10.2478/v10160-012-0007-5

Transactions of the VŠB – Technical University of Ostrava

No. 1, 2012, Vol. XII, Civil Engineering Series

paper #4

Jaroslav SOLAŘ[1]

THERMAL-TECHNICAL EVALUATION OF INNER WALL CAVITIES WITHIN FRAMEWORK OF A SUGGESTION OF WET MASONRY REHABILITATION

TEPELNĚ TECHNICKÉ POSOUZENÍ VNITŘNÍCH STĚNOVÝCH DUTIN V RÁMCI NÁVRHU SANACE VLHKÉHO ZDIVA

Abstract

For excessive wet masonry rehabilitation, except for other methods, the method of air cavities is used. These can be wall or floor cavities. The wall cavities may be situated either on the internal or the external side of the wall. From the height point of view, internal side cavities can be located under the floor or above the floor level. This contribution only deals with the cavities above the floor level. In the projection practice, the air cavities usually are designed only empirically. But it is necessary to carry out their thermal-technical evaluation for their correct capacity. The matter of the evaluation is the topic of the following contribution.

Keywords

Wet masonry rehabilitation, air cavities, wall air cavities, thermal, technical evaluation.

Abstrakt

Pro sanaci nadměrně vlhkého zdiva bývá používáno, kromě jiných metod, také vzduchových dutin, které mohou být jak stěnové, tak také podlahové. Stěnové dutiny pak mohou být situovány na vnější i vnitřní straně sanované zdi. Dutiny na vnitřní straně mohou být z výškového hlediska umístěny pod podlahou, nebo nad úrovní podlahy. V rámci tohoto příspěvku je pojednáno pouze o dutinách situovaných nad úrovní podlahy. V projekční praxi jsou vzduchové dutiny navrhovány zpravidla pouze empiricky. Pro jejich správnou funkci je však třeba provést jejich tepelně technické posouzení. Jeho náplň je těžištěm následujícího příspěvku.

Klíčová slova

Sanace vlhkého zdiva, vzduchové dutiny, vzduchové dutiny stěnové, tepelně technické posouzení.

1 INTRODUCTION

Air cavities rank among methods used in rehabilitation of wet masonry. The air cavities can be vertical (in walls) or horizontal (in floors). For detailed description of rehabilitation of wet masonry by means of air cavities see [1]. The wall (vertical) cavities can be on external or internal sides of enclosure walls. **Wall cavities** which are located on the enclosure wall insides can be located, from the point of view of height:

a) above the floor level,

b) under the floor level.

[1] Doc. Ing. Jaroslav Solař, Ph.D., Department of Building Constructions, Faculty of Civil Engineering, VŠB-Technical University of Ostrava, Ludvíka Podéště 1875/17, 708 33 Ostrava - Poruba, tel.: (+420) 597 32 1301, e-mail: jaroslav.solar@vsb.cz.

Because this topic is rather complex, only air cavities will be discussed here which are located on the inside of the enclosure masonry above the floor level.

2 AIR CAVITIES ON THE INSIDE OF MOIST WALL ABOVE THE FLOOR LEVEL

The wall cavities above the **floor level** include:

1. Offsetting walls

2. Internal lining

In both cases, the air cavities can reach along the wall height (the room height) or only up to the level of excess moisture (up to the limit of the moisture map).

2.1 Offsetting walls

The offsetting walls can be partition walls from bricks laid along the height of the room. Considering air ventilation in the cavity, the offsetting walls on the inside of the wall to be rehabilitated can be divided into:

1. **Air cavities without ventilation** (see Figure 1a).
2. **Air cavities with ventilation** which can be, in turn, divided into:
   a) the air cavities with air flowing into/out of interior (see Fig. 1b),
   b) the air cavities with air flowing into/out of exterior (see Fig. 1c),
   c) the air cavities with air flowing out of interior and flowing into exterior (see Fig. 1d).

2.2 Internal lining

Wood lining, gypsum board of plastic lining are used. In historic building, it would be advisable not to use certain materials. The tiling materials should resist excess moisture from masonry and air. The anchoring of the tiles divides the air cavity. This means, the anchoring material (typically, lining strips) needs to be laid in such a way so that air could be flowing there.

