IMPACT OF THE USE OF A FRONT DOOR ON THERMAL COMFORT IN A CLASSROOM IN A PASSIVE SCHOOL

Hilde Breesch[*1], Barbara Wauman[1,2] and Alexis Versele[1]

1 KU Leuven Campus Ghent, Faculty of Engineering Technology, Sustainable Building
Gebroeders De Smetstraat 1
B-9000 Ghent, Belgium
**Corresponding author: Hilde.Breesch@kuleuven.be*

2 KU Leuven, Department of Civil Engineering
Building Physics Section,
Kasteelpark Arenberg 40, box 2447
B-3001 Heverlee, Belgium

ABSTRACT

A new school building block in Passivehouse standard near Kortrijk (Belgium) is in use since spring 2013. The urban development regulations required that this new building did not influence the incidence of daylight in the adjacent dwellings. This results in an open corridor on the first floor and classrooms with a front door. Draught and increased energy losses are expected. This design choice is contradictory to the basic idea of a passive school that aims to be very airtight and to have very low energy use and excellent thermal comfort.
The aim of this paper is to evaluate the impact of the use of the front door on the thermal comfort in the classroom in this passive school in winter season. The requisite heating capacity at the time the door is opened is also determined and compared to the installed capacity.
This evaluation is based on a survey of pupils and teachers and on measurements in the classroom in winter 2014. The survey studies the experiences of the users. The measurements determine the use of the front door, i.e. the duration and frequency of opening, during one week. In addition, operative temperatures are measured on several positions and heights in the classroom. Finally, the airflow through the door is determined by tracer gas measurements.
The survey concluded that every respondent experiences cold draught and almost all users are annoyed by this draught. Monitoring showed that less than half the openings were expected based on the timetable of the classroom. The most occurring opening durations are 6 and 20s. The airflow was determined by tracer gas measurements for these opening durations. A significant temperature decrease was found close the door. Impact factors on the magnitude of decrease are opening duration, indoor-outdoor temperature difference, wind speed and direction, successive openings. The effect on the temperature is not evenly spread in the classroom. The temperature decrease significantly reduces as the distance to the front door increases. Temperature decrease is more pronounced close to the floor.
Survey and monitoring showed that a the use of the front door influences thermal comfort and increases infiltration losses in this classroom in this passive school. It is advised to consider this effect in the design of heating system in and the assessment of energy performance of future Passive House projects including rooms with front doors.

KEYWORDS

User impact, passive school, thermal comfort, infiltration losses

1 INTRODUCTION

Since the implementation of the European Directive 2002/91/EC on the Energy Performance of Buildings the number of passive non-residential buildings has increased significantly (Kaan, 2006). In Flanders (Belgium), the evolution towards more energy efficient schools in particular was boosted in 2009 by the approval and subsidizing of 24 passive schools, covering almost 65000 m². The following criteria for Flemish passive schools were set forward by the government:

1° annual net energy need for heating $\leq$ 15 kWh/(m².a)
2° annual net energy need for cooling $\leq$ 15 kWh/(m².a)
3° maximum air tightness level (n_{50}) $\leq$ 0,6 h^{-1}
4° maximum E-level = 55 (primary energy performance level as required by EPB (EPB, 2013)

The new school building block in Passive House standard near Kortrijk (Belgium) is one of these 24 schools. The urban development regulations required that this new building did not influence the incidence of daylight in the adjacent dwellings. This results in an open corridor on the first floor and classrooms with a front door (see Figure 2). As this door is expected to be used intensively, draught and increased infiltration losses and thus heat losses are expected. This design choice is contradictory to the basic idea of a passive school that aims to be very airtight (and thus having very low infiltration losses), to have very low energy need for heating and a low primary energy performance level and an excellent thermal comfort. Infiltration losses due to the front door in a German passive school was already studied by Peper et al. (2007, 2008). Extrapolated to a full occupancy of the school, an additional heat loss of 0.5 kWh/m².a was calculated.

The objective of this paper is to evaluate the impact of the use of the front door on thermal comfort and the infiltration losses in a classroom in this passive school in winter season. This paper is based on the results of Houwen and Van Lerberghe (2014).

