Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 78 (2015) 2046 – 2051

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Air leakage of concrete floor and foundation junctions

Üllar Alev[a,]*, Peeter Antsov[b], Targo Kalamees[a]

[a]*Tallinn University of Technology, Ehitajate tee 5, Tallinn, 19086, Estonia*
[b]*Estonian University of Life Sciences, Kreutzwaldi ,1 Tartu, 51014, Estonia*

Abstract

Air leakage of the building envelope is a significant contributor to radon concentration levels. The aim of our work was to determine the air leakage rate through the foundation wall and the floor joint. Different sealing methods were investigated to compare their effect on the air leakage of the joint. Additional tests were made to gather information about the construction quality and the reproducibility of measurement results. The air leakage rate decreased between 1.3 and 86 times depending on the sealing method. Essentially, the air leakage rate was found to depend heavily on the quality of the construction works.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

Keywords: air leakage, radon, foundation, laboratory measurements, construction quality

1. Introduction

Air leakages through different junctions of a building envelope lead to many problems, including higher energy consumption, outdoor or below-floor pollutants [1], and influence indoor radon concentration [2]. Of the leakage places in a building, the joint of the floor and the external floor is prevalent [3,4]; in old buildings, this junction has higher leakage [4]. It is easier to locate the leakage places and analyze the distribution statistically, as reported in [3,4]; another approach used is to measure the leaked air volume through main leakage places [5]. Jelle et al. have developed a calculation method for indoor radon concentrations [6]. One of the components of this formula is the air convection through floor construction. Slab-on-ground foundation is the prevalent type in low-rise residential buildings in Nordic countries and the main radon entry point is the gap between the floor slab and the foundation

* Corresponding author. Tel.: +372 620 2402.
E-mail address: ullar.alev@ttu.ee

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.217

wall [7]. Arvela et al. concluded that 'The key issue regarding radon is the prevention of air leakages in the foundation' [8, p. 11].

As there is lack of information about air leakage rates through building components and joints [9], the main objective of this study is to measure the air leakage rate on the ground junctions of three common wall and floor points and on their improved versions.

Methods

1.1. Measurements

Measurements were performed according to the methods in the standard EVS-EN 12114:2000 [10]. Before the test the surrounding room temperature and relative humidity (RH) were measured to ensure their stability at the time of testing series. Temperature requirement was +15 °C…+30 °C (variability <±2 K) and RH 25%…75% (variability <±5%). Materials were stored in the room before to allow the materials' RH and temperature to be stabilized. The pressure difference varied between 10 to 60 Pa with 5 Pa steps. In each step the parameters were logged with 1 second intervals for 1 minute.

Laboratory measurements were carried out in a specially built test chamber, Fig. 1. The 1.5 m x 1.5 m chamber was made of laminated waterproof plywood, additionally covered with sealed metal sheet on the inner surface to minimize its air leakage. Top and bottom parts of the chamber were removable: the bottom side was left open for measurements and the cover on top was placed and tightened after constructing the structure under investigation.

The under- and overpressure was generated either with an Elmo Rietschle vacuum pump or with a Systemair K 100 XL duct ventilator for lower or higher air leakage volumes, respectively. The leakage air volume was measured with a SPI-125 C Iris damper (with duct ventilator) or Dwyer mass flowmeters and controllers (three different ranges). The pressure difference was measured with a Dwyer Magnesense differential pressure monitor and logged in conjunction with air flow, room temperature and relative humidity into a Grant Squirrel SQ2010 data logger.

1.2. Measured construction designs

First, the air leakage of the original leaky joint was measured and then after each improvement step it was repeated. A couple of improvements were implemented and measured multiple times to find out the repeatability of the results. Three wall and floor joints were measured, which represent the types often used in smaller buildings.

