TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
CIVIL ENGINEERING | BUDOWNICTWO

3-B/2014

SZYMON FIRLĄG*

PRE-WAR PUBLIC UTILITY BUILDINGS – RESULTS OF SURVEYS

PRZEDWOJENNE BUDYNKI UŻYTECZNOŚCI PUBLICZNEJ – WYNIKI BADAŃ

A b s t r a c t

The paper summarizes the results of surveys conducted in three pre-war public utility buildings: a children's home, a forensic medicine department and a nursing home. The study examined the indoor air quality, airtightness, ventilation efficiency and thermal insulation of building envelope. The buildings were surveyed before, during or after modernization works were undertaken.

Keywords: *revitalization*, *public utility buildings*, *quality of the indoor environment*

S t r e s z c z e n i e

W artykule przedstawiono wyniki badań przeprowadzonych w trzech przedwojennych budynkach użyteczności publicznej: domu dziecka, zakładzie medycyny sądowej i domu opieki społecznej. Przedmiotem badań były parametry powietrza wewnętrznego, szczelność powietrzna, efektywność systemu wentylacji oraz izolacyjność cieplna przegród. Badane budynki były przed, w trakcie lub po pracach modernizacyjnych.

Słowa kluczowe: *rewitalizacja*, *budynki użyteczności publicznej*, *jakość środowiska wewnętrznego*

* Ph.D. Eng. Szymon Firląg, Institute of Building Engineering, Faculty of Civil Engineering, Warsaw University of Technology.

1. Introduction

Many pre-war public utility buildings require modernization or renovation. These processes are complicated and expensive. They are usually performed in order to reduce energy consumption, to change the use of a building or to meet current technical and construction standards. Unfortunately, we very often omit to check the efficiency of these measures or to make a careful assessment of the benefits of the status quo. Consequently, the results of such works can prove to be worse than anticipated and internal environmental quality conditions can decrease.

2. Children's Home

The first study was conducted at a children's home located in Otwock. It is a three-storey building from 1930s with basement. The walls are of full brick construction, and the ceilings are made from reinforced concrete. In the 80s, an additional wooden storey was added with a mansard roof, covered with metal sheeting. The building was last renovated in 2005. This work saw external walls and the flat roof insulated, windows replaced and the heating and hot water system modernized. Thermographic measurements were taken to verify the quality of the works carried out. These readings were taken inside and outside the building. Measurements were also taken of indoor and outdoor air conditions – notably relative humidity and temperature. Research focussed on the following spaces: the ground floor dining room, the first floor lounge, and the second floor lounge and bathroom. The measurements were carried out between 11:00 on 02/13/2013 to 13:00 on 02/14/2013 (26 hours – at 1 minute measurement steps).

Table 1

Building envelope before and after renovation

	U-value before [W/m²K]	*U*-value after [W/m²K]
External walls	1.05	0.34
Flat roof	0.58	0.24
Windows	2.6	1.3
Doors	2.5	2.5
Floor	1.07	1.07

External wall insulation had a positive effect in terms of increasing internal surface temperatures. The lowest temperature measured in one corner on the first floor was 19.5°C (where the internal air temperature was about 23°C). Unfortunately the renovation works had no discernible effect on the second floor. Figure 1 clearly shows a significant decrease in surface temperature in the corner and also under a computer table in the computer room on the second floor. The temperatures were recorded as 11.9°C and 10.2°C respectively, with an internal air temperature of about 20°C. Such a situation presents the risk of mould growth – where the surface temperature falls below 12.7°C (at 20°C and with 50% relative air humidity).

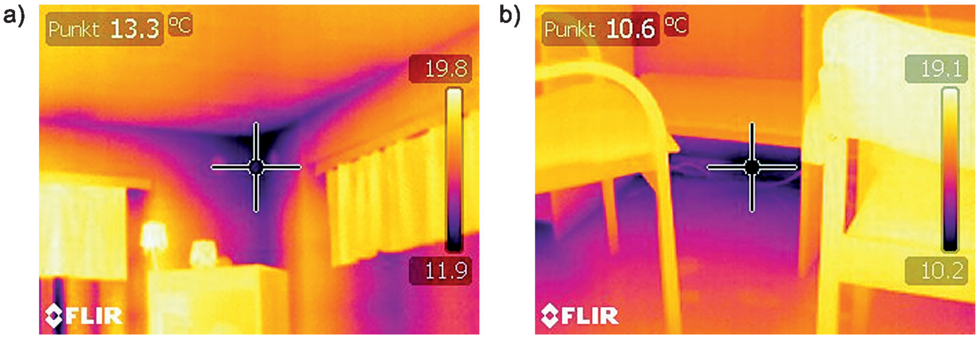

Fig. 1. The computer room on the second floor: a) the corner – at the juncture of the external wall and the second floor ceiling, b) under the computer table – at the juncture of the external wall and second level flooring

