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RESEARCH ARTICLE

Thermodynamic “Damp Proofing” of old buildings

János Várfalvi

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Abstract

The biggest problem of old buildings is the absence of damp proofing.

Making up for this absence is not easy and can not be carried outs imply with mechanical devices, so generally trials with electrical and chemical methods to restore the damp proofing are explored.

It quite often occurs that these types of post-proofing methods cannot be applied.

In this case, we can easily restore the correct moisture of the building by creating particular building physics-conditions in the structure.

Keywords
dampf proofing · wet wall · building

János Várfalvi
Laboratory of Thermophysics, Faculty of Architecture, BME, H–1111 Budapest
Bertalan Lajos u. 4., Hungary
e-mail: varfalvi@lab.egt.bme.hu

There are a lot of buildings where damp proofing is included or its performance has been seriously diminished. These are typically older buildings, with many historic monuments among them.

Importance of dampness and moisture coming from the soil is underlined by the great wall thicknesses, 1 m thick walls are usual, walls of even double this can also be found. From large built masses, two essential physical properties follow:

1 Considerable temperature phase delays are generated between the inner and outer planes of the structure; consequently, we should allow for complicated heat flows.

2 They can retain essential moisture, with values up to 300 l/m^2.

Both physical properties result in a much more sophisticated moisture situation than is usual in normal buildings.

There are several methods available for preventing or decreasing damp effects coming from soil. They can be classified by different aspects.

One of the major groupings is the type of method by which the building becomes damp-proof.

1 Placement of a damp-proof course in the horizontal plane of the wall
With this method, a traditional damp-proof course is placed in the wall structure; obviously, it can only be inserted by breaking through the structure. In this case, structural and technological problems connected with breaking into the structure, are the main concerns.
The damp-proofing method in which a metal sheet is beaten into wall jointing belongs to this group.

2 Chemical methods
In the procedures referred to as chemical damp proofing of walls, a water displacing or impervious material is injected into capillary void structures of the wall, or materials with these kinds of components are applied on surfaces as an impervious mortar.
Success of these methods depends on how much the materials injected from outside can reach the voids, and how effectively the right reactions are generated by the injected materials.

Considering that structural details of an injected wall section cannot be fully explored during a waterproofing procedure, success of these methods is associated with varying levels of risks.

3 Electric methods

During the electric procedures, specific ion migration is generated by electric potential, as a result of which moisture in the protected, however wet wall section, will move to other spaces.

In this case, clarification of the following issues appears to be essential: the moisture level at which the effectiveness of the system becomes questionable, as well as consequences of this moisture limit in terms of building physics both for the internal space and the structure.

Summarizing, we can state that in the method described above an "external" material intervenes in the structure, effectively creating a new moisture system.

The question arises whether it is possible in individual cases to obtain the *proper dryness* in another way, without creating a new chemical or electrochemical condition.

Function parameters of a system depend on the system properties and/or system boundary conditions. This implies that function parameters can be influenced also by changing the boundary conditions. Before discussing this issue, we will examine the meaning of *"proper dryness"* mentioned above.

In general, moisture-caused damage in old buildings does not result from drastic damp effects. This means that surface moisture content of structures is higher than the sorption saturation value in the "wet" periods of the year only and the transpiration plane shifts toward the internal layers in the "dry" period. This kind of "fluctuation" of moisture content increases salt saturation of the surface layers, resulting in the well known problem of plaster separation. In periods of the year when the transpiration zone is in the internal layers of the structure the wall can be termed as "properly dry". In Fig. 1 moisture distributions of cases "properly dry" and "wet" are plotted.

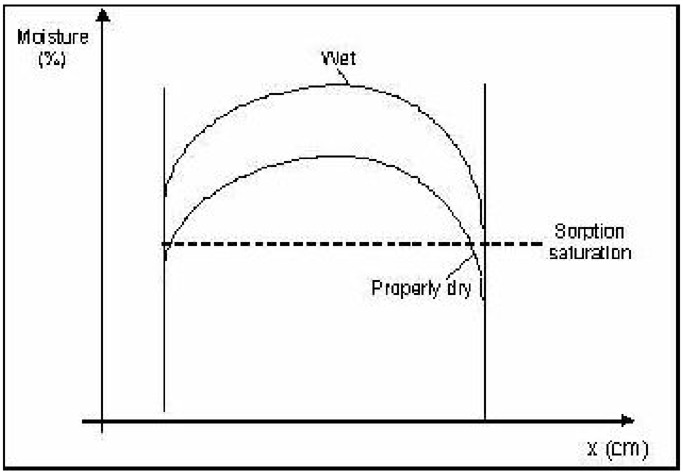

Fig. 1.

