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CHARACTERISTICS OF VENTILATED FAÇADES AND FAÇADE ANCHORS FOR PASSIVE HOUSE BUILDINGS

BY

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Abstract. Recently, awareness of climate change has conducted to the implementation of new concepts, which has determined the prioritization of energy efficiency in the building design process. One such concept is passive house. The facade, as the building envelope, is the element that has a significant impact on the total energy consumption of a building. Currently, the use of ventilated facades in different building types, climates and design configurations has grown considerably. The present study provides a brief overview of ventilated facade features and facade anchors certified as minimum thermal bridges for buildings considered passive houses.

Keywords: Ventilated Façade, Passive House, Energy Efficiency, Thermal comfort, Façade anchor, Building energy performance.

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1. Introduction

Buildings can considerably reduce their energy consumption by implementing energy-saving strategies. These strategies can be broadly classified into passive and active approaches, as stated by Mitterer et al. (2012) and Al-Obaidi et al. (2014).

Passive strategies aim to optimize natural resources such as orientation, glazing, shading, and insulation (Cojocaru and Isopescu, 2021). Conversely, active strategies depend on efficient mechanical systems that produce and use electricity, including HVAC and photovoltaic systems (Ma et al., 2019). The selection of energy-saving strategies for a building should consider both passive and active approaches in the context of the local climate to optimize resource consumption, as emphasized by Serra Soriano et al. (2014) and Yu et al. (2019).

The Passive House standard is an evaluating system that significantly impacts the field's design specialists, beneficiaries, and researchers (Cojocaru and Isopescu, 2021). One of the five fundamental principles of the Passive House concept is implementing high-quality thermal insulation in the building envelope, as illustrated in Figure 1. This principle aims to restrict the thermal transmittance of the opaque components in the building envelope, thereby reducing energy loss. A thermal transmittance (U-value) of no more than 0.15W/(m²K) is necessary for cool-temperate regions to meet the established thermal insulation objectives. This criterion implies that the maximum of 0.15 watts per degree of the temperature difference and per square meter of exterior surface may be lost.

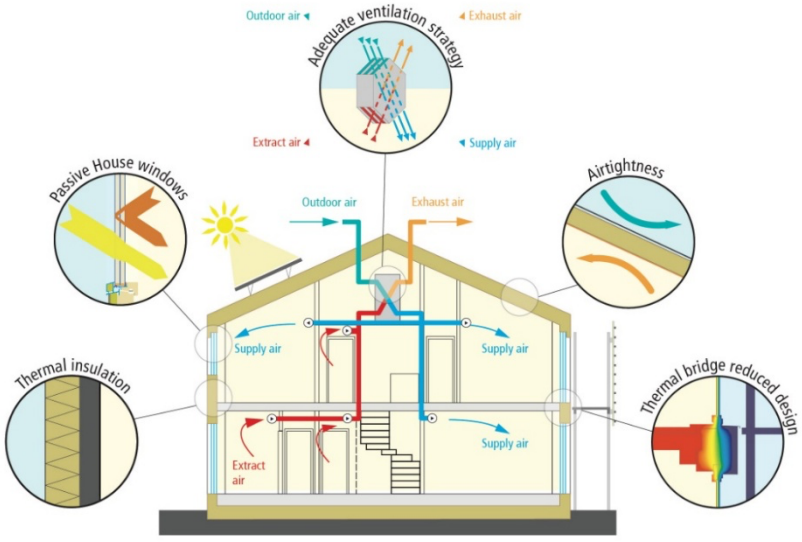


Fig. 1 – The five basic principles of Passive House. Graphics: Passive House Institute.

As mentioned above, one of the most widely implemented measures for enhancing the energy efficiency of building envelopes is the application of high thermal insulation (Doroudchi et al., 2018). This involves using materials with low thermal conductivity, reducing heat loss from the building's interior to the outside environment. The façade plays links the changing of outside environmental factors and the constant internal human requirements.

A ventilated façade is an effective passive energy strategy for climates with warm summers and mild winters, as confirmed by research conducted by Gagliano et al. (2016), Maciel and Carvalho (2019), and Stazi et al. (2020). In recent years, the use of it in various building types, climates, and design configurations has increased considerably (Maciel and Carvalho, 2019). In recent years, ventilated façade systems have gained significant interest, with a range of research and journal papers about Double Skin Façades, Building Integrated Photovoltaic, Solar chimneys, Trombe Wall, Solar Walls, Façade Solar Collectors, and with a lower range of studies about Opaque Ventilated Façades (OVFs).

