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GENERAL PRINCIPLES FOR THE DESIGN AND CONSTRUCTION OF VENTILATED FAÇADES

BY

CLAUDIU ROMILA*

"Gheorghe Asachi" Technical University of Iași
Faculty of Civil Engineering and Building Services

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Abstract. Ventilation of wall and roof elements can decrease the heat transfer through the building envelope and consequently reduce the demand for the conventional insulation materials. Moreover, a two stages tightening protection against wind and rain is obtained, that has been proven to reduce the occurrence of building defects of the outer layer. Nevertheless, there is a few data about the design, execution and maintenance of these constructive systems. This paper aims to provide the basic principles for the correct design and construction of ventilated façades, starting with the specific requirements for each constitutive element and offers general recommendations for ventilated systems design.

Key words: ventilated façades; air channel; design requirements; building defects.

1. Introduction

Building façades have evolved from the monolithic structures of high thermal mass and inertia (brick, stone or clay) to multiple layers systems made from different materials. Unlike monolithic walls, the multiple-skin façades are more complex, harder to assemble and require finer adjustments for a better thermal efficiency.

*Corresponding author: *e-mail*: romilaclaudiu@yahoo.com

A special case of this type of structures is the ventilated façade, where one of these layers is represented by air (Fig. 1). When the exterior layer is detached from the wall assembly, the excess water in liquid form can be eliminated by gravitational drainage while the water vapours are evacuated by convective transport. In addition, the inside air channel provides a capillarity break for water through porous materials, reduces the humidity bridges and equalizes the pressures on the façade; consequently the life cycle of the wall and thus of the entire building is increased.

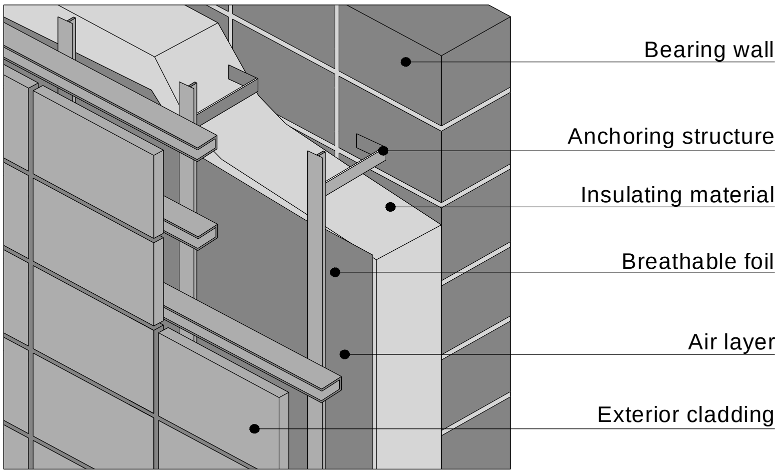

Fig.1 – Constructive elements of ventilated façades.

Ventilated façades are considered to be more energetically efficient in the warm season due to the fact that heat can be transported by convection to the exterior and thus thermal load on the building can be reduced. Reductions of 50% can be achieved for high values of solar radiation intensities and of the outside air temperature (Patania *et al.*, 2010; Ciampi *et al.*, 2003; Mesado *et al.*, 2010; Eicker *et al.*, 2008).

On the other hand, these constructive systems are considered to be less efficient in colder climates, but some energy reduction can still be obtained because the air layer and the exterior cladding add some suplementarry thermal resistance to the wall system. However, in cold and wet climates, a two stage tightening is prefered to the classic compact solution, due to a better protection against the wind driven rain.

In conclusion, if the durability and thermal efficiency of exterior walls are considered, the design, construction and maintenance of ventilated systems are very important parameters when conceiving the next generation of energetically efficient buildings.

2. Principles of Design and Construction of Ventilated Façades

2.1. General Considerations

Requirements related to the sustainable development in the construction industry require that the problems related to construction defects should be kept to a minimum and thereby the life cycle of the building prolonged. Nonetheless, in recent times, building enclosure failures have occurred more frequently. Previously, roofs were responsible for the majority of defects in buildings, but nowadays walls are reported to have a much larger failure rate (Lisø *et al.*, 2006). The largest percentage of failures (76%) was reported to be related to moisture (Sagen, 2004).

