Air permeability requirements for air barrier materials in passive houses – Comparison of the air permeability of eight commercial brands of OSB –

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ABSTRACT

Today, labels introduced in some countries to certify standardised low energy buildings, such as 'Passive House' in Germany and 'Minenergie' in Switzerland, are becoming increasingly applied in Europe. Both labels explicitly require a threshold level of airtightness (0.6 air changes per hour (ACH) at 50 Pa). For timber frame passive houses in Belgium, this requirement is commonly achieved by sealing all the joints in the interior structural sheathing, mostly consisting of Oriented Strand Boards (OSB). Although it was generally believed that OSB is sufficiently airtight to act as air barrier, recent cases proved the opposite. For some cases the only remedy was to install an extra airtight spun bonded foil or provide an airtight paint on top of the OSB. In order to avoid these expensive adaptions in the future, this study compares the air permeability of eight major commercial brands of OSB which cover most of the West European market. The results show a large variation on the air permeance of the different OSB brands tested (<0.001 m³/m²/h/Pa - 0.01m³/m²/Pa). The measured data is used to estimate the impact of the air leakage through the air barrier material on the global n_{50}-value of typical passive houses. For most OSB brands tested, the air leakage through the OSB corresponds with significant share of the Passive House standard (0.6 ACH).
Based on this, the paper suggests an upper limit of 0.0018 m³/m²/h/Pa for air permeance of building materials applied as air barrier in Passive Houses. Although this limit is less severe than the Canadian requirement, only one of the OSB brands tested satisfies the proposed requirement. As a result, applying OSB as air barrier system in Passive Houses seems questionable.

KEYWORDS

Airtightness, laboratory experiments, air barrier material, Oriented Strand Board

INTRODUCTION

Due to the growing concern of energy consumption and sustainability, considerable progress has been made in the last decades to make buildings more energy efficient. Apart from sufficient thermal resistance, a good overall airtightness of the building envelope is a prerequisite to diminish energy consumption (Jokisalo et al., 2009).
As a result of this recent trend towards very low energy buildings, existing recommendations regarding airtightness, such as an n_{50}-value of 1 1/h for buildings with heat recovery systems, regain interest (Wouters and Carrié, 2008). Moreover,

labels introduced in some countries, such as ‘Passive House’ in Germany and ‘Minenergie’ in Switzerland, to certify standardised low energy buildings apply even higher standards regarding airtightness. Both labels explicitly require a threshold level of airtightness of 0.6 air changes per hour (ACH) at 50 Pa. Furthermore, the European parliament recently decided a stepwise introduction of a “near zero” requirement for all new buildings by 2020 (DIRECTIVE 2010/31/EU). While this document does not give a clear technical definition of “near zero”, a recent Belgium law explicitly requires the Passive House standard, and thus an n_{50}-value of 0.6 ACH, for “zero energy dwellings”.

For timber frame houses, the airtightness requirement is commonly achieved by an interior air barrier system. The term ‘air barrier system’ refers to the material layer which prevents air leakage between inside and outside through the building envelope. Consequently, it is important that materials composing the air barrier system be resistant to air transport and that the overall continuity is guaranteed.
For timber frame Passive Houses in Belgium and other European countries this is commonly achieved be the structural sheating, which consists mostly of Oriented Strand Board (OSB). In order to guarantee the continuity of the air barrier system, the joints between the panels are sealed with airtight tape.
It is generally believed that OSB is sufficiently airtight for this application. However, recent cases in Belgium showed that after carefully sealing the OSB panels, the n_{50}-value still exceeded the threshold value of 0.6 ACH. When sealing an airtight foil to the OSB during a de-pressurization test, a ballooning effect (Figure 1) raised relatively fast which indicates the high air permeance of the used OSB. Finally, the airtightness requirement of 0.6 ACH was achieved by covering the OSB surface with an airtight paint for these cases which confirms again that the applied OSB can not be defined as sufficiently airtight for these applications.

