistically significant differences were found between mean values at age 7 and at age 12, parallel or perpendicular. Yet, the mean values obtained in tests perpendicular to particle orientation were expressively lower than those obtained in tests parallel to particle orientation, suggesting that a 25/50/25 face-to-core ratio was not satisfactory in terms of balanced composition. With regard to requirements set by the CSA 0437 standard, the results did not reach the minimum values of 45,000 kgf/cm², 13,000 kgf/cm², 234 kgf/cm² and 96 kgf/cm², for MOE parallel, MOE perpendicular, MOR parallel and MOR perpendicular respectively.

3.3 Cement-bonded wood panels

Table 5 illustrates mean values of water absorption and thickness swell 2 and 24 hours after immersion in water.

No statistically significant differences were found between panels made from wood at age 7 and at age 12, regarding mean values of water absorption or thickness swell 2 and 24 hours after immersion. However, in terms of absolute mean values, it was noted an increasing tendency in thickness swell after 2 and 24 hours for panels made from wood at age 12.

The values of thickness swell – 0.13% and 0.25% after 2 hours, 0.63% and 0.75% after 4 hours – proved below the maximum reference values set by the Bison Wood-Cement Board process (1978), which are 0.8% and 1.8% respectively.

Table 6 provides mean values of internal bond, compression parallel, modulus of elasticity and modulus of rupture from static bending.

The mean value of internal bond for panels made from wood at age 12 is statistically higher than that obtained at age 7. The mean values – 2.04 and 3.16 kgf/cm² – proved below the reference value set by the Bison Wood-Cement Board process (1978), which is 4.0 kgf/cm².

As regards compression parallel, no statistically significant difference was found between mean values at age 7 and at age 12. The mean values – 48.13 and 54.15 kgf/cm² – are compatible with results obtained by Latorraca (2000) for cement-bonded wood panels from *Eucalyptus pellita* and *Eucalyptus citriodora*, which were 48.87 and 40.37 kgf/cm² respectively.

As regards MOE, the mean value obtained for panels made from wood at age 7 did not differ statistically from the mean value obtained for panels made from wood at age 12. The mean values – 12,369 and 14,347 kgf/cm²

Table 5 – Physical properties of cement-bonded wood panels.

Tabela 5 *– Propriedades físicas dos painéis cimento-madeira.*

Age	WA 2h (%)	WA 24h (%)	TS 2h (%)	TS 24h (%)
7	11.63 A	14.50 A	0.13 A	0.63 A
12	11.50 A	15.13 A	0.25 A	0.75 A

Means followed by the same letter are statistically similar at the 95% probability level.
WA: water absorption; TS: thickness swell.

Table 6 – Mechanical properties of cement-bonded wood panels.

Tabela 6 *– Propriedades mecânicas dos painéis cimento-madeira.*

Age	IB (kgf/cm^2)	CP (kgf/cm^2)	MOE (kgf/cm^2)	MOR (kgf/cm^2)
7	2.04 A	48.13 A	12,369 A	43.94 A
12	3.16 B	54.15 A	14,347 A	53.94 B

Means followed by the same letter are statistically similar at the 95% probability level.
IB: internal bond; CP: compression parallel; MOE: modulus of elasticity; MOR: modulus of rupture.

respectively – proved below the values obtained by Latorraca in a study with four eucalyptus species, which ranged between 18,754 and 34,650 kgf/cm². Lee (1984) obtained 15,783 kgf/cm² and 8,858 kgf/cm² as mean values for panels made from coniferous wood in the United States.

As regards MOR, the mean value obtained for panels from wood at age 12 was statistically higher than that for panels made from wood at 7 years. The mean values – 43.94 and 53.94 kgf/cm² – are compatible with results obtained by Latorraca in a study with four eucalyptus species, which ranged between 36.02 and 69.62 kgf/cm².

4 CONCLUSIONS

The results obtained in this work led to the following conclusions:

- As far as particleboard panels are concerned, age difference in the *Eucalyptus urophylla* stand – 7 and 12 – did not significantly influence water absorption, thickness swell, or MOE and MOR from static bending, while in regard to internal bond and compression parallel, panels made from wood at age 7 provided mean values statistically higher than panels made from wood at age 12.

- As far as OSB panels are concerned, except for compression parallel, all physical and mechanical properties being assessed provided statistically similar mean values comparing wood at age 7 to wood at age 12.

- The mean values of water absorption and thickness swell for cement-bonded panels did not differ statistically from each other comparing wood at age 7 to wood at age 12. In regard to mechanical properties, mean values of internal bond and MOR for cement-bonded panels made from wood at age 12 were statistically higher than those for panels made from wood at age 7. Likewise, mean values of compression parallel and MOE were not significantly influenced by age.

- Judging from overall analyses of the physical and mechanical properties in particleboard panels made from *Eucalyptus urophylla* wood at age 7 and at age 12, it is possible to argue that the results are satisfactory in relation to existing literature results. However, static bending and internal bond properties in OSB and cement-bonded panels were found to be below standard reference values.

- Further research in order to test processing variables such as adhesive and wax levels, particle treatment in cement-bonded panels, etc. is suggested.

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