Old limestone foundation and concrete base floor in existing houses (BW/BF, Fig. 2)

- BW/BF-0: original case with a large crack between the floor and the basement wall made of rustic sandstone bricks (dense mineral wool layer separated the slab and the wall during construction and first measurement);

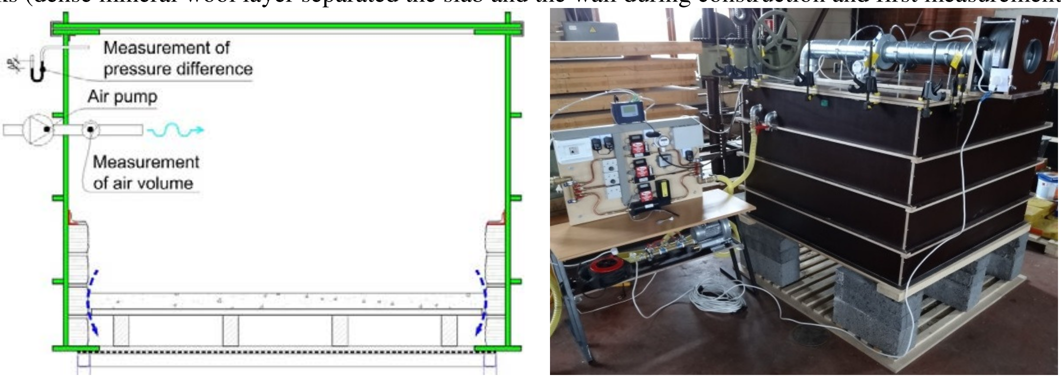

Fig. 1. Section of the air leakage test chamber (left). View of the test chamber with measurement equipment (right).

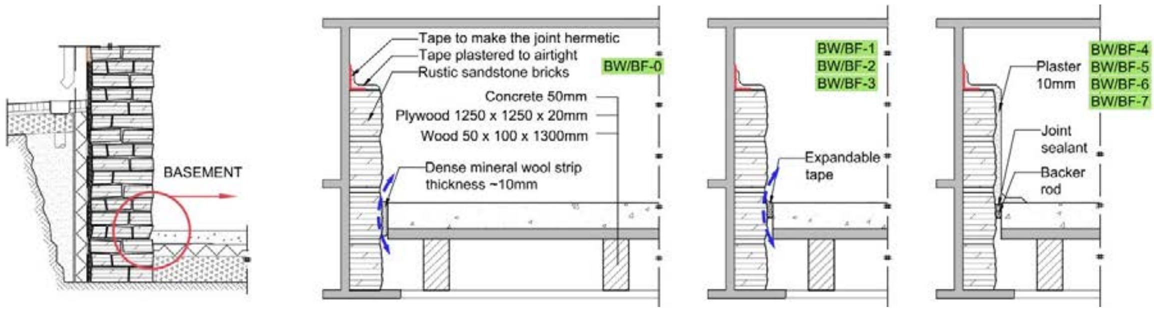

Fig. 2. Actual design (left, M 1:30), section of test design for an old foundation junction and improvements (center and right, M 1:15) .

- BW/BF-1: mineral wool was removed, the crack was cleaned and filled with polyurethane adhesive expandable tape impregnated with acrylic dispersion (advertised as best of that kind of products);
- BW/BF-2: the crack was cleaned and the new expandable tape was installed (the same material as in the previous step) with planned poor installation in corners;
- BW/BF-3: the crack was cleaned and pre-compressed PUR sealing tape impregnated with a fire resistant polymeric dispersion (another comparable product) was installed;
- BW/BF-4: sealing tape was removed, the crack was cleaned and filled with a closed cell backer rod (Ø20 mm);
- BW/BF-5: special joint sealant and adhesive paste were added to the crack and allowed it dry a few days;
- BW/BF-6: joint sealant and backer rod were removed, on two previous steps were repeated two more times;
- BW/BF-7: sealed joint together with siding wall and floor parts were plastered 10 cm to both sides.

Separating wall and its foundation joint with insulated concrete slab-on-ground (SW/SG, Fig. 3)

- SW/SG-0: original case: concrete slab-on-ground was separated from the separating wall (made of expanded clay lightweight concrete blocks; foundation and wall was separated with the capillary break strip) with tightly fitted expanded polystyrene layer (10 mm);
- SW/SG-1: the floor was covered with a self-leveling mortar layer (5 mm thickness, filled also the corner crack) and allow it dry for a few days;
- SW/SG-2: expanded clay lightweight concrete blocks were plastered with 10 mm thick mortar layer (vertical surfaces).

