Air Permeation Rate of Oriented Strand Boards (OSB/3 and OSB/4)

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Measurements of air permeation rate were taken according to EN 12114 for OSB boards, which were manufactured for this purpose in accordance with the requirements of EN 300 by a commercial manufacturer. The study measured the air permeation rate of samples and evaluated the influence of selected parameters on the resulting values. The effects of these factors on the rate of air permeation were specified, showing the particular influences of board thickness (12 mm and 18 mm) and type (OSB/3 and OSB/4). The dependence of the measured values of air permeation rate on the pressure difference was described using linear equations within a regression analysis. The group of OSB/3 samples exhibited a lower resistance to air permeation than OSB/4 (about 61% for both thicknesses). In addition, in both groups, 18 mm samples showed a higher resistance to air permeation than samples with a thickness of 12 mm (OSB/3 by about 40% and OSB/4 by about 41%).

Keywords: Air permeation rate; Air permeability, Air tightness; OSB; Thickness; EN 12114

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INTRODUCTION

Air permeation rate is one of the physical properties of construction materials that is especially important when evaluating the heat resistance of buildings. OSB materials (boards made from oriented stands), which were measured for air permeation rate, are often used in lightweight external cladding of wooden structures, on whose properties the comfort of living depends. The air permeation of OSBs significantly affects the infiltration of outside air into the rest of the wall construction, and into the interior of the building, as well as the escape of warm air from the interior, which occurs *via* thermal transport and diffusion (Kumaran 2007; Li 2007).

Air permeation is a property of material based on the nature of its production, and it is also dependent on porosity (Al-Hussainy *et al.* 2013). OSB is a material made by gluing strands that are oriented and partially randomly overlap. Inner cavities are created through the uneven overlapping of strands, which allows for air flow. The adhesive used for manufacturing will partially seal these pores, but there still remains a measurable rate of air penetration. The main technological parameters that affect the air permeation rate of OSBs include pressing conditions, such as pressure, temperature, and time of press closure (Langmans *et al.* 2010b). From the characteristics of raw materials, they are primarily the average density of strand carpet, size, geometry, and orientation of strands (Gaete-martinez *et al.* 2008).

The permeability of the strand carpet in various wood-based materials, including OSBs, was examined by Haas *et al.* (1998). They found that permeability decreases with increasing adhesive content and moisture of wood particles, and that temperature does not play a role. Better orientation of strands in the surface layers of boards leads to better resulting properties (García *et al.* 2003; Painter *et al.* 2006). Another study focused on the areal density and distribution of strands in the surface layers of the strand carpet. Using a measuring device on the principle of γ-rays, different distributions of surface density were detected within each test specimen (OSB). Within one board are thus formed spaces where air permeation rate is greater than in other areas (Kruse *et al.* 2000). Both the distribution of pressure of the gas contained in the strand carpet and the temperature gradient along the strand carpet have a significant impact (Thoemen and Humphrey 2005). Similarly, if during pressing a higher density and optimal transverse density profile is achieved because of appropriately-set pressing parameters, the OSB achieves better properties, including air permeation rate (Zhou *et al.* 2011).

Air permeation rate is closely related to diffusional transport. These mechanisms of gas transport play a significant part in ensuring that buildings retain heat. Diffusion, *i.e.*, the effort of the internal and external environment to balance temperature difference and water vapour pressure, is balanced using thermal flows, while water vapour pressure is balanced using diffusion (Trechsel 2001). Temperature and water vapour pressure are properties of the air that passes through the material. If the air permeation rate is increased, the rate of the diffusional transport is also increased and the temperature on both sides of the barrier (in this case an OSB) also changes more rapidly (Tariku *et al.* 2010).

Air permeation rate has been investigated comprehensively within either one wall or an entire building directly (Mukhopadhyaya and Kumaran 2001; Saber *et al.* 2012). Several studies involved the comprehensive investigation of finished wall structures. These walls have included not only OSBs that represent a vapour-halting layer, but also other materials that affect other insulation properties of a wall (Salonvaara *et al.* 2001; Maref *et al.* 2002; Langmans *et al.* 2010a; Langmans *et al.* 2011; Langmans *et al.* 2012). These studies were based on comprehensive monitoring of several hygrothermal characteristics of a composite structure.

