Some Physico-mechanical Characteristics of Uncoated OSB ECO-products Made from Scots Pine (*Pinus sylvestris* L.) and Bonded with pMDI Resin

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Some mechanical and physical properties and the formaldehyde content of uncoated oriented strand boards (OSBs) that were made from Scots pine (*Pinus sylvestris* L.), manufactured with different thicknesses, and bonded with polymeric methylene di(phenyl isocyanate) (pMDI) resin were evaluated. All of the mechanical and physical properties were affected significantly by the OSB type (3 and 4) and thickness of the panels, except for the thickness swelling after 24 h and measured formaldehyde content. The measured mechanical and physical properties of the OSB panels satisfied the standard requirements. The densities of the panels ranged from 554.2 kg/m³ to 580.2 kg/m³ and from 573.8 kg/m³ to 610.7 kg/m³ for OSB/3 and OSB/4, respectively, which met the standard requirements. The measured mechanical and physical properties of the OSB/4 panels were higher than those of the OSB/3 panels, but there were no differences in the thickness swelling after 24 h and measured formaldehyde content. Low formaldehyde contents were found for OSB/3 (0.00 mg/100 g and 0.29 mg/100 g) and OSB/4 (0.18 mg/100 g and 0.47 mg/100 g).

**Keywords:** Formaldehyde content; OSB; pMDI; Physico-mechanical characteristics; Scots pine

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**INTRODUCTION**

Oriented strand board (OSB) is a wood-based composite made from wood strands. The surface area of the strands, as well as the elements of other particulates, is not completely covered with resin. It is a commodity product that is subject to market fluctuation (Conrad et al. 2004). Oriented strand board has been designed and developed to be more stable (Barbuta et al. 2012) and have a high bending modulus of elasticity in the parallel direction, close to that of Baltic birch plywood (BBP) in its strongest direction (Barbuta et al. 2011). Oriented strand board has been used to manufacture engineered wood flooring prototypes (Barbuta et al. 2012). More information about the technological development of OSB in North America and China are listed in the review article written by Jin et al. (2016).

Several resins, such as urea formaldehyde (UF), melamine-urea formaldehyde, polyvinyl acetate (PVA), phenol formaldehyde (PF), polyurethane (PUR), and emulsion
polymer isocyanate, have been used to manufacture wood-based panels (Risholm-Sundman and Wallin 1999; Blanchet et al. 2003; Blanchet 2008; Salem et al. 2011a,b; Böhm et al. 2012; Salem et al. 2012a,b, 2013a,b). Of these resins, polymeric methylene di(phenyl isocyanate) (pMDI) was used in Germany for the first time in the early 1970s to manufacture particleboards. Since then, it has been widely used for the production of fiberboards and OSB in Europe and used by a few medium-density fiberboard mills in North America (Papadopoulos et al. 2002). The pMDI resin penetrates deeper into wood cell walls than PF resins used to manufacture OSB (Johnson and Kamke 1994; Frazier and Schmidt 1996; Kamke and Lee 2007), which is related to the low molecular weight of pMDI, as well as the low surface tension. Additionally, Frazier (2003) observed interpenetrating networks of polyurea, as well as biuret linkages, which were found within the cell walls. In wooden buildings, pMDI as a resin for wood-based panels is often used as an alternative to formaldehyde-based resins to reduce the formaldehyde emissions and exposure risks to workers during the production of composite wood-based products (Allport et al. 2003; Vangronsveld et al. 2010). Compared with UF (62.4% solids) at 7, 10, and 13%, pMDI (100% solids) at 2, 4, and 6% not only results in superior board properties, but the amount required is considerably reduced as well (Papadopoulos 2006). The penetration and performance of pMDI wood binders on selected wood species has also been studied (Zheng et al. 2004; Gruver and Brown 2006; Das et al. 2007).

The resin pMDI has been used extensively to manufacture OSB panels from aspen strands with a mixed PF and pMDI resin system (Brochmann et al. 2004), rubberwood (Malanit and Laemsak 2007), red maple (Paredes et al. 2008), a mixture of heartwood cypress (Cupressus sempervirens) and pine (Pinus sylvestris) (Makowski and Ohlmeyer 2005; Amusant et al. 2009; Hrázský and Král 2009; Böhm et al. 2011), bamboo strands (Sumardi and Suzuki 2014), and mixes of strands (Ciobanu et al. 2014).