Figure 1: Ballooning of airtight foil on OSB surface during de-pressurization test

Based on the recent cases where the OSB was too air permeable to achieve an n_{50}-value lower than 0.6 ACH, discussion arose whether OSB is a suitable material for air barrier systems in passive houses. The present paper tries to answer this question and investigates the air permeability of eight different commercial brands which covers most of the West-European OSB production. The measured data is used to estimate the impact of the air leakage through the OSB on the global n_{50}-value of typical Passive Houses. Based on this, suggestions for maximal air permeability requirements of air barrier materials are given.

LABORATORY INVESTIGATION

Oriented strand boards investigated

Oriented Strand Board (OSB) is a fibreboard consisting of strands of wood which are bonded together with a synthetic resin. As mentioned above OSB is today widely used to guarantee horizontal stability in timber construction. Comparable performances but lower costs make OSB an interesting alternative for traditional plywood.

Based on information of the European Panel federation[1] eight commercial brands of OSB from the major West-European manufacturers were selected. The panels investigated are produced in Ireland, United Kingdom, France, Germany, Belgium or Luxembourg. The OSB studied concerns OSB 3 which serves for load-bearing applications in humid conditions (EN300:2006). The thickness of OSB tested is 18mm which is commonly used for timber framed constructions.

Method and accuracy

The air permeability of the different brands of OSB is measured in laboratory conditions (20℃,50%RH) on specimens with a size of 35cm by 35cm. Three specimens are tested for each type. The test setup, which is designed according to the EN12114 standard, consists of a metal frame box open at one side to install the specimen to be measured (Figure 2).

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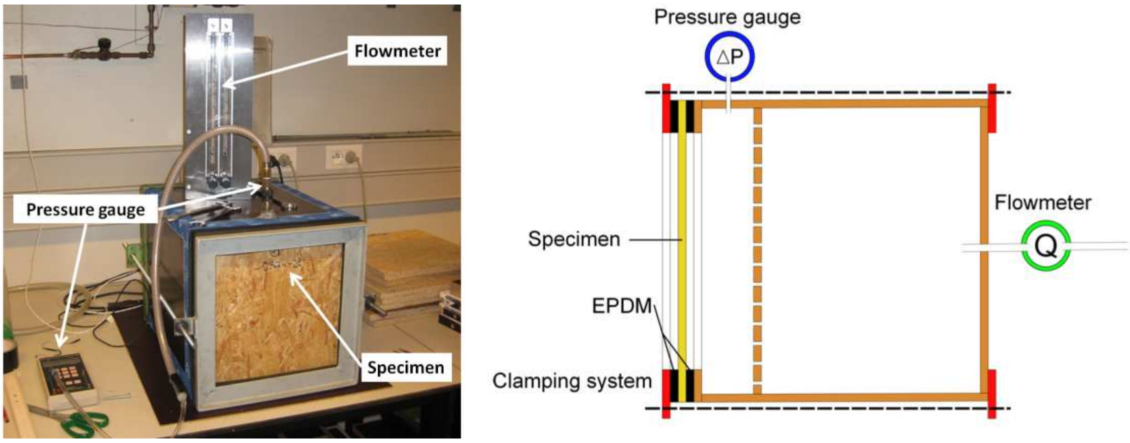

Figure 2: Laboratory test set-up

To avoid unwanted air leakages through the perimeter joints between specimen and airtight boxes, closed cell gaskets with a thickness of 2 cm on both sides of the specimen are used to clamp the specimen airtight with a metal frame against the airtight box. In addition also the four edges of the specimen are sealed with airtight tape to assure a one-dimensional flow through the specimen. After installing the specimen on the airtight box, over-pressure is created in the box. This resulted in an air flow passing through the specimen. By stepwise increasing the pressure in the box and measuring the air flow rate and associated static pressure difference across the specimen a data set is gained. This data can be curve fitted with Eq. (1), since the air flow through a porous media can be assumed to be laminar (Nield and Bejan, 1992):

$$g_a = K_a \Delta P_a \quad (1)$$

Where g_a (m³/m²/h) refers to the airflow , ΔP_a (Pa) stands for the static pressure difference over the specimen and K_a (m³/m²/h/Pa) defines the air permeance of the specimen.