2. Ventilated façade

Ventilated building façades represent an external envelope technique that offers significant advantages over traditional, single-skin façades. These benefits encompass various building physics topics, such as moisture management, thermal efficiency, noise reduction, fire resistance, and structural efficiency (Pujadas-Gispert et al., 2020). Ventilated Façades are building solutions that can enhance the energy efficiency of new and existing structures (Antonio et al., 2016), thereby contributing to indoor comfort.

The concept of ventilated façades has gained significant popularity also in Romania over the past two decades (Baciu et al., 2022). The regulatory framework, NP 135 – 2013 standard, defines ventilated façades as façade systems with a naturally ventilated air layer as one of their components. As a result of the regulatory framework, the use of ventilated façades in Romania has become more standardized, resulting in safer, more energy-efficient, and environmentally sustainable building structures (Baciu et al., 2022).

Ventilated façades are structural elements of a building coated with cladding material and attached to the wall through supports, typically made of metal (aluminium, steel). The supports must ensure proper connection of the cladding material with the plywood boards, while supporting the loads generated by the weight of the components, and endure exposure to the environmental conditions and thermal expansion (Faggembauu et al., 2003).

Ventilated façade systems typically incorporate three primary components: an insulation layer, usually situated on the external surface of the wall, with the support structure, which comprises profiles and supports applied to

the façade to create the necessary space for mounting the insulation, an air cavity, and the outer skin (Ibañez-Puy et al., 2017).

Usually, the air gap within the ventilated cavity allows for air infiltration and may provide pressure equalization across the outer skin (Figure 2). The primary function of the ventilated air layer is to maintain a constant vapour pressure difference between the outside environment and the façade system (Fantucci et al., 2020). Any water that enters the cavity is drained away (de Masi et al., 2021). Vertical continuity of the ventilated air layer and the exterior is crucial (Lahayrech et al., 2022).

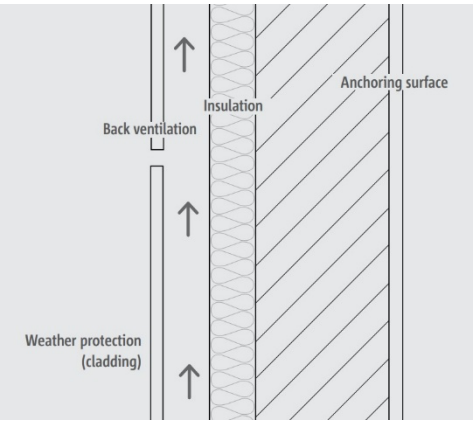


Fig. 2 – The components of ventilated façade. Graphics: Schöck Isolink.

The cladding system is attached using a support system specifically designed to bear the system's mass and the projected wind and earthquake loading. This support system generally consists of vertical or vertical and horizontal fixing rails, which are fixed back to the building's structure through brackets. The substructure comprises various components, including consoles that vary in size and type, with or without thermal insulation plates, and fasteners such as dowels, expanders, or screws to attach the consoles to the wall. Fastening systems for ventilated façades should be adaptable to different cladding materials such as natural and composite stone, ceramics, bond composite materials, aluminium hydroxide composite materials, metal in the form of flat and folded plates or cassettes, HPL, fibro cement, and similar materials, wood, glass, and plastic boards. They should also be adaptable to different stereotypes in architectural projects and be lightweight to facilitate manipulation (Baciu et al., 2022).

The outer layer of a ventilated façade system is typically constructed from modular panels and may feature various types of tiles, including metallic, ceramic, stone, or composite. The external protection component can be constructed using various subassemblies, such as continuous systems like wet

plasters on perforated heat-insulating doubles or grooved plywood finished with thin plasters. The exterior panelling may be continuous, with sealed seams between the panels and holes located at the top and bottom of the cladding for ventilation. On the other hand, the Open Joint Ventilated Façades (OJVFs) have open joints between the panels to withstand temperature-related expansion, allowing external air to flow into and out of the cavity along the entire wall length (Baciu et al., 2022).

