Building and Environment 116 (2017) 121–129

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Air leakage levels in timber frame building envelope joints

Targo Kalamees*, Üllar Alev, Mihkel Pärnalaas

Tallinn University of Technology, Chair of Building Physics and Energy Efficiency, Estonia

ARTICLE INFO

Article history:
Received 19 November 2016
Received in revised form
16 February 2017
Accepted 18 February 2017
Available online 20 February 2017

Keywords:
Air permeability of building components and building elements
Air leakage
Airtightness
Air infiltration
Fan pressurisation test

ABSTRACT

Air leakage levels from eight joints that use different tightening solutions for a prefabricated timber frame building envelope were measured under laboratory conditions. Air tightness levels in field conditions were also studied by using houses that have already been built.

Joints in the external wall with an inserted floor and separating walls, as well as in the external corner of walls, all showed the largest levels of air leakage. The lowest air leakage levels were recorded in the joint between the external wall and the window.

Tightening up the external weather barrier significantly improved the air tightness levels of the joints. Using self-adhesive tape in tightening up the air-vapour barrier and the weathering barrier seems to be the most promising solution when it comes to guaranteeing the air tightness of wooden-framed structures.

The difference between air leakage levels as measured in field conditions and those which were calculated based on laboratory measurements was noticeably large. This was caused mainly by workmanship quality levels on the construction site sealing the building envelope's joints and the fact that there were other leakage places in addition to the typical joints that were studied. Improved research, development, design, construction, and supervision are needed to fulfil airtightness requirements in future construction when it comes to producing nearly Zero Energy Buildings (nZEB).

In order to be able to estimate the airtightness levels of a building in the design phase a larger database is needed, with different combinations made available in terms of joints, materials, and workmanship.

1. Introduction

Air leakage is an important aspect of a building, which influence energy use [1–4], the hygrothermal performance of the building envelope [5–7], indoor air quality [8–10], air pressure conditions over the building envelope [11,12], the performance of natural ventilation [13], and fire safety [14]. The critical influencing factors of air leakage of the building envelope are building management and the methods used in that management process, dwelling type [15,16], the age of the building [17], and the number of stories within the building [17,18]. Two main parameters are required in order to guarantee the air tightness of the whole building: a durable air barrier and its connectivity to other building components.

The location of the air barrier could vary depending on the design solution being used. It can be located either in the interior or exterior surface of the building envelope. The air barrier could be the insulation or the load bearing structures themselves. In cold climates the traditional solution has been to use vapour barrier as an air barrier in a timber-framed building envelope [18–20].

Tightening up and sealing air barrier joints is as important in guaranteeing the airtightness levels of the whole building as the material used in the air barrier itself, because air leakage usually occurs in the building envelope's connections. Relander et al. [21] concluded in their review about airtightness estimations that component leakage methods could be a possible estimation method, but the AIVC [22] and other [23] component leakage databases are rather old and the results are very sensitive to workmanship quality. This could be the reason why this methodology is questionable for Mediterranean countries [24]. The influence of the sealing and tightening method on air leakage has later been studied for its connection to structural floors [25], basement walls [26,27], chimneys [28], and windows [29,30]. Measuring the air leakage rate before signing off a new building for use has become more and more part of common practice. If the air leakage test at the final stage of construction shows too large an air leakage, then repairing the leakage is very expensive and it can be very difficult to reach the

* Corresponding author. Ehitajate tee 5, Tallinn 19086, Estonia.
E-mail address: targo.kalamees@ttu.ee (T. Kalamees).

http://dx.doi.org/10.1016/j.buildenv.2017.02.011
0360-1323/

required target. Therefore, information about air leakage from different building envelope joints is very important when it comes to understanding and proofing performance, as well as guaranteeing the realisation of future nearly Zero Energy Buildings (nZEB).

In this study, typical timber-frame external wall connections to other building envelope parts were studied under laboratory conditions in order to understand air tightness performance levels, and also to be able to get information about air leakage values in joints that utilise different tightening and sealing solutions. In order to be able to see the influence of workmanship and the performance of studied joints in reality, the full air leakage rates of houses which used the same jointing methods were measured on site.

2. Methods

2.1. Laboratory measurements

Measurements of the air leakage from building envelope joints were conducted under laboratory conditions, based on the EN 12114 standard [31]. Air leakage test equipment (Fig. 1) consists of the following:

- Hermetic chamber (plywood with 0.5 mm steel plate) with the test area at a width of 1360 mm, a height of 2260 mm, and a depth of 900 mm.
- Fan (Elmo Rietschle G-BH1, positive pressure difference ≤100 kPa, negative pressure difference ≤90 kPa, air flow 50–2450 m^3/h) for creating air flow; frequency converter (EATON DC1-S24DNN-A20N) to regulate air flow.
- Air flow calibrator (Dwyer: GFC 1109 for 0–5 l/min, GFC 1131 for 0–30 l/min, GFC 1144 for 0–500 l/min, with an accuracy of ±1.5%).
- Differential manometer (Produal PEL-DK for 0–1000Pa and Dwyer Magnesense MS for 0–100 Pa, with an accuracy of ±1%) for pressure difference measurements.
- Temperature and relative humidity sensor (Rotronic HygroClip SC05).
- Data-logger (Grant Squirrel SQ2010, 8 channels) for automatic and simultaneous data reading and saving.