On the basis of the above, the question can be raised whether the boundary conditions existing in the structure "spontaneously" can be influenced so that the transpiration zone would form in the inner part of the structure throughout the year. Of course, this also implies much lower moisture content in the structure than prior to the intervention.

In this case, the wall structure appears as a completely dry structure when investigating it from outside. The difference lies, practically, in the fact that in periods when partial vapour pressure is higher in the wall structure than in the internal space, moisture migrates towards the internal space by vapour diffusion. As a consequence, the moisture load of the internal space rises. In general, this moisture load does not disturb the internal functions particularly, for the following reasons:

1 Large diffusion vapour flows towards the internal space are generated under summer conditions only. However, the more intensive ventilation of the buildings during summer retains the excess moisture load due to this internal drying of the wall structure.

2 Start of vapour diffusion towards the internal space at lower temperatures is only possible with a relatively low relative humidity of the internal air. However, this signals either intensive ventilation or a low internal moisture load. Moisture load coming from the wall structure cannot act unfavourably in the internal function in either case.

3 In a situation where the moisture coming from the wall would unfavourably affect functions in the internal space, realization of a simple ventilation system would solve the problem and remove the excess moisture.

If we want to realize damp proofing by changing the boundary conditions, a method transpiring a part of the moisture coming from the soil to the environment with a particular intensity should be reached in any case. This situation is shown in Fig. 2.

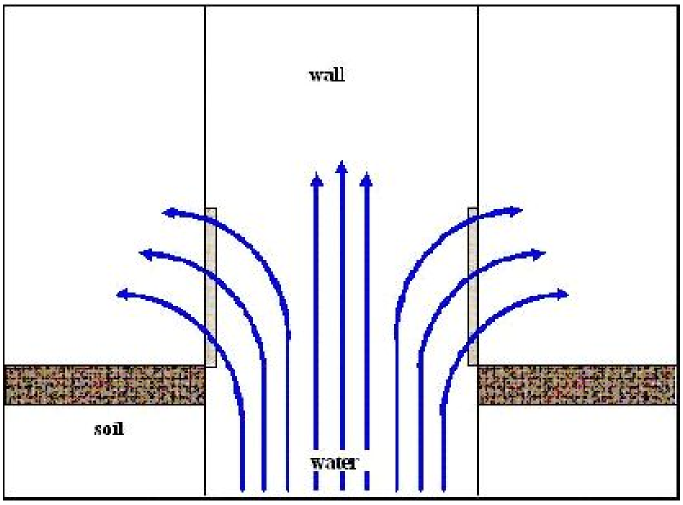

Fig. 2.

How can boundary conditions be changed? Fundamentally, two ways seem to be available for intervention in the moisture migration process by simple means.

1 Change of the temperature conditions of the structure.

2 Change of the diffusion conditions of the structure.

Change of the temperature of the structure, should be understood to be temperature increase.

Effects of the temperature increase can be followed on the example below. The external surface temperature of approximately 60 to 80 cm thick wall structures is about 1 K higher than the outer air temperature in winter. If the external air temperature equals -2 ˚C, the outer surface temperature is -1˚C.

Under these temperature conditions, water transferred to the environment from 1 sq metre of the outer intervention zone as shown in Fig. 2 is equal to 8 g/m^{2}h, if the saturation partial pressure prevails on the external surface of the structure. Raising the external surface temperature also increases the vapour volume transferred to the external space. Considerable increases belong to the different Δt increments.

1 K by 50-60 %

2 K by 100-110 %

3 K by 150-160 %

As the moisture content forming at a given height of a structure results from a moisture balance with a vapour volume transferred to the outer space as a component, we shall assume a moisture drop in the higher layers. This effect may result in the "properly dry" state on the external surface of the structure already mentioned.