The temperature of the external wall surface was 4,5°C (Fig. 2a.) when the outside air temperature was 0°C. The 4.5 K difference illustrates that the thermal insulation of the walls could be improved. The U-value following renovation was 0.34 W/m^{2}K, but according to current regulations it should be no higher than 0.25 W/m^{2}K. Figure 2a and 2b also show there to be a lack of insulation around window openings, on the basement walls and in the thermal bridge coursed by the eaves. The readings have confirmed a reduction of heat loss through the building facade but at the same time have allowed for construction errors to be identified. The insulation is not contiguous which allows thermal bridges to form. The most significant error is that the second floor mansard roof is insufficiently insulated. As a result, heat loss on the second floor is much greater than elsewhere. In such a situation,the interior air and internal surface temperatures decrease. In addition, mould can grow or condensation and rising damp can occur.

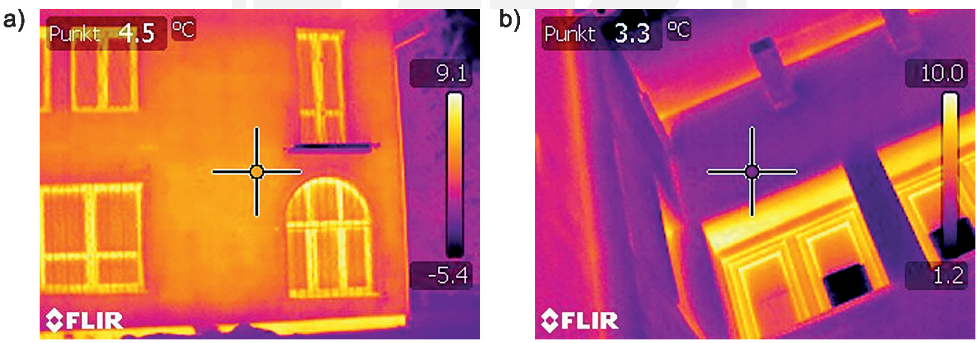

Fig. 2. Termogram of: a) external wall, b) windows openings

Indoor air parameters were checked in relation to the PN-78/B-03421 [1] requirements for winter and low-scale physical activity: namely for optimum and acceptable temperature ranges (20,0–22,0°C), for optimum humidity ranges (40–60%), and for acceptable humidity ranges (30–60%). Readings taken in selected rooms were as follows:

– ground floor dining room, temperature range of 23.2–26.8°C, relative humidity range 22.2–32.7% – excessively high temperatures for 100% of the time, excessively low humidity for 81% of the time, acceptable humidity for 9% of the time;
– first floor lounge, temperature range of 23.4–25.5°C, relative humidity range 23.4–29.6% – excessively high temperatures for 100% of the time, excessively low humidity for 100% of the time;
– second floor bathroom, temperature range of 19.6–21.7°C, relative humidity range 44.5–64.8% – optimum temperatures for 91% of the time, excessively low temperatures for 9% of the time, optimum humidity for 88% of the time, excessively high humidity for 12% of the time;
– second floor lounge, temperature range of 20.2–22.9°C, relative humidity range of 39.4–43.3% – optimum temperatures for 42% of the time, excessively low temperatures for 58% of the time, optimum humidity for 88% of the time, unacceptable humidity levels for 12% of the time.

On the basis of these measurements, it is apparent that the temperatures on the ground floor and first floor are too high. Overheating at lower levels probably occurs due to the un--insulated mansard roof and the heating system failing. In order to keep the temperature on the second floor within a comfortable range, the temperature of the water supplied to radiators have to be increased. Adequate and proper temperature control is not possible because some of the radiators (on the ground and first floor levels) do not have thermostatic heads and the system was not hydraulically adjusted after the renovation works were carried out. The overheating causes a decrease in relative humidity and comfort. Higher humidity levels in the bathroom result from the failing ventilation system – the exhaust ducts are dirty and there is no ventilation grill in the bathroom door. The poor insulation of the mansard roof and the high humidity levels can result in the growth of mould or condensation and rising damp.

