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ORIGINAL ARTICLE

Properties of hybrid strand board composed of virgin and recycled wood strands

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Abstract

This study was to evaluate the feasibility of producing long strands of conventional sizes from post-consumer wood and to assess the impact on the properties of strand boards containing a fraction of such recycled strands. Randomly oriented strand boards were made using varying proportions of recycled wood (0%, 10%, 30%, 50% and 100%) mixed with virgin wood strands. To determine the influence of recycled wood on board properties, we analysed the fractional composition of strands, their wettability, sorption kinetics and cellulose crystallinity for both virgin and recycled wood, and tested various physical and mechanical properties of the resulting strand boards. We then compared the performance of these boards with the requirements of the European standard EN 300 and data from other studies. Boards containing recycled wood exhibited slightly lower but not statistically significant average values for modulus of rupture (MOR) and modulus of elasticity (MOE) compared with the control made from virgin wood. However, the results for internal bond (IB) strength indicated strong adhesion of the recycled strands, attributed to their favourable wetting behaviour. A key benefit of incorporating recycled wood was a significant improvement in the dimensional stability of the boards. In particular, boards made entirely of recycled strands demonstrated a 49.6% reduction in thickness swelling after 24 h of water immersion compared to those made exclusively from virgin wood. The findings indicate that substituting virgin strands with recycled counterparts enables the production of OSB/3 panels using shorter, narrower and thicker strands than standard virgin wood strands.

1 Introduction

Wood is a natural, renewable and biodegradable material, possessing excellent mechanical and thermal properties. These characteristics make it a valuable resource, aligning with the principles of bioeconomy and a circular economy. Consequently, in recent decades, there has been an increase in the use of wood beyond traditional applications, including in the production of construction materials, energy, chemicals and other products (Bernstein et al. 2016). However, recent projections suggest that wood production may not be sufficient to meet demand in Europe by 2030 (Höglmeier et al. 2014).

This rise in wood consumption is accompanied by an increase in the generation of wood waste and post-consumer wood products. From both an environmental and an economic perspective, the efficient recovery of wood waste – produced during wood processing and at the end of the service life of wood products – becomes essential. Processing this substantial amount of wood waste and post-consumer wood products can serve as a source of inexpensive raw materials for manufacturing wood composite materials.

It is not surprising that the growing consumption of wood composites – such as particleboard (PB), medium-density fiberboard (MDF) and oriented strand board (OSB) – has prompted manufacturers to seek new material resources. However, unlike natural wood, wood waste typically

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contains various additives (such as glues, varnishes and paints), contaminants (such as wood treatment chemicals and heavy metals) and pollutants (including glass, plastics and metals). The considerable heterogeneity of these inclusions significantly complicates the waste and recycling processes.

Currently, recycled wood is used primarily in the production of particleboard, largely due to less stringent requirements for the size of the wood particles. There have been numerous studies of the effects of various types of recycled wood and other lignocellulosic waste on particleboard properties (Azambuja et al. 2018a, b; Hameed et al. 2018; Iždinský et al. 2020, 2021).

The use of recycled wood in the production of OSB is complicated by the fact that, to obtain OSB with high mechanical properties, strands are needed with an appropriate slenderness ratio (the ratio of strand length to thickness), which is typically around 150 (Brinkmann 1979). In general, the strands used for OSB production should be between 75 mm and 150 mm in length, 5 mm to 30 mm in width and 0.4 mm to 0.8 mm in thickness (Barnes 2001, 2002).

The strands of waste wood are often shorter than those from native wood. It has been shown that the use of strands longer than 150 mm does not result in a significant improvement in the mechanical properties of the boards (Barnes 2001, 2002), while the use of shorter strands, as expected, degrades the properties of the boards (Nishimura et al. 2004).

There have been only a limited number of studies on the potential use of recycled wood to produce OSB. Saito et al. (1985, 1987) fabricated three-layer random and oriented particleboards with a density of 700 kg/m^3, using ring flakes of sugi (*Cryptomeria japonica*) for the surface layers and lauan (*Shorea* sp.) veneer particles (0.6, 1.4, 2.5–3.0 mm thick) for the core layers. The greatest orientation was observed with particles from the 1.4 mm veneer, while the bending properties generally decreased with increasing veneer thickness.

Hermawan et al. (2007) produced strand boards using sugi (*Cryptomeria japonica* D. Don) and Douglas fir (*Pseudotsuga menziesii*) strands sourced from construction scrap wood. They found that strand boards made from construction scrap wood outperformed standard type 18 particleboard (JIS A 5908). Moya et al. (2008, 2009) suggested that burned timber from prescribed burns and wildfires could serve as a promising alternative bio-feedstock for commercial OSB production. They found that the dimensional stability of OSB produced from severely burned trees was not significantly different from OSB produced from unburned trees. Moreover, the addition of 20% bark (by weight) to the raw wood materials had a significantly positive impact on the hygroscopic and dimensional stability – e.g., water absorption (WA) and thickness swelling (TS) – of the resulting OSB (Moya et al. 2008).

To meet the mechanical and physical property standards of EN 300, Mirski and Dziurka (2011a, b) proposed that small strands obtained by grinding solid wood fragments (carpentry waste, denoted as “scrap”) and unrefined particleboard type P2 (furniture board, denoted as “eco”) could replace virgin strands in the core layer of OSB. They found that OSB boards made with melamine-urea-phenol-formaldehyde (MUPF) and polymeric methylene diphenyl diisocyanate (pMDI) resins, containing up to 75% small strands, gave relatively high mechanical properties. Schild et al. (2019) demonstrated that it was possible to substitute up to 100% of the core layer strands in random OSB panels with unsorted contaminated waste wood particles. Although all properties met the standard requirements, TS and WA did not meet the target specifications.