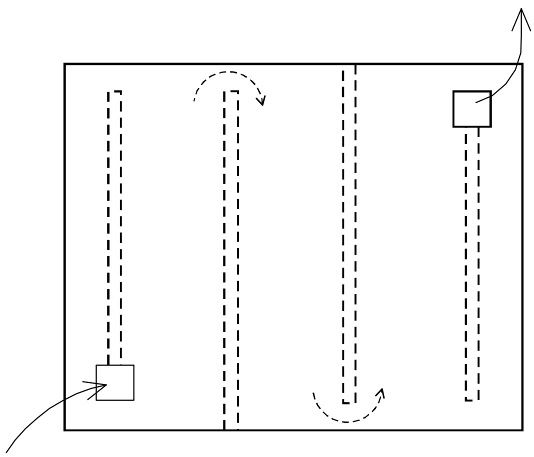
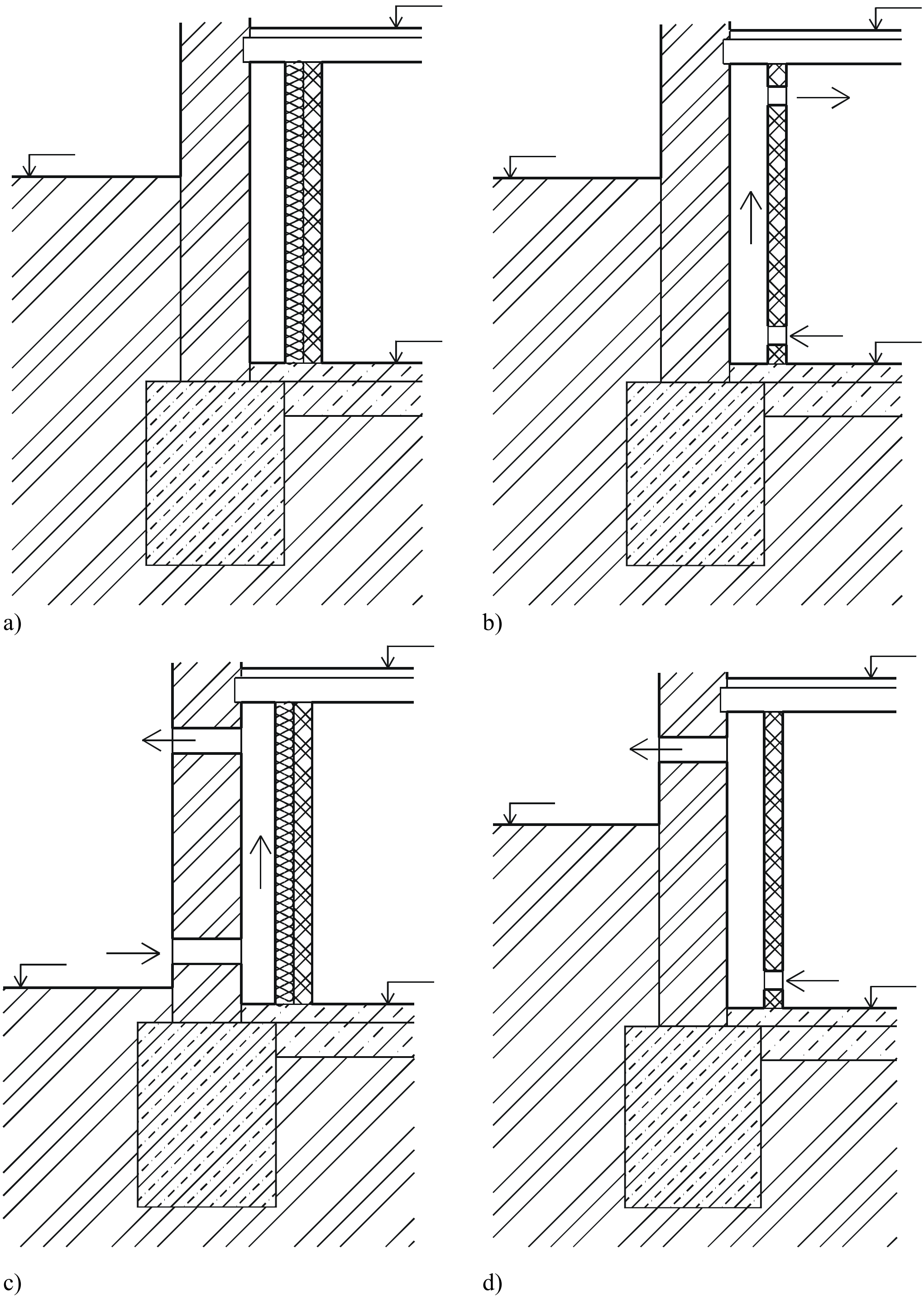