3. Forensic Medicine Department

The Forensic Medicine Department, at the Medical University of Warsaw, ul. Oczki 1, was constructed between 1924 and 1927. During World War II, the building was almost all but completely destroyed, and was rebuilt after the conflict. It is listed in the Ochota district municipal register of Warsaw monuments. A thorough reconstruction of the building began in June 2013, the main objectives being: modernisation and adaptation for teaching and learning for students, residential facilities, and for experiments/examinations. The building works are scheduled to be completed by 1st October 2014.

The research was concerned with assessing the interior environmental air quality (measuring temperature and relative humidity) in selected rooms, namely: a small dissection room, a genetic laboratory, a basement, a planned director's office, a large dissection room, an existing director's office, a toxicology laboratory, a histopathology laboratory, a caretaker's flat, and a library. Exterior air readings were also taken. The measurements were conducted before stage I of the construction work commenced. The stage II evaluations are scheduled to take place following completion of this modernization and renovation work, in order to evaluate changes in the quality of the interior environment. Simultaneous readings were taken in every room over a week-long period between 15:00 on 04/16/2013 and 15:00 on 23/04/2013 – at 5 minute intervals. Readings addressed a range of parameters and absolute humidity calculations are shown in Table 2.

On the strength of these measurements, it is apparent that the following rooms are subject to overheateding: the genetic laboratory, the toxicology laboratory, the histopathology laboratory, the caretaker's flat and the library. This effect can be attributed to heat generated by people and equipment. The highest relative humidity levels were recorded in the small dissection room, the basement and in the large dissection room. However, the absolute humidity was noticeably higher only in the large dissection room and library in comparison with the outdoor air conditions. This increase was probably caused by high moisture gains, e.g. from medical students participating in classes and medical experiments, and by fluids used to clean spaces. A second explanation for the humidity levels in the dissection rooms is likely to be a lack of sufficient ventilation and the presence of new airtight windows. Unlike other rooms inspected, the dissection rooms have a mechanical ventilation system in place. Unfortunately, it is very rarely used because of a high level of noise emission. During the earlier modernization works, old wooden windows were changed for new plastic-framed ones, which caused a reduction in the rate of air filtration from outdoors. In other rooms, the absolute humidity was at very similar levels to that of the outdoor air, which indicates high ventilation. In reality, the fresh air is infiltrating into the building in an uncontrolled manner through the old and poorly-fitting windows. This situation should be remedied as part of the on-going modernization, because the old windows will be changed for new airtight units.

Table 2

Indoor and outdoor air parameters

Room/place	Temperature range [°C]	Relative humidity range [%]	Absolute humidity range [g/kg]
Outdoor air conditions	6.1–22.3	15.4–81.9	2.8–7.7
Small dissection room	17.0–19.6	31.0–66.6	4.1–8.8
Genetic lab	22.1–24.7	21.3–38.5	4.0–7.2
Basement	14.8–16.1	51.1–66.4	5.7–7.4
Planned director's office	19.8–22.0	28.4–45.3	4.2–7.0
Large dissection room	20.2–22.9	26.3–67.8	4.1–11.1
Existing director's office	21.3–22.9	30.9–45.8	5.0–7.7
Toxicology lab	24.5–28.3	20.6–35.6	4.2–7.8
Histopathology lab	23.4–25.3	24.1–37.3	4.5–7.3
Caretaker's flat	22.4–24.0	29.7–40.9	5.4–7.1
Library	20.6–25.9	27.4–46.0	4.1–9.2

4. The Nursing Home

The final subject of the research is a care facility in Otwock, built in 1927. It is a two--storey building, with a partial basement, and is used as a nursing home for the elderly and disabled. The building has a wooden construction with walls built of solid brick. The floors, stairs and the gable roof sections are wooden. The roof is covered with metal tiles. The survey was designed to check the quality of the indoor environment and the efficiency of the ventilation system. Measurements were taken in the dining room and the director's office.

Readings were taken between 11:25 and 14:00 on 13/02/2013 – before, during and after the midday meal. Measurements were taken for the relative humidity, temperature, circulation of air in the rooms and carbon dioxide concentrations (in ppm). The outdoor CO_2 levels were measured at around 460 ppm. The readings were in the following ranges:
- air temperature: 20.3–22.1°C,
- relative humidity: 38.2–53.0%,
- absolute humidity: 5.8–8.2 g/kg,
- air circulation: 0.0–0.03 m/s (max 0,09 m/s),
- CO_2 concentration: 865–1707 ppm.