In contrast, there exist studies that are involved in the air permeation rate of the OSB itself. Langmans *et al.* (2010b) demonstrated that an OSB sample is permeable when they measured and compared the air permeation rate of samples from several major European manufacturers according to EN 12114. OSB samples from various manufacturers showed significant differences in air permeation rate. Kumaran *et al.* (2003) measured the air permeation rate of various types of OSBs and found that it depends on the pressure difference. The method they used worked with pressure ranges from 25 Pa to 600 Pa. This method was first used in the studies of Bomberg and Kumaran (1986).

Air gaps are either between individual strands or in the form of lumens and intercellular areas within each strand. Gaps between strands play a more relevant role in the permeability of the strand carpet during production. In terms of the geometry of strands, the permeability of the board depends more on the thickness of the strands than on their length or width (Dai *et al.* 2005). The number of air gaps is also affected by the dimensional characteristics of the strands in the strand carpet. The smaller the strands, the smaller the gaps between them (Kruse *et al.* 2000). Air gaps may thus be partially eliminated through the addition of a smaller fraction into the strand carpet. With increasing fine material content in the in the middle of the board, an exponential decrease in the permeability of the boards was ascertained (Fakhri *et al.* 2006).

Among other things, air permeation can be monitored in the example of the transfer of water vapour contained in the air that passes through the board. Diffusion flows that mediate the passage of water vapour through the material are mainly dependent on density, moisture content, board thickness, and other factors (Sonderegger and Niemz 2009). Because diffusion and air permeation rate are inextricably linked, these factors are also used to determine values of air permeation rate.

Board thickness is determined by the proportion of the materials (strands and adhesive) and air gaps. These air gaps are created during the layering of various wood elements into the strand carpet, as well as when they are pressed. Air gaps are responsible for air and water vapour flow. The lower the density, the greater the proportion of air gaps, which significantly affects air permeation rate. This density effect on the physical properties of board materials has, for example, been described in the past using a digital X-ray analysis (Chen *et al.* 2010). The size of the gaps increases with increasing humidity. Cellulose molecules absorb water, swell, recede from each other, air gaps widen, and air permeation rate is thereby increased. This may also lead to a reduction in the strength of the board, depending on the adhesive used (Bomba *et al*. 2014). The dependence of the overall permeability of boards on increasing moisture content has been described for OSB material by diffusion (Maref *et al.* 2002).

The main objective of this paper was to describe the variability of air permeation rate of OSB boards produced by one manufacturer. Four samples were prepared and examined (see below). The aim was also to compare the values of air permeation rate between samples and describe the factors that influence them.

EXPERIMENTAL

Material and Methods

Two types and thicknesses of industrially manufactured OSBs were investigated, specifically 12-mm OSB/3, 18-mm OSB/3, 12-mm OSB/4, and 18-mm OSB/4.

The strands to manufacture the boards were sorted through a sieve with mesh dimensions of 3.5 x 30 mm, and the rate of middle and surface strands was 50/50.

All of the test specimens had a format of 1250 x 2500 mm, which was also the production format. All of the test specimens were acclimatized in the environment where the test was carried out (13.4 ºC, 61.9% relative air humidity). The test was carried out on six specimens in each group, *i.e.*, a total of 24 test specimens.

Test samples were subjected to a series of graduated pressure differences (positive and negative), wherein the air flow rate achieved at every level of the pressure difference was measured. The maximum pressure was set at 1500 Pa, and the minimum at 50 Pa. After clamping the sample into the test chamber using fixtures, the sample was subjected to a series of negative pressure differences of 50, 100, 150, 200, 250, 300, 450, 600, 750, 900, 1050, 1200, 1350, and 1500 Pa (Δp_{max}). The air flow rate for each value of the pressure difference was measured in m^3/h. Subsequently, the pressure in the test chamber was aligned with the pressure outside the chamber, and the sample was subjected to a series of positive pressure differences at equal intervals, and the air flow rate was also measured. For an illustrative comparison of deflection in different types of boards evoked by air pressure, a deviation gauge for selected samples from each group was installed.

