

ŁUKASZ NOWAK*, KRZYSZTOF CEBRAT**, ANNA BAĆ***

DOUBLE SKIN HOUSE CONCEPT – A STUDY OF BUFFER ZONE USAGE IN A SINGLE FAMILY HOME

DOUBLE SKIN HOUSE – STUDIUM WYKORZYSTANIA STREFY BUFOROWEJ W DOMU JEDNORODZINNYM

Abstract

The Double Skin House concept presents an attempt at using a building's opaque double façade as a buffer zone. Due to more stable temperatures, these unconditioned areas around the building reduce heat losses during the heating season and present better overheating protection in the summer. In this concept the exterior skin protects building from the weather conditions and the interior skin gives thermal insulation. This paper presents the concept and the simulation results run in order to determine its influence on building energy demand.

Keywords: double façade, buffer zones, energy efficiency, passive house

Streszczenie

Koncepcja Double Skin House jest przykładem wykorzystania podwójnej, nieprzezroczystej fasady jako strefy buforowej w budynku. Takie nieogrzewane przestrzenie wokół budynku, ze względu na mniejsze wahania temperatury, zmniejszają straty ciepła w sezonie grzewczym oraz lepiej zabezpieczają budynek przed przegrzewaniem w lecie. W tej koncepcji zewnętrzna powłoka zabezpiecza budynek przed działaniem czynników zewnętrznych, a wewnętrzna daje właściwą ochronę cieplną. W artykule zaprezentowano koncepcję budynku oraz wyniki przeprowadzonych symulacji w celu określenia jej wpływu na zapotrzebowanie budynku na energię.

Słowa kluczowe: podwójna fasada, strefy buforowe, efektywność energetyczna, budynki pasywne

* Ph.D. Eng. Łukasz Nowak, Division of Building Physics and Computational Design Methods, Faculty of Civil Engineering, Wrocław University of Technology.

** Ph.D. Eng. Arch. Krzysztof Cebzat, Division of Environmental Development, Faculty of Architecture, Wrocław University of Technology.

*** Ph.D. Eng. Arch. Anna Bać, Division of Housing Design, Faculty of Architecture, Wrocław University of Technology.

1. Introduction

1.1. Double façades in buildings

The vast majority of studies on heat flow in the buffer zones are those of glazed double façades used in high-rise buildings. What can also be found is research into the issues of building physics of objects such as greenhouses integrated with buildings. The impact of non-ventilated, non-glazed and unheated buffer zones adjacent to exterior walls of zones with controlled air temperature is not as strongly represented as the aforementioned topic.

There can be some utility areas in a building which due to the nature of their functions, or the period of their use have lower temperature requirements. Therefore, these zones are suitable for the creation of thermal buffers which would reduce static heat loss in spaces where the maintenance of higher temperatures is obligatory. Reducing the temperature difference between the two sides of a partition decreases the heat flux between the rooms. Therefore, temperature zoning of spaces inside a building is one of the basic principles of passive constructions. It appears that locating thermal buffers, regardless of their orientation, should bring a reduction in static heat loss.

This type of solution is part of a long tradition in regional architecture. Often, regardless of the size of a cottage [1], areas exposed to extreme conditions to the north, east or west (depending on the region) were often separated and used as chambers, stores or even barns. In turn, locating glazed buffer zones in areas facing south – the equivalent of traditional porches – was to achieve greater energy gains from solar radiation. In general, the gains were greater as the surface area of glazing increased, as did its thermal resistance. Additional introduction of air circulation between the buffer zone and the interior of the heated space was to improve the energy balance of the building.

Brown and DeKay [2], and Goulding et al. [3] distinguish three variants of glazed buffer zones, which impact the indirect solar gains of a building. These solutions differ in thermal resistance of the buffer zone's exterior glazing and the interior glazing of the heated spaces.

Profits arising from the creation of this glazed buffer zone are defined as a linear function the values of which depend on:

- the difference between the computed outside and inside temperatures of the building and the heated zone respectively,
- the proportion of glazed surfaces in the outer wall of the buffer zone and the wall separating the buffer zone from the heated space, and
- the thermal resistance of the glazing.

However they do not depend on the size (volume) of the buffer zone.