Given the limited literature available on the potential applications of post-consumer wood in strand boards, in this study we aimed to evaluate the feasibility of producing long strands of conventional sizes from post-consumer wood and assess the impact on the properties of strand boards of including such recycled strands with virgin wood strands in their manufacture. Informed by the findings of Narayanamurti et al. (1958), we hypothesized that incorporating recycled-wood strands would improve the dimensional stability of hybrid OSB.

2 Materials and methods

2.1 Materials

For the recycled wood, silver fir (*Abies alba*) beams from a demolished 19th -century building were used. Based on dendrochronological analysis of tree-ring widths (TRW) using a TimeTable device with a resolution of 0.01 mm (SCIEM, Vienna, Austria), it was determined that the trees used in the construction were felled between late summer 1826 and summer 1827. To make the recycled wood strands, wooden beams with dimensions 200 × 200 mm were cut to a length of approximately 120 mm and split these into smaller parts with a thickness and width of approximately 70 mm. For the virgin wood, Norway spruce (*Picea abies*) juvenile logs with a diameter in the range of 150–200 mm and moisture content (MC) of around 110% were cut to a length of 120 mm and split them in half to secure parallel orientation to the knife during cutting in the knife ring flaker.

Most of the recycled wood with an initial MC of 10% was immersed in water at a temperature of 50 °C for 24 h, at which point it had reached approximately 40% MC. The wetting was to soften the wood and decrease the size of the

(a) virgin wood (b) dry recycled wood (c) wet recycled wood

(d) virgin wood (e) wet recycled wood

Fig. 1 Strands used for the manufacture of strand boards: **a**, **b** and **c** after disintegration; **d** and **e** after screening (>10 mm)

Table 1 Types of manufactured strand boards with different proportions of recycled wood strands

Boards	Proportion of recycled wood
R0	0%
R10	10%
R30	30%
R50	50%
R100	100%

particles during disintegration; some dry recycled wood was retained to test this effect. The virgin, dry recycled and wet recycled wood were separately disintegrated into strands (Fig. 1a) using a knife ring flaker (Maier MSF 1400, Dieffenbacher-CZ s.r.o., Czech Republic). The dried recycled wood was also disintegrated to study how the wetting process affects the dimensions of the strands. All strands were dried in a kiln dryer at 80 °C until they reached 8 ± 1% MC and then size-graded on 5-mm and 10-mm screens (Fig. 1). Strands smaller than 5 mm were discarded; those with dimensions 5–10 mm were used to make up a 10% proportion of strands for board production; 90% of the strands used were larger than 10 mm.

The resin we used was polymeric 4,4-diphenyl methane diisocyanate (pMDI) resin (Ongronat® WO 2750; BorsodChem Zrt., Hungary) with a solid content of 100% and viscosity of 170–230 mPa.s; while the wax was a water-based paraffin wax emulsion (SVH – 60; Dřevozpracující družstvo, Czech Republic) with a solid content of 60 ± 2% and a viscosity of approximately 24 mPa.s.

2.2 Manufacturing the strand boards

Randomly oriented strand boards were made with different proportions of recycled wood and virgin wood strands (Table 1) – three each of five different compositions. In making single-layer random OSBs, the strands were sprayed with 3% pMDI resin and, in the next step 0.5% wax by weight by spraying with an EL-4 model spinning disk atomiser (Coil Manufacturing, Surrey, BC, Canada) at a speed of 10,000 rpm. The result was three 600 × 600 mm^2

boards with 12 mm thickness and a target density 600 kg/m^3 for each composition. The boards were laboratory formed without any attempt to orient the strands by hand. The pressing parameters were: pressure 3.5 MPa, temperature 180 °C and time 30 s for closing, 240 s in position, and 80 s for continuous decrease of the pressure.

2.3 Testing procedures

2.3.1 Dimensions of strands

Fifty dried strands of each composition were measured for all dimensions (thickness, width and length), from which their slenderness ratio (SR) and the flatness ratio (FR) were determined. The SR (length/thickness) and FR (width/thickness) were calculated using equations suggested by Moslemi (1974).

The specimens were conditioned at 20 °C and 65% relative humidity (RH) until they reached a constant weight, before physical and mechanical testing. All properties were tested in accordance with European standards.

2.3.2 Dynamic water vapour sorption

Sorption isotherms of recycled and virgin wood samples were measured using a dynamic vapour sorption (DVS) instrument (DVS Resolution, Surface Measurement Systems Ltd., UK) that consists of a high-precision microbalance housed in a temperature- and humidity-controlled chamber. Before measurement, 20–30 mg samples were sectioned from each specimen group using a sledge microtome (WSL, Switzerland) and then placed in the sample holder of the DVS microbalance. For each group, five replicate measurements were taken, and the average sorption isotherm was calculated. Equilibrium moisture content (EMC) was determined over a relative humidity (RH) range of 0% to 90% in 10% increments, followed by a reverse sequence from 90% back to 0%. Water vapour was used as an absorbent throughout the experiment. The measurement procedure included an initial drying phase, followed by both sorption and desorption branches of the isotherm. Sorption measurements were taken at a constant temperature of 25 ± 0.1 °C under a nitrogen flow of 200 standard cubic centimetres per minute (sccm). Samples were dried before measurement by exposing them to dry nitrogen and heating them to 95 °C for 120 min. During sorption, the samples were subjected to a stepwise increase in water vapour partial pressure, up to a maximum of 90% RH, after which desorption began using a reverse sequence. Each RH step was maintained until dynamic equilibrium was achieved. Equilibrium was defined as the point at which the rate of mass change was less than 0.001% of the reference mass per minute. All measurements were completed in 6,000 min. The moisture content (MC) at each RH step was determined based on the oven dry mass, in accordance with EN 13183-1 (2002).