Air leakage measurements were conducted at different air pressure differences, depending on the individual test, of up to ±600 Pa together with three pressure pulses (Fig. 2, left) according to EN 12114 standard. The air flow rate and static air pressure differences were measured and recorded at each step automatically. The relation between the pressure difference and the airflow through the building envelope (Fig. 2, right) allowed the results to be presented using the power law (Eq (1)):

$$\dot{V} = C \cdot \Delta P^{n}, \;\; \text{m3/h} \tag{1}$$

Where $\dot{V}$ [m^3/h] is the airflow, ΔP is the air pressure difference [Pa], and C [$m^3/(h \cdot Pa^{\,n})$] and n [-] are constants obtained from curve fitting, with n ranging from 0.5 to 1.

By knowing the characteristics of all air leakages (joints from i to x and building envelope parts from j to y), it is possible to estimate future air leakage across the whole building (Eq (2)):

$$\sum \dot{V} = \sum_{joint\;\;i} C_i \cdot \Delta P^{n_i} + \sum_{joint\;\;x} C_x \cdot \Delta P^{n_x} + \sum_{building\;\;envelope\;\;j} C_j \cdot \Delta P^{n_j} + \sum_{building\;\;envelope\;\;y} C_y \cdot \Delta P^{n_y} \tag{2}$$

2.2. Structures studied

Timber-framed external wall connections with other building envelope parts were subject to current measurements. The external wall ($U \approx 0.17$ $W/(m^2 \cdot K)$ was fully insulated with 240 mm (195 mm + 45 mm) mineral wool. In order to regulate the moisture diffusion a vapour barrier (plastic sheet) was installed on the inner part of the insulation (45 mm from the internal side of the insulation), for the external walls that were studied. The vapour barrier also functioned as an air barrier. The external side of the insulation was covered with a wind barrier (9 mm gypsum board) and a weathering membrane. As both of them have some level of air resistance, they also provide the sole means of ensuring airtightness in the joint. The building envelope joints that were studied (Fig. 4, Fig. 3) were selected based on the field study [18] as the most typical examples:

- The external wall joint with the external wall (EW/EW): 1 - without a taped weathering membrane; 2 - with a taped weathering membrane; the air-vapour barrier was installed with an overlap in both cases;

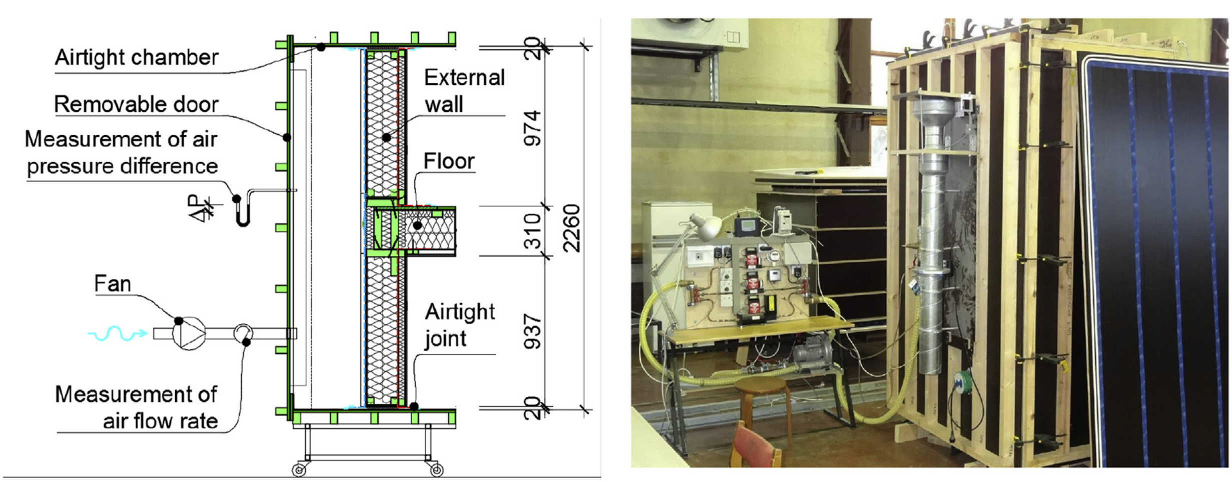

Fig. 1. Test arrangements for the tests of structures in the air leakage test equipment (dimensions in mm).