THE VENTILATED FACADES

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Abstract

The topic of this article is ventilated facades. My doctoral studies are focused on ventilated facades. This article deals with the basic division of ventilated facades, design procedures according to standards and the different types of ventilated facades. The ventilated facades have a lot of using. For example, architectural design of the building or avoiding overheating, or the creation of a vegetation wall. The disadvantage of this type of facades is mainly the complexity of the design, and the price of execution. The focus of this paper is to highlight different perspectives.

Keywords

Ventilated facades, air duct, fire safety, energy savings, opaque ventilated facades

1 INTRODUCTION

Today, our society is dealing with a climate crisis. For this reason, efforts are being made to reduce the energy requirements of buildings. One of the many solutions is to reduce heat loss by reducing the heat flow from the interior to the exterior. This heat exchange occurs at the building envelope. A wall creates the envelope of the building. The roofs or ceilings or floors create it too. For this reason, I have decided to introduce ventilated facades to you. This article is a review about the ventilation facades, their basic design, their constructions, and a few research on ventilated facades. My doctoral studies are focused on ventilated facades too.

One of the most important design data is the heat transfer coefficient. This coefficient shows us how much heat energy passes from the interior to the exterior through the structure at a difference of 1K per area per 1m^2. Other important parameters are the point and linear heat transfer coefficients accounting for the effect of thermal bridges and thermal bridges in building structures. They are used to account for the influence of thermal insulation anchors, anchors that fix external cladding. At the same time, the energy intensity of the building is influenced by its overheating in summer and cooling in winter. All these thermo-technical parameters of building structures are determined by the standard values in the standard ČSN 73 0540-2:2011+Z1:2012. The standard gives us the required, recommended, and passive values of the heat transfer coefficient, the point and linear heat transfer coefficient and other values.

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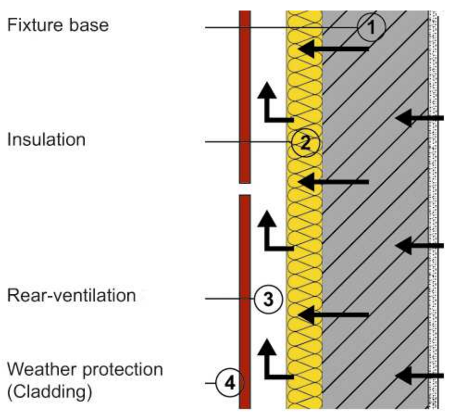

Fig. 1 The ventilation façade [1].

The ventilated facade creates the envelope of the building. The ventilated facades form an important architectural element. There are many types of ventilated facades. There is also a huge variety of materials of which a ventilated facade can be made, such as stone, concrete, ceramic, glass, wood, steel, or other combinations. A comparison of the advantages and disadvantages can be found in Tab. 1.

The ventilated facade is formed by two skins separated by a ventilated gap for example is the construction of the ventilated facades is shown in Fig. 1. The first skin, called the inner skin, separates the interior and the ventilated gap. It prevents heat exchange from the building and therefore has a thermal insulation function. It can also be called as having an acoustic function. At the same time, it also has a load-bearing function for the external so-called view cladding.

Ventilation of the gap causes a chimney effect. Cold air is brought in, and warm heated air is brought in. The warm air has a lower density than the cold air and therefore just rises upwards. The inlet vents are located at the bottom and the outlet vents at the top. The outlet must have 10% more surface area than the inlet. The vents must be protected against insects, birds. At the same time, the distance between them is important [2]. The ventilated gap is often formed by the supporting grid of the outer skin.

The outer skin has a mainly visual function and protects the inner skin from the weather. Its visual function creates the first architectural impression of a building clad with a ventilated façade. It may be transparent, opaque, open joints, close joint joints or may be vegetated. The difference between open joints and closed joints is illustrated in Fig. 2. Fig. 3 shows the axonometry of the ventilated façade with the supporting layer of the outer skin.

2.1 Advantages and disadvantages of ventilated facades

Tab. 1 Advantages and disadvantages.

Advantages	Disadvantages
Possibility of architectural design of the facade (creativity of design)	Higher price
Limits overheating (heat attenuation in summer from the sun)	Laboriousness
Ventilation of water vapour passing through the structure (chimney effect)	Higher number of point thermal bridges (or linear thermal bridges)
Limits condensation of water vapour (mineral insulation)	Higher load on the structure (for heavier tiles)
Sound absorbing properties (mineral insulation)	Less lighting due to the thickness of the structure
Protection against weather conditions	
Can be treated even in poorer conditions	
Longer service life of the structure [3]	
Possibility of replacing the cladding without major intervention in the structure (repairs)	

2.2 Types of ventilated facades

By number of skins:

- double skin facades,
- triple or more skin facades.

