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Moisture transport in the ventilated channel with heating by coil

Влагоперенос в вентилируемом канале с нагревательным элементом

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Ключевые слова: здания; вентилируемый фасад; влагоперенос; облицовочный слой; теплоизоляция; воздушный зазор; нагревательный элемент

Abstract. This article considers the moisture transport phenomenon in the vertical ventilated channel. HVF construction parameters are determined influencing the rate of moisture transport. It is necessary to have $h \leq L/25 \approx 8$ cm. The greatest air movement is created in the construction with the open rustications. The optimal location of the heat sources on the channel height, as well as their favorable combination from the point of view for the process of drying the outer surface of the thermal insulation material, was identified. The air velocity dependences on height of an air gap are determined and it was found that the greatest values taken at the maximum height velocity. Ratio between the moisture transport and the distance to the heat source is installed. Drying processes are compared with the various combinations of heat sources. The direct dependence of the vaporation weight rate of the time is installed.

Аннотация. В данной статье изучается явление влагопереноса в вертикальном вентилируемом канале. Определяются параметры конструкции НВФ, оказывающие влияние на скорость влагопереноса. Необходимо иметь $h \leq L/25 \approx 8$ см. Наибольшее движение воздуха создается в конструкции с открытыми рустами. Выявлено оптимальное расположение источников тепла по высоте канала, а также их выгодные сочетания с точки зрения процесса высушивания наружной поверхности теплоизоляционного материала. В результате исследования скорости движения воздуха по высоте вентилируемого зазора, было установлено, что на максимальной высоте скорости принимают наибольшие значения. А также выведено соотношение между массовой скоростью переноса влаги и расстоянием до источника тепла. Сравниваются процессы высушивания при различных сочетаниях нагревательных элементов. Установлена прямая зависимость массовой скорости испарения от времени.

Introduction

In the design of these systems radically affected increasing requirements for heat transmission resistance of enclosure structures. It is a practical impossibility to create a high-quality enclosing parts without using effective thermal insulation materials.

Clearly, the most favorable location of the thermal insulation in the design is its location at the outer surface. This ensures the offset of dewpoint temperature in the stream.

This is the principle used in the HVF constructions.

Fiber thermal insulation material having a high air permeance is most popular for the HVF constructions.

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Modern fibrous mineral-cotton materials have low density, their use is economic. The lower the density of the mineral wool, the higher its air permeance. This parameter has an effect on moisture removal rate from the ventilated gap.

The moisture transport is the process of the movement of moisture which represents transfer of vacant and physically-bounded water under the influence of gravitational and sorption (molecular and capillary) forces.

The control of moisture level is necessary is necessary to create an optimum operating conditions of the ventilated facade. The timely identification of excessive moisture appearance sources avoids the adverse effects of excessive moistening such as corrosion of metal products and parts, destruction of concrete, stone and brickwork during freezing and thawing, the color change of the building architectural detail, biological damage and deterioration of thermal properties.

Thus, quantitative calculation of moisture transfer is one of the most important in the multilayered enclosure structure designing.

This article conditions conducive to the most optimal process of removing moisture from the hinged ventilated facade gap by simulating moisture transport processes in different parameters HVF model are formulated.

A special contribution to the study of moisture transport process in the vertical ventilated channel was made by [1-24].

In this work [1] is investigated the impact of the presence of the technological gaps (rustication) the rate of air flow in the gap. The speed dependence on the width of the ventilated gap is established empirically for the construction with open and closed rustications.

The authors identify in the article [2] the conditions under which there is a cold air filtration in the ventilated gap. The publication [3] considers features of work of facades with and without rustications. The article [11] is assessed the effect of moisture transport on the dispersed and cellular materials. The authors of the publication [14] define adequate existence conditions of the free convection stream in the vertical conduit. In the work [22] consider issues of a natural ventilation of the vertical channel. In the work [27] the wall building with the ventilated facade thermal protection taking into account a longitudinal air filtration are investigated.

Purpose and goals of article are:

– to determine the most effective combination of heat sources depending on the air velocity in the gap.

