Contradiction of Methodical and Technological Points of Views on Moisture Fighting Technologies On Walls of Architectural Heritage Buildings

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Abstract. The moisture affects all materials on the earth surface, but we have developed a specific sensitivity toward moistening of architectural heritage buildings. Water in construction materials and on their surface influences partially their technical state like their stability, but usually not that much as people can think. Unwanted moisture is usually dangerous at very soft construction materials, like clay bricks. But especially the water soluble salts, the water transports through the masonry, can act as a very dangerous destructive material, influencing destructively especially surface plasters. And in the case of historical wall paintings are the losses on cultural heritage invaluable. To deal with moisture effectively we can use some specific technologies, but the most effective ones have a specific destructive influence on the historical construction material. And this is the point of conflict between technical and methodical points of view. So the basic scientific questions in this field can be such ones: are the destructive technologies for fighting moisture in historic masonry really effective? And are they to be accepted also methodically?

1. Introduction
The capillary moisture, which invades traditional masonry walls made of bricks and stones, is a typical wide spread problem of the built architectural monuments. The moisture in constructions causes not only technical, but also hygienic problems. Water acts as a destructive element destroying construction materials (usually in a long term view of course) and also as an element causing hygienic problems, as it supports the development of fungi and algae. So it is crucial to fight such unwanted moisture in a historic masonry and its plasters.

2. Selection of appropriate technologies for fighting moisture in masonry
Nowadays construction industry can offer a couple of different technologies to deal with unwanted moisture. But effective technologies include a certain level of invasive and destructive interventions into the historic material. This is then a turning point for a lot of officers working in State monument bureaus. Their reserved approached towards such effective technologies is backed by some specific international methodical document, like for example by the Venice charter. According to the Declaration No. 91 of the National Council (Parliament) of the Slovak Republic from the year of 2001 we should respect such international agreements and recommendations. The Charter of ICOMOS asks for introduction of technologies which are as less invasive as possible and all technical intervention
into historic substance should be reversible. Effective moisture fighting technologies are definitively not such ones.

So let us have a look on introduction of several different approaches to fight unwanted moisture in historic masonry of some architectural monuments in Slovakia:

3. Introduction of undercutting the masonry
In the case of a baroque Manor House in Bratislava - Rača a high level of moisture on the surface of brick masonry was identified by the measuring. This is a typical situation almost of all historical building in Central Europe. Its reasons can be found in absence of insulation materials of the walls. Partially because there were not widely accessible in the time the buildings were constructed and partially from other reasons. For the fight with such unwanted moisture was the technology of undercutting of masonry selected. Here are the results, presented in selected figures:

Table 1. Measuring of humidity on the surface of altar construction of the church of Piarists

| Place of measurement | Height of measuring [cm] | Mass moisture [%] | Date | Height of measuring [cm] | Mass moisture [%] |
|----------------------|--------------------------|------------------|------|--------------------------|------------------|
|                      |                          |                  | 16.5 |                          |                  |
|                      |                          |                  | ‘17  |                          |                  |
|                      |                          |                  | ‘18  |                          |                  |
|                      |                          |                  | 20.6 |                          |                  |
|                      |                          |                  | ‘18  |                          |                  |
|                      |                          |                  | 14.9 |                          |                  |
|                      |                          |                  | ‘18  |                          |                  |
|                      |                          |                  | 16.5 |                          |                  |
|                      |                          |                  | ‘17  |                          |                  |
|                      |                          |                  | ‘18  |                          |                  |
| M13                  | 10                       | 16.7             | 5.3  | 2.6                      | 180              | 11.9             | 1.6  | 2.0  |
| M14                  | 10                       | 11.0             | 2.0  | 1.8                      | 180              | 16.4             | 1.6  | 1.5  |
| M15                  | 10                       | 17.0             | 2.0  | 1.8                      | 180              | 10.4             | 1.4  | 1.8  |
| M20                  | 10                       | 10.0             | 3.1  | 1.0                      | 180              | 8.5              | 3.7  | 2.8  |
| M25                  | 30                       | 9.4              | 1.6  | 1.8                      | 100              | 5.4              | 3.1  | 3.6  |
| M26                  | 30                       | 8.3              | 7.4  | 1.1                      | 100              | 17.3             | 6.9  | 2.3  |
| M27                  | 30                       | 17.4             | 8.8  | 2.0                      | 100              | 2.9              | 2.5  | 5.0  |
| M28                  | 50                       | 18.5             | 2.8  | 2.3                      | 100              | 17.5             | 3.3  | 3.2  |
| M29                  | 30                       | 17.5             | 2.6  | 2.3                      | 100              | 5.1              | 5.1  | 2.6  |
| M30                  | 30                       | 15.5             | 0.7  | 0.8                      | 100              | 17.4             | 8.8  | 6.8  |
| M32                  | 30                       | 8.4              | 8.0  | 1.7                      | 100              | 5.0              | 5.4  | 5.3  |
| M33                  | 30                       | 12.1             | 5.5  | 2.0                      | 100              | 4.7              | 3.0  | 2.5  |
| M35                  | 30                       | 10.4             | 12.5 | 6.7                      | 100              | 14.4             | 6.5  | 7.1  |
| M36                  | 30                       | 17.4             | 17.5 | 6.7                      | 100              | 6.5              | 3.0  | 4.1  |
| M37                  | 30                       | 10.1             | 13.2 | 7.8                      | 100              | 17.5             | 17.6 | 7.1  |
| M38                  | 30                       | 17.1             | 16.4 | 11.1                     | 100              | 9.5              | 9.4  | 4.0  |