Table 1. Production Characteristics of Test Samples

Conditions	OSB/3 Surface Layer	OSB/3 Middle Layer	OSB/4 Surface Layer	OSB/4 Middle Layer
Pressing pressure (N/mm^2)	< 3		< 4	
Pressing temperature (°C)	180 to 225		190 to 245	
Pressing factor (s/mm)	≈ 5		≈ 4	
Used adhesives	MUF	PMDI	MDI	
Adhesive quantity (kg/1-m^3 board, dry matter)	35, (8.5%)*	12, (3.5%)*	27 (3.5%)*	
Paraffin(kg/1-m^3 board)	2.7		10	
Paraffin emulsion (%)	1.2	1.2	-	
H_2O (l/1-m^3 board)	30		30	
H_2O (dosing converted to the desired moisture of strands)	10.5%	5.5%	6.0%	5.5%
Hardener	2.4%*	-	-	
Wood material (kg/1-m^3 of the board, ATRO, coniferous)	535		551	
Used raw material	Spruce 80%, Pine 20%		Spruce 80%, Pine 20%	
MUF, MDI concentration	65%, 100%		MDI 100%	
Hardener concentration	60%		-	
Paraffin emulsion concentration	34%		-	
* Percentage content of component on the weight of strands at 0% moisture				

Measurements were carried out in a certified test laboratory in the airtight chamber FPS 3525/450 MSD-digital PC (K. Schulten Fenstertechnik) for measuring the air permeation rate of lightweight external cladding (EN 12153), and air permeation rate of building components and parts (EN 12114). Before the test was carried out, the residual air permeation rate (air permeation rate of the test chamber) $+Q_V$ and $-Q_V$ was measured, which was later included in the calculation within the data correction. The air flow rate values measured under laboratory conditions were converted to standard reference conditions specified by a standard (temperature, pressure, and relative air humidity),

$$\dot{V}_0 = \dot{V} \cdot \sqrt{\frac{\rho}{\rho_0}} \tag{1}$$

where $\dot{V}_0$ is the air flow rate relative to the reference conditions (m^3/h), $\dot{V}$ is the air flow rate measured under laboratory conditions (m^3/h), ρ_0 is the air density under the reference conditions ρ_0=1,1988 kg/m^3, and ρ is the air density under laboratory conditions, which is calculated using Eq. 2:

$$\rho = \frac{p_a - 0.378802 \cdot p_w}{287.055 \cdot T} \tag{2}$$

p_a is the atmospheric pressure (Pa), T is the thermodynamic temperature (K), and p_w is the partial water vapour pressure (Pa), which is calculated from Eq. 3,

$$p_w = 610.5 \cdot \varphi \cdot e^{\left(\frac{21.875 \cdot (T-273.15)}{T-7.65}\right)} \tag{3}$$

where φ is the relative air humidity.

After corrections, the measured results were averaged according to groups and individual pressure difference degrees. The coefficient of variation (COV) was determined, and surface air permeation rate (V_A), showing air permeation rate after being recalculated to 1 m^2 of the board (m^3/m^2/h). The results were subjected to regression analysis and equations of the linear dependence of permeability on the pressure difference were developed.

RESULTS AND DISCUSSION

The average air permeation rate values for each group of test specimens are specified in Table 2. The average values of air permeation rate ($\overline{V}_0$) and surface air permeation rate ($\overline{V}_A$) were calculated within all pressure difference degrees; these two average values therefore relate to the scope of pressure differences from 50 Pa to 1500 Pa, as well as the COV value.