For the test setup a pressure gauge 4 DG-700, with an accuracy of 1% was applied. The flow rate is determined with a Vögtlin variable area flow meter. In a range from 0.02 m³/h to 0.900 m³/h the flow rate can be measured with an accuracy of 2%. The global test-setup is validated with an orifice within an error domain of 5%. Furthermore, repeatedly testing the same specimens proved that the precision error of the measurement, which expresses its reproducibility, is lower than 2%.

The overall leakage of the test setup itself, including the ductwork connections, is determined by performing a test on an airtight plexiglass specimen. From this the leakage of test-setup is estimated to be 5E-05 m³/h/Pa, which can be translated to a fictitious air permeance of the test-setup by dividing it with the measuring area. This results in a $K_{a,box}$ of 0.0007 m³/m²/h/Pa and must be subtracted from the measured air permeability of the specimens K_a. In the remainder of the paper always corrected air permeability's (K_a) will be given. However, for very airtight specimen the correction will exceed the target accuracy. Therefore, if the correction exceeds 50% of the measured value, the air permeability of the specimen will be referred as <1E-03 $m^3/m^2/h/Pa$. As will be explained in the remainder, the obtained accuracy is sufficient to assess the air permeability of OSB.

EXPERIMENTAL RESULTS

In order to avoid commercial interference, the OSB studied will be identified with characters (A-H) instead of using product names. The results of the measured air permeability's are summarized in Figure 3. Here, the bars present the mean air permeability K_a ($m^3/m^2/h/Pa$) for each brand and the corresponding spreading indicates the maximum and minimum measured value. As explained above, due to limitation of the test setup, air permeability's lower than 0.001 $m^3/m^2/h/Pa$ are measured with less accuracy. Therefore permeability's lower than this limit are not quantified anymore but defined as less permeable then 0.001 $m^3/m^2/h/Pa$. In this study only OSB B appears to be below this limit.

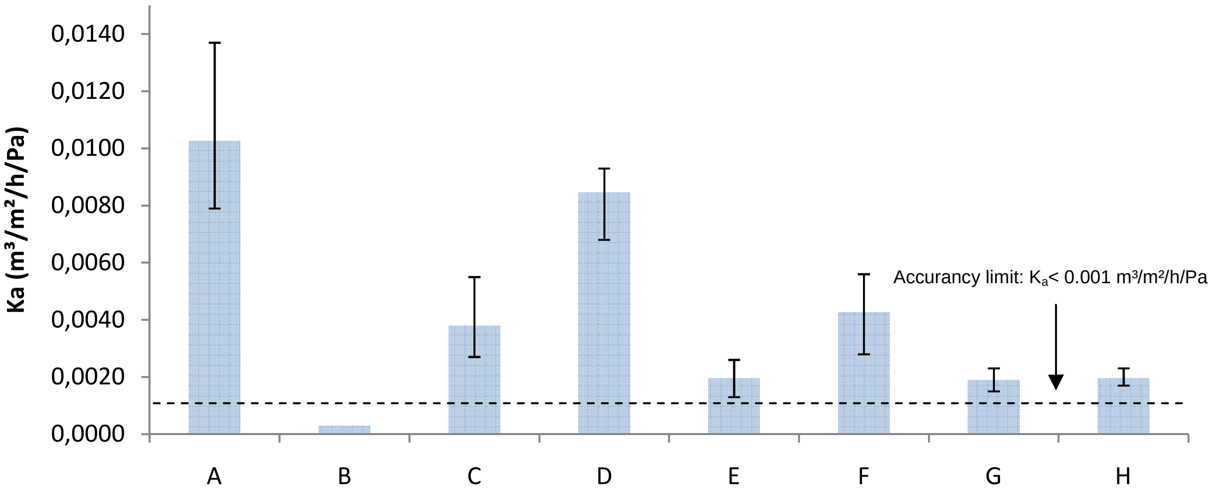

Figure 3: Air permeability of the different brands of OSB tested

The results in Figure 3 clearly indicate a large difference between the air permeance of the different OSB brands tested. For example, OSB B is at least ten times more airtight then OSB A. Furthermore, although only three specimens where measured for each brand, a large variation is noticed within the same brand.