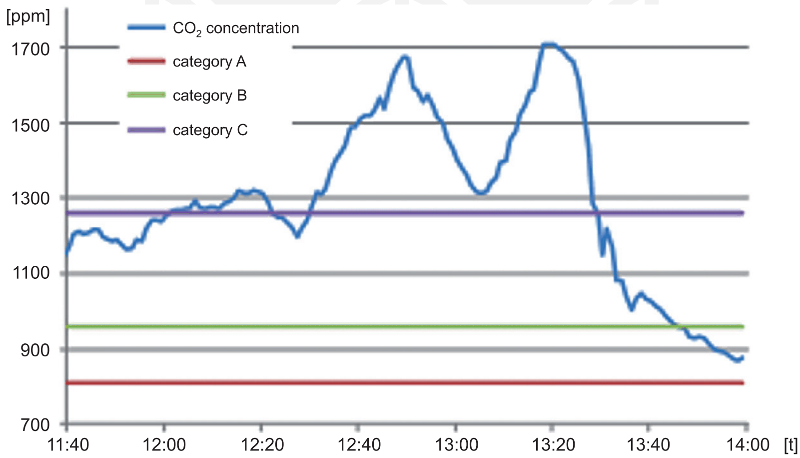

Fig. 3. Change of CO_2 concentration levels in the dining room with PN-EN 15251 categories A, B & C marked

Indoor air quality was assessed on the basis of CO_2 concentration levels, in relation to the PN-EN 15251 [2] categories (A, B & C). The highest concentrations in each category are shown in the graph: 810 ppm for A, 960 ppm for B and 1260 ppm for C. Air quality readings exceeded all categories for a signicant period of time. CO_2 concentration levels decreased only after the residents had left the dining room, firstly dropping below the category C threshold and then the category B limit.

These measurements show that indoor air quality (CO_2 concentration) levels are unsatisfactory, despite optimal measures to control indoor air parameters in regard to temperature and relative humidity. A further indication that the ventilation system is failing is that the relative humidity levels in wintertime are at the 50% level, when humidification does not occur.

The decline of CO_2 concentration levels (as recorded in Fig. 3.) was used to determine the rate of air exchange in the dining room. Calculations were based on the following formula:

$$N = \frac{\ln\left(\frac{C_o - C_i(\tau)}{C_o - C_{io}}\right)}{-\tau} = \frac{\ln\left(\frac{460-868}{460-1707}\right)}{-0.633} = 1.76 \;\; 1/\mathrm{h} \tag{1}$$

The outdoor CO_2 concentration level (C_o) was 460 ppm. The maximum indoor concentration level (C_{io}) was 1707 ppm. The decline rate (τ) was 38 min. The lowest indoor concentration level ($C_{i(\tau)}$) was 868 ppm. The estimated air exchange rate (n) was 1.76 h^{-1}. The ventilation rate in the dining room is below adequate standards. Accordingly, it is recommended [3] that the air exchange rate should be between 5–10 h^{-1}.

In light of the wooden construction of the nursing home, it is likely that the building envelope is prone to airleaks. The director's office was tested because it has a corner location, lacks ventilation ducts and can be taken out of service on a temporary basis. The tests were designed to determine the n_{50} coefficient values, to locate air leaks and to estimate the approximate rate of air exchange under normal conditions. In a preliminary examination, (where air pressure was about 80 Pa) leaks and cracks were identified using an infra-red camera. It was possible to do so due to a high temperature difference inside and outside the building. Cold air seeping into the rooms showed up well on the thermographic pictures, as shown below.

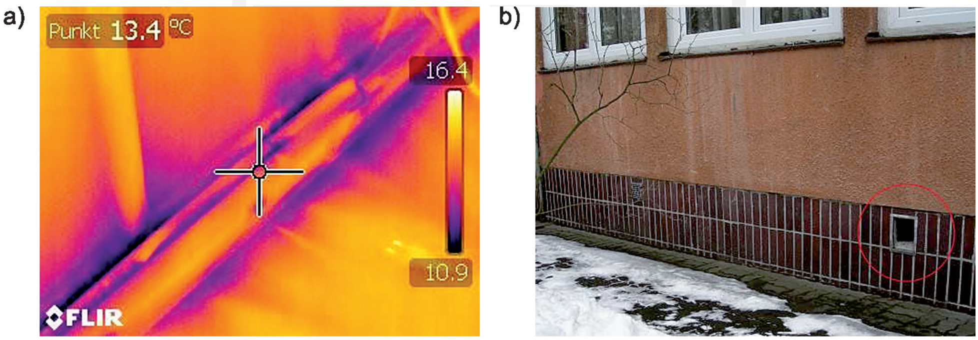

Fig. 4. Leaks: a) at connection of external wall with floor and their source, b) ventilation space under the floor – marked the vent in the socle