Hegger et. al. [4] indicates that the static heat loss can be reduced through the use of non-ventilated and not glazed buffer zones. Energy savings depend on the location of a zone within the structure of a building, which in turn influences the calculation of outdoor temperature (the temperature in the buffer zone). The reported values of the temperature correction coefficient in the buffer zone to the outdoor temperature are as follows:

- for confined spaces above the ceiling of heated rooms – 0.8,
- for confined spaces adjacent to the walls of heated rooms – 0.5, and
- for confined spaces under floors of heated rooms (recessed into the ground) – 0.6.

Temperature correction coefficients do not depend on the orientation of the building nor was a value for the glazed buffer zones specified.

1.2. Double Skin House – concept and design features

The design premise was to have an outer skin to create a heat buffer, reducing temperature fluctuations in cold periods and protecting technical equipment (Fig. 1a). In summertime, the outer skin provides shading for the house (Fig. 1b). A buffer zone created in this way limits the daily temperature fluctuations and protects technical equipment. This translates also into a continuous thermal insulation around the residential area (no structural breaks), good air tightness and minimized appearance and influence of thermal bridges.

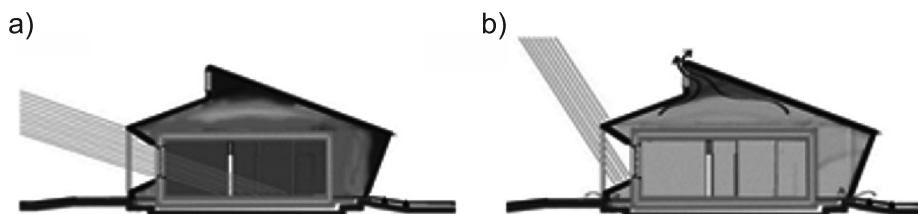


Fig. 1. Building section – buffer zone functions: a) winter heat loss reduction and passive solar gains, b) summer overheating protection [5]

Additional window niches facing south, east and west are working like shading devices, which protect from heat during summer, but provide solar gains during winter (Fig. 2). Furthermore, the roof shaped like a solar chimney and equipped with an awning window provides natural ventilation and cooling of the intermediate cavity between skins during cooling periods.

Being aware that the temperature in the space between the two shells shall not be less than that in the external environment and not more than the temperature inside the heated zone during the heating period assumes that to some extent this will limit the static heat losses of the house. By contrast, during the summer the assumption is that the opening of the outer shell should provide both a cooling effect and reasonable thermal comfort almost without the need to use air conditioning.

High energy performance standard requirements are met using double skin, both for the façades and the roof. The outer skin of the walls is made of wood – a material of low ecological cost, which is easily accessible, and can be obtained through recycling or be recycled later. The outer skin of the roof is made of metal sheets. The outer layers are presumed to protect the internal shell from weather conditions while the internal layers provide thermal insulation.

A single storey house was designed with a net area of 122.83 m², with a built-up area of 255.26 m² and an internal volume of 331.64 m³. It was functionally divided into a common open space and a private area [5]. A kitchen that opens onto a living room is conducive to the integration of its inhabitants (Fig. 2). Additionally, during warm periods of the year, a covered, louvered terrace expands the living area. The compact nature of the house, with its built-in terrace allows for the house to be placed on relatively small plots. The house

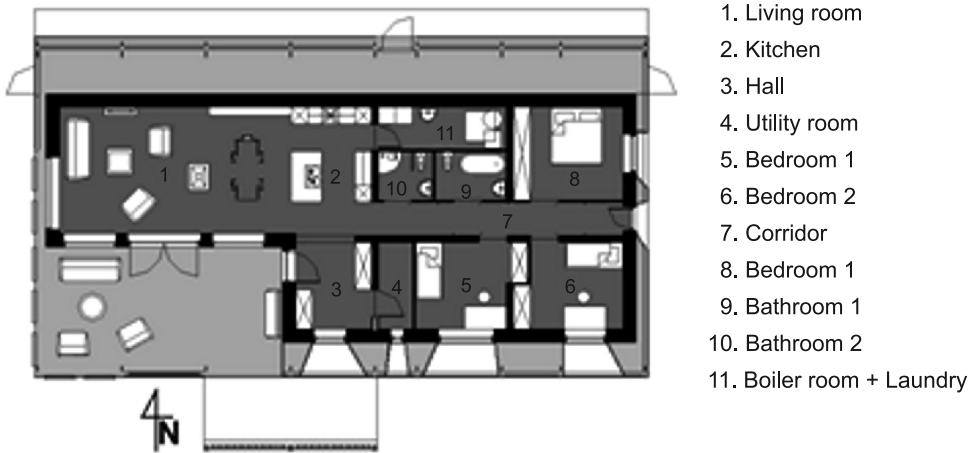


Fig. 2. Double Skin House – building plan and room layout: dark grey – residential area, light grey – buffer zones