IMPACT ON BUILDING AIRTIGHTNESS

As the results from the previous paragraph only give absolute air permeability's, they do not provide information about the impact of OSB on the global n_{50}-value of typical dwellings. Therefore, to illustrate the importance, in this section the measured permeability is converted to a theoretical contribution to the n_{50}-value:

$$n_{50,OSB} = \frac{A_{OSB}}{V}.K_a.\Delta P_a \tag{2}$$

where $n_{50,OSB}$ is defined as the share of the n_{50}-value corresponding to air transport through the OSB (1/h), A_{OSB} (m²) is area of OSB provided in the air barrier system, V (m³) is the total heated volume and the pressure difference (ΔP_a) is 50 Pa.
The ratio between the OSB surface and the total volume is specific to each project. For a small house where the total air barrier system is composed of OSB, this ratio can easily be twice as high compared to a large compact house with OSB only used in the walls.
In order to use a realistic value for this parameter, data from ten recently build passives houses in Belgium was collected. For these houses this ratio varies from 0.6 to 1.1 1/m with an average value of 0.8 1/m. In the remainder of the analysis these three scenario's will be used to investigate the potential impact on the building airtightness. The worst scenario of the data set, which corresponds to a ratio between the OSB surface and the total volume of 1.1 1/m will be referred as 'high'; the average value (0.8 1/h) is identified as 'mean' and the least critical ratio (0.6 1/h) is referred as 'low'. Figure 4 summarizes the effect of the eight brands of OSB tested on the n_{50}-value for the three mentioned scenarios.

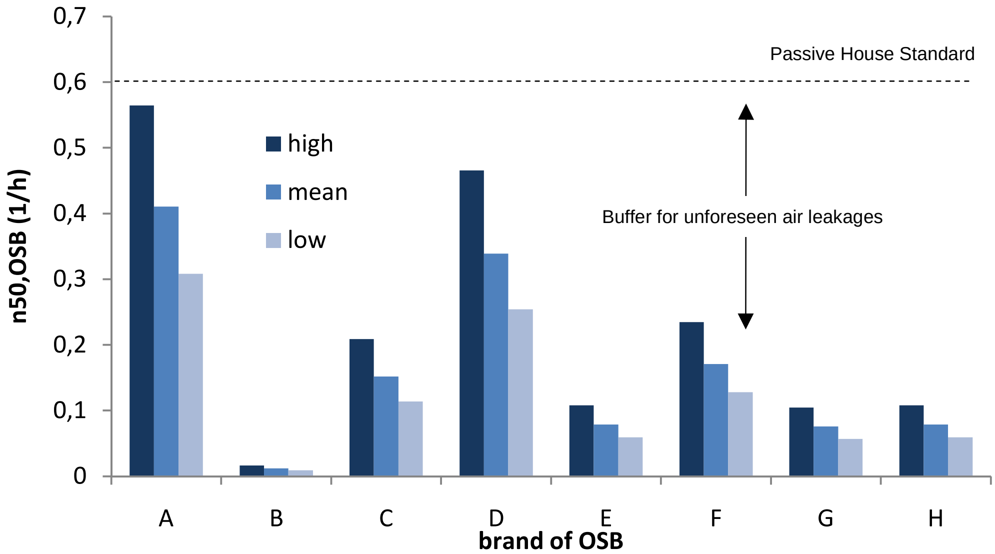

Figure 4: Theoretical contribution of air transport through OSB to global n_{50}-value

Figure 4 shows a large contribution for OSB A and OSB D to the global n_{50}-value. For these two brands the $n_{50,OSB}$-value in the worst scenario almost reach the threshold n_{50}-value for from the Passive House Standard of 0.6 ACH. Adding unforeseen leakages on top, this threshold will most probably be exceeded.