2 BUILDING DESCRIPTION

The new school building block in Passive House standard has a floor area of about 1500 m² and includes 3 floors with classrooms, labs, offices and a study hall. A plan of the first floor and a cross section are shown on Figure 1 and Figure 2. Dimensions of the class room and SE wall with front door are indicated on Figure 3. The classroom has a floor are of 49.8 m², dimensions of front door are 1.15m x 2.36m. Balanced mechanical ventilation is provided, the airflow in the classroom is 750 m³/h. For heating purposes, the air is preheated by an air-to-air heat recovery. Additionally, a central and local heating coil of 24 kW and 2.5 kW respectively are integrated in the supply duct. Lessons start at 8h20 and ends at the latest at 16h50. Table 1 defines in detail the use of the classroom.

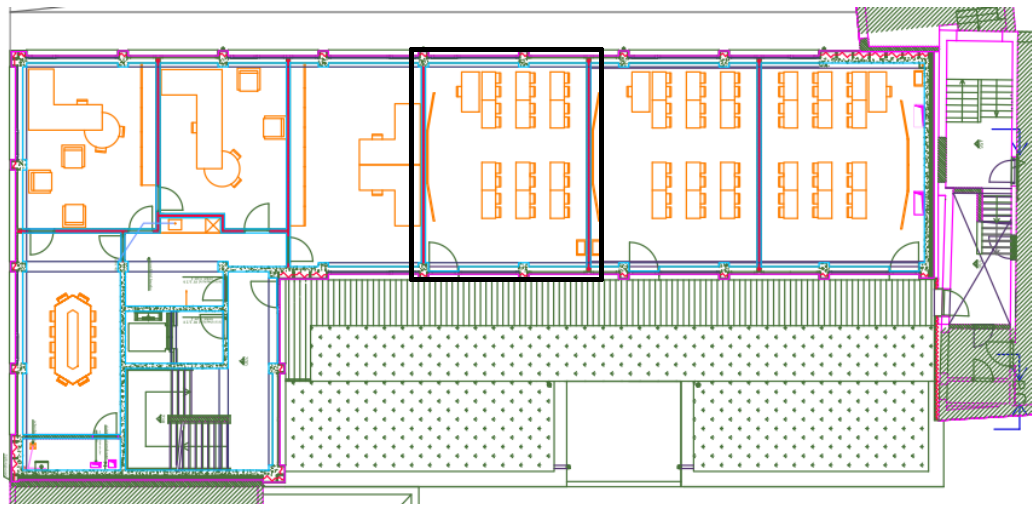


Figure 1: Floor plan of new passive school building block, classroom indicated with a black rectangular

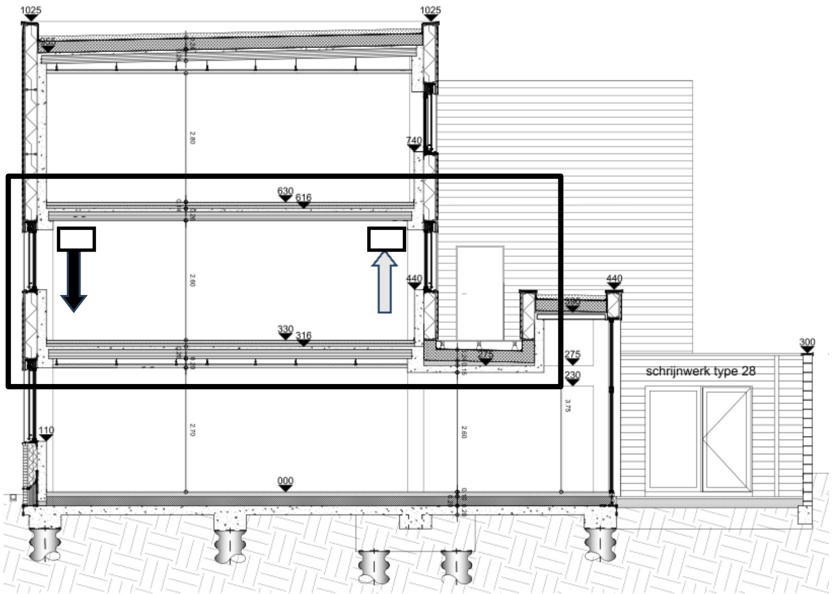


Figure 2: Cross section of new passive school building block, classroom with open corridor indicated with a black rectangular