3. Benefits of ventilated façade

Overall, ventilated façades offer a range of benefits that can improve the energy efficiency and sustainability of buildings while providing a comfortable indoor environment for occupants (Meggers et al., 2012). The thermal benefit of a building can be optimized through a combination of closed heat insulation and back ventilation. The ventilation façade functions as a shading mechanism for thermal insulation, allowing the accumulated heat from solar radiation to be directly removed from the ventilation gap. In the context of a ventilated façade, the heat exchanges between the walls of the façade and the interior of the building are governed by three main mechanisms: convection, conduction, and radiation. Convection inside the air cavity is primarily generated by the velocity of the airflow (wind) and the temperature gradient between the façade's surfaces and the air. In the absence of wind, the external wall absorbs and stores solar radiation, causing the air in the channel to heat up and become less dense. This creates the stack effect, which causes the air to rise and flow into the room, exiting through the top outlet vent and resulting in a pressure drop at the bottom of the air channel (Lahayrech et al., 2022). This pressure drop brings cold air into the cavity through the inlet vent, resulting in what is known as natural convection. Alternatively, in the presence of wind, ventilation in the air gap is caused by the chimney effect and the mechanical force of the wind.

Furthermore, ventilated façades can also provide heat to the interior of the building. As there is still a temperature gradient between the interior and exterior air, the outer wall releases heat absorbed and stored during the day through radiation mechanisms. However, this process takes time, and the heat released depends on the wall's thermal mass. This indirect heat gain can be advantageous as it provides heat during night-time when temperatures typically drop (Lahayrech et al., 2022).

The design of components plays a crucial role in determining the thermal performance of a ventilated façade. Specifically, factors such as the distance between the two layers, the type of material used for the exterior cladding, and the typology of joints in the exterior cladding (open or closed) significantly impact the performance of the façade (Stazi et al., 2020).

The process of back ventilation in a façade enables faster dissipation of accumulated room and component humidity resulting from diffusion, as compared

to homogeneous wall structures. Furthermore, the ventilated façade ensures the protection of the wall structure from various weather conditions throughout the year. In terms of building envelope design, this type of façade protects the thermal insulation layer by shielding it from moisture, direct sunlight, and heat, thus enabling it to perform its intended function. Furthermore, any potential moisture infiltration penetrating the façade is promptly removed through the ventilation gap (de Masi et al., 2021). This feature ensures the durability and longevity of the façade system by preventing the accumulation of moisture within the insulation layer, which can lead to structural damage or a reduction in thermal performance. Also, this system's high level of fire resistance has been extensively tested and proven across a diverse range of systems. Thus, investment in these façades is advantageous from an economic perspective, making them an attractive solution for representative buildings that need to maintain their rentability and profitability over the long term (de Masi et al., 2021).

4. Façade anchors as thermal bridges

According to the fifth principle of the Passive House Standard, thermal bridges must be eliminated by thoroughly planning and executing all edges, corners, connections, and penetrations in detail. The occurrence of thermal bridges and leakages may result in potential risks such as condensation and discomfort due to indoor temperature variations. In instances where thermal bridges are unavoidable, it is imperative to minimize them to the maximum possible extent, as emphasized by Colclough et al. (2018).

In traditional building envelopes, the impact of point thermal bridges is generally insignificant. However, in ventilated façades, this is different. These constructions require a relatively large number of points to secure the external envelope to the internal-substrate envelope, which typically involves steel or aluminium brackets penetrating the insulation layer (Lahayrech et al., 2022). Despite the brackets' significantly smaller volume compared to the insulation layer, their thermal conductivity can be over 2000 times higher, resulting in substantial thermal bridging heat transfer between the warm interior wall, located behind the thermal insulation, and the cold structural metal frame in winter, and vice versa in summer. Recent studies have demonstrated that neglecting point thermal bridges in such constructions can lead to a more than 20% underestimation of the actual heat flow magnitude, which depends on various factors (Colclough et al., 2018).

The need for mechanical strength limits the choice of materials to those with low thermal conductivity. Despite their excellent thermal insulation properties, such materials often fail to meet the required strength level, while materials with high mechanical strength generally exhibit poor thermal insulation performance. Hence, the optimal solution in most cases is to incorporate a thermal break layer with a thermal conductivity of around 1 W/(m·K) and a thickness of

not more than 6mm to comply with the necessary mechanical strength criteria. Furthermore, it is worth noting that the thermal break layer only reduces heat transfer through the direct contact of the bracket with the wall and does not affect the anchor that penetrates the wall (Colclough et al., 2018).

