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SOME ASPECTS REGARDING THE METHODS AND MATERIALS USED FOR COMBATING THE HUMIDITY IN HERITAGE BUILDINGS

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ABSTRACT. *The paper presents some aspects regarding the methods and materials used to combat humidity in heritage buildings. It is known that the moisture in a wall reaches variable heights according to the physical characteristics of the masonry (depending on the porosity and capillary sizes). Taking into account these characteristics, some solutions for improving the masonry of buildings are presented. Thus, some details regarding the interventions at the building foundation level are exposed. At the same time, some materials used for wall ventilation as well as the BIS system for dehumidifying the floor and wall support are presented. The result of the study emphasize that the method which uses ventilation holes to dry masonry can only be applied when we are not dealing with a wetting due to a capillary increase from a water table.*

Keywords*: wall moisture; foundation; BIS system; heritage building;*

1. General aspects regarding the water circulation in the soil

The main varieties of water existing in the ground that influence the behavior of the ground as a foundation or as a material in constructions are: bound water, capillary water and free water.

Bound water or adsorbed water represents water attracted around electrically charged clay particles as a result of the properties of water molecules to orient themselves in an electric field.

Within the envelope of bound water around the clay particle, two layers are distinguished:

- a very thin layer with the thickness of 3 or 4 water molecules, located in the immediate vicinity of the particle and held by it with very high pressures, called tightly bound water layer.
- further, up to the limit where the attraction of the particle ceases, there is the layer of weakly bound water.

Free water is found outside the envelope of bound water.

Capillary water - it is found in the pores of the soil made up of fine granules, above the free level of the water table. The increase of water in the ground is caused by the action of surface tension (Manoliu, 1977). The water column of a certain height, hc, is supported by the surface tension force that develops on the circumference of the meniscus that forms at the contact between the water and the wall of the capillary tube (Popa, A., Popa, D, 2002).

Free (gravitational) water is water that moves in the ground under the influence of gravity. Unlike bound water and capillary water that are retained on the surface of soil particles by electrochemical forces (adsorption) and physical forces (surface tension), gravitational water is free from the mineral skeleton, being present especially in the pores of non-cohesive soils (Păunescu et all, 1982).

The humidity conditions of the soil represent in most cases the decisive factor that determines its mechanical properties, that is, its behavior under the action of external stresses. Experience shows that shear resistance and compressibility, swelling or contraction, shear resistance, compaction capacity, additional settlement by soaking, wetting and dissolution in water, erosion resistance as well as other aspects related to the behavior of the soil as a foundation soil or as a material for constructions are decisively conditioned by its humidity (Popa D., 2007). Since the humidity conditions are not something static but are constantly changing, it is of interest not only to know the humidity state at a given moment but also to predict the changes that may occur over time. For this it is necessary to establish:

- the interaction between the constituent phases of the soil;
- the internal and external factors that condition the phenomena of water movement through the soil;
- the laws of movement of water through the soil;
- the phenomena generated by the movement of water through the pores of the soil.

2. Humidity caused by capillary increase of water

The water or water vapor present in the masonry elements causes the condition known as "wetting the masonry". Moisture can occur for various reasons, the most common of which are:

- moisture due to water infiltrations coming from the ground and seeping into the masonry through capillarity;
- moisture due to technological water (water from the execution process) appears in recently completed constructions, but also in old ones, if the thickness of the wall is large and the air content of the mortar in the internal joints could not be eliminated, and the mortar does not harden, remaining in a fluid state.
- moisture due to condensation is due to the condensation of water vapor in the air, both inside and outside the building element.
- moisture due to meteoric waters, occurs when the collection and evacuation of rainwater is done incorrectly, which favors the penetration of water into the masonry elements.
- moisture due to accidental causes such as clogging of drains, clogging of rainwater collection gutters. Capillary ascent is one of the major causes of the presence of moisture in old buildings, at the level of the basement or immediately above the level of the natural terrain, respectively of the street pavement. Water losses that reach the construction element through water migration can occur accidentally based on several causes, namely:
- improperly collected rainwater
- infiltrations from the drainage system
- wells
- water collection works
- water from condensation in contact with the ground. Any of these causes can cause the walls in contact with the ground to soak to a certain extent and implicitly the capillary ascent of water through the walls (Popa D., 2007).