Different factors affect the formaldehyde emissions from OSB and other wood-based panels, such as the raw materials, press temperature, mat moisture content, resin treatment, resin-free formaldehyde, pressing time, and thickness of the panels (Carlson et al. 1995; Böhm et al. 2012). The perforator method (EN 120 1993) is widely used for production control in measuring the formaldehyde content (FC) in the wood-based panel industry in Europe and China, and has shown significant and positive correlations with the referenced chamber methods (Risholm-Sundman and Wallin 1999; Salem et al. 2011a,b, 2012a,b; Liu and Zhu 2014).

In the present work, the physico-mechanical properties of uncoated OSBs made from industrially strands of dried Scots pine (P. sylvestris L.), manufactured with different thicknesses, and bonded with pMDI resin were evaluated.

**EXPERIMENTAL**

**Materials**

**OSB/3 and OSB/4 panels**

Two types of typically industrial boards taken from continuous production of OSBs were used, OSB/3 and OSB/4, with thicknesses of 12 mm, 15 mm, 18 mm, 22 mm, and 25 mm (Table 1). The panels were manufactured from industrially manufactured strands of dried Scots pine (P. sylvestris L.). The strands were manufactured using a ring splitting machine, and the resulting strands were in the dimensions of 0.4 to 0.6 mm in thickness, 5 to 20 mm in width, and 60 to 150 mm in length. The strands with the long length were used.
for the surface layers and the small ones were used for the middle layer. The strands were distributed equally (50/50) in the middle and surface layers. The manufactured panels were cooled to ambient temperature after hot pressing and cut to the dimensions of 1250 mm x 2500 mm. The edges of the OSB were wrapped with aluminum-coated tape. The panels were conditioned at 23 °C and 50% relative humidity (RH). The industrial properties of the manufactured panels are presented in Table 2.

Table 1. Number of Samples Cut from Each Thickness for OSB/3 and OSB/4 Testing

<table>
<thead>
<tr>
<th>OSB Type</th>
<th>12 mm</th>
<th>15 mm</th>
<th>18 mm</th>
<th>22 mm</th>
<th>25 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSB/3 ECO</td>
<td>13</td>
<td>18</td>
<td>11</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>OSB/4 ECO</td>
<td>6</td>
<td>6</td>
<td>16</td>
<td>14</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2. Properties of the OSB/3 and OSB/4 Panels

<table>
<thead>
<tr>
<th>Condition</th>
<th>OSB/3 ECO</th>
<th>OSB/4 ECO</th>
<th>OSB/3 ECO</th>
<th>OSB/4 ECO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material</td>
<td>Industrially strands of dried Scots pine (P. sylvestris L.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture content of the strands before blending (%)</td>
<td>5.1</td>
<td>3.9</td>
<td>5.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Pressing pressure (N/mm²)</td>
<td>&lt;3</td>
<td>&lt;4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressing temperature (°C)</td>
<td>180</td>
<td>190</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adhesive quantity (kg/m³ board, dry matter)</td>
<td>12 (3.5%)*</td>
<td>27 (3.5%)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraffin (kg/m³ board)</td>
<td>2.7</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraffin emulsion (%)</td>
<td>1.2</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂O (l/m³ board)</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂O (dosing converted to the desired moisture of strands)</td>
<td>6.0%</td>
<td>5.5%</td>
<td>6.0%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Hardener</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wood material (kg/m³ of the board, ATRO, coniferous)</td>
<td>535</td>
<td>551</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of glue (pMDI percent (%))</td>
<td>3.1</td>
<td>3.5</td>
<td>3.1</td>
<td>3.5</td>
</tr>
<tr>
<td>pMDI concentration</td>
<td>100%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressing of the OSB</td>
<td>Dieffenbacher CPS 280-53/OSB continuous press (Dieffenbacher CZ hydraulické lisy, s. r. o., Czech Republic)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to EN 300 (2006), the OSB/3 and OSB/4 boards were manufactured as load-bearing boards and heavy-duty load-bearing boards for use in humid conditions, respectively.