The interruption of the direct contact between the substrate wall and the aluminium bracket significantly reduces heat flow, as studied by T. Theodosiou et al. in 2017. When the substrate wall material exhibits low thermal conductivity, the thermal break's impact is relatively limited since the substrate wall also provides thermal resistance, thus minimizing the thermal break's contribution.

The Passive House Institute provides a comprehensive component database, including certified façade anchors (Fig. 3). These anchors are designed to meet specific requirements that ensure their ability to provide sufficient structural support while also minimizing thermal bridging and preserving airtightness.

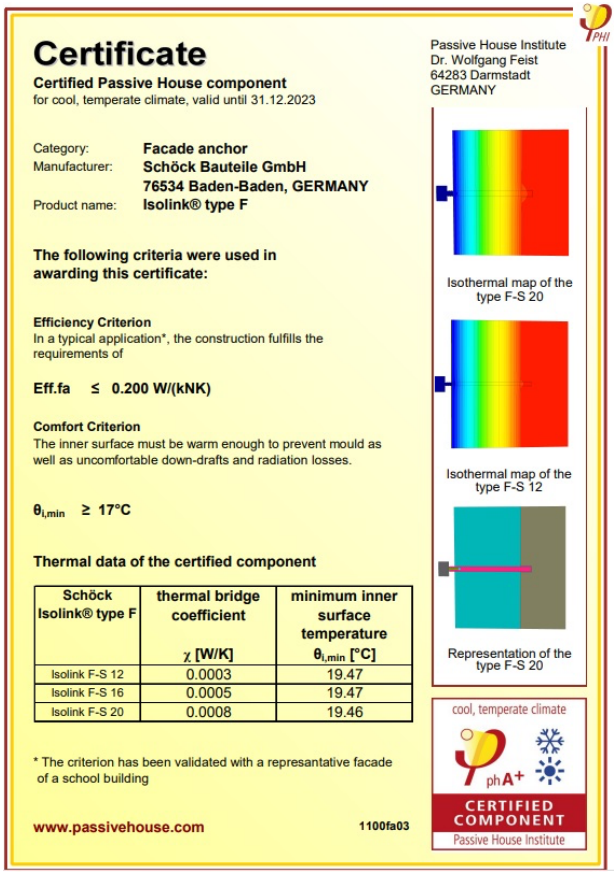


Fig. 3 – Certified façade anchor. Graphics: Passive House Institute.

To fulfil their intended function, façade anchors must be able to bear the weight of the building's façade, including wind and seismic loads and other external forces (Lahayrech et al., 2022). Moreover, façade anchors must be constructed from materials with low thermal conductivity, such as carbon fiber or fiberglass, to limit thermal bridging. Properly installing façade anchors is crucial to maintaining the building envelope's airtightness, necessitating attention to detail, including appropriate sealants and gaskets. Additionally, façade anchors must be designed to endure the building's expected service life, which requires carefully evaluating the materials and environmental factors to which they will be exposed. An installation-plan reference façade of the certified component is mandatory (Fig. 4) with a table with the classification criteria and the load class allocation (Fig. 5).

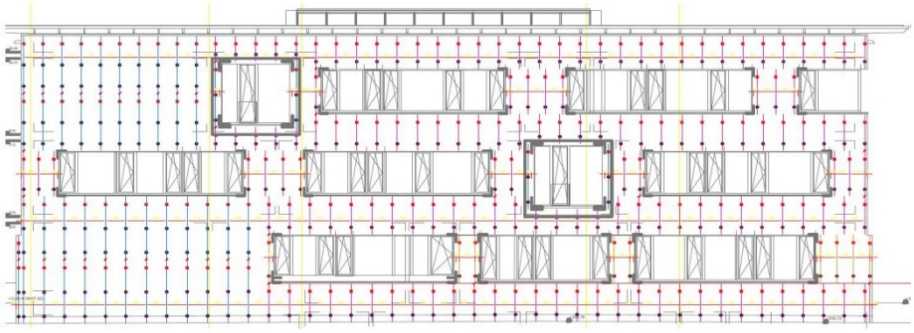


Fig. 4 – Installation-plan reference façade of the certified component. Graphics: Passive House Institute.