According to given figures it is clear that the dehumidification activity was highly successful. As the figures show the moisture level went on all controlled points down – mostly even significantly. At most of the control points it went down even during one year of the introduction of the undercutting technology.
4. Introduction of injection technology
During the research, which was undertaking in the baroque church of the Piarists order in Nitra very wet construction of the altar was identified. As the construction was made of bricks (especially on its surface) an injection technology to solve the problems with moisture was identified.

| Date of measuring | 9.3. '10 | 6.10. '10 | 21.6. '11 | 5.10. '12 | 19.6. '13 | 3.12. '13 | 12.4. '13 | 30.10. '13 | 10.12. '13 | 2.7. '14 |
|------------------|---------|---------|-------|-------|-------|--------|--------|--------|--------|--------|
| No of measuring  | 34a     | 35a     | 36a   |
| Height of measuring | 20     | 50     | 50    |
| %                | [14.0]  | [10.1]  | [8.0] |
|                  | [13.6]  | [9.9]   | [7.6] |
|                  | [13.2]  | [9.6]   | [7.9] |
|                  | [13.0]  | [9.7]   | [7.0] |
|                  | [10.9]  | [9.6]   | [6.1] |
|                  | [6.7]   | [5.9]   | [4.9] |
|                  | [6.1]   | [4.6]   | [4.7] |
|                  | [4.7]   | [4.0]   | [4.6] |
|                  | [3.8]   | [4.1]   | [4.1] |
|                  | [4.6]   | [3.7]   | [4.2] |

After the application of the injection technology a significant success was achieved in the time of approximately one year.

Figure 2. Restored altar after the application of injection technology in Nitra.
5. Introduction of ventilation technology
During the above mentioned research in baroque church of Piarists in Nitra (built during 18th century) a hidden crypt was found. The environment in this crypt was very unhealthy as there were still remains of buried bodies preserved and at the same time all ventilation openings were additionally closed – probably in the half of 20th century. So the maintenance interventions were for the first focused on renewing the original baroque ventilation system.

Table 3. Measuring of humidity on the surface of wall constructions in the crypt of the church of Piarists

| Date of measuring | 9.3. '10 | 6.10. '10 | 21.6. '11 | 5.10. '12 | 19.6. '13 | 3.12. '13 | 12.4. '13 | 30.10. '13 | 10.12. '13 | 2.7. '14 |
|-------------------|---------|----------|----------|----------|----------|----------|----------|----------|----------|---------|
| No of measuring   | [ % ]   | [ % ]    | [ % ]    | [ % ]    | [ % ]    | [ % ]    | [ % ]    | [ % ]    | [ % ]    | [ % ]   |
| Height of measuring | 47     | 120      | 12.1     | 12.3     | 12.5     | 12.0     | 11.8     | 11.8     | 11.8     | 12.0     | 11.4    | 11.3    |
|                   | 48      | 180      | 13.7     | 13.2     | 13.1     | 12.5     | 12.7     | 12.4     | 12.2     | 9.5      | 9.1     | 9.1     |
|                   | 49      | 160      | 14.1     | 12.1     | 12.1     | 12.1     | 12.3     | 14.6     | 14.2     | 13.3     | 13.1    | 12.9    |
|                   | 50      | 160      | 14.2     | 13.8     | 13.4     | 13.1     | 12.9     | 12.6     | 12.4     | 12.0     | 10.2    | 10.0    |
|                   | 51      | 160      | 14.0     | 13.9     | 14.0     | 13.5     | 13.2     | 11.8     | 11.0     | 11.4     | 11.2    | 11.6    |
|                   | 52      | 200      | 14.2     | 13.8     | 12.4     | 11.5     | 11.1     | 9.7      | 12.5     | 13.4     | 14.2    | 11.5    |
|                   | 53      | 140      | 14.3     | 14.3     | 14.8     | 14.2     | 14.3     | 14.8     | 13.9     | 14.4     | 13.3    | 13.0    |

As the figures from measuring show the revitalisation of the original baroque ventilation system has ensured a very limited success. The air condition in the crypt was significantly improved – instead of a heavy, dank air inside the crypt there is now a very pleasant atmosphere for breathing. But it has to be stated, that also the remains of the stored bodies were moved into two niches. So the intensive ventilation helped with the quality of the air inside the crypt, but it had definitively not solved the problem with moisture in walls.