For OSB C, E, F, G and H, the contribution of the air transport through the OSB is lower than 0.25 ACH for all three scenario's. However, this corresponds still to a significant share of air transport through the air barrier material itself. It is interesting to note that only for OSB B the air permeance of the OSB is negligible compared to the global building airtightness requirement.

From Figure 4, question rises how much of the n_{50}-value can be assigned to the air transport through the OSB. As depicted in Figure 4, the Passive House Standard imposes an upper limit of 0.6 ACH. Of course, materials composing the air barrier system should be significantly more airtight to achieve this value since unforeseen leakages are unavoidable. In fact, the concept of tolerating a substantial share of the global building leakages caused by the air barrier material itself is highly questionable. While this contribution could be perfectly controlled, additional leakages caused by the on field execution of the air barrier system are much more difficult to reduce and control. Even extremely carefully sealing all the joints in the air barrier system small leakage will remain. Therefore, the safety buffer to cover these additional leakages, as depicted in Figure 4, should be sufficiently large.
In (Langmans, 2010a/b) a case study is described, where an exterior air barrier system is completely sealed and still unexpected air leakages corresponding with 0.2 ACH occurred. Regarding the circumstances – for this case study where the air barrier was installed with special care – a realistic safety buffer for additional and unforeseen leakages is most probably 0.5 ACH.

RECOMMANDATIONS

The recent trend toward very airtight building requirements, such as the Passive House Standard necessitates upper limits for the air permeance of air barrier materials. In contrast with the requirements for global building airtightness, no such recommendations for the air permeance of the air barrier system exist in Europe. As a result, information of the air permeance of materials applied for air barrier systems is relatively rare. In Canada on the other hand, were the National Building Code (NBC) imposes an upper limit of 0.00096 m³/m²/h/Pa for materials composing the air barrier system, building materials permeability's are better documented (Rousseau, 1998).

Assuming that the buffer, necessary for unforeseen leakages, should be at least 0.5 ACH as mentioned above, the air leakage through the air barrier material must be lower than 0.1 ACH according to the Passive House Standard. Based on the worst scenario used above, corresponding with a compactness of 0.91 m (A_{OSB}/V=1.1), the upper limit for the air permeance results in 0.0018 m³/m²/h/Pa. This proposed limit is still less severe than the Canadian requirement.