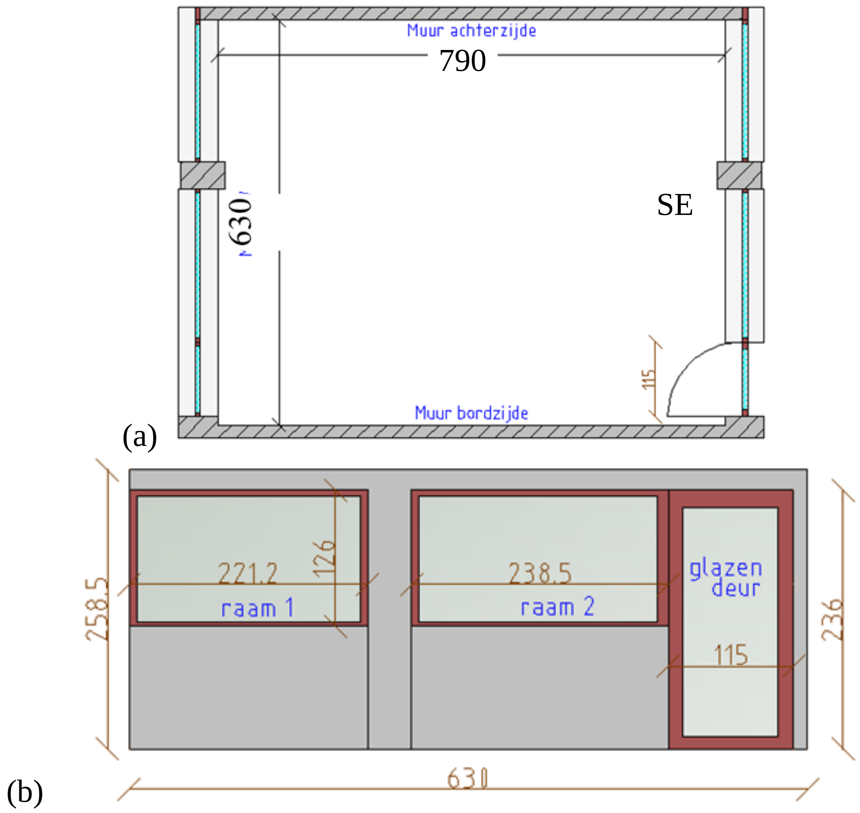


Figure 3: Floor plan (a) and SE wall (b) of the classroom

Table 1: timetable of lessons in the classroom

Day	8h20	9h10		10h15	11h05		13h15	14h05		15h10	16h
Mon	■	■		■	■		■	■			■
Tue		■		■	■					■	
Wed	■	■									
Thu							■	■		■	■
Fr				■	■		■	■		■	

3 METHODS

3.1 Survey

The evaluation of the impact of the use of the front door is based on a survey of 48 pupils and teachers. The survey was conducted during the week of January 6 to 10, 2014. The survey studies the experiences of the users and tries to answer to following questions. How do they evaluate the thermal comfort in the classroom? Do they feel a draught due to the opening the front door? Are they annoyed by this draught due to the opening of the door? Can this experience linked to their position in the classroom, the time of the day or the weather? Which actions do they take?

3.2 Measurements

Measurements determine the use of the front door, i.e. the duration and frequency of opening, during one week. An event data logger, recording the changes in state: open/closed, was put on the front door. In addition, operative temperatures are measured on 6 positions and 2 heights, i.e. on 10 cm and 60 cm as advised by EN ISO 7726, in the classroom. Figure 4 shows the measurement set up. Two aspects are studied: the local effect close to the door (sensor T1 at 10 cm above the floor) and the zone of influence in the classroom. The accuracy of temperature sensors is ± 0.35°C. The measurements were carried out every 10s from February 24 to 28 2014. Furthermore, the airflow through the door is determined by tracer gas (SF_6) measurements according to EN ISO 12569. The concentration decay test method is used. A small test room of 7.54 m³ is constructed around the front door. Tracer gas is injected at a height of 2.4 m, samples are taken at a height of 1.1 m and 1.8 m every 2 min. A fan ensures a uniform distribution of the tracer gas. The measurement is repeated 3 times for each opening duration. Outdoor temperature, wind speed and direction are obtained from the nearby meteorological station of Izegem. Measurements are conducted on March 27 2014.