Figure 3. Crypt of the church in Nitra - revitalised with the use of ventilation.

6. Introduction of the principle of consecutive steps
This method was recommended by the document of ISCARS in 1999 and by the Charter of ICOMOS in 2003. So it was chosen for dealing with moisture in a mediaeval monastery of the Franciscans. The moisture was fought by the use of non-destructive methods – ventilation of rooms, insulation of the floor and application of diffusion plasters.
Table 4. Measuring of humidity on the surface of wall constructions in the monastery of the Franciscans

| Date of measuring | 2.2.’16 | 11.10.’16 | 31.03.’17 | 25.10.’17 | Notice |
|-------------------|---------|-----------|-----------|-----------|--------|
| Place of measuring/appr. height of measuring [cm] | Moisture [%] | Moisture [%] | Moisture [%] | Moisture [%] |        |
| 7/20              | 10.4    | 6.2       | 11.0      | 3.2       | 2.4    | 3.1    | Diff. plaster |
| 7/80              | 9.7     | 9.0       | 10.9      | 4.7       | 5.9    | 3.2    | 4.2    | Diff. plaster |
| 7/150             | 2.2     | 8.6       | 10.7      | 4.5       | 6.4    | 3.0    | 3.9    | Diff. plaster |
| 8/20              | 13.1    | 4.1       | 10.9      | 5.8       | 9.9    | 1.5    | 3.1    | Diff. plaster |
| 8/80              | 10.6    | 14.2      | 10.9      | 5.4       | 9.9    | 2.0    | 3.4    | Diff. plaster |
| 8/150             | 5.3     | 4.6       | 10.9      | 5.0       | 7.7    | 2.2    | 3.6    | Diff. plaster |
| 13/20             | 17.4    | 17.5      | 10.9      | 4.0       | 5.0    | 6.7    | 8.9    |        |
| 13/80             | 12.9    | 5.9       | 10.1      | 4.2       | 6.4    | 11.9   | 9.6    |        |
| 13/150            | 12.4    | 7.4       | 10.9      | 6.5       | 9.0    | 14.9   | 10.9   |        |
| 30/20             | 16.7    | 8.9       | 10.1      | 5.9       | 7.5    | 13.8   | 15.1   |        |
| 30/80             | 17.3    | 14.1      | 16.2      | 9.2       | 10.9   | 10.7   | 11.8   |        |
| 30/150            | 8.7     | 6.3       | 8.3       | 5.4       | 8.3    | 5.8    | 6.6    |        |
| 47/20             | 8.2     | 7.7       | 9.8       | 8.0       | 10.9   | 7.2    | 7.9    |        |
| 47/80             | 13.4    | 11.0      | 10.4      | 9.1       | 10.8   | 8.3    | 8.8    |        |
| 47/150            | 11.0    | 10.1      | 12.1      | 12.4      | 12.9   | 10.2   | 11.5   |        |
| 50/20             | 12.3    | 5.6       | 4.3       | 5.3       | 4.4    | 8.1    | 9.9    |        |
| 50/80             | 9.6     | 8.6       | 9.4       | 7.5       | 8.2    | 8.2    | 9.5    |        |
| 50/150            | 16.1    | 11.4      | 14.1      | 7.3       | 6.5    | 8.4    | 10.0   |        |

As it is visible – no significant success was achieved. Only such surfaces, where the industrial diffusive plasters were applied looks dry. But under the plasters the masonry remains still very wet and water vapour, which evaporates through the plasters, influences the interior environment of the monastery in a negative way.

Figure 4. Cloister of the Franciscan monastery after finishing of construction works.
7. Evaluation of measurements

Measurements were evaluated according to Czech standard [ČSN P 73 0610], which divides the moisture concentration in masonry into 5 categories:

| Degree of deterioration | Moisture (μM) [%] |
|-------------------------|------------------|
| 1                       | Very low moisture | < 3.0          |
| 2                       | Low moisture      | 3.0 – 5.0      |
| 3                       | Increased moisture| 5.0 – 7.5      |
| 4                       | High moisture     | 7.5 – 10       |
| 5                       | Very high moisture| > 10           |

8. Conclusions

But at the end it has to be stated, that in no one of the internationally accepted methodical documents the issue of fighting moisture in historic masonry is directly stated. There are only several general recommendations, which can be reached for this topic. Therefore, there is a wide field for interpretation of such recommendations on each national level. As above given examples showed, there are technologies which can act really effectively. Unwanted moisture in masonry of historic buildings standing under architectural heritage protection can be fought quite effectively. This is the message which needs to be postponed to architectural heritage authorities. They must understand that we really need to repress the moisture in construction even by the use of invasive means. Otherwise it will continuously damage the buildings.

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