On the inner side a different situation occurs, mainly due to the fact that temperatures on the inner side, thus, also the partial pressure generated on the surface are higher even in winter. Just like before, determining vapour quantity transferred to the environment, we get the following values:

Assuming a surface temperature of 17 ˚C with an inner temperature of 20 ˚C, a maximum vapour transfer of 60 g/m^{2}h can be expected on a 1 sq m intervention zone on the outer side. In old buildings with discontinuous heating or without any heating, in practice, the values mentioned for the outer intervention zone hold. In the case of heating, a moisture transfer of considerable intensity is generated compared to the outer side, so no intervention for the inner space seems to be justified.

This statement holds until the moisture content on the surface is close to the material's sorption saturation. When the transpiration plane appears on the outer surface, it can be shifted towards the inner courses of the structure by heat input to the structure; thus, damage due to damp can be prevented.

Until now, changes of boundary conditions involving temperature increase in the structure have been discussed. It has been stated that just even an increase of 1 or 2 K on the outer side of the structure may considerably raise moisture transfer. The same applies to the inner side of the structure if there is no heating or only intermittent heating .

With continuous heating on the inner side, the temperature of the structure should be increased if the transpiration plane as a liquid-gaseous transition forms near the inner surface.

The other way of changing boundary conditions involves intervention in vapour flow circumstances. This intervention aims at a decrease of moisture transfer resistance between the internal structural units and the external environment. This perforation can be realized in numerous ways, always in accordance with the given circumstances. A possible perforation can be seen in Fig. 3.

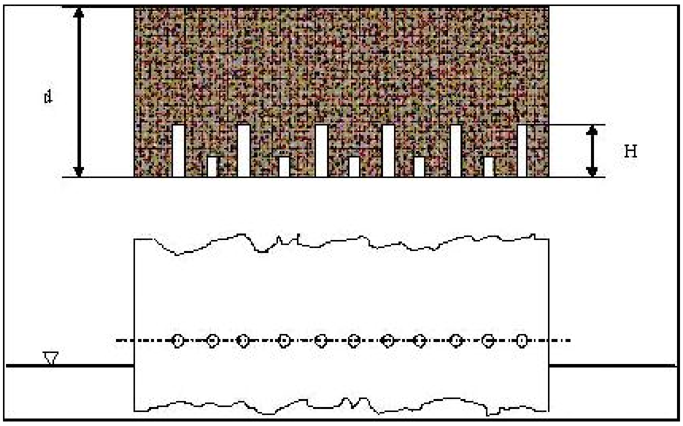

Fig. 3.

When creating perforations within the structure, the question is how deep holes the outer surface plane should be made. This question can be answered by the following consideration.

A line of holes should be created that practically makes the external surface layers dry below the sorption saturation value. This can be reached by 5-10 cm deep holes at distances of about 5 cm. After this hole line, every second one should be bored to the proper depth. This proper depth can be determined on the basis of the saturation pressure curve of the structure. This is demonstrated in Fig. 4. Multiplying the vertical intersection belonging to the saturation pressure of the outer surface by 0.9, we get the value of partial pressure generated on the external surface (point "A"). Drawing a tangent from point "A" to the line of saturation pressure (point "E"), the length "h" of the hole can be obtained as the distance of points "A" and "E".

Temperature increase of the structure and change of vapour diffusion resistance (perforation) have been investigated separately so far. However, both options can be applied together as shown in Fig. 5 as a possible solution. Moisture conditions of uninsulated wall structures essentially depend on weather. In hot, sunny, dry periods, moisture conditions improve while in cold weather, worsening moisture conditions should be expected. Consequently, the system arranged in Fig. 5 should not work continuously. This can be realized by a control unit. The moisture sensor of the control unit will be placed in a hole chosen expediently. This sensor measures the moisture value in the hole, and the control unit compares it to the prescribed value. If the moisture content of the hole is higher than the prescribed value, heating will be switched on. By setting the prescribed value, the optimum moisture and operation conditions can be generated.