* Percentage content of the component on the weight of strands at 0% moisture

Methods

Measurement of the physical and mechanical properties

The bending strength (modulus of rupture, MOR, N/mm²) and modulus of elasticity (MOE, N/mm²) in the parallel and perpendicular directions were measured (EN 310 1999) for OSB/3 and OSB/4 using a UTS 100K instrument (measuring range 5 kN to 100 kN; Dongguan ZME Instrument Trading Co., Ltd., Guangdong, China). The density (kg/m³) and thickness swelling (TS, %) after 24 h were measured according to EN 322 (1993) and EN 317 (1993), respectively.
The tensile strength perpendicular to the surface (internal bond strength) was measured according to EN 319 (1993). After the 50 mm x 50 mm specimens were conditioned at 65% RH and 23 °C for 48 h (EN 319 1993) and boiled (EN 1087-1 1995), the measured internal bond (IB, N/mm²) was calculated.

**Measurement of the formaldehyde content**

The manufactured OSB panels were first conditioned for 4 weeks at 20 °C and 65% RH. The FC (mg/100 g o.d board) was then measured with the perforator method (EN 120 1993). Samples of 110 g with the dimensions 25 mm x 25 mm from each type and thickness were used and subsequently extracted with boiling toluene (600 mL) for 2 h in the perforator apparatus (Soxhlet extractor, WENK LabTec GmbH, Germany). The released FC was measured according to the acetylacetone method (Nash 1953). All of the FC values were corrected by normalizing the moisture content to 6.5% (EN 312 2003).

**Statistical analysis**

The physical and mechanical properties and the corrected FC of the studied OSBs were statistically analyzed using SAS version 8.2 (SAS Institute Inc., Cary, NC, USA). An analysis of variance of completely randomized designs was applied to show the significant differences between the measured values with the Duncan’s multiple-range test at a 0.05-level of probability as affected by two factors (OSB type and thickness) and the interaction between them. The values were presented as the mean plus or minus the standard deviation.

**RESULTS AND DISCUSSION**

**Influence of the OSB Type and Thickness on the Properties of the OSBs**

Table 3 shows most of the studied parameters were significantly affected by the OSB type, thickness, and the interaction between them. The pressing factor was an exception and was not significantly affected by the interaction between the OSB type and thickness. The TS was not affected by the OSB type and thickness or the interaction between them. Additionally, the FC was not affected by the OSB type. The significant results measuring the correlation coefficient and coefficient of determination (Table 4) showed that all of the studied parameters were significantly affected, except for the TS and FC.

**Table 3. Significant Effects of the OSB Type, Thickness, and Interaction on the Selected Measured Properties**

<table>
<thead>
<tr>
<th>SOV</th>
<th>Pressing Factor</th>
<th>Density</th>
<th>MOR (II)</th>
<th>MOR (II)</th>
<th>MOE (II)</th>
<th>IB after Boil Test</th>
<th>TS</th>
<th>CFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSB Type (A)</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>****</td>
<td>***</td>
<td>ns</td>
</tr>
<tr>
<td>Thickness (B)</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>ns</td>
</tr>
<tr>
<td>A*B</td>
<td>ns</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>ns</td>
</tr>
</tbody>
</table>

SOV: source of variance; IB: internal bond; TS: thickness swelling; CFC: corrected formaldehyde content; =: parallel; II - perpendicular

*: significant, **: highly significant, ***: extremely highly significant, ns: not significant