Load-class (LC)	Facade cladding	Facade weight [kN/m²]	Efficiency criterion fulfilled?
I	ACM	0.10	yes
II	HPL	0.15	yes
III	Fibre-cement-plates	0.20	yes
IV	Fibre-cement-plates	0.25	yes
V	Glassfacade	0.30	yes
VI	Marble	0.60	yes

Fig. 5 – The classification criteria and the load class allocation. Graphics: Passive House Institute.

To meet the Passive House standards, it is suggested to use certified components that are designed for different climate zones. These components have specific characteristics that ensure they meet the standards recommended by

Martinez-Soto et al. in 2020. The component database includes 30 certified façade anchors that can be used in the cool, temperate, and cold climate zones. Most of those façade anchors use composite fiberglass, such as Combar®, with extremely low thermal conductivity. This thermal conductivity is estimated to be roughly 15 times lower than that of stainless steel and nearly 300 times lower than that of aluminium, as seen with the help of isotherms in Fig. 6.

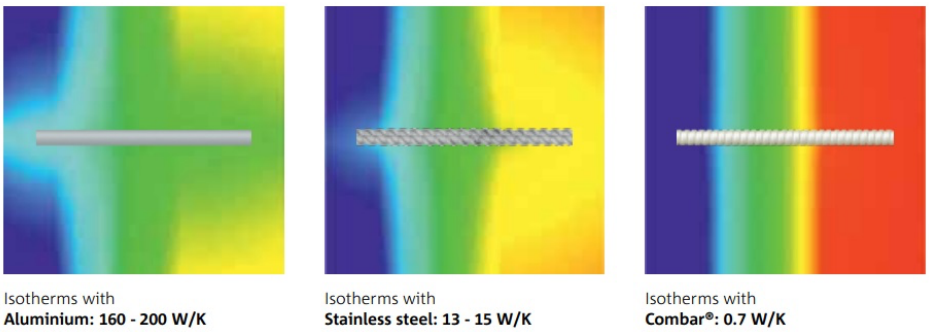


Fig. 6 – Influence of the materials on the U value. Graphics: Schöck Isolink.

4. Conclusions

Alongside ensuring a comfortable and healthy environment for occupants, energy efficiency is now considered an essential aspect of modern building architecture aimed at reducing overall energy consumption. Using ventilated façade as a passive strategy would help improve the energy efficiency balance of the buildings by providing thermal benefits. Furthermore, using ventilated facades in Passive House buildings aligns with the five principles of the concept. However, the main challenge in the thermal study of ventilated facades is the facade anchors.

Facade anchors are integral to the structure of ventilated facades and support the loads applied to the building envelope, such as wind and seismic loads. However, using facade anchors can lead to thermal bridging, which occurs when heat flows through the building envelope at a higher rate than the surrounding materials. This may compromise the energy efficiency balance of the building, which is undesirable in Passive House buildings that prioritize energy efficiency. Future research in ventilated facades and facade anchors will significantly enhance the design and construction of energy-efficient buildings. Exploring new materials and techniques for constructing facade anchors could lead to even more significant improvements in energy efficiency. Additionally, new insights into the performance of ventilated facades and facade anchors in different climatic conditions and geographical locations could also inform building designs in the future.

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CARACTERISTICILE FAȚADELOR VENTILATE ȘI A ANCORILOR DE FAȚADĂ PENTRU CONSTRUCȚII DE CASE PASIVE

Recent, conștientizarea schimbărilor climatice a condus la implementarea de noi concepte, ceea ce a determinat prioritizarea eficienței energetice în procesul de proiectare a clădirilor. Un astfel de concept este casa pasivă. Fațada, ca anvelopă a clădirii, este elementul care are un impact semnificativ asupra consumului total de energie al unei clădiri. În prezent, utilizarea fațadelor ventilate în diferite tipuri de clădiri, clime și configurații de design a crescut considerabil. Studiul de față oferă o scurtă privire de ansamblu asupra caracteristicilor fațadei ventilate și a ancorelor de fațadă certificate ca punți termice minime pentru clădirile considerate case pasive.