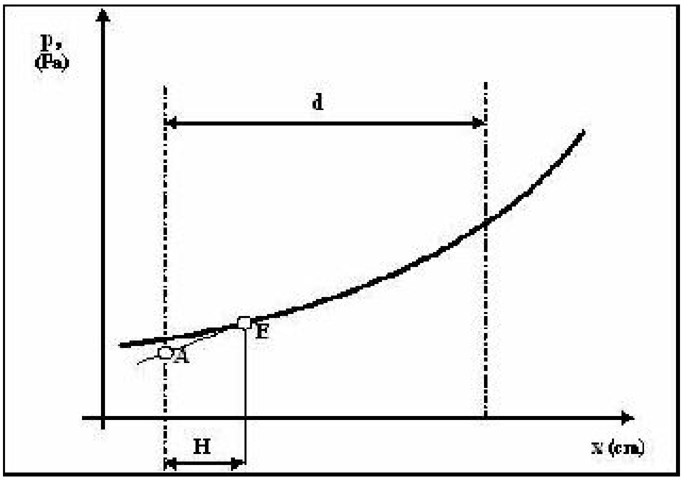

Fig. 4.

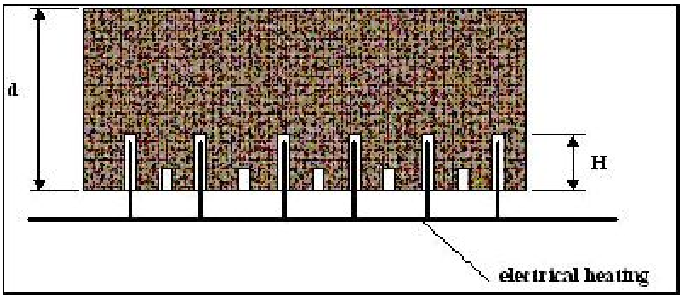

Fig. 5.

Solution realised

As a summary of the thermodynamic options demonstrated above, a successful intervention will be demonstrated illustrating that a "concrete" solution can always be defined for a concrete building.

The building in question is a historic monument building of the Eötvös Lóránd University of Sciences in Szerb Street in the 5^{th} district. Wall plaster over the thermo-cover of the plinth has been damaged to a length of several hundred meters due to moisture effect and has separated.

After removal of the stone face, marks of insulation procedures applied in through holes can be seen. The wall structure has a considerable moisture content, reaching in some places 15-20 m%. In this case, intervention options could have been identified as follows:

1 Perforation

2 Heating

3 Convective ventilation of plinth

Perforation

Perforation arrangement can be studied in Fig. 6. In this case again, perforation serves two purposes:

1 Connection of the internal layers of the structure with the ventilated air layer - realized by connecting holes.

2 Assuring dry surface layers by surface drying holes.

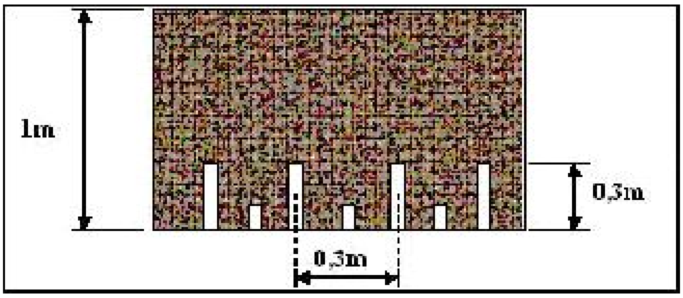

Fig. 6.

Heating

The double-targeted heating is depicted in Fig. 7:

1 Heating surfaces

2 Improving convection in the ventilation gap.

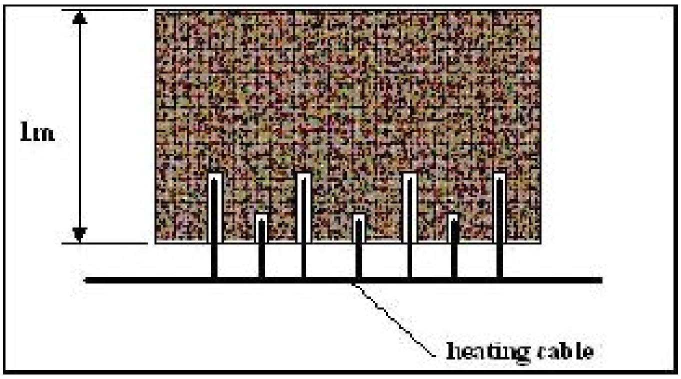

Fig. 7.