**Table 4.** Correlation Coefficient (R) and Coefficient of Determination (R²) of the Studied OSB Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Multiple-R</th>
<th>Multiple-R²</th>
<th>Adjusted-R²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressing factor (s/mm)</td>
<td>0.63</td>
<td>0.40</td>
<td>0.35</td>
<td>***</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>0.68</td>
<td>0.46</td>
<td>0.41</td>
<td>***</td>
</tr>
<tr>
<td>MOR = (N/mm²)</td>
<td>0.71</td>
<td>0.51</td>
<td>0.46</td>
<td>***</td>
</tr>
<tr>
<td>MOR II (N/mm²)</td>
<td>0.72</td>
<td>0.51</td>
<td>0.47</td>
<td>***</td>
</tr>
<tr>
<td>MOE = (N/mm²)</td>
<td>0.61</td>
<td>0.37</td>
<td>0.31</td>
<td>***</td>
</tr>
<tr>
<td>MOE II (N/mm²)</td>
<td>0.53</td>
<td>0.28</td>
<td>0.22</td>
<td>***</td>
</tr>
<tr>
<td>IB (N/mm²)</td>
<td>0.68</td>
<td>0.47</td>
<td>0.42</td>
<td>***</td>
</tr>
<tr>
<td>IB after boil (N/mm²)</td>
<td>0.48</td>
<td>0.23</td>
<td>0.16</td>
<td>***</td>
</tr>
<tr>
<td>TS</td>
<td>0.28</td>
<td>0.08</td>
<td>-0.01</td>
<td>ns</td>
</tr>
<tr>
<td>Corrected FC (mg/100 g)</td>
<td>0.35</td>
<td>0.12</td>
<td>0.05</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns: not significant

**Physical and Mechanical Properties of the OSBs**

For OSB/3 and OSB/4, the values of the pressing factor ranged from 6.38 s/mm to 7.24 s/mm and from 7.26 s/mm to 9.07 s/mm, respectively (Fig. 1A). The panel densities were between 554.2 kg/m³ and 580.2 kg/m³ and between 573.8 kg/m³ and 610.7 kg/m³ for OSB/3 and OSB/4, respectively (Fig. 1B). These values fall in the range of the densities (260 kg/m³ to 650 kg/m³) of OSBs made from strands of pine wood (P. sylvestris) (Mirski and Dziurka 2015), and glued using a 3% loading of pMDI.

**Table 5.** Minimum Requirements for the Physical and Mechanical Properties of the OSBs

<table>
<thead>
<tr>
<th>Standard</th>
<th>Density (kg/m³)</th>
<th>MOR = (N/mm²)</th>
<th>MOR II (N/mm²)</th>
<th>MOE = (N/mm²)</th>
<th>MOE II (N/mm²)</th>
<th>IB (N/mm²)</th>
<th>IB after Boil Test (N/mm²)</th>
<th>MC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 300 (2006)</td>
<td>±15%</td>
<td>22</td>
<td>11</td>
<td>3500</td>
<td>1400</td>
<td>0.34</td>
<td>0.15</td>
<td>2-12</td>
</tr>
</tbody>
</table>

IB: internal bond

There were differences in the MOE and MOR values along the parallel and perpendicular directions (Table 5). The MOR of OSB/3 ranged from 19.11 N/mm² to 22.88 N/mm² (parallel, Fig. 2A) and from 10.04 N/mm² to 12.03 N/mm² (II, Fig. 2B). For OSB/4, the values of the MOR were between 22.27 N/mm² and 29.60 N/mm² (=, Fig. 2A) and between 12.07 N/mm² and 15.48 N/mm² (II, Fig. 2B). The lower values of the MOR and MOE were found in the perpendicular direction, which is the minor axis (Ciobanu et al. 2014). The average MOE values of OSB/3 ranged from 4515.4 N/mm² to 4795.6 N/mm² (=, Fig. 3A) and from 1981.9 N/mm² to 2124.1 N/mm² (II, Fig. 3B). For OSB/4, the values of the MOE ranged between 4694.9 N/mm² and 5779.0 N/mm² (=, Fig. 3A) and between 2075.0 N/mm² and 2487.3 N/mm² (II, Fig. 3B). For OSB/3 bonded with pMDI, these results were in agreement with those from Hrázský and Král (2009), who found that the MOR (=) ranged from 21.33 to 25.44 N/mm² and from 13.30 to 16.47 N/mm² (II), and MOE with 4278 to 5102 N/mm² (=), and 2095 to 2399 N/mm² (II), and Böhm et al. (2011) who found that MOE measured 762 to 4836 N/mm² (=) and 2007 to 2076 N/mm² (II).
Fig. 1. Effect of the OSB type and thickness on the (A) pressing factor and (B) density of the boards

Fig. 2. Effect of the OSB type and thickness on the MOR in parallel (A) and perpendicular (B) directions