2.3.3 Water contact angle measurement

Changes in the wettability of virgin and recycled wood surfaces were determined by measuring the static contact angle using the sessile drop method. The evolution of the contact angle between a drop of deionised water and the tested sample was tracked at different times from the point at which the drop was laid on the surface (time steps of 10 s). Twelve sessile drops of 2 µl volume were used for the wettability evaluation. A contact angle goniometer of SEE System E (Advex Instruments, Brno, Czech Republic) was used for the measurements.

2.3.4 FTIR analysis

FTIR spectra were measured on a Bruker Vertex 80v spectrometer equipped with a diamond ATR crystal. The resolution was 4 cm^{-1}; aperture 8 mm and measured region 400-4,000 cm^{-1} for 100 scans. Fifty spectra were chosen for each composition sample to provide good data for averaging. The spectra were modified in Opus software using background modification and min-to-max normalisation for all spectra. From the modified spectra, the average spectrum for virgin wood (REF) and the average spectrum for recycled wood were calculated. The REF calculated values for intensity rates are stated as 100%.

2.3.5 Density and density profile

The density EN 323 (1993) was determined for four specimens cut from each panel. Density profiles were measured on three 50 mm × 50 mm × 12 mm specimens cut from each panel. Vertical density profiles (VDPs) were obtained at an interval of 0.05 mm through the sample thickness using an X-ray density profile analyser (DPX300-LTE, Imal, Italy) and the average density profile was calculated.

2.3.6 Wood-water relations

The MC was determined for ten specimens with dimensions of 50 mm × 50 mm, in accordance with EN 322 (1993). The TS and WA were measured in accordance with EN 317 (1996) using 12 specimens of the same dimensions. These measurements were taken after 24 h, 48 h and 168 h (7 days) of immersion in water.

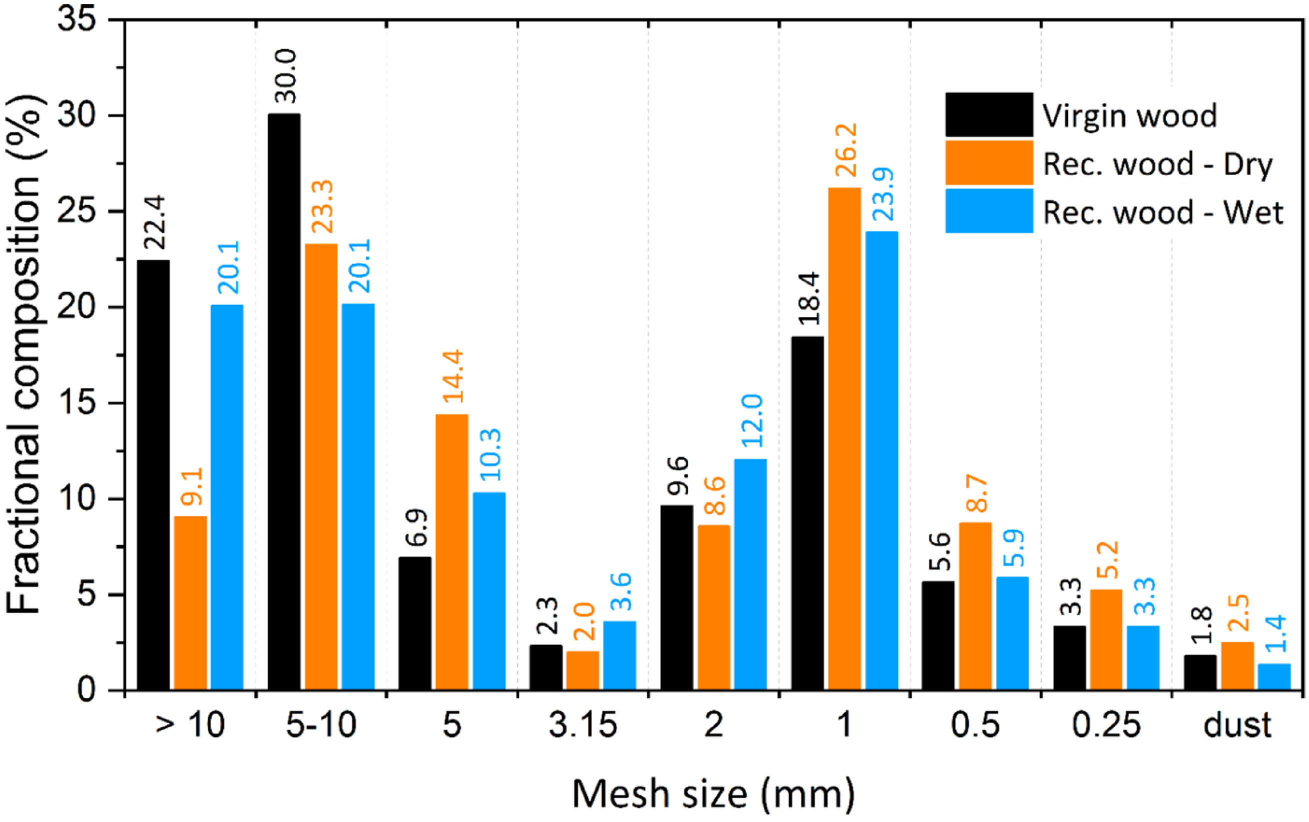


Fig. 2 Sieve analysis – percentage representation of virgin, and dry and wet recycled wood strands

2.3.7 Mechanical properties

Three-point bending tests were conducted in accordance with EN 310 (1993) to determine the modulus of elasticity (MOE) and modulus of rupture (MOR) of four specimens cut from each panel, with dimensions of 290 mm × 50 mm and a span of 240 mm. The internal bond (IB) strength was determined according to EN 319 (1993) for 12 specimens, each measuring 50 mm × 50 mm. Mechanical testing was performed using a Zwick® Z050 universal testing machine equipped with testXpert v11.02 software and a 50 kN load cell (Zwick GmbH & Co. KG, Ulm, Germany).