3. Experimental Results and discutions

Solutions for renovating the masonry of heritage buildings It is known that the moisture in a wall reaches variable heights according to the physical characteristics of the masonry (depending on the porosity and capillary sizes).

On the face seen compared to the middle of the wall, the height is lower due to the possibility of direct evaporation into the atmosphere through the porosity of the actual material and the plaster. The height h (visible face) of the evaporation surface depends on the thickness of the masonry, the porosity of the construction material, the radius of the capillaries, the foundation depth and the accidental prevention of evaporation conditions. Evaporation depends on the type of pores (closed, open, canalicular, etc.) and is also influenced by the size of the masonry blocks, the alternation and the size of the joints, as it is known that mortars usually have a higher porosity than bricks if the mortars are made of lime and smaller than bricks, if cement mortars were used (Popa D., 2007).

Capillary absorption of moisture is higher in materials with small and fine pores than in materials with large pores. It was found that lime mortars absorb 45 g water/h, while cement ones only 3.3 g water/h, on the other hand, water evaporates faster from a lime mortar than from a cement mortar (Moraru, 1969)

The simplest ventilation method we have when the cause of the moisture was accidental and there is no danger of its repetition, and it consists in stripping the plasters from the flooded surface on both sides of the masonry. The operation is performed at the beginning of the warm season and the moisture is removed by direct evaporation.

The removal of plaster favors this evaporation, especially if they were made with cement, a binder that reduces their permeability.

Reduced foundation depths make the length of the capillaries shorter and therefore the flow resistance lower. An important role is played by the foundation land, from the point of view of nature, stratification, permeability and water supply.

Also, local atmospheric conditions influence evaporation (air temperature and humidity, wind intensity, rain that can beat on the facades, the proximity of trees or plants). In this way, the humidity level can increase or decrease.

In heated constructions, the evaporation and vapor pressure of the air on the interior walls is modified.

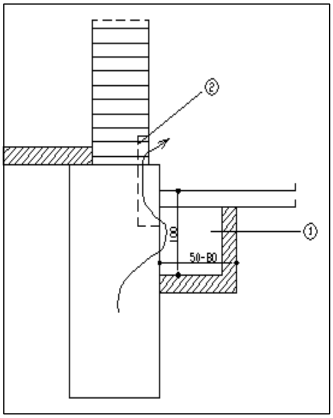
The solution represents one of the oldest interventions applied to constructions to eliminate the phenomenon of moisture. It appears in older works in several constructive forms.

A first group of solutions is the execution of ventilation channels on one of the faces of the foundation and the plinth. The most common solutions for existing constructions (Popa, A, 1996) consist in the execution of a ventilation channel having a rectangular or ovoid shape executed on the outer perimeter of the foundation (fig. 1.).

Evacuation of water vapors is carried out through horizontal and vertical ventilation channels with the evacuator in the brickwork area. For the constructions with a basement, a solution used for the natural ventilation of the humidity from the land was that of the execution of some perimeter drains (fig. 2) inside the building (1) and the execution of a vertical exhaust system (2) made of perforated PVC tubes (arranged at approximately 1.00-2.00 m).

The solution also contributes to maintaining the level of underground water at a level lower than the floor. A solution recommended but not used on a large scale due to the fact that its efficiency and purpose or the method of intervention of the builders were not known is the one in fig. 3. The solution consists in the creation of horizontal ventilation channels executed above the level of separation between the foundation and the masonry and of perforated sheet air vents at distances of 1.5-2.0 m.