By outer skins:

- vegetation facades,
- transparent facades,
- opaque facades,
- facades with photovoltaic panels,
- smart facades.

By opening joints:

- open joint facades,
- close joint facades.

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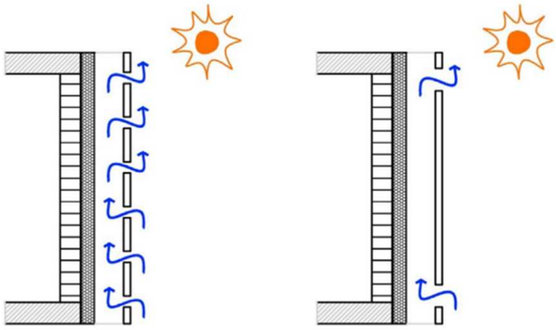

Fig. 2 Comparison open joint and close joint facades [4].

Smart facades are a very interesting part of buildings because it has elements controlled automatically. The controllable elements can also be flaps on the air vents. The intelligent façade is based on the principle of control elements, such as ventilation openings in the outer (or inner) shell, sunscreens or blinds, or other elements.

These openings can be controlled by, for example, temperature, humidity. For a smart façade to be "smart", the individual systems need to be set up correctly and interconnected correctly. All systems must be in a certain hierarchy, the connectivity of the systems is a key. Smart facades consist of a set of sensors and sensors measuring data and boundary conditions of the building and the surrounding environment, a control unit that processes these measured data, evaluates them, gives commands to servos and motors, which, after receiving a command from the control unit, perform actions to change the conditions.

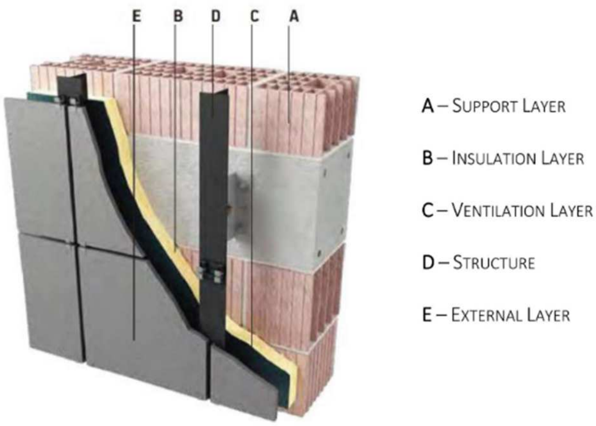

Fig. 3 General system components [5].

2.3 Basic design principles

Each structure must have standard and legislative requirements. These are thermal engineering, acoustics, statics. Each structure must meet certain standard required values for the heat transfer coefficient U. At the same time, for new buildings it is important to comply with the requirements for nearly zero energy buildings, which are characterised using renewable energy sources and an average building envelope heat transfer coefficient of at least 0.7. This coefficient is the ratio of the values of the design heat transfer coefficient and the required heat transfer coefficient by the standard. The water vapour balance is important. Moisture content can affect the individual properties of materials. For the design of the width of the ventilation gap in Czech Republic, the standard for the design of the ventilated gap in the roof is applied. It is ČSN 73 1901 – Roof design – Part 2: Roof with folded roof covering. The minimum is 40 mm up to a height of 10 m. For each additional meter +10% extra is added. This is to provide airflow [2]. The air is supplied through the air inlets in the lower part and is exhausted in the upper part through the air vents. All openings shall be protected against the ingress of rain, vermin, and birds. Their minimum area shall be based on the venting area and specifically 1/400 of the venting area and the vents shall be 10% larger. The effective area should also include the area of the cover.

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A too small ventilation gap width can cause insufficient ventilation of moisture from the structure and at the same time a too large ventilation gap width can reduce the velocity of the airflow and even stop the airflow at certain points [4].

The heat transfer coefficient of the inner skin also has a significant influence on the airflow. The larger it is (more heat energy escapes to the exterior), the more it helps to increase the flow velocity in the ventilated gap. This is why the effort to minimize heat loss leads to a slower airflow in the ventilation gap.