2.4 Statistical analysis

Data were processed in Statistica 10 software (StatSoft Inc., USA) and evaluated using a one-factor analysis of variance (ANOVA), completed with Tukey's honest significance test (HSD test).

Table 2 Strand characteristics

Wood species	Length (mm)	Width (mm)	Thickness (mm)	Slenderness ratio (SR)	Flatness ratio (FR)
Virgin wood	93.7 (25.9)	22.4 (8.2)	0.82 (0.25)	114.3	27.3
Recycled wood	88.5 (23.5)	12.9 (3.9)	1.04 (0.30)	85.1	12.4

Numbers in parentheses represent the standard deviation

3 Results and discussion

3.1 Strand characterisation

Sieve analysis (Fig. 2) revealed the relative distribution of the size fractions of strands, made from virgin wood and dry and wet recycled wood, pertinent to the production of particleboard. Figure 2 shows that the dry recycled wood produced fewer large strands and a higher proportion of small strands. However, the performance of recycled wood improved with soaking, producing a greater number of large strands and fewer small ones. This distribution more closely resembles that of virgin wood.

The results of the strand measurements are illustrated in Table 2, which gives the dimensions (length, width and thickness), slenderness ratio (SR) and flatness ratio (FR) of the examined samples. The average MC of the strands was 7.8%. It was observed that the samples of virgin and recycled wood differed significantly in strand size and aspect ratio. This discrepancy occurred despite the fact that the recycled wood was immersed in water for 24 h prior to disintegration. On average, recycled wood strands were 5.5% shorter than virgin wood strands. Specifically, the average lengths of the virgin and recycled wood strands were 93.7 mm and 88.5 mm, respectively. More pronounced changes were observed in the width and thickness of the strands. On average the recycled wood strands were 42.4% narrower than the virgin wood strands, while the recycled wood strands were 26.8% thicker than the virgin wood strands. The SR and FR for the virgin wood strands were 25.5% and 54.6% higher, respectively, than the recycled wood strands. These differences could significantly affect the mechanical properties of the resulting boards.

Our observations are in agreement with previous studies that have examined particle length reduction as a result of reprocessing. Other authors (Azambuja et al. 2018a, b), who evaluated the use of recycled wood particles from construction and demolition waste in the production of particleboards, also found that industrial particles exhibited higher average slenderness ratios and surface areas per unit weight, showing statistically significant superiority compared to particles derived from construction and demolition waste.

3.2 Dynamic water vapour sorption

The sorption kinetics for virgin and recycled wood, illustrated in Fig. 3, show that the virgin wood reached a higher EMC than the recycled wood. It is evident that the deviation between recycled and virgin wood started to increase significantly at sorption above 60% RH. At 80% RH, recycled wood reached almost 1% point less EMC, 15.02% for virgin wood and 14.15% for recycled wood. In desorption, the curve between recycled and virgin wood corresponds at lower than 40% RH. Recycled wood samples also achieved less hysteresis than virgin wood samples. Other authors (Kohara and Okamoto 1955; Sonderegger et al. 2015) also observed that the sorption values of aged woods were similar or slightly lower than those of recent woods.

3.3 Wettability of strands

The evolution of the contact angle over time for both virgin and recycled wood surfaces is presented in Fig. 4. There is a distinct and substantial difference in wetting behaviour between virgin and recycled wood surfaces. For the recycled wood surface, the contact angle values were much smaller than for the virgin wood surface (Fig. 5). The contact angle decreased with increasing wetting time. On a virgin wood surface, spreading was the dominant mechanism, whereas on the recycled wood surface, penetration prevailed. Water droplets penetrated more rapidly into the recycled wood surface than the virgin wood surface, which may have been due to more brittleness or microcracks, checks, splits or mechanical damage in the recycled wood (Falk 1999). These structural features facilitate water intrusion, thereby improving surface wettability. However, an accurate explanation of this phenomenon requires further study. Wood wettability is an important parameter that has a great influence on the bonding strength and mechanical properties of boards. The greater wettability of recycled wood may indicate that recycled strands bond together better.