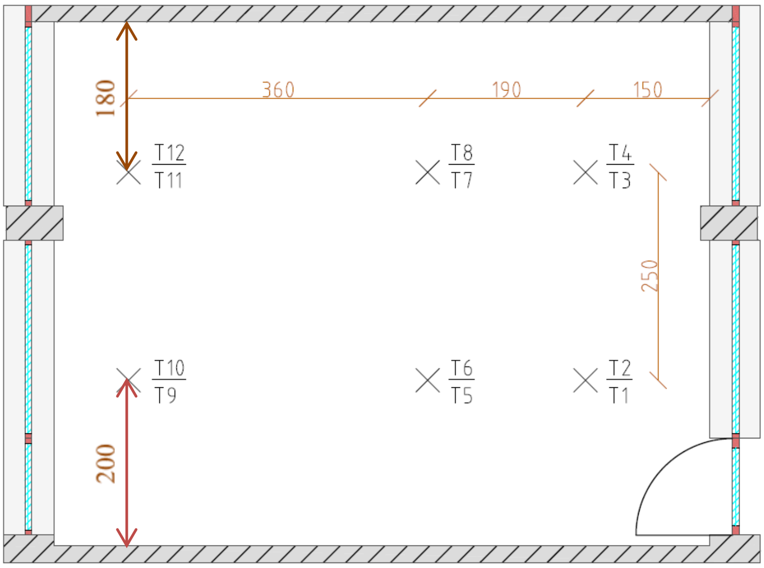


Figure 4: Position of temperature (T) sensors in the classroom

4 RESULTS AND DISCUSSION

4.1 Survey

Figure 5 evaluates the general thermal comfort in the classroom at the start of the day, classified as predicted mean vote (PMV). The majority of the respondents is satisfied with the thermal comfort in this week in January. Thermal comfort is experienced as neutral or slightly cool/warm by 79% of the respondents. Figure 6 shows the experience of and annoyance to draught due to opening of the front door. Everyone experiences cold draught of whom about half of the pupils always or often. 90% of the pupils are annoyed by this draught, 38% always or often. This means that this experience has to be examined more in detail.

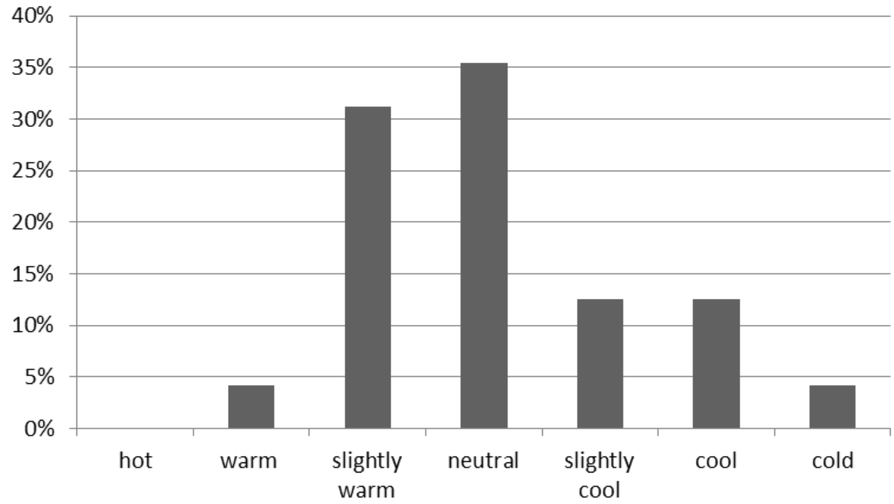


Figure 5: Experience of thermal comfort (PMV-values)

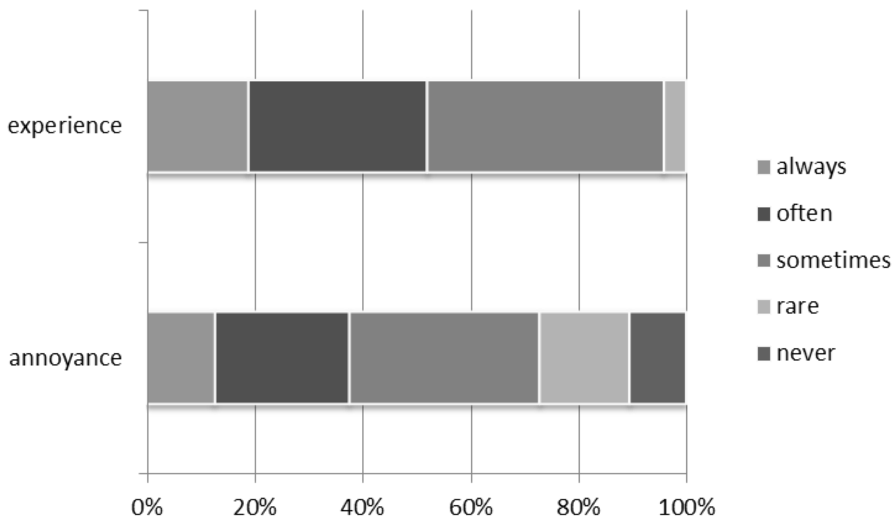


Figure 6: Experience of and annoyance to draught caused by front door opening

Pupils were also questioned about the conditions of this experience. No clear link to the position in the classroom was found. There is no significant difference in experience in pupils sitting next to the door and sitting in the rest of the classroom. In addition, respondents answer that the time of the day has no impact on their experience. By contrast, strong link is found to the following situations: 83% of the pupils experience draught when someone enters the classroom and 60% at the start of the course. Moreover, 69% of the people link their experience to the weather conditions: wind (56%) and cold weather (29%) are the most