External wall and slab-on-round in new buildings (EW/SG, Fig. 4)

- EW/SG-0: original case: foundation wall made of expanded clay lightweight concrete blocks, wall made of autoclaved aerated concrete blocks and insulated concrete slab on ground; water vapor barrier of the floor is not connected with the capillary break strip between the foundation and the wall;

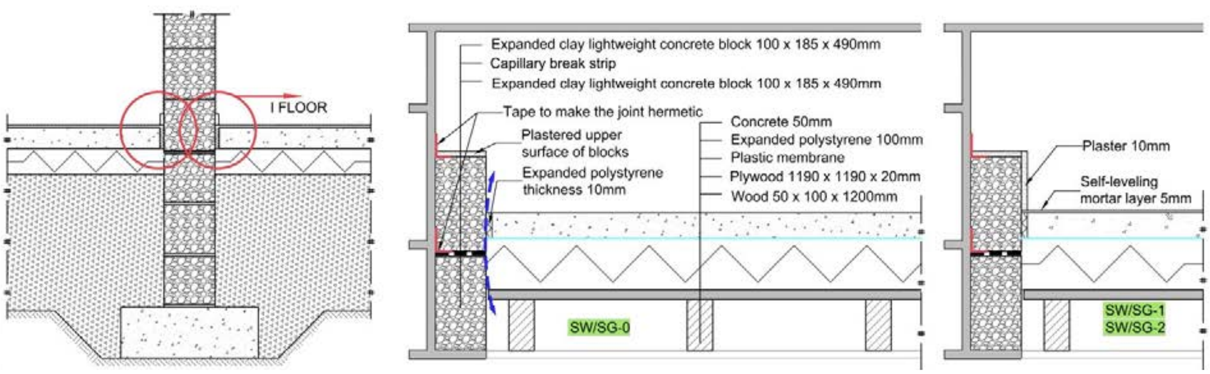

Fig. 3. Actual design (left, M 1:30), section of test design for a separating wall junction and improvements (center and right, M 1:15).

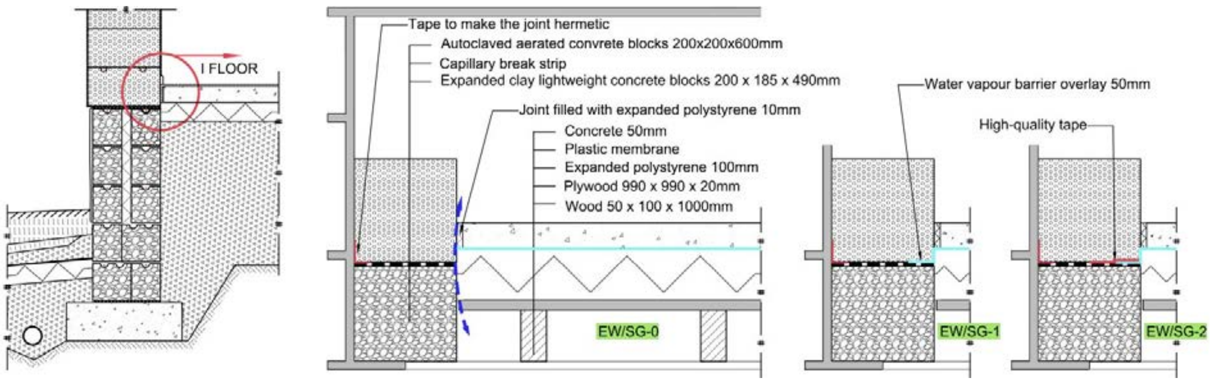

Fig. 4. Actual design (left, M 1:40), section of test design for a new foundation junction and improvements (center and right, M 1:15).