2.4 Difference between open joint and close joint facades

One study is focused on the influence of the panel orientation in open joint ventilated facades. That research addressed the arrangement of the panels and the joints between them. The distribution of joints in the façade influences the behaviour of the air flow in gap [4]. That research examined difference arrangements (landscape and portrait). Both of opaque facades had the same layers and material properties, but they had different panel arrangement [4]. The results of both facades were compared with conventional sealed facades. The author analysed summer and winter conditions. They used CFD model in ANSYS Fluent to study the orientation of panels.

The analysis of the results shows similar temperature trends. The exterior surface of open joint ventilated facades had a temperature of about 10 °C lower than the conventional façade. The ventilation façade had more effectivity in safe thermal energy because it has about 30% less heat transfer in summer than convectional façade [4].

The difference between the arrangement of the joints is not great. The horizontal arrangement is 3% more efficient than the vertical one [4]. Horizontal arrangement maximises heat exchange due to air flow and the plane minimises heat transport into the building in summer [4]. It can be said that the orientation of the gaps between the panels does not matter that much [4]. The reason is that the differences are small.

2.5 Humidity control

A ventilated façade can regulate indoor humidity. Moisture is always directed from a place of higher humidity to a place of lower humidity, just as in the case of heat. When we design a façade structure with diffusely open materials, the principle applies that moisture will go from the interior to the exterior, provided that the humidity in the interior is higher than that in the exterior. The problem arises when we are in a warm and humid environment [6]. This means that the moisture goes from the exterior to the interior. High level of relative humidity causes healthy problems. On the other hand, low indoor humidity causes dry exes, dry skin. Nowadays, there is an effort to create fewer demanding methods, the so-called direct methods [6].

The tested system was installed in an office building in a hot humid environment [6]. The air flow rate was determined to meet the hygiene requirements. The system consisted of a rotating packed bed, a ventilated façade, and an air-to-air heat exchanger [6]. The rotating packed bed has a desiccant based air. The ventilated façade is insulated with air-air thermal insulation. This thermal insulation has a low diffusion resistance [6].

The system works by the outside air entering the dehumidifier, the resulting hot and dry air is cooled by the outside air before being introduced into the air gap [6]. The dry air takes the moisture from the interior to the exterior. This ventilation creates a moisture gradient that pushes moisture from the interior to the exterior. The outdoor conditions were taken from the city of Jeddah, KSA [6]. The designed system reduced the humidity sparingly.

2.6 Fire safety

The ventilated facades have a problem with fire safety in a ventilation gap. In our standards, we must design non-combustible thermal insulation into ventilated facades. As there is no standard directly aimed at ventilated facades, various general articles and appendices are used. The windproof layer, a diffusion-opened plastic-based film, can also be a problem because it is flammable, but it is not considered from the point of view of the standards because its thickness is small, and it is taken as a surface treatment.

In a cavity fire, the fire can spread through several floors within the building. At the same time, the cavity is difficult to extinguish.

The name of that article is ”Effect of cavity parameters on the fire dynamics of ventilated facades”. In this paper, the flame height and heat flux in the cavity were measured [7]. From the measurements, it was found that the heat flux and flame height in the cavity increased as the cavity became smaller [7].

Our fire protection standards specify the individual requirements for the flammability of materials. We should design non-combustible thermal insulation (mineral wool – reaction to fire class A1). The windproof layer has a small thickness and is therefore treated as a surface treatment [8]. The individual requirements for the reaction to fire class of the proposed materials are described in Tab. 2 [8].

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Tab.2 Requirements for materials according to reaction to fire class [8].

Fire height of the building	Fire reaction class	
	Thermal Insulant	Cladding
Single-storey, h = 0	E	E
0 < h ≤ 12	A1, A2 *	E
12 < h ≤ 22.5	A1, A2 *	B, A1, A2
h ≥ 22.5	A1, A2 *	A1, A2 *

* Not explicitly stated – the assumption is based on Article 3.1.3.4 in CSN 73 0810.

2.7 Solar ventilated facades with thermoelectric energy harvesting panel

This study addresses the design of a facade ventilation with integrated thermoelectric energy harvesting (SVF-TEHP). It seeks to produce renewable electricity while increasing the thermal resistance of the structure through a passive ventilation measure. The key parameters that have a significant impact are solar radiation intensity, height and gap width [9]. At the same time, a conventional solar ventilated façade was compared with a solar ventilated façade with an integrated thermal energy panel in terms of ecology and operating costs. The façade can add photovoltaic modules or phase change materials that release or absorb sufficient energy during the phase change to provide useful cooling or heating [9], [10]. Adding a photovoltaic panel to the façade of a building will help us to overheat the façade in winter and reduce the temperature in summer [10]. Thermoelectric modules as power generation devices are interesting because they are small, noiseless, and highly reliable [9]. Seebecks effect and Peltiers effect are used for achieving power generation and refrigeration [9].

