Energy and Buildings 75 (2014) 60–69

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

The facade system with ventilated channels for thermal insulation of newly constructed and renovated buildings

M.I. Nizovtsev [a,*], V.T. Belyi [b], A.N. Sterlygov [a]

[a] *Laboratory Problems of Energy Savings, Institute of Thermophysics, Russian Academy of Science, Siberian Branch, 1 Lavrent'ev Avenue, Novosibirsk 630090, Russia*
[b] *Thermoland Ltd., 38, Stantsionnaya Street, Apt. 5, Novosibirsk, Russia*

ARTICLE INFO

Article history:
Received 4 March 2013
Received in revised form 29 January 2014
Accepted 1 February 2014

Keywords:
Ventilated facade
Heat-insulating panel
Ventilated channels
Brick wall
Moisture analysis

ABSTRACT

In the present paper, we describe a new thermal-insulating facade system for newly constructed and renovated buildings, based on heat-insulating panels with ventilated channels. The calculated data on thermal resistances of heat-insulating panels and on the reduced thermal resistances of brick walls with an external facade system, formed by the panels with ventilated channels, are reported as a function of panel thickness. Heat transfer performance uniformity factors of brick walls with different numbers of anchors used for mounting a panel on the brick wall are determined. The calculations show that the heat transfer performance uniformity factors of ventilated panels can be substantially increased in comparison with similar factors for traditional ventilated facade systems. Non-stationary thermal and moisture calculations of newly constructed and renovated buildings with brick outer walls were carried out to determine the humidity dynamics of heat-insulating and structural wall layers over a period of three years. The calculations prove that the examined configuration of ventilated channels is capable of providing for low moisture content and good heat-insulating properties of the walls. Photos and thermograms of building facades, thermally insulated with ventilated channels, are presented.

1. Introduction

In recent years, ventilated facade systems have found widespread use in various climatic zones due to their high energy performance, rich variety of available design solutions, reduced effect of solar radiation on indoor microclimate, good noise reduction properties, and possibility of rapid building repair and reconstruction [1].

Performance characteristics of ventilated facades are influenced by the outdoor conditions (the solar irradiance, the wind direction and speed, and the outdoor air temperature), and also by the indoor conditions (the temperature and humidity of the indoor air) and facade design features (air interlayer configuration, composition of used materials and their layout) [2].

In recent years, the wide use of ventilated facades in civil engineering and involvement of many factors, affecting the performance of such facades, stimulated numerous simulation studies aimed at gas dynamics and heat–mass transfer analysis of ventilated facades [3–6]. Fundamentals of free-convection flows, moving along vertical surfaces under heating or cooling, were laid down in the classical works by Bar-Cohen and Rohsenow [7], Rohsenow et al. [8], and Sparrow et al. [9].

It should be noted, however, that, in spite of the permanently increasing number of numerical studies of ventilated facades, the development of valid engineering procedures for simulating such facade systems still remains an urgent problem. This is why of much significance are also experimental studies of ventilated facades, aimed at verification and optimization of simulation procedures [10–12].

In recently reported studies, special attention was paid to several design features of ventilated facades. For instance, it was noted in [13] that, although the external skin can play an important role in a facade system, the choice of external-skin material for ventilated facades was previously given insufficient attention. In [14], results of the study of the effect of a heat-reflecting film, provided on the surface of ventilated air cavity, were described; and the high performance of the film, especially at night in the winter season was shown. In [15], attention was drawn to the necessity of taking the building envelope mass into account while analyzing the performance of ventilated facades.

The literature also contains the results gained in the studies of performance characteristics of various “active” facades with forced

* Corresponding author. Tel.: +7 383 316 53 36; fax: +7 383 316 53 36.
E-mail address: nizovtsev@itp.nsc.ru (M.I. Nizovtsev).

http://dx.doi.org/10.1016/j.enbuild.2014.02.003
0378-7788/

Nomenclature

d	panel thickness (mm)
D	effective moisture diffusivity (m/s^2)
H	enthalpy of the humid material (J/kg)
h	phase-transition heat (J/kg)
k	absorption coefficient for solar radiation
n	number of mounting anchors per panel
P	water-vapor pressure (Pa)
R	thermal resistance, reduced resistance to the transfer of heat ($K\,m^2/W$)
r	heat transfer performance uniformity factors of the anchored panel
t	temperature (°C)
W_V	volume humidity (kg/m^3)
W	relative mass humidity
x, y	coordinates (m)
q_t	heat-flux density (W/m^2)
q_m	moisture flux density ($kg/m^2\,s$)
q_s	incident flux of solar radiation (W/m^2)

Greek symbols

τ	time (s)
φ	relative humidity
μ	vapor permeability coefficient (kg/m s Pa)
α	heat-transfer coefficient ($W/m^2\,K$)
β	mass-transfer coefficient($kg/m^2\,s\,Pa$)
λ	thermal conductivity (W/m K)

Subscripts

air	air
b	boundary
o	structural layer
p	panel
red	reduced quantity
req	required value
req^+	reduced value with allowance for anchors
sat	saturated water vapor

ventilation and adjustable shading elements [16] or with solar batteries, installed on the external surface [17,18].