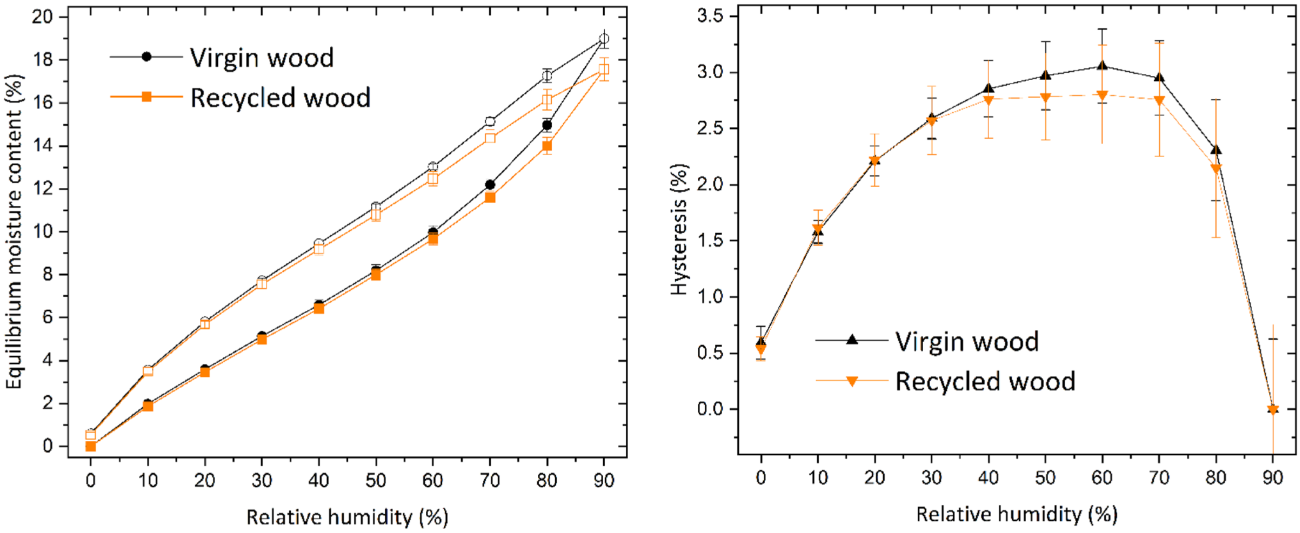


Fig. 3 Sorption isotherms of samples on the left, hysteresis between sorption and desorption on the right

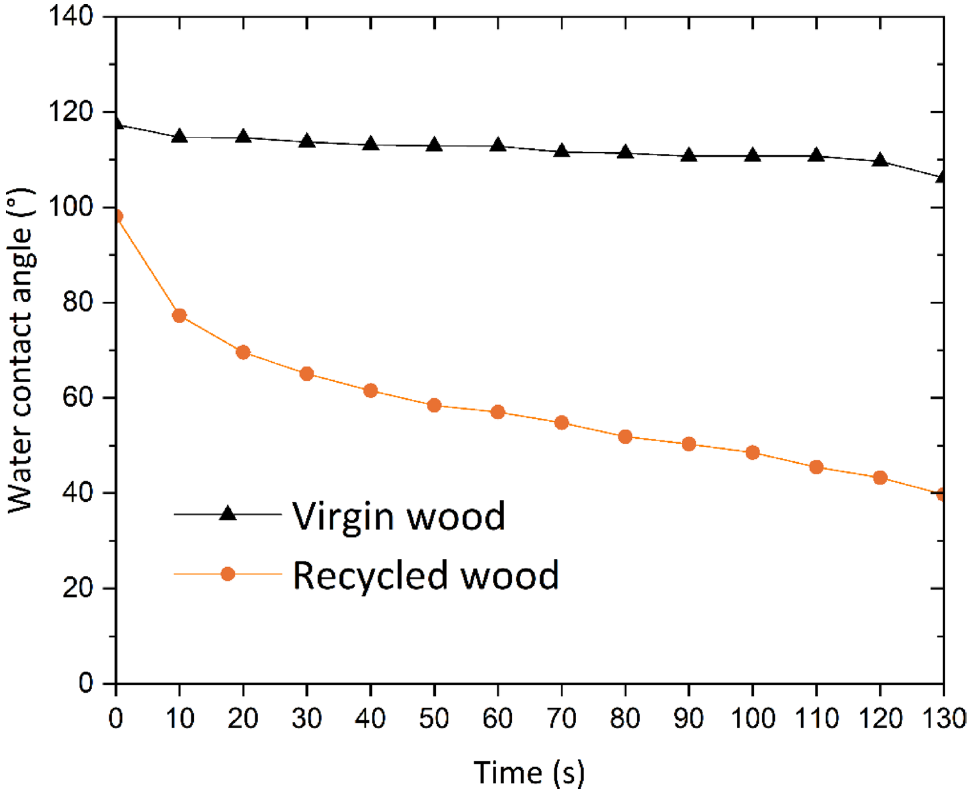


Fig. 4 Changes in contact angle of distilled water as a function of time on virgin and recycled wood surfaces

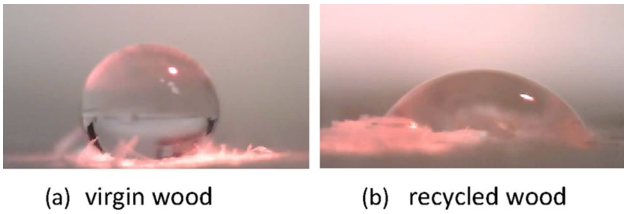


Fig. 5 Water drop shape on virgin **a** and recycled **b** wood surfaces

3.4 FTIR analysis

The colour of wood depends on its basic chemical composition and, thus, the discolouration observed in recycled wood (Fig. 1e), should be a result of alterations in its chemical components. From the IR spectra (Figs. 6 and 7), several changes in the signal intensities were observed. The most pronounced change was that at 1,734 cm^{-1}, attributed to the C=O stretch in xylan (hemicelluloses). The peak intensity