Fig. 2: Example - internal lining

In case of the lining with ventilated air cavities, it is possible to induce air from the interior through a slot, diffusion strip or through several rather small holes. Outlet holes should look like similarly as inlets, or shut-off strips should be used there.

The anchoring strips should be vertical. Non-corroding materials (such as brass bolts or screws) should be used to anchor both the strips and tiling.



a) b) c) d)

Fig. 1: Air cavities in offsetting walls on the inside of the moist wall above the floor level

a – without ventilation (close cavities), b – the air cavity with air flowing into and out of interior, c – the air cavity with air flowing into and out of exterior, d – the air cavity with air flowing from interior into exterior

3 THERMAL ASSESSMENT OF AIR CAVITIES ON THE INSIDE MASONRY ABOVE THE FLOOR LEVEL

3. 1 Air cavities without ventilation

This method is absolutely not intended for rehabilitation of masonry with much moisture caused by water creeping from subsoil. The reason is that water vapours or even water could cumulate step by step in the air cavity and the water could penetrate then into the offsetting wall or even into the masonry which should be rehabilitated. **This solution is, however, suitable for condensation of water vapours on the inside surface of interior walls.**

If the situation includes both cases, this means excess moisture in masonry because of water creeping from subsoil as well as surface condensation of water vapours, this method can be used – but only for elimination of surface condensation of water vapours. Another method (such as a mechanical method, chemical measures or electroosmosis...) should be used to eliminate undesirable water creeping.

In certain cases, heat overcladding is needed for the offsetting wall. A thermal and technical assessment will provide information whether the heat overcladding is necessary.

The thermal and technical assessment of the closed air cavity will be in line with ČSN 73 0540 – 2 [2] and will consist of following parts:

a) Assessment of the heat transmission coefficient, *U* [W.m^{-2}.K^{-1}] , for the new multi-layer wall.

b) Assessment of the heat factor of the internal surface, f_{Rsi}, in risk places.

c) Assessment of water condensation in the middle of the new multi-layer wall.

a) Assessment of the heat transmission coefficient, *U* [W.m^{-2}.K^{-1}], for the new multi-layer wall.

In this case, Chapter 5.2 in ČSN 73 5040 – 2 [2] should be followed as well and the heat transmission coefficient, *U* [W.m^{-2}.K^{-1}], for the multi-layer wall should be such so that the condition below could be fulfilled:

$$U \leq U_N \quad [\mathrm{W.m^{-2}.K^{-1}}] \qquad (1)$$

where:

U_N [W.m-^{2}.K^{-1}] is the required heat transmission coefficient (see ČSN 73 5040 – 2 [2]).

For assessment of the heat transmission coefficient, *U* [W.m^{-2}.K^{-1}] , a suitable software application should be used (for instance, TEPLO 2011 [3]).

Considering requirements set forth in ČSN 73 5040 – 2 [2], it is likely that it will be essential to design heat overcladding (made from EPS Perimeter or extruded polystyrene) which will be inserted into the air cavity. This will increase heat insulation of the enclosure structure from the inside. In this case, if water does not creep from the subsoil but these are only water vapours which condensate on the inside surface of the enclosure wall, the air gap is not needed at all.

The need to use the overcladding and the required heat transmission coefficient *U*, depend on the material and depth of the enclosure wall and on the level under the terrain. If there is an air gap in the wall, this value the heat resistance of the air gap will be included into the calculation. If the enclosure wall masonry is too moist, the heat resistance will be lower.