The intervention in fig 3 presents a more complex solution that involves several adjacent measures namely (Popa, A, 1998):



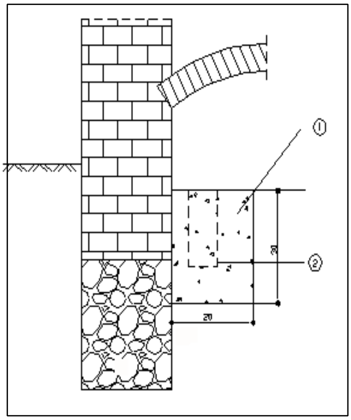


Fig. 1. External perimeter ventilation channel Fig. 2. Basement perimeter drains
(Source: Popa, A., Technical expertise, Rehabilitation and consolidation of the Pharmacology and DSV building, Cluj - Napoca 1998)

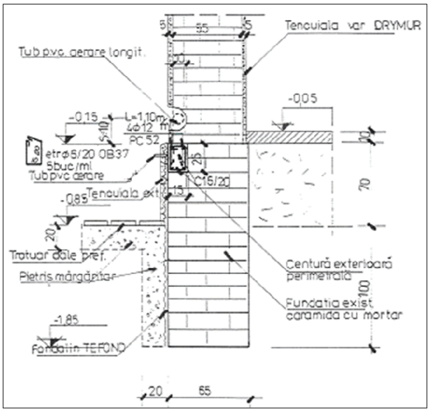


Fig. 3. Foundation intervention detail
(Source: Popa, A., Expertiză tehnică, Reabilitarea şi consolidarea clădirii Şcolii Generale nr.52, Oradea)

a) on the outside **-** On the upper part of the belt, the perforated longitudinal ventilation tube made of PVC was revised and repaired.

To protect the walls on the outside against water from the ground that migrates transversely onto the foundations as well as water from precipitation that can reach the surface of the wall by ricochet, a polyethylene membrane called TEFOND is provided.

This membrane, in addition to not allowing the infiltration of new amounts of water into the wall, due to the shape of the profile it has, allows ventilation on the entire protected surface by means of an aeration tube placed transversely in the wall, communicating with the outside;

- the exterior plastering on a 60 cm portion can be done with "ApaStop P";
- to break capillarity, a 20 cm layer of pearl gravel is placed on the entire perimeter;
- the sidewalk around the building was made of prefabricated tiles, being permeable;

b) inside

- Was created a lime plaster with the addition of Drymur, which allows the creation of a cellular plaster with a macroporous structure, which is able to retain salts without favoring an increase in pressure. At the same time, the rate of evaporation of moisture from the walls increases considerably, allowing a large amount of air to circulate inside the walls to dry the moisture. The aerated lime mortar with Drymur responds very well to the action of mold condensation and efflorescence.

Regarding the use of polyethylene membranes (see measures taken on the outside), for the elimination of moisture from the walls of the rooms through ventilation, a few more considerations could be made, namely:

a. the complete isolation of the wet surfaces of the walls due to the phenomenon of dampness with profiled foils called in the specialized literature foils with nopeuri, is one of the procedures frequently used for a quick environmental conditioning, without requiring the elimination of the cause that produced the dampness (Technical specifications – Drainage plates).
b. the procedure consists in isolating the walls of the rooms with moisture, infiltrations or condensation with plastic films with protrusions, mechanically fixed to the wall, so that a free space is created that can be ventilated naturally or forced, realizing the evacuation of water vapor to the outside

Depending on the height of the area affected by moisture, the insulation can be done on the entire height of the wall or only on the affected area. Depending on the way of ventilation of the space behind the foil, there are the following alternatives:

- Ventilation in open circuit in the conditions in which draft is achieved through ventilation gaps to the outside. The draft can be natural or forced, with fans that suck the vapors from behind the foil and lead them to the outside;
- Closed circuit ventilation when the natural draft is directed towards the inside of the room through ventilation gaps oriented towards the room space. In this case, the final evacuation of the channeled water vapor from behind the film is done by ventilating the room;

A ventilation solution for external stone or brick masonry walls with a stone plinth is represented in figure 4.