Air leaks (Fig. 4a.) were detected around the perimeter of the room and were caused by poor flushing between the floor and the external wall. The air penetrated into the room from ventilated spaces under the floor (Fig. 4b.). Carpeting provided the only sealing layer, which had been taken up for the test. Other leaks were also detected in gaps between the old wooden window frame and the external wall (Fig. 5a.). New plastic windows were installed in old

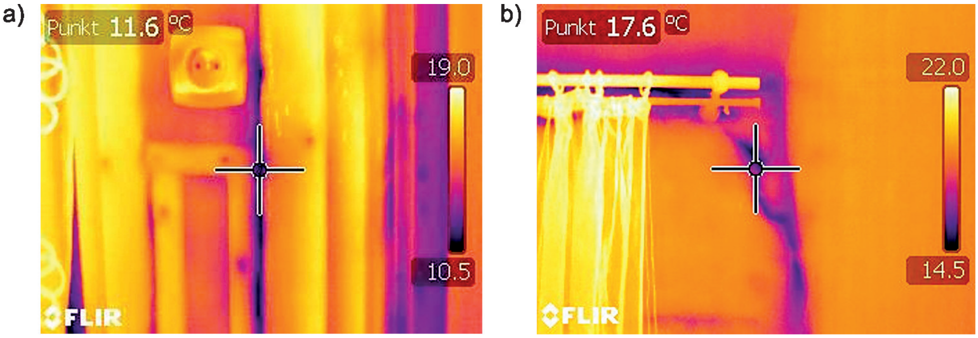

Fig. 5. Leaks: a) in a gap between the old wooden window frame and the external wall, b) in a crack in the external wall in a corner of the room

wooden frames. A crack in the external wall in a corner (Fig. 5b) also enabled air to leak into the room.

A full test was undertaken after all leaks were identified. Automatic measurements were carried out using a Minneapolis Bower Door 4 at under and over pressures. The test results gave the following mean values:

– V_{50} = 1048 m^3/h – air flow rate at a pressure difference of 50 Pa,
– n_{50} = 11.69 h^{-1} – air exchange rate at pressure difference of 50 Pa.

The results obtained show that the room has a very low score in terms of its airtight--ness. According to the WT2014 requirements, n_{50} should be lower than 3.0 h^{-1} in a building with natural ventilation. The test result was almost four times higher. The estimated exchange rate resulting from air infiltration can be calculated using the following formula: $n = n_{50}/20 = 0{,}58$ h^{-1}. The air flow rate attributable to air infiltration is about 52,6 m^3/h. Two people occupy the director's office so the air flow rate should be about 40 m^3/h (20 m^3/h per person). The tests show that in spite of the lack of ventilation ducts, excessive infiltration of air occurs in the room. This is an undesirable situation, because ventilation should be controlled. Moreover, air entering the room through the cracks and gaps lead to a decrease in thermal comfort levels. Measurements show that measures to make the Nursing Home more airtight need to be taken before the ventilation system is modernized. Only if that is done can there be any improvement in the effectiveness of the ventilation in the building.

5. Conclusions

In the light of the research carried out in these pre-war public utility buildings, the following conclusions have been drawn:

– the rooms often overheate because the heating system does not comply with the relevant regulations. There is a significant potential for energy savings, by modernizing and adjusting the heating systems;
– the building lacks an efficient ventilation system, suited to the activities carried out in the rooms – much of the fresh air enters the rooms in an uncontrolled manner through gaps and cracks;

- modernization works often result in a deterioration of indoor air quality, e.g. by installing new bathroom doors without ventilation grills;
- plans for modernization works are not always as comprehensive as they should be, and do not address the requirements of the building,
- research to measure the quality of the internal environment and the efficiency of the installations should be conducted before modernization and/or renovation works are planned and undertaken;
- in too many instances, building managers lack the necessary knowledge about the maintenance and general usage needs of the ventilation systems and installations/controls.

References

[1] PN-78/B-03421 Wentylacja i klimatyzacja. Parametry obliczeniowe powietrza wewnętrznego w pomieszczeniach przeznaczonych do stałego przebywania ludzi.
[2] PN-EN 15251 Kryteria środowiska wewnętrznego, obejmujące warunki cieplne, jakość powietrza wewnętrznego, oświetlenie i hałas.
[3] Nowakowski E., *Wentylacja w salach konsumpcyjnych zakładów żywienia*, Polski Instalator 3/2001.