Table 2. Ascertained Values of Air permeation Rate of OSBs, Density, and Variation Coefficient

Material	Thickness (mm)	No. (-)	Density (kg/m^3)	$\overline{V}_0$ (m^3/h)	COV (%)	$\overline{V}_A$ (m^3/m^2/h)	$\overline{V}_{50}$ (m^3/h)
OSB/4	18	6	606.55	3.04	2.15	1.08	0.46
OSB/4	12	6	606.27	5.13	0.23	1.83	0.72
OSB/3	18	6	593.02	7.82	0.28	2.79	1.08
OSB/3	12	6	592.85	13.09	2.02	4.66	1.65

$\overline{V}_0$=Average air permeation rate, $\overline{V}_A$=Surface air permeation rate, $\overline{V}_{50}$=Air permeation rate for pressure difference 50 Pa, COV=Coefficient of variation

The lowest air permeation rate values were found in the 18-mm OSB/4 sample (3.04 m^3/h), and slightly higher values were found in the 12-mm OSB/4 sample (5.13 m^3/h), followed by the 18-mm OSB/3 sample (7.82 m^3/h). The weakest air barrier proved to be the 12-mm OSB/3 sample (13.09 m^3/h), for which the air permeation rate was more than four times higher than for the 18-mm OSB/4 sample. It can be clearly seen from these values that the OSB/4 had globally lower air permeation rate values than the OSB/3. This is because of the combination of factors that play a role when the boards are manufactured. In relation to other pressing conditions (higher pressing pressures, different composition of adhesive mixture, *etc*.), the OSB/4 had a higher density, and thus a lower subsequent value of air permeation rate. Likewise, lower air permeation rate were measured for 18-mm boards than for 12-mm boards. The differences between the groups are described in Fig. 4. With increasing OSB thickness, air permeation rate decreased.

From all of the degrees of pressure difference, the difference of 50 Pa was selected. The corresponding air permeation rate values for this degree are shown in Table 2. This was the lowest air pressure induced during the test. It is also the same air pressure used for measuring the airtightness of buildings using the Blower-Door method. This therefore represents the data that is directly usable in the construction of structures and building structures, and in determining theoretical air permeation rate.

The results were subjected to a regression analysis. In all of the cases, the dependence of air permeation rate on air pressure had an increasing tendency. Table 3 shows the mathematical expression of this relation in the form of linear equations for each sample separately, together with a coefficient of determination (COD). The smallest relative deviations were achieved by the 18-mm OSB/3 sample (dependence described as more than 98%); for other samples the coefficient of determination was always higher than 95%.

Table 3. Relationship between Pressure and Air permeation rate

Material	Thickness (mm)	Regression Equation	*COD (-)
OSB/4	18	$y=0.0042 \cdot x+0.4079$	$r^2=0.9582$
OSB/4	12	$y=0.0072 \cdot x+0.5913$	$r^2=0.9795$
OSB/3	18	$y=0.0105 \cdot x+1.1803$	$r^2=0.9808$
OSB/3	12	$y=0.017 \cdot x+2.3267$	$r^2=0.9623$

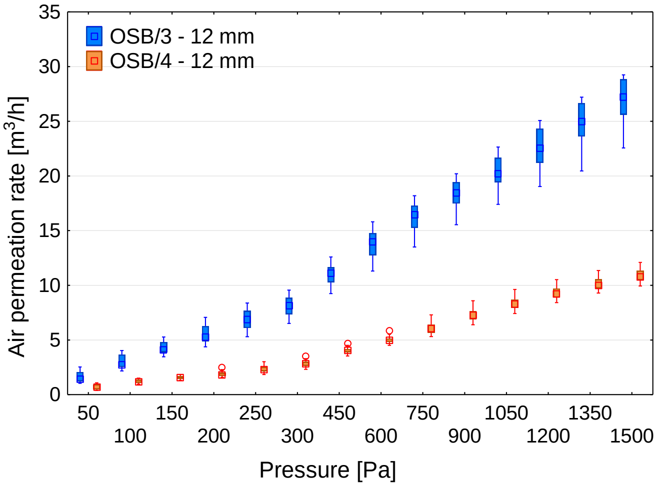

Fig. 1. Effect of air pressure on air permeation rate values for boards with a thickness of 12 mm for OSB/3 and OSB/4