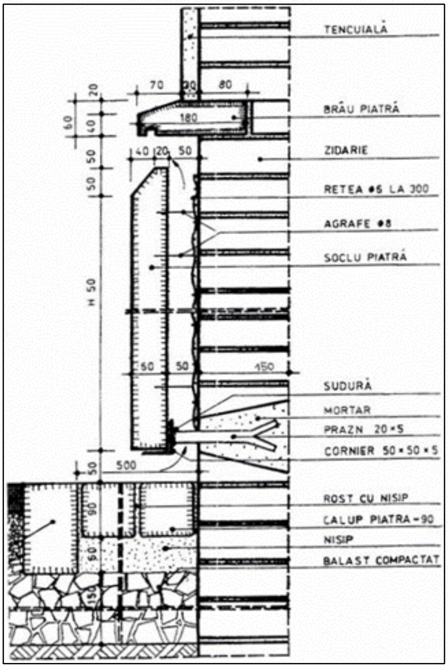


Fig. 4. Section through an exterior wall portion
(Source: Popa, A., Technical expertise - Technical intervention solution for a wall affected by humidity, Arcalia Castle, Bistriţa Năsăud)

The plinth is fixed at a distance of 5 cm from the masonry by means of clips fixed in the wall, respectively a corner to which a bolt embedded in the wall is welded (Popa, A., 1999). At the top of the plinth is a stone girdle that protects the wall from meteoric waters. The sidewalk around the building is permeable, made of stone molds, the joints being filled with sand.

For foundations made of stone masonry with variable thicknesses per height, a solution used in the rehabilitation of historical monuments (Castel Arcalia) is the one in fig. 5. This figure shows a detail of a stepped foundation made of stone masonry, to which a drainage-ventilation trench is applied in order to eliminate the possibility of water acting transversely on the foundation (Popa, A., 1999).

To solve this technical problem externally, the following measures were taken:

- the smoothing plasters will be made using the Tenpor additive, thus creating the conditions for a breathable plaster.
- by means of bolts Φ = 4mm, a layer of geotextile felt and a draining plate, Plastidren type, is attached to the foundation and the second layer of filtering geotextile felt is supported in a vertical position by the two sorting filtering layers, respectively by the layer of compacted soil. At the bottom, there is a prefabricated saddle on which rests the ventilation system shown above, as well as the drainage tube (perforated at the top), which can take over any water infiltrations. On the upper part, the framework of river boulders is arranged,