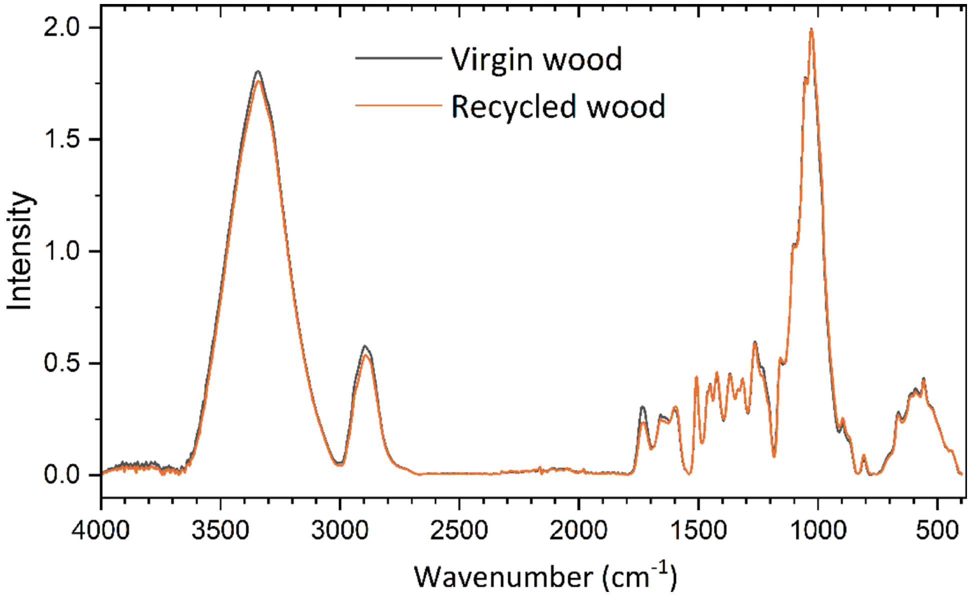


Fig. 6 Average FTIR spectrum for virgin and recycled wood samples

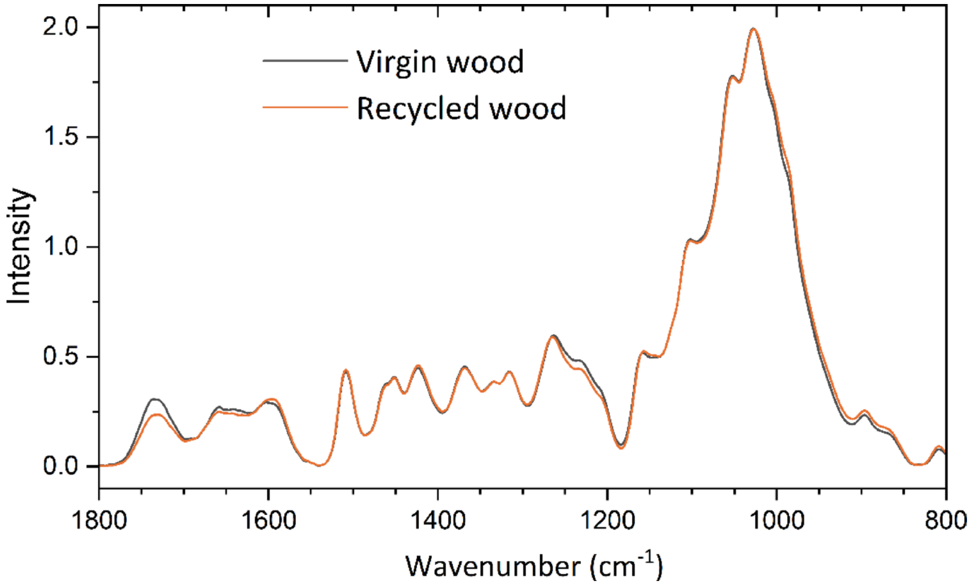


Fig. 7 Average FTIR spectrum for virgin and recycled wood samples - detail

Table 3 Physical properties of strand boards

Board	Density (kg/m^3)	TS24 (%)	TS48 (%)	TS168 (%)	WA24 (%)	WA48 (%)	WA168 (%)
R0	612 (30) A	22.4 (2.4) B	28.9 (2.1) C	34.5 (3.1) C	42.7 (3.3) C	54.9 (4.0) C	86.8 (5.3) C
R10	622 (36) A	14.8 (3.4) A	22.5 (2.9) B	31.6 (2.1) B, C	35.8 (4.0) B	47.6 (5.0) B	79.3 (4.5) B
R30	623 (31) A	13.7 (3.7) A	21.3 (3.1) A, B	29.9 (2.2) A, B	31.0 (2.4) A	41.5 (3.8) A	74.4 (2.6) A
R50	628 (27) A	11.7 (2.7) A	18.8 (3.5) A, B	29.3 (1.9) A, B	29.6 (2.5) A	39.8 (3.1) A	72.6 (2.9) A
R100	637 (19) A	11.3 (2.0) A	17.7 (3.0) A	27.5 (2.4) A	29.6 (2.5) A	39.3 (2.9) A	72.3 (2.8) A

decreased by 27.5% for the recycled wood sample, suggesting a natural decomposition of hemicellulose. Furthermore, the peak intensity at 1,658 cm^{-1}, associated with absorbed water and conjugated C-O, was 20.4% lower for the aged sample. The recycled wood also gave a slight increase of the $I_{1,508}$/ $I_{1,368}$, i.e., the lignin/carbohydrate intensity band ratio, namely from 0.94 to 0.99. For 400-year-aged spruce wood, a similar increase was reported in the work of Ganne-Chedeville et al. (2012). The suggested explanation for the increase was the formation of more condensed structures in the lignin of naturally aged (old) samples.

Cellulose crystallinity was assessed using two methods: lateral order index (LOI) and total crystallinity index (TCI), from the peak intensity ratios of $I_{1,422}/I_{893}$ and $I_{1,368}/I_{2,900}$, respectively. For both methods, recycled (aged) wood gave a higher level of cellulose crystallinity, namely 3.7% and 1.6% for LOI and TCI, respectively. A higher crystallinity index observed in the recycled wood can improve the dimensional stability of the strand boards (Chedeville et al. 2012).