The conclusion of this research was that the influence of the environment affects output performance. At a solar radiation intensity of 900 W/m^2 the output power is 0.37 mV [9]. At the same time, the temperature of the inner wall increases by 26.1 °C [9]. The height of the ventilation gap improves the output performance but reduces the thermal insulation properties of the structure. Comparing SVF-TEHP or SVF and CW, so the efficiency of SVF-TEHP was found to be 1.1% higher [9].

2.8 An experimental study of the summer and winter thermal performance of an opaque ventilated facade in cold zone of China

Conditions in China are varied and the ventilated facades there have been tested for hot summers and cold winters. The study highlighted the fact that the intensity of sunlight can affect, especially in summer, so it is necessary to optimize the ventilated façade systems. In winter, in turn, the elements that limit ventilation gaps affect the most. Optimal solutions achieved a reduction in energy consumption of 11.4% and 6.5% compared to a conventional façade [11]. At the same time, it has been shown that daytime energy savings is more significant than nighttime energy savings.

The colour of the shell affects the surface temperature due to short-wave solar radiation. Colour affects the absorption of sunlight [11]. The effect of colour is less pronounced than the open joint ratio [11]. It is significant in the summer period, by appropriate colour coating of the outer skin we can achieve a reduction of the heat load. This effect can reach up to 52%. Dark colours increase heat gains from the sun [11].

This study tested weathered facades in the city of Tianjin, China. Based on measurements, it tested the joint ratio, the colour of the outer skin, the openness of the ventilation openings, the width of the cavity and their effect on the thermal performance of the structure.

One of the most significant factors influencing the thermal properties, especially in winter, is the width of the ventilated cavity [11]. A width of 200 mm has the most reliable airflow with admitted gaps in the summer period [11]. This width will ensure a reduction in heat gain. At the same time, it provides the best thermal insulation properties in winter provided ventilation is restricted [11].

The most important parameter is the ratio of open joints [11]. In summer, it is necessary to reduce solar gains by shading, and in winter it is necessary to ventilate less, thus reducing heat loss and just using the heat gains from the sun [11].

3 DISCUSSION

Ventilated facades have many advantages and disadvantages, just like every other thing in this world. In my opinion, they have more advantages than disadvantages, but the problem is always the financial cost, which is considerable. The monetary cost of construction is one of the most important things in the construction of buildings. Although the input costs may be higher than with a sandwich wall, it can be said that the operating

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costs of the building (heating, cooling) can be reduced. Ventilated facades are the future of the building industry. Ventilated facades allow for different architectural forms of the building, they can create an interesting first impression of the building. This is made possible by the different structural designs of the external cladding.

Ventilated facades can reduce the heat load in summer [2], [3], [4], [11]. With the right design of a structure that meets diffusion openness, they can dehumidify the internal environment of the building [6].

Another interesting feature of ventilated facades is that they can generate an electrical voltage [9]. For example, when they contain photovoltaic panels or cells that use the Seebeck effect. This effect is based on a temperature gradient that generates a voltage [9]. Ventilated facades are a relatively unexplored topic, but still have a high potential.

4 CONCLUSIONS

This article is a review from topic of my doctoral study. The façade is an important component of building from point of view thermal performance. Ventilated facades form an important architectural element of buildings and can be made of different materials. This topic is quite broad and can be approached from many different angles.

Like everything in the world, everything has its positive and negative sides. Ventilated façades can help reduce the energy consumption of buildings [2], [4], or in the case of green façades, reduce overheating of the surrounding area, reduce dust in the neighbourhood. The facades can have integrated photovoltaic panels [10] or panels that generate electricity from heat [9]. The disadvantage of ventilated facades is certainly their cost, which affects the possibility of their construction. This is influenced by its individual elements (e.g. insect screens, individual anchor bolts, anchor pads). The most important consideration for the investor must be a comparison of advantages and disadvantages, the ordering price, and the payback.

The most important element in the study of ventilated façades is the climatic conditions, i.e., the relative humidity of the surroundings, the temperature of the outside air, the intensity of solar radiation.

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