was divided into zones based on temperature requirements: rooms necessitating the highest internal temperature (i.e. two bathrooms) were placed in the centre. The buffer located in the northern part of the house conceals a storage space. The orientation of the house toward the south facilitates the installation on its rooftop area of both solar hot water panels and solar panels for the generation of electricity. The building has a compact shape (its A/V ratio being at 0.83) and no glazing at the north façade.

1.3. Double Skin House – energy performance

The heated residential zone of the building (dark grey area in Fig. 2) was enclosed with the following partitions (each described from its outermost to its innermost layer):

- external walls ($U = 0.09 \text{ W/m}^2\text{K}$) – 1 cm cement plaster, 20 cm stone wool boards between wooden spacers, a 20 cm timber frame structure filled with stone wool, a PVC vapour barrier, an OSB and gypsum plasterboard,
- flat roof ($U = 0.07 \text{ W/m}^2\text{K}$) – 15 cm stone wool, a 30 cm timber frame structure filled with stone wool, a PVC vapour barrier, and a gypsum plasterboard,
- ground floor ($U = 0.12 \text{ W/m}^2\text{K}$) – 20 cm hard Styrofoam, a 20cm reinforced concrete slab, PVC foil, 5 cm Styrofoam elements for underfloor heating, 7 cm levelling layer, flooring.

The internal walls were also constructed around a timber frame so the thermal mass was located mainly in the ground floor slab. The buffer zone (light grey area in Fig. 2) was bounded by external walls made of 20 mm wooden facade boards ($U = 3.47 \text{ W/m}^2\text{K}$) and a roof made of trapezoidal steel sheets placed on a wooden roof construction. Windows and doors are designed to be mounted in a layer of thermal insulation; the calculated U_w values for the windows are within the 0.67–0.78 $\text{W/m}^2\text{K}$ range while the U_d values for the doors in the 0.76–0.77 $\text{W/m}^2\text{K}$ range. Glazing involves a triple pane set – 4 mm Low-E glass/14 mm Argon gap/4 mm float glass/14 mm Argon gap/4 mm Low-E glass and their properties are: $U_g = 0.6 \text{ W/m}^2\text{K}$, SHGC = 0.49 [–] and LT = 0.71 [–].

The numerical calculations for the heat flow in the construction details were performed using THERM software and the linear thermal transmittance coefficient values, Ψ_e , ranged from -0.056 to 0.025 W/mK. The high air tightness value set at $n_{50} = 0.6$ ac/h, was achieved through a minimization of structural breaks, proper window assembly and the use of vapour control membranes and appropriate sealing tapes. The house is equipped with heat recovery ventilation with 90% efficiency.

A house designed in such a way fulfils the requirements of the so-called NF15 standard [7]. In order to be deemed in compliance with the National Fund for Environmental Protection and Water Management an object must maintain the usable energy demand index (EA) for heating and ventilation at a level below 15 kWh/m²a [6]. The EA index for this particular building, calculated according to Polish energy performance certification (EPC) calculation regulations [7] for the Wroclaw location, equals 13.97 kWh/m²a.

2. Analyzed building cases in energy simulations

The building was located in Wroclaw (TMY weather data was used) and had heating system temperatures set to 24°C in bathrooms and to 20°C in other rooms (there was no air conditioning system in the building). The mechanical ventilation air flow rate was at 0.6 [ac/h] and the heat recovery efficiency was at 90%. The air tightness of the heated zone partitions was set as a passive building standard at $n_{50} = 0.6$ [ac/h]. Two design cases were analyzed (Fig. 3):

Case 1 – a building with a single skin façade (i.e. only an internal skin with thermal insulation), where the heat loss through the building envelope was calculated as for the external environment; in order to maintain the same shading conditions window overhangs and sidefins were modelled on the case of the double skin façade.