reported. No link is reported to rain. This can be explained by the orientation of the front door (southeast) related to the dominant wind direction (south) as shown in Table 2. This table summaries the weather conditions from January 6 to 10, measured in the local weather station of Izegem, at 16 km of the school building. Weather was determined by mild maritime airflows. Temperatures were abnormally high for January. Dominant wind direction was south. Wind speed and amount of rain were normal for January (RMI, 2014).
The pupils also responded the positions on the body where they feel the draught: mostly at the head (67%), hands (54%), legs (52%) and arms (48%). This means that cold was spreaded throughout the height of the classroom. This will be checked by the temperature measurements.

Table 2: Weather conditions Jan 6-10, Feb 24-28 2014 weather station Izegem (Extreme Weather, 2014)

Date	Temperature (daily min) (°C)	Temperature (daily mean) (°C)	Wind speed (daily mean) (km/h)	Wind speed (daily max) (km/h)	Wind direction (daily mean) (°)	Rain (daily total) (mm)
Jan 6	9	12	23	65	188	2.0
Jan 7	9	10	22	61	189	0
Jan 8	7	9	10	39	180	3.3
Jan 9	5	9	13	54	174	2.5
Jan 10	3	5	10	35	190	0
Feb 24	5	9	10	43	168	0
Feb 25	5	9	16	56	182	7.9
Feb 26	3	6	7	30	189	0
Feb 27	2	5	12	69	182	4.8
Feb 28	3	4	7	30	159	7.6

4.2 Measurements

First, the use of the front door, i.e. the frequency and duration of opening, is determined. Frequency of opening is shown on Figure 7 for February 24. The door was intensively used and was opened 110 times during one week. It has to be remarked that classroom was not used on Thursday. Only 39% of the openings were expected based on the timetable in Table 1. This means that 61% of the openings were not linked to this schedule: 45% extra openings during classes, 16% before or after classes.

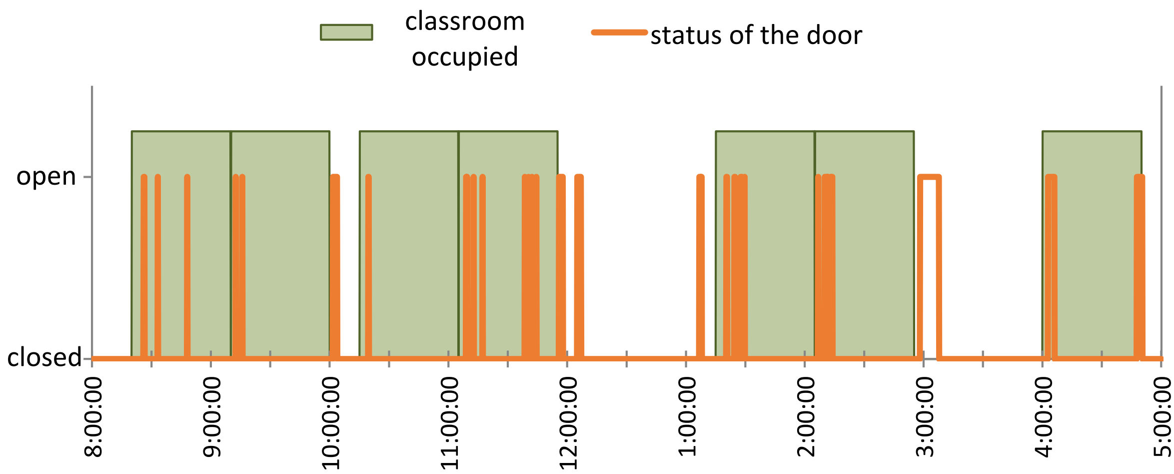


Figure 7: Use of the front door on Monday February 24 2014

In addition, Figure 8 shows the distribution of the opening durations of the front door in classes of 5s. It can be noticed that 50% of the time the door is opened less than 10s and 5% of the time even more than 200s. Distribution shows peaks at 5-10s and 20-25s. Therefore, data is studied more in detail by dividing it into classes of 2s: a peak at a duration of 6-7 s and

20s is concluded. Subsequently, the airflow is determined by tracer gas measurements for these opening durations.