- EW/SG-1: water vapor barrier was replaced with a larger one, 50 mm overlay on the capillary break strip (between the foundation and the wall blocks);
- EW/SG-2: water vapor barrier and capillary break strip were taped together with a high-quality tape.

Results

The measurement results are presented in Figs. 5 and 6 and in Table 1. The influence of the quality of workmanship is presented in Fig. 5 (right), at 50 Pa pressure difference, the small defects in four corners (the tape was just curved rather than cut and placed in two pieces) increased the leakage rate by 19% according to measurements. Fig. 5 (right) shows that at proper placing, the results are quite well repeatable, but at failure when the backer rod was removed from the crack and the same one was placed again, the air leakage increased more than two times (backer rod 2). The highest decrease of the air leakage rate of the old limestone foundation wall (BW/BF) can be achieved by sealing the joint with a special sealant paste (more than 500 times compared to the original case and more than 100 times compared to the backer rod installed below the sealant) (Table 1).

In SW/SG junction, the self-leveling mortar filled the crack between the concrete slab and the wall, which decreased the leakage rate by 3.5 times, but the air leakages through the wall material stayed. In BW/BF junction, the influence of plastering of the wall was smaller than in SW/SG junction (2.4 compared to 24 times, respectively), because of higher air permeability of the foundation wall material (sandstone bricks and expanded clay lightweight blocks). EW/SG junction showed that overlay of the plastic membrane and the capillary break strip resulted in a substantially lower leakage rate (22 times), but taping these together is also important, as it gave an additional decrease of the leakage rate by 7.9 times at 10 Pa pressure difference.

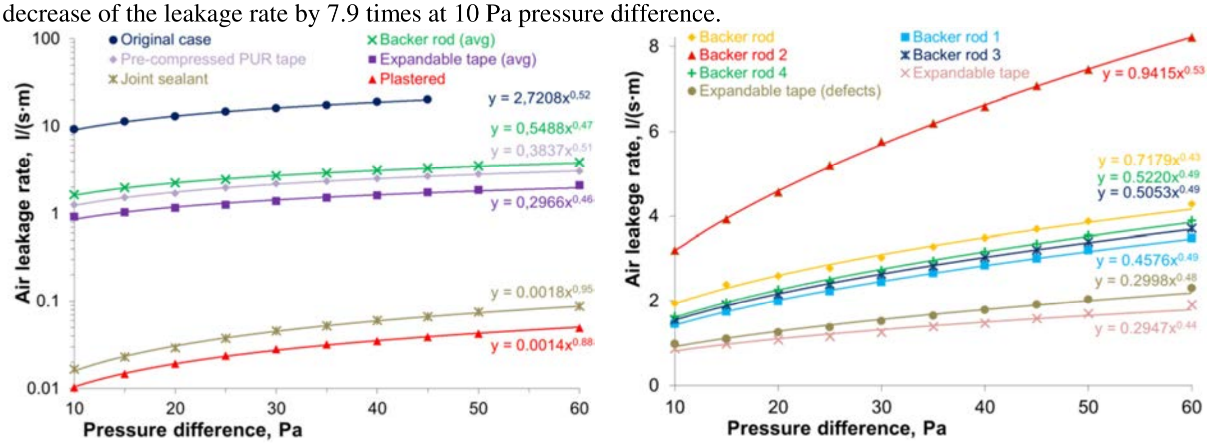

Fig. 5. Air leakage rate of the test design BW/BF (left), test samples of expandable tape and test samples of backer rod (right).