– to consider the influence of the sources location of mechanical heat on the moisture transfer in the HVF gap.

– to determine the mass rate of moisture vaporization.

– to identify the mass velocity dependence on the distance from the heat source.

Methods and Results

The imperfection of building structures leads to their excessive moistening. Therefore, more and more attention is given to the moisture accumulation ability of materials and the possibility of their drying out. The majority of the moisture control methods are focused on reducing the heat- and moisture input into the air gap.

The main reason for the movement of moisture in the HVF construction is a difference of humidity, temperature and differential pressure of the air-steam mixture in the material. A zone of the greatest moistening is the layer of a mineral wool heat insulation adjoining the gap. Let us consider its rate of drying for different parameters HVF design.

To identify the optimal design parameters for the study of moisture vented we will consider the stylized scheme of the ventilated gap between the "hot" plane $y = 0$ (with $T_h = 67$ °C) and the cold plane $y = h$ (with $T_c = 22$ °C).

Heating is provided with three heating elements located throughout the height of the installation. For equal distribution of heat elements attach to a tin sheet, therefore $T_h = \text{const}$. The model height is equal to $L = 204$ cm, and $L \gg h$. While producing a facade sample we consider the temperature difference of external and internal layers proved by performance of heating systems. The model considers wall heating and heat input from it in the air layer. The external air is supposed to come into the air layer through the lower air hole. It rises through the ventilated channel and leaves through the top air holes. Air temperature increases and its relative moisture changes during the rise. At the same time moisture increases throughout the height of the layer [1]. To conduct this experiment a different combination of heat sources: “lower-middle”, “lower-upper”, “middle-upper” are used.

To identify an optimum variant for the study of moisture transport construction it is necessary to know the air velocity in the gap. It depends on the supply air method into the installation - with open or pressurized rustications.

Let us carry out an experiment. We measure the air velocity inside the HVF model depending on the gap width with and without rustications with various combinations of heat sources. We use thermal anemometer for measurement.

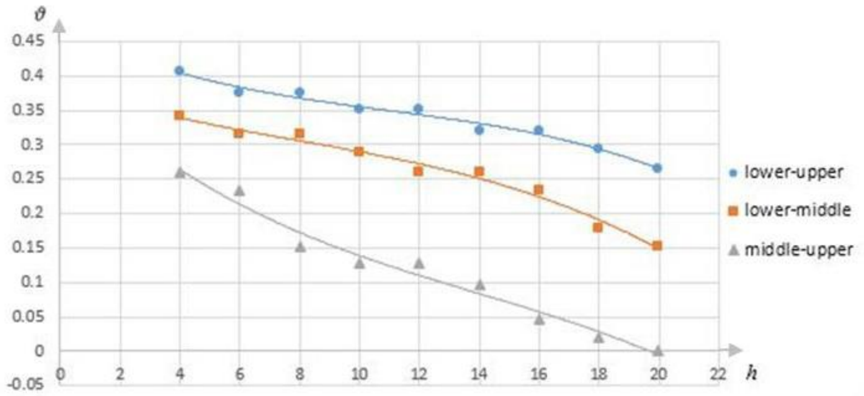

Figure 1. Sealed rustications

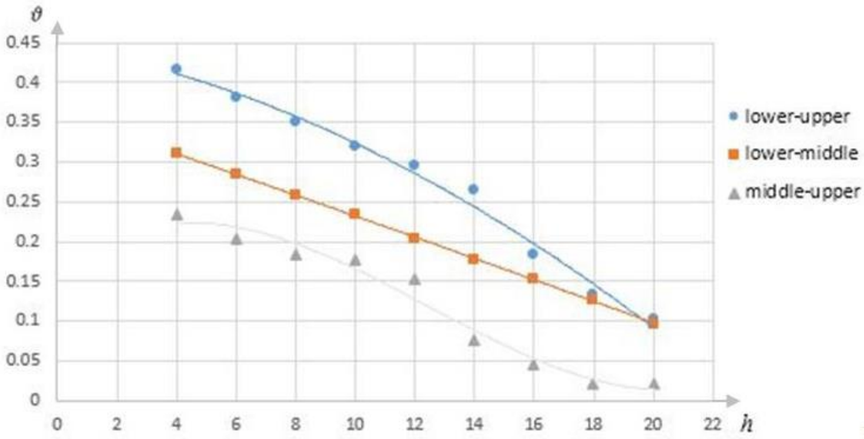

Figure 2. Open rustications

From the resulting graphs it follows that:

– the most air movement is created in the open rustications, because of the greater volume of heated air, as well as of various combinations of heat sources.

– in the design with a sealed rustications – "perfect channel" – is the air volume is less because the current is only from the bottom, reducing the drying speed.

– the most disadvantageous of the considered combination is the combination of heating elements – “middle-upper”. This is due to the fact that the air is not heated when entering to the canal at the bottom of the battery, and there is no difference in temperature, therefore, there is no active air movement. Basically, the current is through the rustications, involving the construction of cold air. At the same time the height velocity decreases and tends to zero when large gaps.

We will use mineral-cotton samples 95 x 210 x 50 mm for further experience. The dry sample weight is 140 g. The wetted sample weight is 160 g.

We will put the first sample in the HVF air gap with a combination of batteries "lower-middle", the second sample with a combination of "lower-upper" and will consistently record the mass at regular intervals under the above combinations of heating elements.

To simulate channel is necessary to have L/h ≥ 25, $h \leq \frac{L}{25} \approx 8\ cm$ [1].

We will find a mass rate of vaporization for each measurement:

$$m^* = \frac{\Delta m}{\Delta t} \tag{1}$$

where Δm – the mass difference of two consecutive measurements, Δt – the interval between measurements, Δt = 600 s.

We will construct a dependency graph of the mass velocity m^* on the distance from a moisture source for height z to of the heating element.

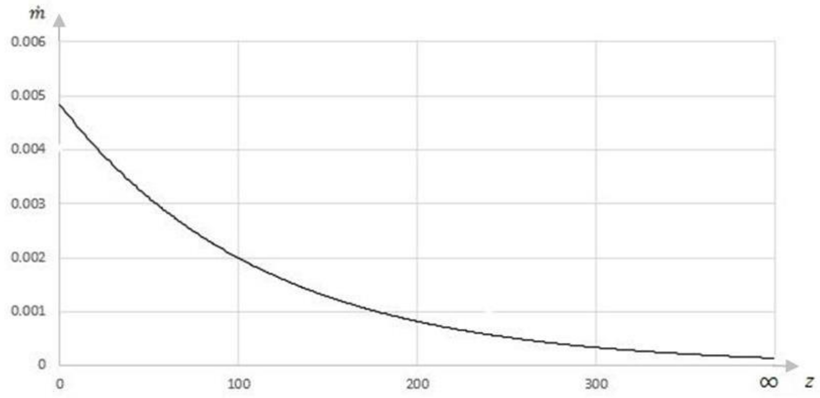

Figure 3. The dependency graph of the mass velocity on the distance from a moisture source for height.

It can be observed that in the case when the lower battery is disconnected, the current is not carried out, the mass transfer rate in the model equivalent to the mass transfer rate in natural conditions, therefore, the chosen combination is enabled the lower heat source are optimal.

Thus, it was established that the combination of "lower-middle", "lower-upper" with open rustications are the best for mass transfer mechanisms studying in the HVF construction.

The average mass rate of vaporization are:

$m_1^* = \frac{\Delta m}{\Delta t} = \frac{13}{5400} = 0.0024$, combination of "lower-middle",

$m_2^* = \frac{\Delta m}{\Delta t} = \frac{14}{5400} = 0.0026$ combination of "lower-upper".

Thus, it was established that the maximum mass transfer rate is observed at the open rustications.