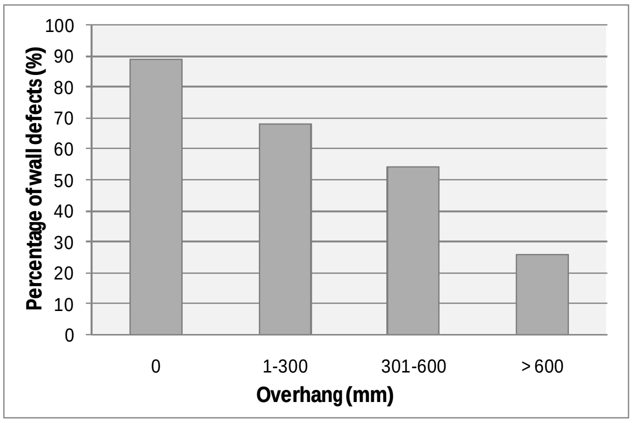

Fig. 2 – Percentage of exterior wall defects function of the overhang dimension (Rousseau & Hazleden, 1998).

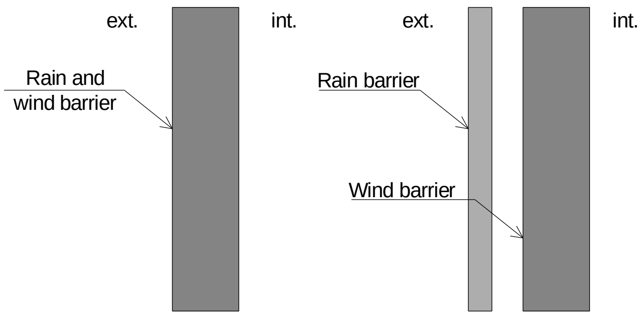

Fig. 3 – Basic schematics for one and two stage tightening.

Some authors reported that, between the dimension of the overhang and the percentage of failures of walls exists an inverse correlation, especially in wet and rainy climates, as presented in Fig. 2.

The protection of the exterior walls against the outside factors can be done in a one-stage or a two-stages tightening, depending if the rain and wind barriers are separated, as shown in Fig. 3.

One stage tightening walls systems consist in a compact wall structure, made from one or more materials. In case of wetting from wind driven rain, building defects caused by moisture can occur, mainly due to poor workmanship. This type of walls is considered more economic and more suited for buildings situated in dry and warm climates (Nore, 2009).

Furthermore, because of the climate change, more extreme weather is expected, with increased precipitations, higher temperatures and increased freeze – thaw cycles that will result in faster façade decay. Therefore, the two-stages tightening system (also named ventilated wall cladding, ventilated screen type wall systems or pressure equalized screen) must be considered.

Ventilated façade design differs from country to country and even from area to area, depending on the local climate and architectural constraints. For example, the exterior wooden claddings of residential houses in Nordic countries are air tight in order to obtain a sealed cavity, while in Scotland the open joint claddings are preferred (Fig. 4). The open joint façade allows pressure equalization on the cladding and the usage of poorer types of wood and offers greater energy efficiency in summer (Sanjuan *et al.*, 2011).

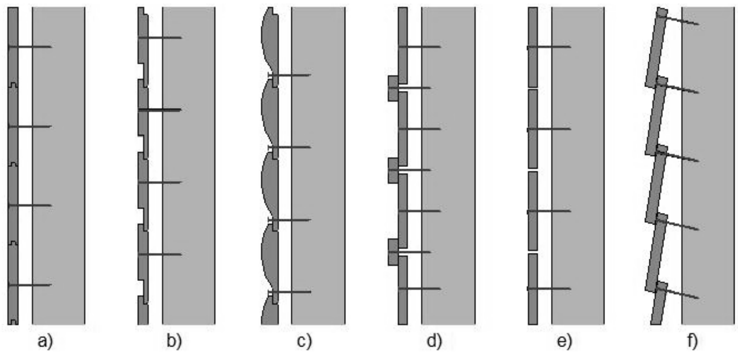

Fig. 4 – Tight (a-d) and open jointed wood claddings (e-f).