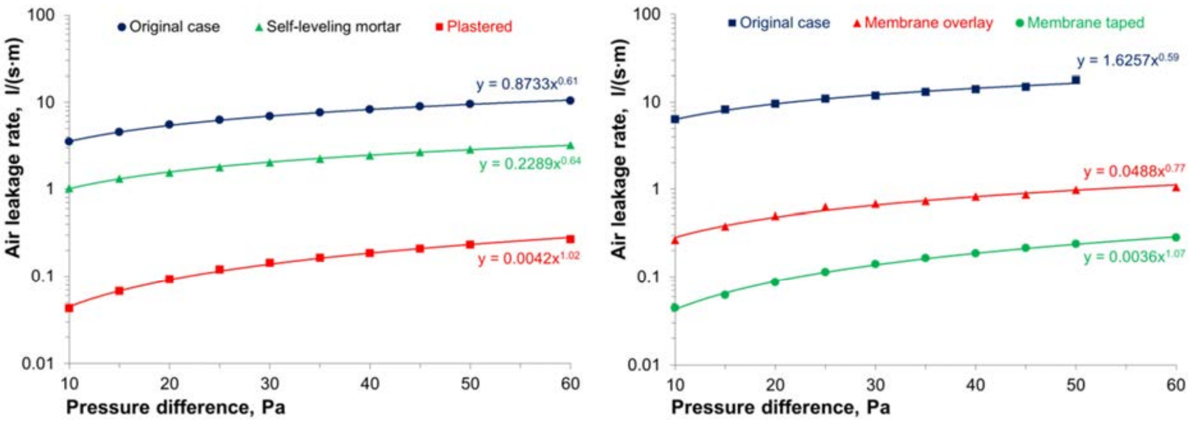

Fig. 6. Air leakage rate of the test design SW/SG (left) and the test design EW/SG (right).

Formulas in Figs. 5 and 6 are based on the measurement results, but the physics behind is represented as an air flow rate equation, where *C* is the flow coefficient and *n* is the flow exponent. The values of *n* are in the range 0.5–1. Therefore, the formulas in the figures were corrected and then presented in Table 1 with the decreased air leakage rates from the previous and the original case result of the test. The selected comparison pressure difference is 10 Pa.

Table 1. Air leakage rate of test designs and the decrease from original case

Construction design	Air leakage, m^3/s	Air leakage rate through the junction, l/(s·m)			Decrease @10Pa, times	
	$\dot{V} = C \cdot \Delta p^n$	Δp =4Pa	Δp =10Pa	Δp =50Pa	from original	from previous
Test 1: Original case	$V=2.7208 \cdot \Delta p^{0.52}$	5.6	9.1	21	-	-
Backer rod	$V=0.5488 \cdot \Delta p^{0.50}$	1.1	1.7	3.9	5.2	5.2
Pre-compressed PUR tape	$V=0.3837 \cdot \Delta p^{0.51}$	0.78	1.2	2.8	7.3	1.4
Expandable tape	$V=0.2966 \cdot \Delta p^{0.50}$	0.59	0.94	2.1	9.7	1.3
Joint sealant	$V=0.0018 \cdot \Delta p^{0.95}$	0.0067	0.016	0.075	560	58
Plastered	$V=0.0014 \cdot \Delta p^{0.88}$	0.0047	0.011	0.043	860	1.5
Test 2: Original case	$V=0.8733 \cdot \Delta p^{0.61}$	2.0	3.6	9.5	-	-
Self-leveling mortar	$V=0.2289 \cdot \Delta p^{0.64}$	0.56	1.0	2.8	3.5	3.5
Plastered	$V=0.0042 \cdot \Delta p^{1.0}$	0.017	0.042	0.21	85	24
Test 3: Original case	$V=1.6257 \cdot \Delta p^{0.59}$	3.7	6.4	17	-	-
Membrane overlay	$V=0.0488 \cdot \Delta p^{0.77}$	0.14	0.28	0.98	22	22
Membrane taped	$V=0.0036 \cdot \Delta p^{1.,0}$	0.014	0.036	0.18	180	7.9

2. Discussion

Although the soil below the floor slab was not included in the laboratory tests, the level of decrease in Table 1 will probably stay the same. The original case was chosen and constructed to be leaky but still realistic in real constructions, therefore the total decrease shown in Table 1 will overestimate the actual possible decrease of the air leakage rate.

Based on our or any other laboratory or in-situ measurements, the airtightness of a building cannot be accurately predicted, as reported by Relander [11]. Relander et al. have reviewed different approaches and models used to estimate the airtightness of the whole building based on the components [11]. The conclusion was that the airtightness cannot be accurately estimated in the planning stage and the stepwise blower-door tests are suggested during the construction process. Nevertheless, it is important to choose junction solutions in the planning stage, which will guarantee an airtight envelope with higher probability.