If the required set forth in the standard cannot be fulfilled, justified reasons should be specified for this in line with Section 5. 2. 6 v ČSN 73 5040 – 2 [2].

b) Assessment of the heat factor of the internal surface, f_{Rsi}, in risk places.

The purpose of this assessment is to check whether vapour vapours could condensate in risk places (in the horizontal upper and lower corners in the wall which needs rehabilitation).

The assessment is carried out in accordance with principles specified in Chapter 5.1 ČSN 73 0540 – 2 [2]. The heat factor of the internal surface, f_{Rsi}, will be calculated in a suitable software application (such as AREA 2011 [4]). The assessment should be performed in the upper and lower corners because surface temperatures are there lower than in the wall surface. The reason is two-dimensional conduction of heat in those places.

In places with the relative humidity of the air $\varphi_i \leq 60\%$ the following condition should be fulfilled:

$$f_{Rsi} \geq f_{Rsi,N} \quad [-] \tag{2}$$

where:

f_{Rsi} [–] – the heat factor of the internal surface,

$f_{Rsi,N}$ [–] – the required lowest heat factor of the internal surface.

Considering requirements set forth in ČSN 73 5040 [2 –2], it is likely that it will be essential to design heat overcladding made from EPS Perimeter or extruded polystyrene – see a) above.

Fig. 3 and 4 show the temperatures for the wall made from solid bricks (thickness: 450 mm) with unventilated air cavity (thickness: 100 mm) and EPS polystyrene overcladding (thickness: 100 mm) without air cavity.

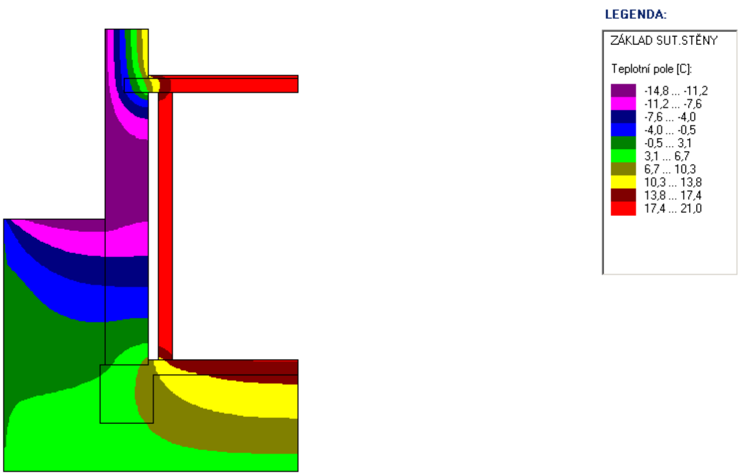


Fig. 3: Temperatures at the enclosure wall from bricks (thickness: 450 mm) with non-ventilated air gap (thickness: 100 mm) and a partition wall made from solid bricks (thickness: 150 mm.) Processed in AREA 2011 [4].

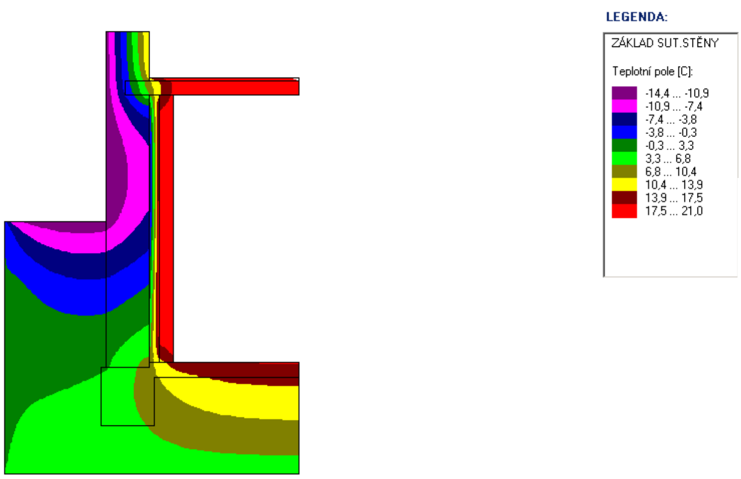


Fig. 4: Temperatures at the enclosure wall from bricks (thickness: 450 mm) with EPS Perimetr and a partition wall made from solid bricks (thickness: 150 mm. Processed in AREA 2011 [4].

c) Assessment of water condensation in the middle of the new multi-layer wall.