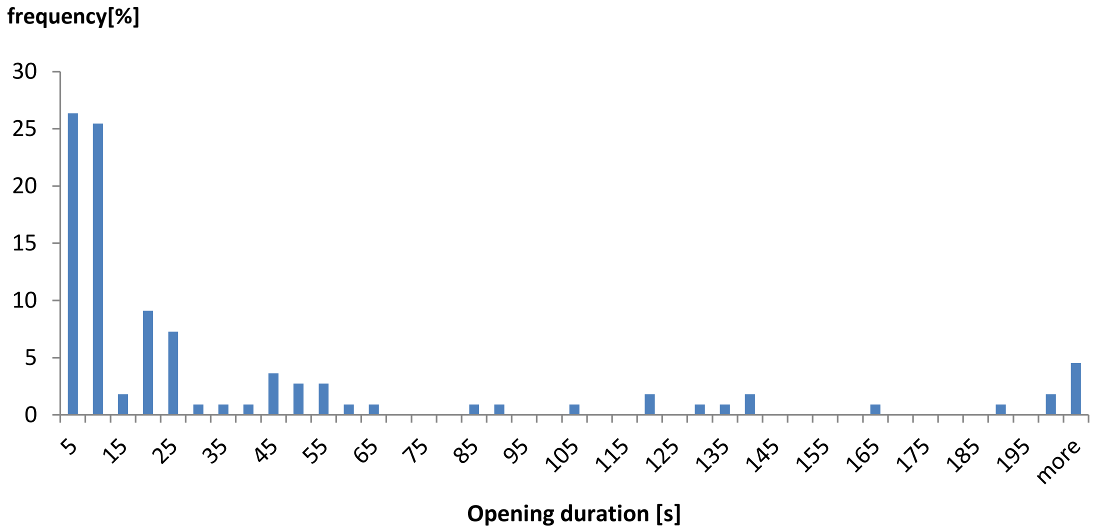


Figure 8: Duration of front door opening

Figure 9 shows the results of concentration decay method (trial 6) for an opening duration of 20s, sampled at a height of 1.1 m. The influence of door opening is clearly noticeable: the concentration decreases significantly after opening the door (indicated with red squares). The air change rate is calculated from the gradient of this curve. Figure 9 also shows that the concentration was decreasing a little bit before the door was opened (curve with blue diamonds). This means that the test room was not sealed completely airtight. This small air change rate is considered in the calculation of the airflow rate. The average airflow rates and exchanged volume for a duration of 6s respectively 20s are determined in Table 3. An average airflow rate of 72.7 and 232.8 m³/h respectively is found. The weather conditions during the tracer gas measurements are summarised in Table 4. The outdoor temperature was extremely high for March. An average indoor-outdoor temperature difference of 10.2 °C and 8.9°C respectively was noticed during measurements of opening duration 6 and 20s. The main wind direction was east, the wind speed was light to moderate.

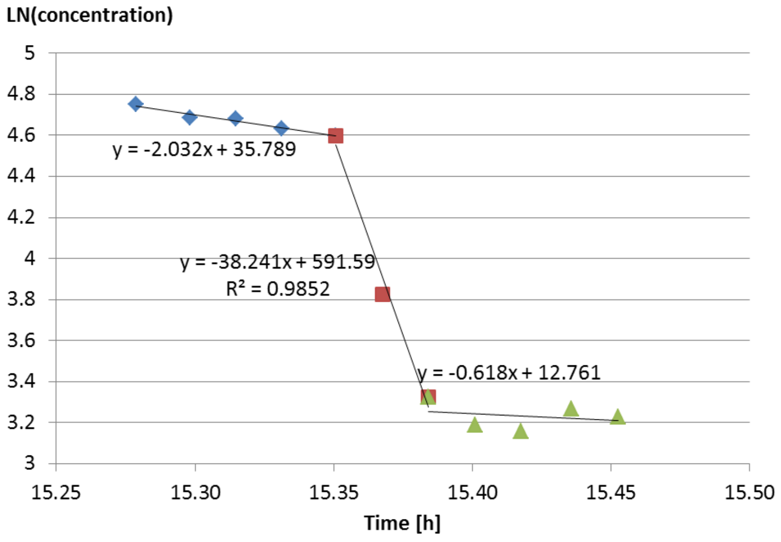


Figure 9: Result of concentration decay method of front door opening of 20s (trial 6)