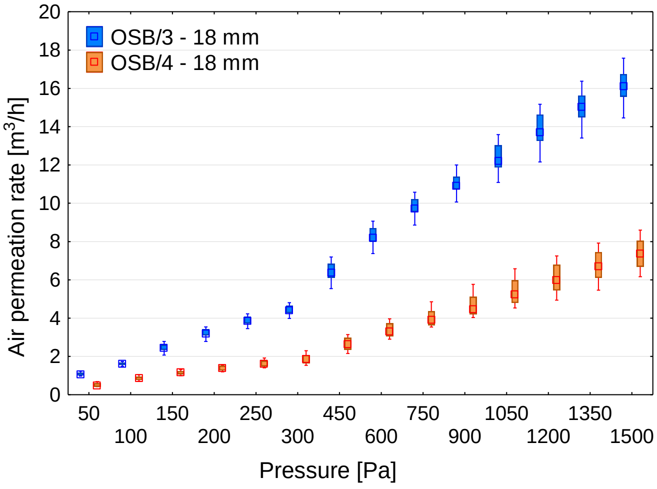

Fig. 2. Effect of air pressure on air permeation rate values for 18-mm boards separated into OSB/3 and OSB/4

Figures 1 and 2 show an increase in air permeation rate with increasing air pressure. The results are described using box plots with the median being expressed, a probability interval of 25 to 75%, and marginal values. Each displayed result represents the measured values of the air underpressure and overpressure of six test specimens. Figure 1 shows the effect of air pressure on air permeation rate for a 12-mm OSB. The values are divided into OSB/3 and OSB/4. Figure 2 shows the same for samples with a thickness of 18 mm. In both cases, we noted an apparent variance in the measured values with increasing pressure. For all samples, we observed an increasing trend of air permeation rate with increasing pressure. It is also evident from both figures that OSB/4 showed lower air permeation rate values than OSB/3.