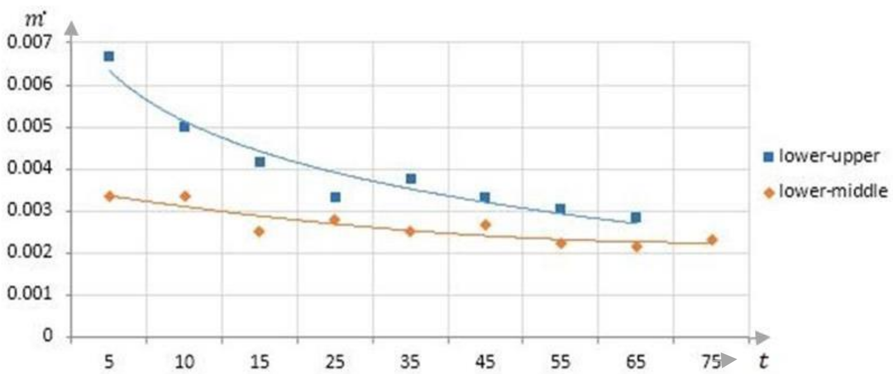

Figure 4. Dependence of m^* on t

Thus, it was established that the maximum mass transfer rate is observed at the open rustications.

Obviously, the rate of vaporization repeated the air velocity. The greater the air velocity, the greater the rate of vaporization.

The highest velocity values were observed when combinations of heat sources "lower-upper".

We give a graph of air velocity in the HVF gap on the installation height.

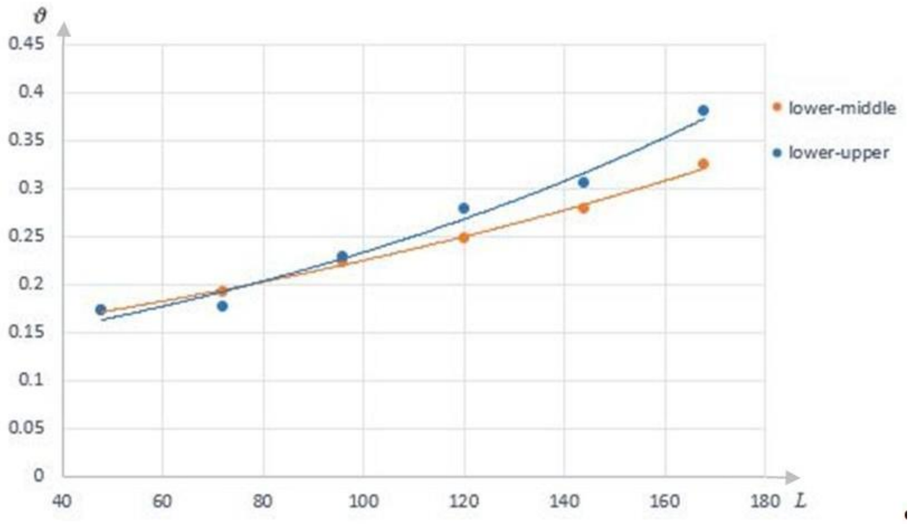

Figure 5. Dependence air velocity in the HVF gap on the installation height

Based on the obtained results, it may be concluded that that the greatest values taken at the maximum height of the velocity. Therefore, the installation upper part is the most favorable location for the study of mass transfer.

Discussion

The great bulk of work on this topic is aimed at the moisture transport mechanisms study from the point of view of physics, practical tests was conducted [10, 25–26]. In this article the emphasis is placed on the experimental determination of the air flow dependences in the ventilated facade channel.

In the articles of other authors on the same topic is assumed constant the temperature of the warm surface wall ($T_h = const$), whereas in this study the effect of the variable position of the heat sources.

Conclusions

Building humidity control is a key condition of increase of their durability, effective use and a healthy microclimate.

On the ground of the experiments we draw the following conclusions:

– the greatest air movement is created in the construction with the open rustications because of larger volume of heated air, as well as the use of different heat combinations, which contributes to the process of moisture transfer.

– the heating the air at the entrance of channel is not when the heat source is off , and there is no difference in temperature, consequently, there is no active air movement.

– the greatest values taken at the maximum height velocity.]

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