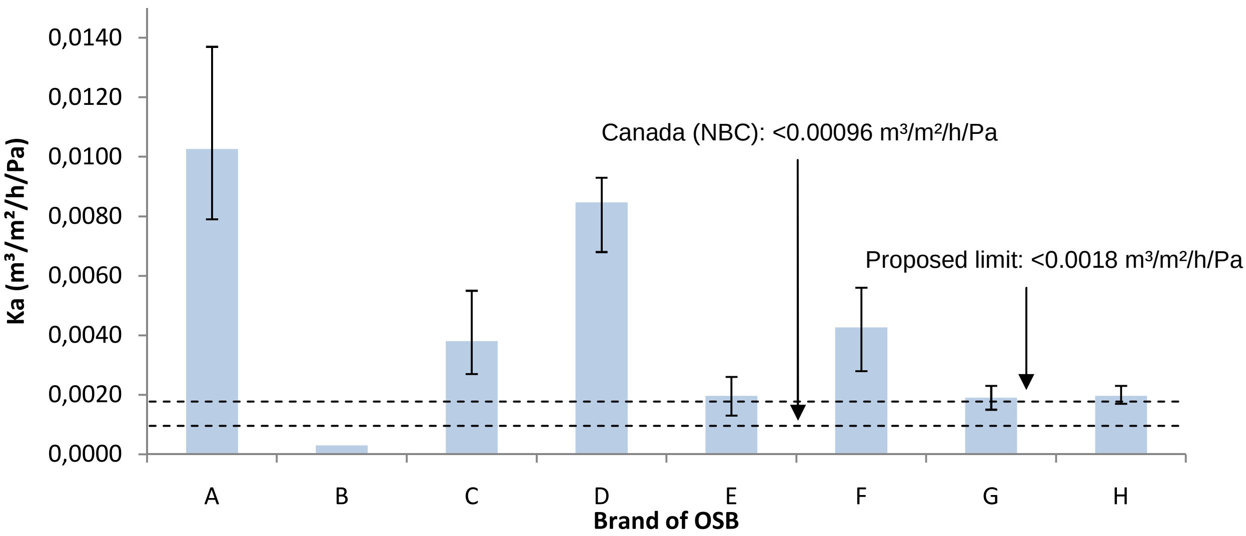

Figure 5: Limits for air permeance of air barrier components against tested materials

Figure 5 summarizes the measured air permeability's together with the proposed limit and the Canadian requirement. As can be seen in figure 5, only OSB B meets both requirements.

CONCLUSION

This paper studies the permeability of eight major commercial brands of OSB, produced in West-Europe. Because it is generally believed that OSB is sufficiently airtight, it is widely applied as air barrier in timber frame structures. However, this study indicates a large variation on the air permeability between the brands tested. Indeed, for some manufactures the air leakage through the OSB can be neglected whereas other brands of OSB are so leaky that it is unlikely that the threshold value of 0.6 ACH for the building can be achieved.

To avoid these problems, this paper suggests an upper limit of 0.0018 $m^3/m^2/h/Pa$ for air permeance of building materials applied as air barrier. Although this limit is less severe than the Canadian requirement, only one of the OSB brands tested satisfies the proposed requirement. As a result of the large variation between the different brands, applying OSB as air barrier system in passive houses seems questionable.

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REFERENCES

DIRECTIVE 2010/31/EU on the energy performance of buildings (recast), 2010

EN 300:2006 Oriented strand boards OSB. Definitions, classification and specification.

EN12114: Thermal performance of buildings - Air permeability of building components and building elements – Laboratory test method

Feist W., Schnieders J., Dorer V., Haas A. (2005). Re-inventing air heating: Convenient and comfortable within the frame of the Passive House concept. *Energy and Buildings*. **37:11**. 1186-1203.

Jokisalo, J., Kurnitski, J., Korpi, M., Kalamees, T., and Vinha, J. (2009). Building leakage, infiltration, and energy performance analyses for Finnish detached houses. *Building and Environment.* ***44:2***. 377-387.

Nield A. and Bejan A. (1992) *Convection in porous media*. Springer-Verslag New York

Langmans J., Klein R., De Paepe M. Eykens P., Roels S. (2010a) Feasibility of using wind barriers as air barrier in wood frame constructions, Thermal Performance of the Exterior Envelopes of Whole Buildings XI, Clearwater Beach, Florida, Accepted

Langmans, J., Klein, R., De Paepe, M., and Roels, S. (2010b) Potential of wind barriers to assure air-tightness of wood-frame low energy constructions, *Energy and Buildings*, Vol. In Press, Accepted Manuscript.

Rousseau J. (1998). Air permeance of Building Materials, Research Highlights. Technical Series: 98-109. (Available on http://www.cmhc.ca/publications/en/rh-pr/tech/98109.htm)

The Minergie®-Standard for buildings (2008) (Available on www.minergie.ch/tl_files/download_en/Faltblatt_Minergie_Standard_e.pdf)

Wouters P., Rémi Carrié F. (2008) Implementation of Energy Performance Regulations: Opportunities and Challenges related to Building Airtightness. EPBD building platform