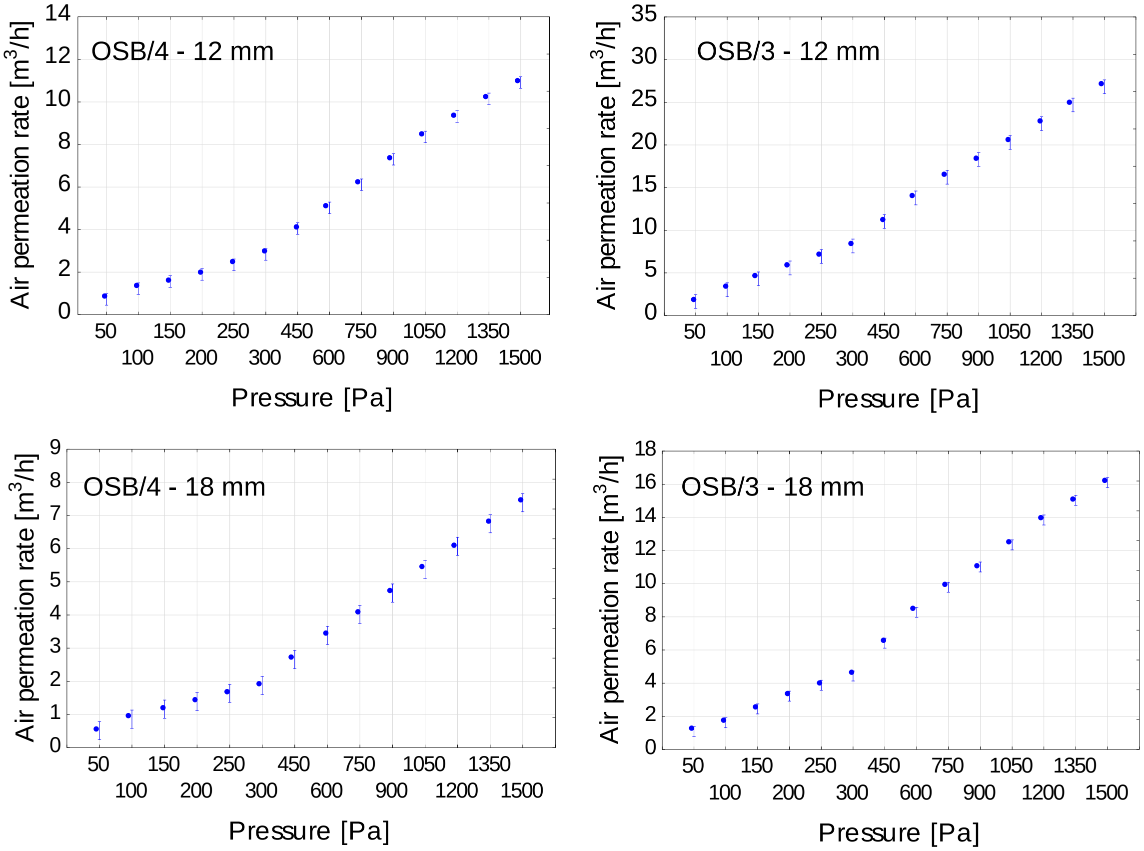

Fig. 3. Results of the analysis of air permeation rate variance values dependent on pressure difference for individual sample groups

Figure 3 shows a 95% confidence interval of the occurrence of measured air permeation rate values for each group of samples, including average values. The narrowest confidence interval was achieved by the 18-mm OSB/3 sample, followed by the 12-mm OSB/4, the 12-mm OSB/3, and the 18-mm OSB/4.

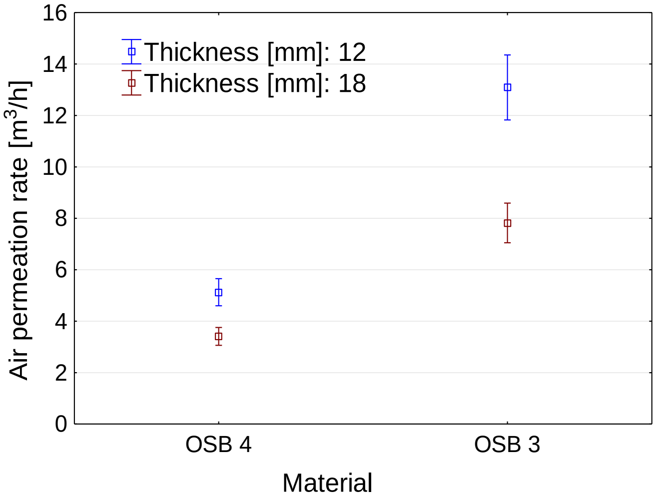

Fig. 4. Comparison of resulting values for each sample group according to the type and thickness of the OSB

In particular, Figures 1 and 2 reveal an increase in air permeation rate with increasing pressure difference. The dependence of these two variables was demonstrated in a study by Kumaran *et al.* (2003). Because they worked with OSB boards with a maximum thickness of 11.5 mm, the results of the two studies cannot be directly compared. The cited authors did, however, demonstrate that air permeation rate is dependent on pressure in a pressure range of 25 Pa to 600 Pa. The facts mentioned herein expand this claim to 1500 Pa.

Figure 4 shows the relationships between sample groups. Here it has been shown that the OSB/4 had lower air permeation rate values than the OSB/3, and, similarly, the 18-mm OSB exhibited a lower air permeation rate than the 12-mm OSB. According to Fig. 4, it was demonstrated that the thickness of the material had a direct impact on air permeation rate. With increasing thickness, air permeation rate decreases. A similar conclusion was arrived at when comparing the OSB/3 and OSB/4. As described above, the OSB/4 within a pressure difference in the range of 50 Pa to 1500 showed lower air permeation rate than the OSB/3.