This is necessary so that water condensation would not increase moisture of walls and overcladding and, in turn, would not deteriorate the function. Taking into account climate in the Czech Republic, water vapours will diffuse from interior into the air cavity for most days during the year. Conditions specified in ČSN 73 0540 – 2 [2] should be mentioned there, namely:

$$\boldsymbol{M_c < M_{ev}} \quad (3)$$

where:

M_c [kg.m^{-2}.year^{1}] – quantity of water condensation inside the structure,

M_{ev} [kg.m^{-2}.year^{-1}] – quantity of water vapours inside the structure which can evaporate,

the limitation being:

$$\boldsymbol{M_c \leq M_{c,N}} \quad (4)$$

where:

$M_{c,N}$ = **0.10 kg.m^{-2}.year^{-1}** or 3% surface density of the material where water vapours condense if the specific density exceeds 100 kg.m^{-2}. If the specific density $\rho \leq$ 100 kg.m^{-2}, 6% of the surface density will be used.

and $M_c \leq M_{c,N}$ = **0.510 kg.m^{-2}.year^{-1}** or 5% surface density of the material where water vapours condense if the specific density exceeds 100 kg.m^{-2}. If the specific density $\rho \leq$ 100 kg.m^{-2}, 10% of the surface density will be used.

In the structure where the water which condenses inside the structure could jeopardise the function, the water condensation should be avoided. This means:

$$\boldsymbol{M_c = 0} \quad (5)$$

For assessment of the water vapour condensation in the structure, a suitable software application should be used [for instance, TEPLO 2011 (3]).

A suitable moisture stop should be placed as close as possible to the inside surface of the inside wall in front of the overcladding - this will reduce condensation of water vapours inside the wall or will even eliminate the condensation completely.

3.2 Air cavities with ventilation and air flowing into/out of interior

The disadvantage is that the humid air returns back to the rooms. In this case, it is essential to consider microclimate inside the building with a particular attention to the intended use. The reason is that there is more likely that mould fungus will be growing after rehabilitation is over and that harmful effects will influence the interior.

In the wall which needs rehabilitation, masonry will be removed up to 800 mm above increased moisture and joints will be cleared down to 20 mm. If it is possible thanks to cohesion of the remaining mortar and load-carrying capacity of the masonry, it is recommended to keep the joints open in order to crease as big surface for evaporation as possible.

Technical assessment should be carried out for the cavity. Items of the technical assessment are, in fact, same as in Chapter 2.1.The only difference is that the calculation of the heat transmission coefficient, U, does not consider the air layer and the offsetting wall. When calculating the heat factor for the internal surface, f_{Rsi}, and internal condensation of water vapours, the air gap and offsetting wall will be included into the calculation, but the air gap will be regarded as a closed one.

3. 3 Air cavities with ventilation and air flowing into/out of exterior

In this case, it is necessary to consider heat losses caused by the internal offsetting wall which is cooled down by the flow of the outdoor air. Heat losses will not be as big as in the air cavity where the air is taken from the interior (see Chapter 2.4), but heat overcladding is still needed for the internal offsetting wall. Because the interior climate is not influenced in this case, this **method could be recommended.**

In the wall which needs rehabilitation, masonry will be removed up to 800 mm above increased moisture and joints will be cleared down to 20 mm. If it is possible thanks to cohesion of the remaining mortar and load-carrying capacity of the masonry, it is recommended to keep the joints open in order to crease as big surface for evaporation as possible.