3.5 Physical properties of boards

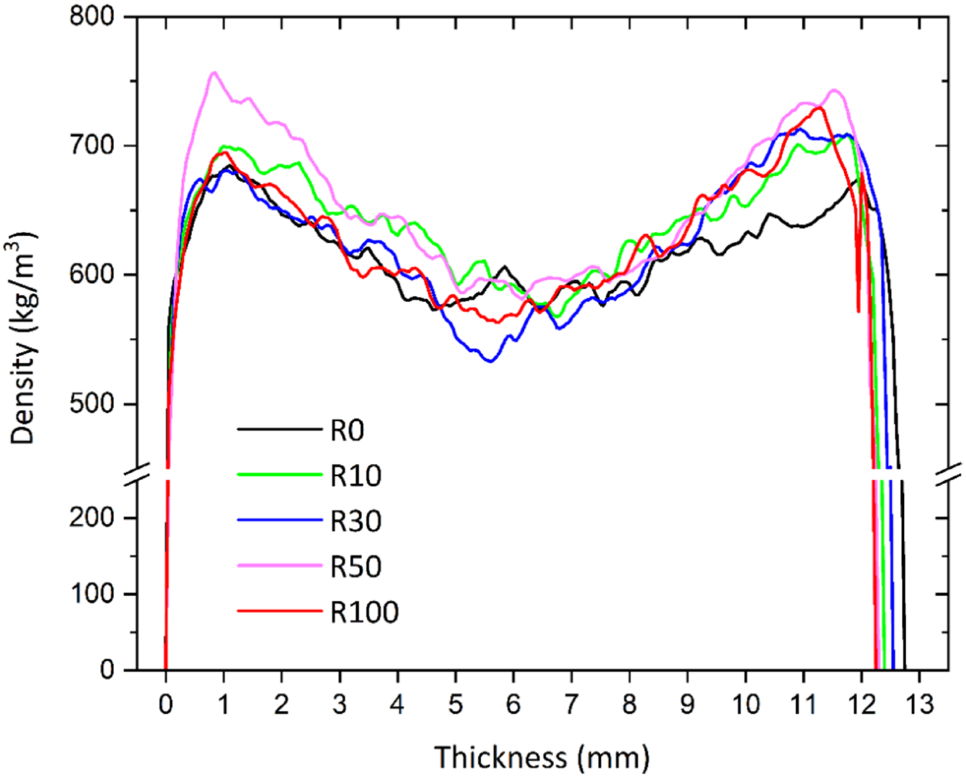
The results of the experiments investigating the physical properties of the manufactured boards are presented in Table 3; Fig. 8.

Means with the same letter in the column do not differ statistically according to Tukey’s test ($\alpha = 0.05$). Numbers in parentheses represent standard deviation.

The density of the strand boards ranged from 612 kg/m³ for R0 to 637 kg/m³ for R100 (Table 3). All average densities exceeded the target value of 600 kg/m³; however, no significant differences were observed between the densities of boards made of virgin strands and those made from recycled wood. The density of boards made with recycled wood was slightly higher than that of control boards (R0, which contained 0% recycled wood strands). This can be attributed to the smaller size of the recycled wood strands (Table 2), which helped to fill the hollow spaces between the strands. The measured VDPs (Fig. 8) were consistent with those reported in earlier studies on strand boards (Jin et al. 2009; Schild et al. 2019). All VDPs exhibited typical profiles, with higher densities observed in the faces and lower densities in the cores.

The TS values after 24, 48 and 168 h of immersion for strand boards made of recycled wood were lower than those reported for boards made from virgin wood. Similarly, the average WA values after 24, 48 and 168 h of immersion for boards made from recycled wood were also lower than those for control boards made from virgin wood. Furthermore, the TS values after 24, 48 and 168 h were statistically lower for the same group of boards that showed lower

Fig. 8 Vertical density profiles for strand boards with different proportions of recycled wood



WA. However, there were no statistically significant differences in TS after 24 h between boards containing 10%, 30%, 50% and 100% recycled wood. There is a noticeable trend correlating the reduction in TS and WA values to an increased proportion of recycled wood. As the proportion of recycled wood in the board increased from 0% to 100%, the TS after 24 h decreased by nearly half (49.6%), and the WA after 24 h decreased by 30.7%. Therefore, boards containing strands of recycled wood exhibited a clear reduction in swelling compared to those made from virgin wood, primarily due to the recycled (aged) wood's lower sorption behaviour (Fig. 3), lower hemicellulose content (Fig. 7) and higher crystallinity. Narayanamurti et al. (1958) attributed the lower amount of water taken to the old timber samples by a clear decrease in their hygroscopicity.

After 24 h of immersion, the TS values for all boards made of recycled wood (R10, R30, R50 and R100) met the 15% minimum requirement of the European standard EN 300 (2006) for OSB/3.

In contrast, the study conducted by Schild et al. (2019) reported average TS and WA values for OSB with contaminated waste wood particles that exceeded the 15% limit specified by the CSA 0437 Series-93 standard. In another study (Azambuja et al. 2018a, b), particleboards containing 50% recycled timber residue also gave lower average TS values than the control. However, after 24 h of water immersion, none of the treatments met the minimum requirement of 15% specified by the European standard EN 312 (2010).

3.6 Mechanical properties of boards

Strand boards containing recycled wood gave lower average MOR and MOE values than the control sample made of virgin wood (Fig. 9); however, these differences were not statistically significant. The highest MOR value of 24.9 MPa was recorded for boards made of virgin wood (R0), while the lowest value of 21.7 MPa was observed for boards made entirely from recycled wood (R100). Therefore, a trend of decreasing MOR and MOE values was observed as the proportion of recycled wood strands increased from 10% to 100%. This result may be attributed to the slenderness ratio of the virgin wood strands, as a higher SR is typically associated with improved bending properties (Moslemi 1974; Maloney 1993). Furthermore, the reduced bending strength of boards made from recycled wood can be attributed to an increase of their brittleness, which negatively affects the mechanical properties of aged wood (Kránitz et al. 2016).

All average MOR and MOE values for the strand boards, regardless of their composition, exceeded the minimum requirements of 20 MPa and 3,500 MPa, respectively, as specified in the European standard EN 300 (2006) for OSB/3.