Control

This is realized by three control units over a length of about 250 m.

Dimensioning

Major steps of dimensioning are illustrated in the theoretical scheme of Fig. 8.

Concerning this process, the following relationships can be written for a 1 m long wall section:

Water volume transferred by ventilating airflow (W):

$$W = L_{ki} \cdot \Delta x$$

where

L_{ki} air flow leaving ventilation air gap

Δx change of absolute moisture content of the air in the gap

Ventilation air flow leaving the gap, L_{ki}, can be computed with the following formula:

$$L_{ki} = A_k \cdot \alpha_k \cdot \sqrt{\frac{2 \cdot \Delta p_k}{\rho_r}}$$

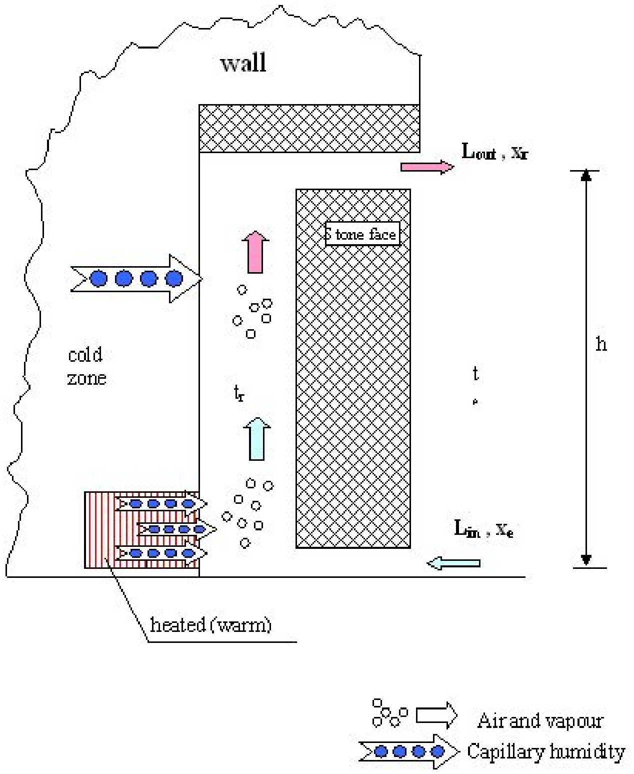

Fig. 8.

where

A_k	departure cross-section
α_k	outlet factor at departure
ρ_r	air density in gap
Δp_k	air pressure drop at departure

Total pressure drop during ventilation air flow, Δp:

$$\Delta p = (\rho_e - \rho_r) \cdot g \cdot h$$

where

ρ_e	external air density
g	free fall acceleration

Pressure drop at departure can be computed from the total pressure drop:

$$\Delta p_k = a \cdot \Delta p$$

where

a	proportionality factor

Moisture regained by the ventilation air consists of two parts:

$$W = W_m + W_h$$

where

W_m	moisture volume transpiring from the heated warm zone
W_h	quantity transpiring from the cold area above the heated zone

The above two components can be calculated as follows:

$$W_m = \beta_m \cdot (p_m - p_r)$$

$$W_h = \beta_h \cdot (p_h - p_r)$$

where

W_m	moisture transfer on warm surface
W_h	moisture transfer on cold surface
β_m	surface moisture transfer factor on warm surface
β_h	surface moisture transfer factor on cold surface
p_m	partial pressure on warm surface
p_h	partial pressure on cold surface
p_r	partial pressure in the gap

Heating depth, average temperature of the warm zone and perforation parameters are system properties of the “thermodynamic damp proofing”. Definition of system parameters involves actually system dimensioning.

System properties act in the way shown in the block diagram below:

Experience

1 This system has been working for almost 2 years without any problem.

2 Moisture content of the wall structure has dropped considerably.

3 At present, not 1 sq. cm of damage can be found above the plinth rock, although, former repairs had failed early on.

Future development directions

Results of the research OTKA T30097 are encouraging concerning the use of solar energy for obtaining properly dry conditions, especially in historic monument buildings.

In this method, the structure would be “over-dried” in periods with much solar energy by the energy produced in solar collectors, and in the wet periods, damage periods would be decreased or eliminated by build up processes.

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