A heat and thermal assessment is needed for the designed air cavity. The assessment should cover following aspects:

a) Assessment of the heat transmission coeficient, U [W.m^{-2}.K^{-1}] , for the inside wall.

b) Assessment of the heat factor of the internal surface, f_{Rsi}, in risk places.

c) Assessment of water condensation in the middle of the inside wall.

d) Assessment of the air flow and condensation of water vapours in the air gap.

e) Assessment of condensation of water vapours on the inside surface of the enclosure wall (to be rehabilitated).

For detailed description of the heat and technical assessment mentioned in a) through c) above see Chapter 2.1. A suitable software such as MEZERA 2011 [5] will be used to calculate the **air flow and possible condensation of water vapours** in the air gap and to assess condensation of the water vapours on the inside surface of the enclosure wall (which needs rehabilitation). Then, several alternatives can be analysed and the best thickness of the air gap can be proposed. It is also possible to design ventilation holes (the quantity, size and surface) which would prevent condensation and which would create sufficient air flow in the gap that is needed for withdrawal of the water vapours.

The bottom of the air gap should be properly insulated (for instance, using EPS Perimeter or extruded polystyrene). This will reduce negative impacts of the ambient air on the footing bottom in the moist wall and floor in the room during winter. It is also advisable to overclad a part of the wall in the air gap where the moisture has been removed (for instance, up to 200 mm).

A detailed analysis of the air flow in the air cavity could by performed using CFD (computational fluid dynamics), for instance, in ANSYS – FLUENT [6]. The method should be similar to that which is described for horizontal air cavities (in floors) in [7].

Fig. 5 shows development of temperature in a vertical air cavity with ventilation with takes air from exterior and supplies air to exterior, and without heat overcladding on the air cavity bottom.

Fig. 6 shows examples of results of the assessment of the air flow and possible condensation of water vapours in an air gap and condensation of the water vapours on the inside surface of the enclosure wall.

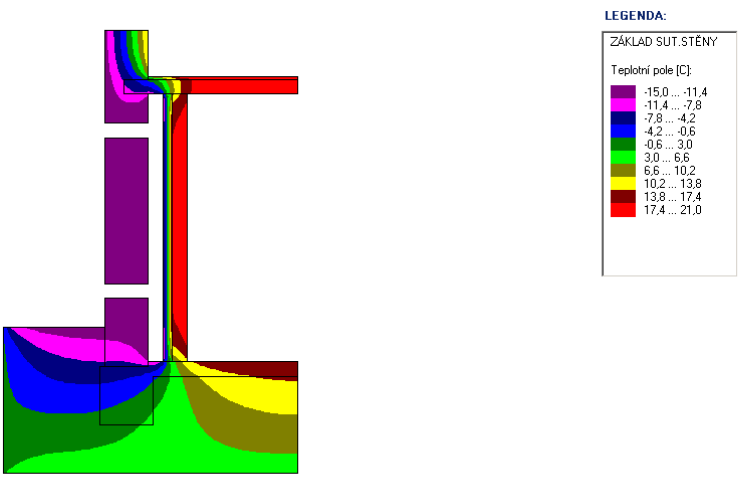


Fig. 5: Temperatures at constructions which form the vertical ventilated air gap with air supply and air extraction from/to exterior without heat overcladding on the air gap bottom.
Processed in AREA 2011 [4].