Thus, despite the lower SR and FR of strands derived from recycled wood compared to those from virgin wood, their use resulted in MOR and MOE values comparable to those of boards made entirely from virgin wood. These findings align well with the results of Mirski et al. (2016),

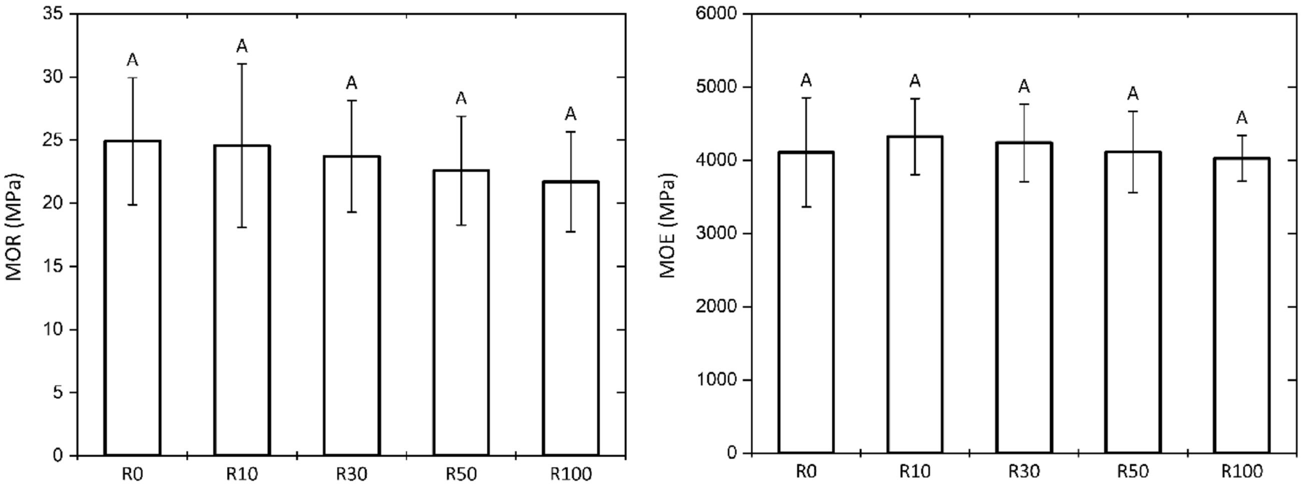


Fig. 9 Bending strength (MOR) and modulus of elasticity (MOE) of strand boards with varying proportions of recycled wood strands

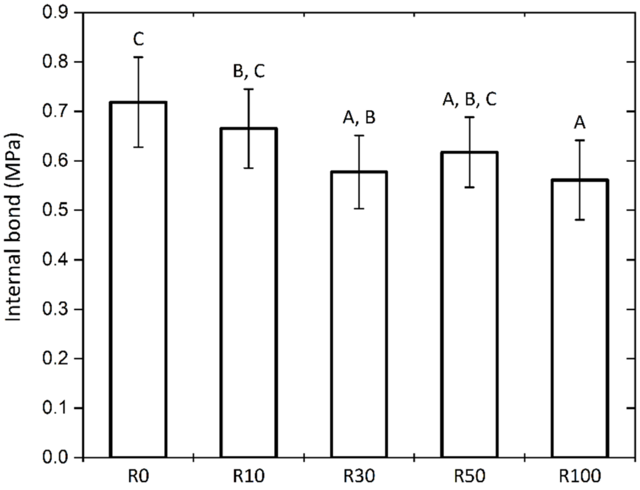


Fig. 10 Internal bond (IB) of strand boards with varying proportions of recycled wood strands

who demonstrated that replacing the strands of external layers with smaller strands allowed for the manufacturing of OSB/3 using strands up to four times shorter than standard strands. Several authors (Mirski and Dziurka 2011a; Schild et al. 2019) have reported that the MOR and MOE of OSB decrease with increasing levels of waste wood particles in the core layers, particularly when standard core layer strands are replaced by waste wood particles.

A trend of decreasing average IB values was observed as the proportion of recycled wood increased from 0% to 100% (Fig. 10). The average IB values ranged from 0.56 MPa for boards with 100% recycled strands (R100) to 0.72 MPa for boards with 100% virgin strands (R0). Our results demonstrate that the boards made with recycled wood strands exhibited IB values comparable to those of the control boards made from virgin wood. The boards produced with 10% and 50% recycled wood strands (R10 and R50) exhibited IB values that were statistically equivalent to those of the control boards. The IB values of all boards tested met the regulatory requirements, indicating adequate bonding between virgin and recycled strands, as well as between recycled strands. One of the factors that contributed to the strong bonding of the strands of recycled wood was their favourable wetting behaviour (Fig. 4). All boards met the European standard EN 300 (2006) requirement of 0.32 MPa for OSB/3.

4 Conclusion

Based on the results of this study, the following conclusions can be drawn:

1. It was found that recycled wood can effectively substitute virgin wood in the production of oriented strand boards (OSBs), achieving comparable mechanical and physical properties. This performance parity was observed despite the notable dimensional differences between the strands derived from recycled and virgin wood: the recycled strands were approximately 5.5% shorter, 42.4% narrower and 24.8% thicker.
2. To mitigate the formation of fine strands during processing, it is recommended that dry recycled wood be moistened before stranding.
3. One significant advantage of recycled wood is its superior wettability compared to virgin wood. This enhanced wetting behaviour promotes efficient adhesive bonding, both between recycled strands and between recycled and virgin strands.
4. A key benefit of incorporating recycled wood is the improved dimensional stability of the resulting boards. The strand boards made entirely of recycled strands

exhibited approximately 50% less thickness swelling than those made solely from virgin wood. One contributing factor to this improvement is the slightly lower sorption capacity of recycled wood compared to that of virgin wood. This increase in dimensional stability could also be associated with the decomposition of hemicellulose and the higher crystallinity index observed in recycled wood.

5. In general, these findings indicate that substituting virgin strands for recycled ones is a feasible strategy for the manufacturing of OSB/3 panels without compromising the material performance.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

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