Table 3: results of tracer gas measurements

Duration (s)	Air volume (m³)	Air flow (m³/s)	Air flow (m³/h)
6	0.14 ± 0.06	0.020 ± 0.007	72.7 ± 26.0
20	1.29 ± 0.31	0.065 ± 0.015	232.8 ± 55.8

Table 4: Weather conditions March 27 2014 Izegem (Extreme Weather, 2014)

trial	Duration (s)	time	Temperature indoor (°C)	Temperature outdoor (°C)	Wind speed (km/h)	Wind direction (°)
1	6	11:47	21.9	10.5	11.1	88
2	7	12:29	22.4	11.5	16.7	132
3	7	14:48	21.7	13.4	7.6	88
4	20	13:33	21.8	12.1	13.0	88
5	20	14:20	21.7	13.1	10.9	88
6	20	15:19	21.5	13.0	7.4	110

Furthermore, the effect of front door opening on the temperatures in the classroom is determined. Figure 10 shows the local effect close to the door, measured in temperature sensor 1 (T1, see Figure 4) on Friday February 28 2014. A significant temperature decrease is noticed when the door is opened. Impact factors on the magnitude of decrease are opening duration, indoor-outdoor temperature difference, wind speed and direction, successive openings. Weather conditions are shown in Table 2. The average indoor-outdoor temperature was 16°C. Dominant wind direction was the same as the orientation of the front door, i.e. southeast. The wind speed was light to moderate.
Zone of influence in the classroom is also determined. Figure 11 shows the temperature decrease on every position (see Figure 4) and the duration to the minimum temperature after closing the front door for an opening duration of 47s on Friday Feb 28 2014, 3.12 pm. The effect on the temperature is not evenly spread in the classroom. The temperature decrease in T3 and T5 (closest to T1) is significantly reduced. Temperature decrease is more pronounced on a height of 10cm than of 60cm. This difference reduces as the distance from the front door increases. Duration to minimum temperature after closing the door is reached within 1 min close to the door. This time increases with increasing height and distance the door.