Also the present results are consistent with those of Ciobanu et al. (2014), who found that the MOR ranged from 22.8 N/mm² to 26.8 N/mm² and from 12.1 N/mm² to 15.4 N/mm² parallel and perpendicular to the length axes, respectively, for the OSB/3 board made from a mixture of strands. For the same boards, the MOE ranged from 3934 N/mm² to 4769 N/mm² and from 1667 N/mm² to 2186 N/mm² parallel and perpendicular to the length axes, respectively. The MOE and MOR values of the OSB bonded with pMDI resin were found to be 3916.2 N/mm² and 25.117 N/mm² for the commercial OSB panel, and 7018.9 N/mm² and 42.5 N/mm² for the OSB from red maple, respectively (Paredes et al. 2008). Also, the average values of the MOE and MOR were found to be 2401 N/mm² and 22.03 N/mm², respectively, for the P. euroamericana strands made with PF resin (Cavdar et al. 2008).
After conditioning the panels, the IB strength values of the studied OSB/3 ranged from 0.32 N/mm² to 0.37 N/mm², which were slightly above the minimum requirements for OSB/3 (0.34 N/mm²) according to EN 300 (2006). For OSB/4, the IB values ranged from 0.36 N/mm² to 0.48 N/mm² (Fig. 4A), which were slightly lower than the values stipulated by the standard (0.45 N/mm² for boards > 10 mm to 18 mm, and 0.4 N/mm² for boards > 18 mm to 25 mm). For OSB 3 it required as follows: (0.34 MPa for boards 6-10 mm, 0.32 for > 10 mm to <18 mm, 0.30 MPa for 18 to 25 mm, and 0.29 MPa for boards > 25 mm to 32 mm).
After the boil test, the values were decreased and ranged from 0.13 N/mm² to 0.14 N/mm² for OSB/3 and from 0.13 N/mm² to 0.16 N/mm² for OSB/4 (Fig. 4B), which was within the range of values required by the standard (0.15 N/mm² for boards > 10 mm to 18 mm, and 0.13 N/mm² for boards > 18 mm to 25 mm).

![Graph A](image1)

**Fig. 4.** Effect of the OSB type and thickness on the IB strength (A) after conditioning at 65% RH and 23 °C for 48 h, and (B) after the boil test

Paredes *et al.* (2008) found that in dry conditions, the IB values of the OSB bonded with pMDI resin were 0.627 N/mm² for commercial OSB and 0.806 N/mm² for OSB made from red maple. However, in wet conditions, the IB values were 0.16 N/mm² and 0.24 N/mm² for the commercial and red maple OSBs, respectively, for boards with thicknesses of 0.025 inches, 0.035 inches, and 0.045 inches. The IB ranged from 0.39 N/mm² to 0.43 N/mm² and decreased to the range of 0.13 N/mm² to 0.18 N/mm² after the boil test for boards with 10 mm thick (Ciobanu *et al.* 2014). Additionally, pretreating the strand with hot water extraction decreased the IB to 0.103 N/mm². For the OSB (1.8 cm thick) made
from *P. euroamericana* strands and glued with PF, the average IB value was 0.55 N/mm² (Cavdar et al. 2008).

The OSB boards with *Pinus* sp. and castor oil-based PU resin was found to have average MOE (parallel), MOR (parallel), and IB values of 8126 MPa, 56.5 MPa, and 1.55 MPa, respectively. These values were higher than those obtained for the OSB/4 boards with 10 mm thickness (de Souza et al. 2014). Other studies have reported MOR and MOE values of 57.50 MPa and 8061.18 MPa along the parallel direction, and 20.82 MPa and 222.31 MPa along the perpendicular direction, respectively, with a TS of 23.6% and IB of 0.61 MPa for OSB panels of 15.7 mm thickness made from *P. taeda* and bonded with PF (Mendes et al. 2013). Also, the values of the IB, MOR (parallel), and MOE (parallel) were 0.495 MPa to 0.950 MPa, 69 MPa to 72 MPa, and 8135 MPa to 9050 MPa, respectively, for aspen/birch OSB-Ponderosa pine OSB bonded with PVA type I with thickness of 12 mm (Barbuta et al. 2012).