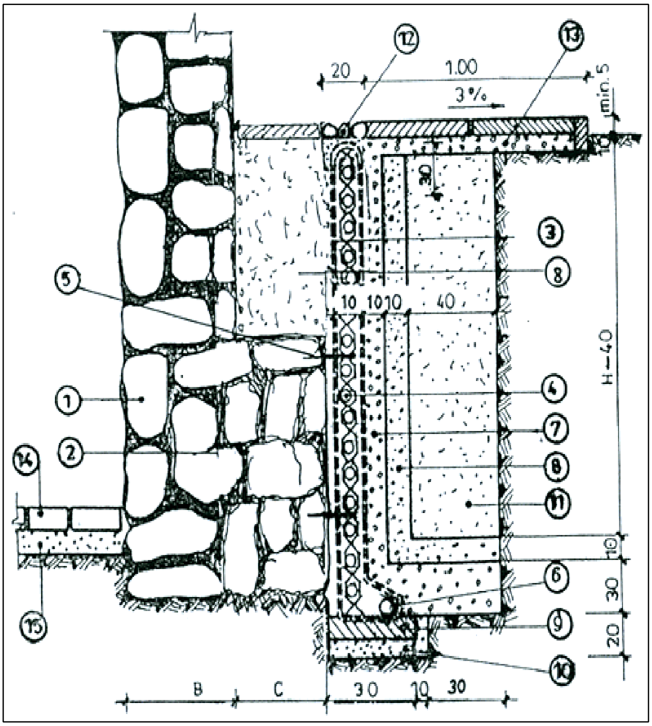


Fig. 5. Detail of a stepped foundation

1. Stone or brick masonry foundation, 2. Smoothing plaster of cement mortar M100 with Tenpor additive only for local unevenness over 2 cm. 3. Geotextile filtering felt overlapped at the closure for 30 cm. 4. Drain-Away plate, Plastidren. 5. Bolts ø 4 mm with rubber washers, mounted in dowels ø 8 mm. 6. Drainage pipe ø 80 – 110 mm. 7. Filter layer sort 15 – 30 mm. 8. Filter layer sort 0 -3 mm. 9. BC 15 prefabricated saddle. 10. Bed of compacted ballast 10 cm thick. 11. Hand-compacted soil fill in 30 cm layers. 12. Frame from river boulders ø 5 – 10 cm. 13. Pavement made of prefabricated BC 15 concrete slabs on a 10 cm thick ballast bed. 14. Flooring of solid bricks. 15. Anticapillary sand layer 3 – 5 mm, 10 cm thick. A – foundation depth. B - foundation width. C – width of foundation steps or foundation struts.

(Source: Popa, A., Technical expertise - Technical intervention solution for a wall affected by humidity, Arcalia Castle, Bistriţa Năsăud) which allows the evaporation of water that could accumulate under the pavement made of prefabricated tiles.

As can be seen, several cumulative measures have been taken so that the possibility of water acting transversely on the foundation is eliminated. On the inside, we do not have activities of a social, administrative or technological nature with special conditions, being provided with a floor made of solid bricks. A particularly effective solution used in the rehabilitation of buildings with a basement is the one shown in figure 6.

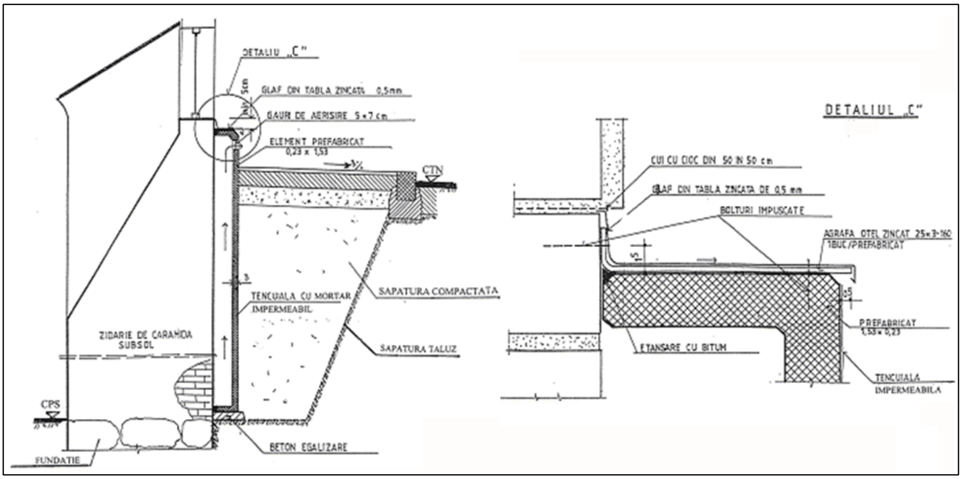


Fig. 6. Ventilation channel installation detail
(Source: Popa, A., Technical expertise - Rehabilitation and consolidation of the pharmacy and court building, Cluj-Napoca, 1999)

This figure shows a detail of the installation of a ventilation channel, made of prefabricated elements, to a basement wall made of brick masonry (Popa, A., 1999). The prefabricated element on the lower part is placed on a leveling concrete, and on the upper part it is protected from meteoric waters, with a galvanized steel sheet. Ventilation holes are provided on the side, and the prefabricated element is plastered with an impermeable mortar. A sidewalk with a 3% slope to the outside is provided around the building. Through the adopted system, two problems were solved, namely:
- the possibility of water migration acting transversally on the construction was interrupted. - by means of the prefabricated element and the pressure difference, the water vapor from the surface of the wall is evacuated to the outside, thus reducing the degree of humidity of the wall.