Leaks in the outer layer should be less than 3 mm in order to prevent water entering into the channel. Otherwise, the vapour barrier should be stronger to resist to water penetration to the insulation layer. In areas where the action of the climatic factors is more severe and the outer layer is constructed in open jointed version, horizontal joints between the wooden boards should have an outward sloping drainage in order to reduce water infiltrations (Fig. 5).

Wind action is always uneven on the outer cladding. Given this, pressure gradients on the plane of the wall determine air movements behind the cladding, which can also move water into the wall or the insulation material.

For this reason, it is important to seal the air channel at the corners, as shown in Fig. 6 for a ventilated wood cladding wall.

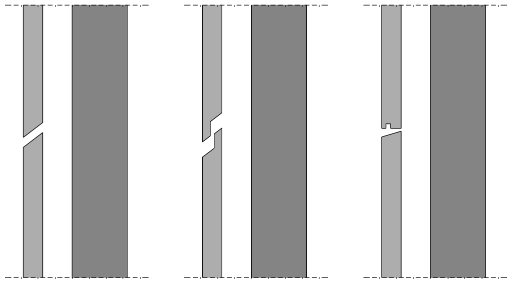

Fig. 5 – Joints with an outward sloping drain (Johanson & Seifert, 2003).

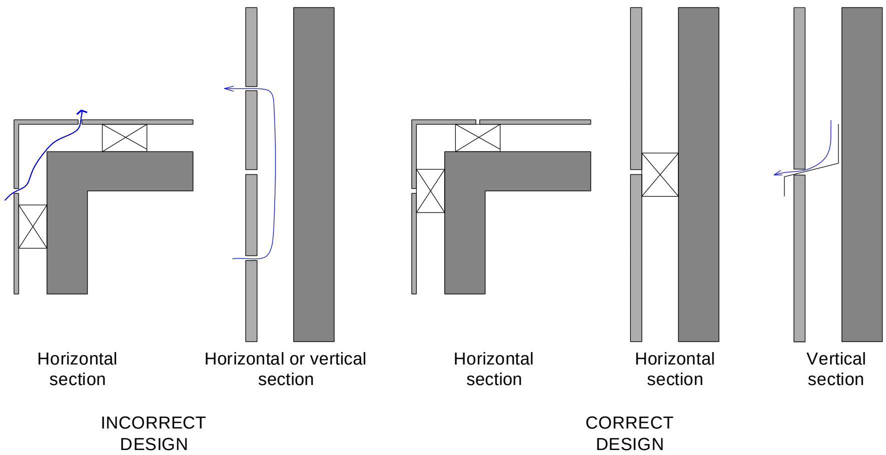

Fig. 6 – Incorrect and correct design of the wood ventilated façades.

2.2. Requirements of the Constitutive Elements

As mentioned before, a typical ventilated wall consists of several constitutive elements: bearing wall, anchoring structure, insulating material, breathable foil (or wind barrier), air layer and the outer layer. Each element should fulfil some basic requirement in order to obtain an efficient and durable ventilated façade.

The bearing wall represents the support base for the other components of the ventilated system. The strength condition is the most important requirement that should be met. Also, deviations on the height and length must be kept to a minimum. The bearing wall must provide sufficient thermal insulation to the building and water vapour permeability.

Although there is a great number of *anchoring systems* types, the basic requirements that should be satisfied by the support frame remain the same: to be strong enough to support the weight of the outer layer, to be able to withstand the wind, mechanical shocks and seismic action, to provide sufficient space for mounting the outer layer and to be optimized in order to reduce the thermal bridges.

The insulation layer (usually mineral or basalt wool) is disposed in contact with the ventilated air layer, outside the bearing wall and it protects the wall from temperature variations or from freeze–thaw cycles that can cause deformations. The thickness varies with the energy efficiency requirements imposed on the building. The choice of the insulating material depends on several specifications: thermal and acoustic protection, water tightness, fire resistance and sometimes colour (when the joints in the outer cladding allow the viewing of the material).

The breathable foil detains the penetration of water vapours in the insulation layer, but also allows the removal of the moisture from inside the building. Even if some manufacturers offer products that have membrane already applied on the rigid plates, it is recommended to dispose a continuous membrane that covers the entire thermal insulation layer, in order to reduce the thermal bridges at the insulating panel's connection and the „cooling" effect on the insulation.