The values of the TS were between 11.85% and 13.34% for OSB/3 and between 11.39% and 12.70% for OSB/4 (Fig. 5). These values were below the maximum values required by the standard (15% for OSB/3 and 12% for OSB/4). Other studies have reported that the values of the TS were 14.0% and 11.6% for commercial OSB and OSB made from red maple strands, respectively (Paredes et al. 2008), and 12.99% for OSB made from *P. euroamericana* strands (Cavdar et al. 2008). The TS ranged from 2.63% to 7.60% for OSB made from bamboo strands and bonded with pMDI (Sumardi and Suzuki 2014). Ciobanu et al. (2014) reported that the TS ranged from 20.23% to 22.60% for OSB/3 made from a mixture of strands with a core layer blended with pMDI.

![Fig. 5. Effect of the OSB type and thickness on the TS after 24 h](image)

**Formaldehyde Content**

Very low FC values were measured for the studied OSBs. Figure 6 shows that the FC values of OSB/3 were up to 0.29 mg/100 g, and between 0.18 mg/100 g and 0.47 mg/100 g for OSB/4 (Fig. 6). All of the values were extremely lower than the E1 emission class, as given in EN 120 (1993) (≤ 8 mg/100 g). The authors’ previous work (Böhm et al. 2018).
2012) showed that the formaldehyde emission from wood of *P. sylvestris* were 0.0053±0.0004 ppm and 0.016±0.002 mg/m² h as measured by EN 717-1 and EN 717-2, respectively. This amount is generated when the wood exposed to the manufacturing conditions of the panels, where the formaldehyde can be raised with the thermal degradation of wood polysaccharides (Roffael 1999; Schäfer and Roffael 2000; Salem and Böhm 2013).

Previously, Bartekova *et al.* (2006) reported that all of the tested uncoated isocyanate-bonded OSB/3 and OSB/4 made of Scots pine had very low volatile organic compound (VOC) emissions and met the conditions for “very low emitting materials”. The resin itself had a very low level of free formaldehyde (0.2%). The main emission of formaldehyde occurred at the press stage and from the wood itself because of condensation reactions (Vangronsveld 2012).

Also, Salem *et al.* (2017) found that OSB bonded with PUR resins and made from mixed wood strands with 80% Norway spruce and 20% Scots pine had extremely low FC values, which was limited to the natural FC in the solid wood. Furthermore, the increase in the FC and VOC emissions was related to the increase in the thickness of the panels (Ohlmeyer *et al.* 2008; Salem *et al.* 2011a,b; Böhm *et al.* 2012; Salem *et al.* 2012a,b, 2013a,b, 2017).

![Fig. 6. Effect of the OSB type and thickness on the corrected FC (mg/100 g)](image)

In Europe, the manufactured types of OSB/3 and OSB/4 are widely used for many purposes, *e.g.* heavy-duty load-bearing boards in humid conditions. Overall, the mechanical strength and physical characteristics of the studied panels satisfied the minimum requirements given in the standard (EN 300 2006). Formaldehyde and other VOC emissions were likely to be lower with pMDI compared with the press emissions when using other formaldehyde-based resins (Jian *et al.* 2002).
CONCLUSIONS

1. The MOR values of OSB/3 ranged from 19.11 to 22.88 N/mm² (=) and 10.04 to 12.03 N/mm² (II), while with OSB/4, it was 22.27 to 29.60 N/mm² (=) and 12.07 to 15.48 N/mm² (II). The MOE values for OSB/3 were 4515.4 to 4795.6 N/mm² (=) and 1981.9 to 2487.3 N/mm² (II). These mechanical properties of the manufactured OSB panels were satisfied the standard requirements.

2. The density ranged between 554.2 kg/m³ and 580.2 kg/m³ and between 573.8 kg/m³ and 610.7 kg/m³ for OSB/3 and OSB/4, respectively, which met the requirements of EN 300 (2006).

3. The measured mechanical and physical properties of the OSB/4 panels were higher than those of the OSB/3 panels, but there were no differences in the TS after 24 h and FC.

4. Lower values for the MOR and MOE were found in the perpendicular direction.

5. The measured FC of the OSB/3 was up to 0.29 mg/100 g, and between 0.18 mg/100 g and 0.47 mg/100 g for OSB/4. These values were extremely lower than the E1 emission class given in EN 120 (1993) (≤ 8 mg/100 g).

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