Another system that incorporates several functions, including the dehumidification of floors and walls/waterproofing of the structure of building elements, is: BIS – Building International System (Technical specifications – BIS). The BIS system is a high-performance multifunctional system for constructions that provides for the use of two joined membranes (BIS1 / white and BIS2 / cream) made of flexible plastic materials (PVC). Particular: - the presence of ridges and the "dovetail" shape in the exterior areas favors the good mechanical grip of the profiles between them and with the cement adhesive mass.

a) Dehumidification of the floor and wall support with moisture resulting from infiltrations or leaks

It ensures the removal from the structure of moisture resulting from infiltrations or leaks from the outside, in the form of vapors, through a tube mounted at the end of the profiles. In this way, the appearance and expansion of moisture is prevented. The particularities of the profile extension tube system allow the circulation of moist air directly outside, ensuring a good circulation of water vapor and thus effective dehumidification (fig. 7).

b) Realization of the waterproof structure of construction elements below ground level

Another use of the BIS system for underground constructions (foundations, cellars, etc.) - fig. 8 which are constantly subject to a high degree of humidity and the risk of water infiltration. BIS membranes ensure optimal waterproofing and very good ventilation of the structure.

c) Waterproofing and ventilation of walls exposed to atmospheric agents

Overlapping and staggered membranes are fixed with dowels. With this application, an optimal air circulation is obtained through the spaces between the wall and the membrane - fig. 9. For this application, it is necessary to use perforated angular profiles.

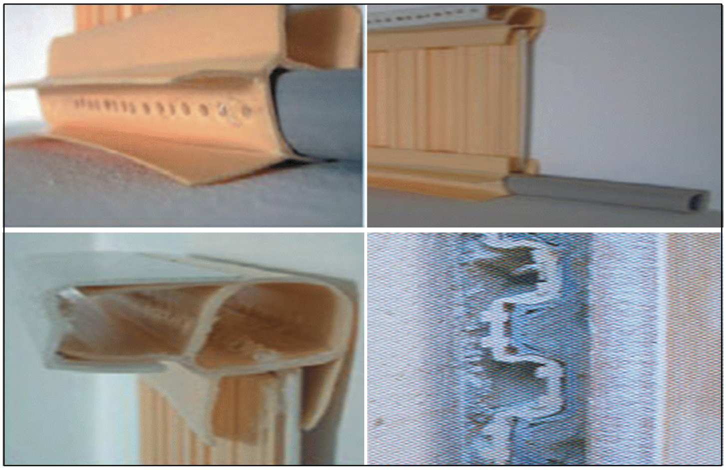


Fig.7. BIS system for dehumidifying the floor and wall support
(Source: Technical specification – BIS – BUILDING INTERNAŢIONAL SYSTEM)

Fig. 8 BIS system for underground constructions
(Source: Technical specification – BIS – Building Internaţional System)

The mortar will be applied to the BIS1 (white) profile in two successive layers, following the instructions for use of the product (mortar). It is recommended to use a net (nets) for mortar between the two layers of mortar. From a technological point of view, it should be mentioned that the success of these solutions depends on the correctness of the execution of the work.

Conclusions

The practical application of sanitation solutions in the form of procedures can only be done through the in-depth analysis of the theoretical bases of the phenomena, taking into account at the same time the causes, effects and methods of combating waterlogging.

The method that uses ventilation holes to dry masonry can only be applied when we are not dealing with a wetting due to a capillary increase from a water table.

Application in such cases would mean a real perpetuum mobile of upward migration, which is accompanied by transport of salts, expansive crystallizations etc., which lead over time to the disaggregation of construction materials (bricks, mortars, plasters).

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