Inside the channel, *the air layer* enables heat and moisture circulation and it does not allow the water vapours from outside or inside the building to accumulate on the wall surface or inside the thermal insulation. Moreover, the air layer provides thermal insulation in the cold season and heat removal in the warm season. In order to obtain a correct design of the air layer, the following requirements should be satisfied:

a) the contact between the wall and the outer cladding to a minimum must be reduced to a minimum;

b) sufficient drainage for the wind driven rain should be provided;

c) sufficient space for ventilation in summer must exist;

d) communication with the outside environment through orifices and openings located at the top and bottom part or through the open joints of the outer layer must be assured.

The outer layer, or *the wall cladding*, offers protection for the entire system against adverse atmospheric conditions (precipitations, wind, solar radiation, air pollution, etc.). It also gives aesthetics to the building. Specific requirements for the outer layer are: to stop the penetration of water inside the channel, to provide mechanical protection for the thermal insulation and permeable membrane, to have low emissivity in order to reduce heat transfer by radiation and not to suffer from degradations due to solar radiation.

2.3. Design and Construction of Ventilated Façades

Hydrothermal efficiency of the ventilated façade is influenced by many factors, therefore it is difficult to assess what type of ventilated façade should be applied in a given situation, but several basic rules can be observed from good practice experience:

a) air circulation must be accomplished only by the thermal and pressure differences across the height of the channel;

b) channel geometry must assure sufficient ventilation for water vapours transportation and of convective heat; a minimum 2 cm thickness is required;

c) inner air circulation must be avoided;

d) inlet and outlet openings should have the same dimensions;

e) the constitutive layers should be disposed in an ascending order of the permeability from the interior to the exterior;

f) the maximum height of the channel should be less than 18 m; however some norm recommend a 3 m height of the channel;

g) two different metals should not be in direct contact;

h) the solution for the cleaning of the exterior cladding should be detailed in the design project;

i) the anchoring system must be treated against corrosion in case of metals and against decay in the case of wood;

j) obstructions of the ventilation section channel or of the admission/ evacuation openings should be kept to the minimum;

k) the physical contact between the wall and the cladding must be avoided as much as possible; when this is not possible, the presence of a flashing is compulsory;

l) a vapour barrier over the insulating layer is needed for water drainage and for limiting the convective heat losses during the winter season.

Supplementary measures can be taken, function of the specific climate requirements. For example, in wet rainy climates, when open jointed claddings are used, a stronger vapour barrier is needed in order to eliminate all the excess water that has entered the channel.

3. Conclusions

The ventilated façade is a distinctive constructive system which is increasingly used in Europe for the rehabilitation of existing building stock. Depending on the local climate and architectural constraints there are many types of ventilated wall systems but not all have performed in a satisfactory manner because errors in the building design, construction or maintenance have led to the occurrence of defects to the building façade.

In our country only a few such buildings have been build, especially from reasons related to the poor seismic behaviour and initially bigger construction costs. Therefore, a few data exist on the basic principles of design and construction requirements for this kind of constructive system.

This work proposes to represent such a basis for the civil engineers and architects interested in applying ventilated façades systems. Only general principles for the design and construction are discussed, since thermal performance depends on the complex interaction between atmospheric conditions and channel geometry.

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PRINCIPII DE PROIECTARE ȘI CONSTRUCȚIE ALE SISTEMELOR DE PEREȚI VENTILAȚI

(Rezumat)

Ventilarea sistemelor de pereți şi acoperişuri reprezintă o soluție constructivă care poate conduce la o scădere semnificativă a transferului de căldură şi, prin urmare, la o reducere a cantității de material termoizolant necesar. Mai mult, fațadele ventilate realizează o protecție împotriva vântului şi a ploii în două straturi, care s-a dovedit că reduce apariția de defecte în stratul exterior. Cu toate acestea, în țara noastră există puține informații legate de proiectarea, execuția şi întreținerea pereților ventilați. În lucrare sunt prezentate cerințele de bază legate de proiectarea şi execuția acestor tipuri de structuri, plecând de la descrierea fiecărui element constitutiv. De asemenea, sunt propuse recomandări generale privind alcătuirea pereților ventilați.