3. Conclusions

The air leakage rate of three commonly used foundation and slab-on-ground junctions was measured in laboratory conditions: an old construction with limestone walls, an external wall made of lightweight blocks and a separating wall made of lightweight blocks. After improvements made to each construction, the leakage rate was measured again. When the original leaky rustic sandstone brick wall (imitated the limestone) and the floor junction were sealed using a backer rod with a joint sealant paste, the air leakage decreased more than 500 times. The effect of an added plaster layer was lower. When the plastic membrane below the slab was overlaid on the capillary break strip on the foundation, the air leakage rate was 22 times lower than the original separated version. Taping the overlay with the capillary break resulted in a further decrease of 7.9 times. The air leakage rate was 3.5 times lower when self-leveling mortar laid over the slab filled the crack between the slab and the separating wall; when the wall was plastered, an additional decrease of 24 times was achieved.

Acknowledgements

The study has been conducted as part of the IUT1-15 project “Nearly-zero energy solutions and their implementation on deep renovation of buildings“. The research was supported with a grant from the European Union, through the European Social Fund, Mobilitas grant No MTT74 “Nearly zero energy buildings (nZEB) in Estonia: energy, durability and indoor climate performance analyses combined with cost optimality assessment for transformation”.

References

[1] Airaksinen M, Pasanen P, Kurnitski J, Seppänen O. Microbial contamination of indoor due leakages from crawl space. Indoor Air 2004. 2004. p. 55–64.
[2] Ljungquist K. A Probabilistic Approach for Evaluation of Radon Concentration in the Indoor Environment. Indoor Built Environ 2005 14(1):17–27.
[3] Kalamees T, Korpi M, Eskola L, Kurnitski J, Vinha J. The distribution of the air leakage places and thermal bridges in Finnish detached houses and apartment buildings. In: Rode C, editor. Proceedings of the 8th Symposium on Building Physics in the Nordic Countries. Copenhagen: Dept. of Civil Engineering, Technical University of Denmark; 2008. p. 1095–102.
[4] Alev Ü, Kalamees T. Field Study of Airtightness of Traditional Rural Houses in Estonia. In: Karel Kabele, Miroslav Urban, Karel Suchý ML, editor. Proceedings of CLIMA 2013. 2013. p. 6882.
[5] Jelle BP, Noreng K, Erichsen TH, Strand T. Implementation of radon barriers, model development and calculation of radon concentration in indoor air. J Build Phys 2010;34(3):195–222.
[6] Pereira PF, Almeida RMSF, Ramos NMM, Sousa R. Testing for building components contribution to airtightness assessment. In: Proceedings of the 35th AIVC - 4th TightVent - 2nd venticool Conference , 24-25 September, Poznan 2014. AIVC. p. 322–330.
[7] Arvela H, Holmgren O, Reisbacka H. Radon prevention in new construction in Finland: a nationwide sample survey in 2009. Radiation protection dosimetry. 2012. p. 465–74.
[8] Arvela H, Holmgren O, Reisbacka H, Vinha J. Review of low-energy construction, air tightness, ventilation strategies and indoor radon: results from Finnish houses and apartments. Radiat Prot Dosimetry. 2014;162(3):351–63.
[9] Sandberg PI, Sikander E. Lufttäthetsfrågorna i byggprocessen - Kunskapsinventering, laboratoriemätningar och simuleringar för att kartlägga behov av tekniska lösningar och utbildning, SP Rapport 2004:22.
[10] EVS-EN 12114:2000. Thermal performance of buildings - Air permeability of building components and building elements - Laboratory test method.
[11] Relander T-O, Holøs S, Thue JV. Airtightness estimation—A state of the art review and an en route upper limit evaluation principle to increase the chances that wood-frame houses with a vapour- and wind-barrier comply with the airtightness requirements. Energy Build. 2012;54:444–52.