Case 2 – a building with a double skin façade (i.e. an internal skin with thermal insulation and an external skin made of wooden panels and a steel roof), which means that the heat loss through the building envelope was calculated for unconditioned buffer zones, taking into account that the double façade thickness varies from 0.3 to 1.6 m. The unheated buffer zones were modelled as cavities, so they were ventilated by the infiltrating outside air and gained heat from adjacent internal partitions. The air tightness of the external skin was set low at $n_{50} = 10.0$ [ac/h], due to its construction (wooden and steel panels only). There was also

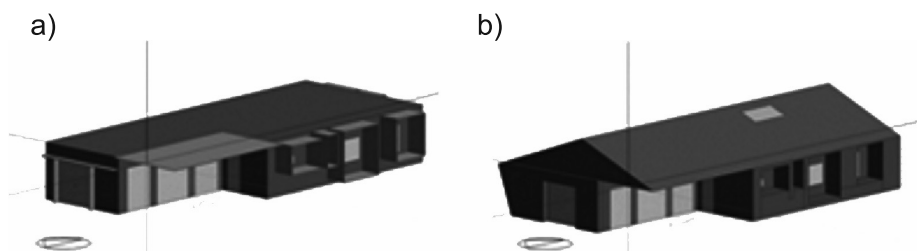


Fig. 3. Analyzed building cases: a) Case 1 – single skin, shading, no buffer zones, b) Case 2 – double skin, shading and unconditioned buffer zones

a roof window which was set as opened in the summer and closed in the winter. Shading conditions were the same as in Case 1.

Both cases were analyzed by two different methods: Method 1 – calculations according to Polish EPC regulations, Method 2 – DesignBuilder software simulations (ver. 3.2.0.073).

3. Results

3.1. Usable energy demand index – EA

The results from energy simulations (Method 2) were compared with previously made EPC calculations (Method 1) with and without buffer zones being taken into account. The changes in the usable energy demand EA indices, calculated for a Wrocław location, are at a 2% level for the EPC method and at a level of 8 % for simulations in favour of cases with buffer zones. There are also visible differences due to the method of calculation, but there is need for further testing if Method 2 is more reliable. Some of the energy simulation knowledge resources [8], indicate that there should be an increase of between 5% to 20% of energy savings due to using buffer spaces, thus the results obtained by simulations look appropriate.

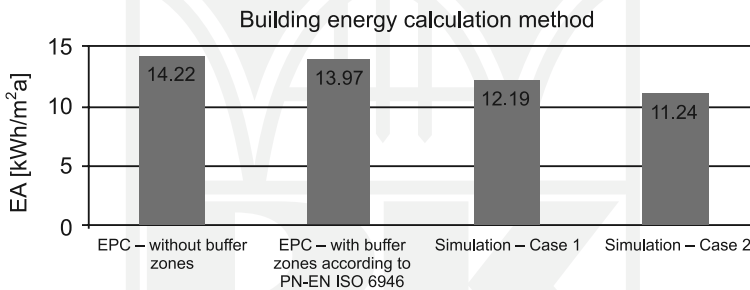


Fig. 4. Usable energy index for heating and ventilation purposes according to calculation method: EPC – energy performance certificate, Simulation – DesignBuilder software

3.2. Air temperatures

Besides slightly better energy performance of buildings incorporating a buffer zone, the other important reason for using them is their ability to stabilize air temperatures. This should mean less heat loss in the winter and less overheating (lower inside air temperatures) in the summer. According to the air temperature charts in the sample winter week (Fig. 5), the air temperature in the buffer zone is 2–3°C higher than the outside air temperature. This has significant influence on lowering the inside air temperature fluctuations connected with heating system specificity.

Looking at the air temperature charts in the summer week (Fig. 6), it can be observed that Case 2 (building with buffer zones) can have up to a 2.5°C (average 1°C) lower inside air temperature compared to Case 1 (building without buffer zones). The thermal buffer effect