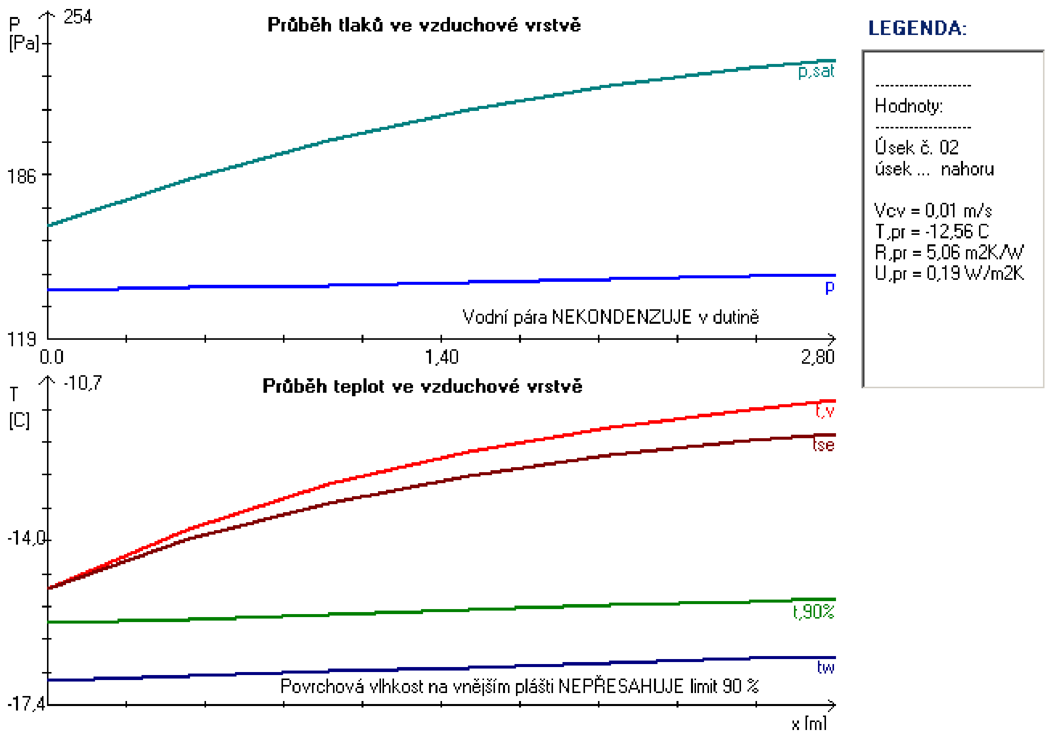


Fig. 6: Results of assessment of the ventilated air gap with air supply and air extraction from/into exterior. Processed in MEZERA 2011 [5].

3. 4 Air cavities with ventilation and air flowing out of interior into exterior

This method reduces air humidity in the interior. The problem is that much heat losses occur in winter. This means, ventilation flaps should be installed on suction holes which would prevent heat losses from occurring, to a certain extent at least. If the flaps are shut off for a long time, the system will fail. In summer that the temperature of the ambient air is higher than that inside the building, the air flow in the reverse direction – from the exterior into the interior. **This solution is applicable under certain conditions only.** In the wall which needs rehabilitation, masonry will be removed up to 800 mm above increased moisture and joints will be cleared down to 20 mm. If it is possible thanks to cohesion of the remaining mortar and load-carrying capacity of the masonry, it is recommended to keep the joints open in order to crease as big surface for evaporation as possible.

Technical assessment should be carried out for the cavity. Items of the technical assessment are, in fact, same as in Chapter 2.3 (the air cavity with the air taken from/supplied to the exterior):

a) Assessment of the heat factor of the internal surface f_{Rsi}, in risk places.

b) Assessment of condensation of water vapours on the inside surface of the enclosure wall (to be rehabilitated).

c) Assessment of the air flow and condensation of water vapours in the air gap.

For detailed description of individual parts of the heat and technical assessment see above.

REFERENCES

[1] BALÍK, M. et al.: *Odvlhčování staveb*. 2nd edition Grada Publishing, a. s., Praha, 2008. 307 p. ISBN 978-80-247-2693-9.

[2] ČSN 73 0540 – 2 Tepelná ochrana budov – Část 2: Požadavky (2011).

[3] SVOBODA, Z. *TEPLO 2011*. Commercial software for PC.

[4] SVOBODA, Z. *AREA 2011*. Commercial software for PC.

[5] SVOBODA, Z. *MEZERA 2011*. Commercial software for PC.

[6] *ANSYS – FLUENT*. Commercial software for PC.

[7] SOLAŘ, J. & KALOUSEK, M. *Posouzení proudění vzduchu v podlahové vzduchové mezeře metodou CFD.* Tepelná ochrana budov č. 2/2008. ISSN 1213-0907.

Rewievers:

Doc. Dr. Ing. Zbyněk Svoboda, Department of Building Structures, Faculty of Civil Engineering, Czech Technical University in Prague.

Doc. Ing. František Kulhánek, CSc., Department of Building Structures, Faculty of Civil Engineering, Czech Technical University in Prague.