In hot-climate regions, ventilated facades allow diminishing the influence of heating of external building-wall surfaces on the indoor microclimate [2,19]. Since the thermal-insulating properties of mineral wool heat-insulating materials are largely defined by the moisture state of the materials, in the region with low winter temperatures and with a long cold period, one of the main functions of ventilated facades is maintaining the outer heat-insulation layer in a dry state [20].

In ventilated facades with a heat-insulation layer, various materials were used; nonetheless, as a rule, such facades normally feature a design common to all such facades. During installation of a ventilated facade on a building wall, an intersystem formed by metal outriggers and supporting profiles is first mounted. Then, at a certain distance from the heat-insulation layer, an external-skin layer is to be installed. Thus, in installation of a standard ventilated façade, all operations are performed on the construction site; this circumstance makes the inspection of work quality difficult and prolongs the time necessary for the mounting.

In the present article, we describe a new facade system based on factory-produced heat-insulating panels with ventilated channels and report results of thermal and moisture calculations, performed for brick walls of newly constructed and renovated buildings, provided with the new facade system.

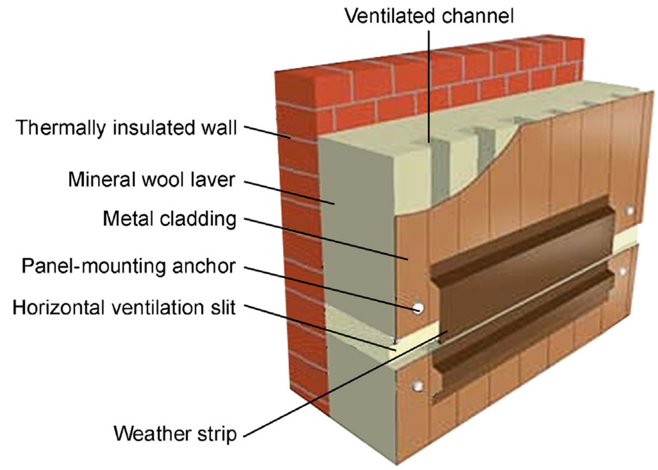

Fig. 1. The facade system with ventilated channels.

2. The facade system with ventilated channels

Developing the new facade system, we intended to design a high prefabrication system, suitable for thermal insulation of building walls in both newly constructed and renovated buildings. Such a facade system with ventilated panels was developed. The new facade system (see Fig. 1) is based on heat-insulating panels admitting their line production at factories [21]. From the outside, each panel is provided with a thin metal cladding, covered with a special decorative coating. The cladding is glued onto a mineral wool layer, provided on the outer side with longitudinal ventilated channels (Fig. 2). The cross-section of the ventilated channels is 20 mm × 40 mm, the separation between neighboring channels being 62 mm. The latter dimensions were chosen based on the heat–moisture analysis, whose results are reported below. The total thickness of the panel heat-insulating layer d varies depending on the particular panel application. The dimensions of a standard panel are 3000 mm × 1190 mm.

The panels are mounted on a newly constructed or renovated building wall with steel anchors (Fig. 1). In mounting the panels, in between them, horizontal gaps are left to be filled with mineral wool down to the bottom of ventilated channels; in this way, horizontal ventilation slits, covered from the outside with weather strips, are formed.

3. Thermophysical analysis

In construction and renovation of buildings, whose structural layer has a reduced thermal resistance R_0, there is a need to determine the thickness of a heat-insulating panel, providing for the reduced outer-wall thermal resistance

$$R_{req} = R_0 + R_p,$$

where R_p is the panel thermal resistance.

Using the computer program "Term 5" [22], allowing 2D simulation of building structures, we carried out thermal calculations of ventilated panels of various thicknesses. In the calculations, for the thermal conductivity of the mineral wool layer in the panels, a value 0.042 W/m K, typical of a wide range of mineral wool thermal insulators, was adopted. Data for one of the analyzed designs are shown in Fig. 2. From an analysis of the plots of R_p vs d, it follows that this dependence is linear in the interval 80 mm ≤ d ≥ 250 mm; this linear dependence can be presented as

$$R_p = 0.0238\,(d - 80) + 1.621$$