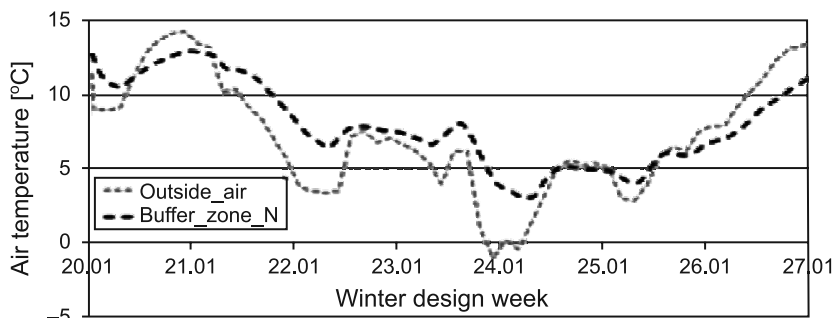


Fig. 5. Air temperatures in the buffer zone from the north side during a winter week (20–26th January)

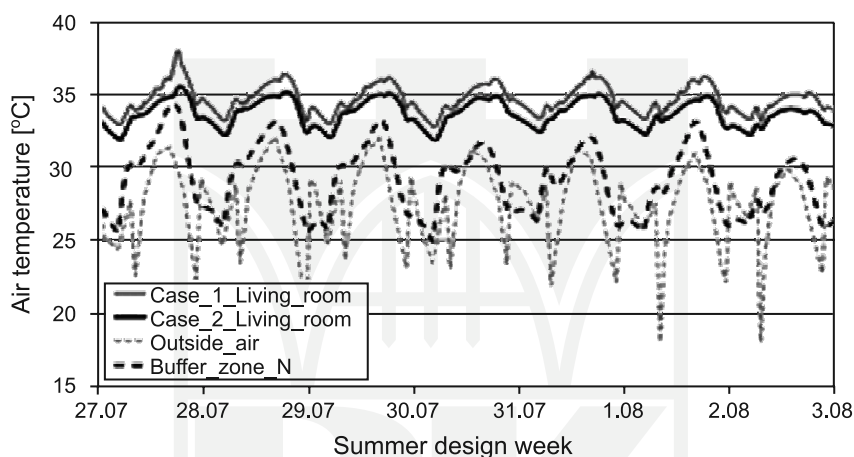


Fig. 6. Air temperatures in living room facing the south and in the adjacent buffer zone from the north side during a summer week (27th June–3rd August)

and scheduled natural ventilation in the summer, which rejects warm air from the space between the skins, reduces the temperatures (mainly the peak ones), even in the rooms facing south.

3.3. Future plans – in situ measurements

Further research will be focused on attempting to measure the value of the heat flow in the buffer zones of buildings: both in the existing building, as well as in matching computer models designed to obtain empirical data. It is assumed that the first step is the measurement of an existing single-family residential building. The building is a single storey, occupied, single-family house, built with timber frame technology. The buffer zone is a greenhouse with western exposure, with the outer wall and the greater part of the roof glazed (wall – openable windows and solid roof – polycarbonate). The measurement will be carried inside

the building's heated zone (with temperature and humidity sensors), in the buffer zone (measuring temperature and humidity) and outside with weather data station (air temperature, humidity, wind speed and direction and solar irradiation measurement).

4. Conclusions

The use of buffer zones gives real benefits in terms of noticeable influences on the energy performance of buildings. Even when there are no glazed areas in the exterior skin (the outside façade), the more stable temperatures of unheated thermal buffers lead to less heat loss through building fabric in the heating season and give slightly better overheating protection in the summer. Nevertheless, there is a need to conduct further evaluation of this design combined with other factors such as natural ventilation scheduling and thermal mass in order to achieve better results. Also, as mentioned earlier, planned in situ measurements of collected values will be compared with simulation models to obtain an optimal modelling approach of such buffer zones.

Building regulations, which are currently being implemented, aim towards near-zero energy demands, and are a serious challenge for modern architecture of both small and of large scale objects. Solutions presented in the design of the Double Skin House concept are an original reaction to the demand for a modern energy-efficient house, allowing for widely understood comfort of use (functional, spatial and climatic) and low maintenance costs [5].

Architecture of the proposed house conforms to the energy efficiency and minimal energy consumption, manifesting in the selection of building materials and a simple, compact volume which can easily be adapted for a specific site as well as the needs of the investor, changing over the years.

Design Team: architecture: grupa synergia: Cebzat K., Bać A. energy performance: Nowak Ł.; structure: Miś G., cost estimation: Fantaziński S., visualizations: Stec W., graphical layout: Gałwiaczek A.. The Double Skin House project received an honorable mention of Isover, a sponsor in the Murator competition for Energy Efficient Affordable Houses 2013.

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