For test measurements, boards from the same manufacturer were selected in order to ensure the same production technology. A study dealing with the air permeation rate of OSBs from different manufacturers was carried out by Langmans *et al.* (2010b). They tested 18-mm OSB/3 from eight different manufacturers at a pressure difference of 50 Pa. The average values of air permeation rate ranged (with the exception of one sample, wherein an air permeation rate of less than 0.001 $m^3/m^2/h/Pa$ was measured, which corresponds to 0.05 $m^3/m^2/h$) from about 0.1 $m^3/m^2/h$ to about 0.5 $m^3/m^2/h$, thus clearly refuting the claim that OSB is a vapour barrier. With all of this in mind, all of the test samples were classified according to the functional requirements of the European standard for lightweight external cladding (EN 12152).

The pressure values at an air permeation rate of 1.5 $m^3/m^2/h$ (Table 4) were calculated using the equations specified in Table 3. According to classification into groups (EN 12152), it is possible to determine in which group the lightweight external cladding may or may not belong to, in which the OSB is used as the main retarding element for the air permeation rate of structures. The 18-mm OSB/4 went into a so-called exceptional group with an air permeation rate of less than 1.5 $m^3/m^2/h$ at a pressure of 600 Pa; and, adversely, the 12-mm OSB/3 with an air permeation rate greater than 1.5 m^3/m^2/h at a pressure of 150 Pa could not be classified.

Table 4. Results of Surface Air Permeation Rate for 50 Pa and Classification into Air Permeation Rate Classes According to EN 12152

Material	Thickness (mm)	Surface air permeation rate $\overline{V}_{A,50}$ (m^3/m^2/h)	Pressure during air permeation rate (1.5 m^3/m^2/h)	Classification According to EN 12152
OSB/4	18	0.17 (0.04)*	905.61	AE (>600 Pa)
OSB/4	12	0.25 (0.06)*	502.8	A3 (450 to 600 Pa)
OSB/3	18	0.38 (0.01)*	288.68	A1 (150 to 300 Pa)
OSB/3	12	0.59 (0.27)*	110.87	unclassified

***** Variation coefficient of sets during a pressure difference of 50 Pa

There are thus several parameters that affect the air permeation rate of OSBs. One of the primary factors is density. Its distribution along and across the board affects not only many mechanical properties (Painter *et al.* 2006), but also air permeation rate, as is evident from the figures above. Furthermore, the measured data are a confirmation of the study carried out by Kumaran *et al.* (2003), which states that air permeation rate is directly proportional to pressure. The effects of the board types (OSB/3, OSB/4) and thicknesses (12 mm, 18 mm) on air permeation rate values are also described above. The measured air permeation rate values at the 50 Pa pressure difference from three sample groups (18-mm OSB/4s, 12-mm OSB/4s, and 18-mm OSB/3s) were close to values measured by Langmans *et al.* (2010b), who only used 18-mm OSB/3 samples.

This suggests that OSB properties, including air permeation rate, are largely dependent on the specific technology used in their manufacturing.

CONCLUSIONS

This article dealt with evaluating the air permeation of OSBs in a laboratory environment. When using OSBs for the construction of external cladding, overall air permeation rate is influenced not only by the properties of the OSBs, but also by the technological process of attaching boards or other insulating materials used. Despite this, the following conclusions can be inferred from this study:

1. Measuring the air permeation rate of OSBs demonstrated that when air pressure acting on the board from one side is increased, its rate of air permeation increases linearly.
2. A low air permeation rate was observed for samples with a greater thickness. Similarly, a lesser air permeation rate was observed for the OSB/4 compared with the OSB/3, which is because of production conditions and the density of the boards.
3. In order to achieve better airtightness of OSBs with the same thickness, it is necessary to ensure greater resulting board density during production.

4. For building lightweight external cladding for buildings that are diffusely open, it is better to choose an OSB with lower air permeation rate, *i.e.*, the OSB/4 or OSB/3 with greater thickness.
5. To achieve better airtightness of lightweight external cladding, it is better not to use an OSB as the main airtightness element, particularly when using the OSB/3.
6. To ensure correct functioning of the lightweight external cladding in terms of air permeation rate, it is necessary to take into consideration all of the aforementioned facts.

Respecting the above information will lead to decreasing energy demands for the structures, in particular in the passive standard.

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