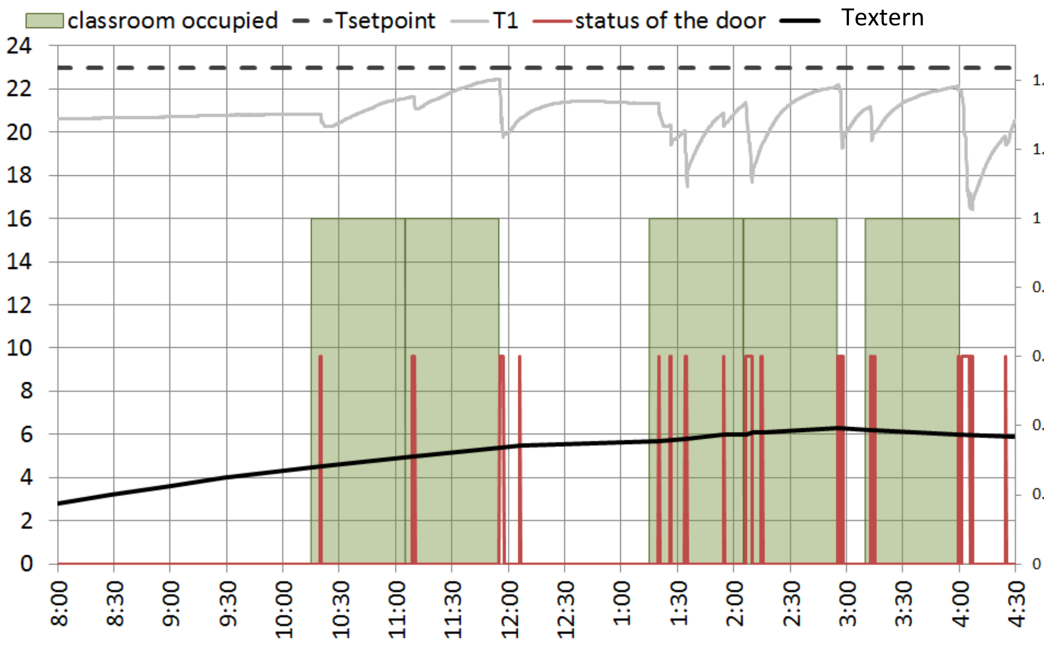
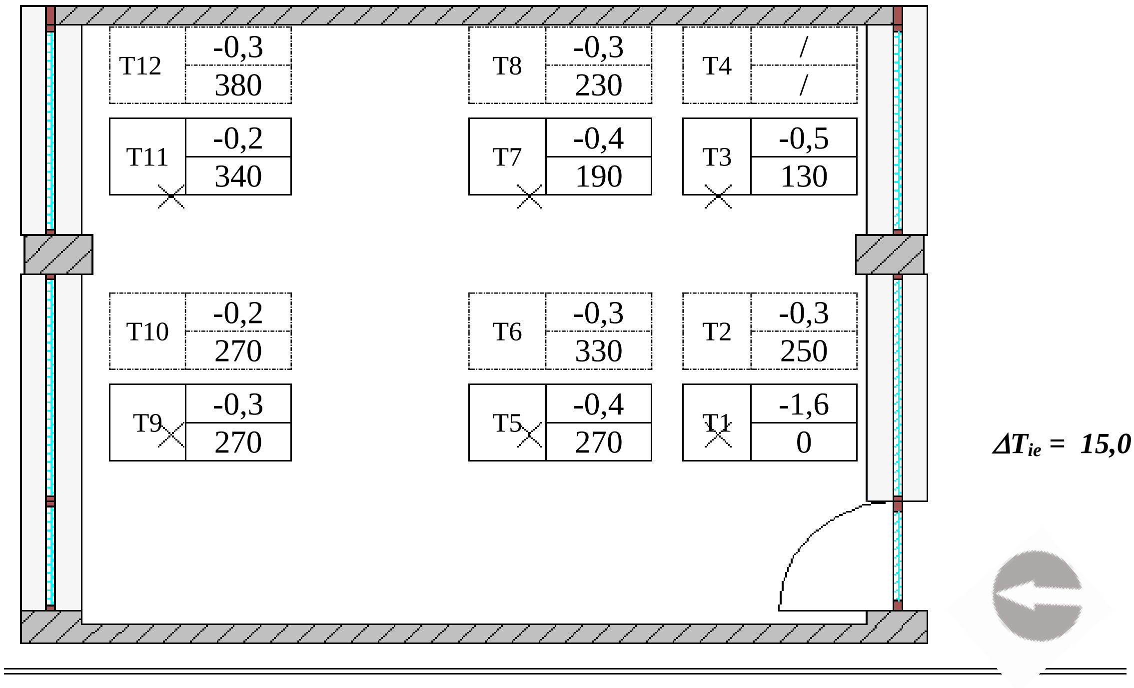


Figure 10: Temperature course measured in sensor T1 on Friday Feb 28 2014



Temperature sensor ← → Temperature decrease [°C]
→ duration to minimum after closing the door [s]

5 CONCLUSIONS

The impact of the use of the front door on thermal comfort and the infiltration losses in a classroom in a passive school in winter season was studied. The survey of pupils and teachers concluded that every respondent experiences cold draught of whom about half always or often. Almost all users are annoyed by this draught. No clear link to the position in the classroom was found. A strong link was found to situation where someone enters the classroom and to the start of the lesson. Moreover, the majority of the respondents link their experience to wind and cold weather.
The status (open/closed) of the front door was monitored during one week. It was shown that less than half the openings were expected based on the timetable of the classroom. Duration of opening was also studied: 50% of the time the door is opened less than 10s and 5% of the time even more than 200s. The most occurring opening durations are 6 and 20s. The airflow was determined by tracer gas measurements for these opening durations. An average airflow rate of 72.7 and 232.8 m^3/h was found for 6s and 20s respectively for an average indoor-outdoor temperature difference of 10.2 °C and 8.9°C and a light to moderate wind speed. The effect of front door opening on the temperatures in the classroom was determined. A significant temperature decrease was found close the door. Impact factors on the magnitude of decrease are opening duration, indoor-outdoor temperature difference, wind speed and direction, successive openings. Zone of influence in the classroom was also determined. The effect on the temperature is not evenly spread in the classroom. The temperature decrease significantly reduces as the distance to the front door increases. Temperature decrease is more pronounced close to the floor.
Survey and monitoring showed that a the use of the front door influences thermal comfort and increases infiltration losses in this classroom in this passive school. It is advised to consider this effect in the design of heating system in and the assessment of energy performance of future Passive House projects including rooms with front doors.

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