EMERISDA

Description of techniques, procedures and criteria for assessment of effectiveness of intervention

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Participants: *BBRI, CNR-ISAC, UNIVE, RESP, DIASEN*

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1. Introduction

The aims of the WP2 "Collection and exchange of knowledge" in the Emerisda project are to 1) Obtain an overview of existing solutions against rising damp and their expected effectiveness and 2) Define procedures and criteria for the evaluation of the effectiveness of intervention in-situ. The first objective has been reached and detailed illustrated within the DL2.1 elaborated by TUD.

On the basis of the mentioned deliverable, the partners identified, during the 1st year meeting held in Bologna on 22-01-2015, the possible techniques to evaluate the effectiveness of interventions on case studies and scale models.

One important method (gravimetry and determination of hygroscopic behaviour) has been identified as the basis of the evaluation. Next to this central method, depending on the availability of equipment by the different partners, other methods are identified, that will be used on a non-general way, to accompany the gravimetry-experiments.

2. Overview

Methods for assessing effectiveness of intervention	Partner
MC/HMC (gravimetry)	All
Capacitance/electric resistance	BBRI
Monitoring of RH in holes	BBRI
Infrared thermography	BBRI, UNIVE, CNR-ISAC
Microwave measurement	UNIVE
Porosity	CNR-ISAC
Sclerometric test	UNIVE
Ion chromatography	CNR-ISAC
Conductivity	CNR-ISAC, UNIVE
Colour in water	CNR-ISAC (In scale models)

The description of the tests follow mainly the descriptions to be found in DL 2.3 (Existing techniques for the assessment of effectiveness of interventions). For most of the techniques, additional remarks will be formulated to, in specific connection to this project.

3. Determination of the moisture content (MC) and hygroscopic moisture content (HMC), by means of gravimetry.

3.1. General

This method should be employed by each partner, as it forms the most precise method to determine the humidity of the masonry. As far as low-invasive techniques are allowed on the test cases.

Principle of the method:

- Sampling the masonry, by slow drilling, of the masonry.
- Drying of the samples at a low temperature, in order to obtain the moisture content (MC):
    - MC (%) = 100% x (initial mass of the sample-dry mass of the sample)/(dry mass of the sample)
- Subsequently the determination of the Hygroscopic Moisture Content (HMC) by conditioning the samples in a wet atmosphere (e.g. 96% RH) at normal temperature (23°C), to equilibrium or for 4 weeks (whichever comes first).
    - HMC (%) = 100% x (mass conditioned sample-dry mass of the sample)/(dry mass of the sample)
- For more details, see DL 2.3

3.2. Application of the method in the EMERISDA-project.

Sampling:

- Sampling is carried out on a vertical line, at different heights:
    - 0.2 m, 0.5 m, 1 m,1.5 m, possibly higher if the height of the space allows it. Intermediate steps of 0.5 m. Height measured above the floor level of the space.
- Sampling at different depths:
    - 0-2 cm, 2-5 cm, 5-15 cm, 15-25 cm, as deep as possible, but not deeper than the centre of the wall.
- Possibly variations of these depths and heights, depending on the possibilities of each site, can be employed, but care has to be taken that during each subsequent campaign the same depths and heights have to be maintained, in order to be able to evaluate the evolution in the masonry.

- The samples have to be stored into air- and vapourtight vessels (e.g. small bottles) until they can be weighed. Evidently the vessels have to be weighed prior to the sampling.

- The vertical sampling profile should be as close to the centre of each test zone, in order to avoid as much as possible side-effects.

- If possible, samples should be taken in both bricks and/or stones and the mortar.

- If it is impossible to harvest sufficient sample (a few grams should be ok), then a bigger drill might be used. Or one can sample in two holes next to each other.

- Important remark: sampling should take place in all treated zones, but also a reference zone (without any treatment) needs to be identified and sampled, at the condition that such a zone can be identified.

Determination of the MC:

- As fast as possible after the sampling, the vessels with the samples should be weighed. The required precision is at least = 0.01g. As such, with a sample of a few grams, one can express the MC to a precision of 0.1%. Possibly the samples can be weighed on site, but it proves to be difficult to perform very precise weight measurements on site: the sensible balances suffer from air currents. So the weighing may take place in the laboratory.

- The drying of the samples takes place in a stove until constant weight is reached. During the meeting, it has been decided that 60°C would be ok. If this is not possible, a lower temperature may be used. One has to make sure that during all the campaigns, the same drying temperature has to be used. Because of practical reasons (availability of working stoves), BBRI will employ 40°C. In all cases, if the materials contain gypsum, this drying temperature should be maximum 40°C, in order to avoid loss of crystallisation-water.

Determination of HMC:

- As described in DL 2.3, the samples will be stored for 4 weeks in an atmosphere of high relative humidity (96% according to DL 2.3), at normal temperature (according to European standards, that is usually 23°C, but 20°C should be possible too, as long as the same temperature is used during the different campaigns).
    - It is possible that no equilibrium will be reached after 4 weeks, but as long as this period is always used in the subsequent campaigns, results can be compared.
    - The atmosphere of 96%RH can be obtained in a climatic chamber, or in a closed space where there is sufficient amount of saturated salt solution available. The amount of salt solution should be much more than the total amount of salts, in order to avoid that the salts in the samples can influence the RH in the space.

- An example of such a salt solution may be a saturated K_2SO_4-solution, where a RH of 97% will be reached. With K_2SO_4, one obtains a RH of 96%. Using $NH_4H_2PO_4$, a RH of 93% can be established. It is important to note that there should always be an amount of solid salt in the saturated salt solution, to be sure that the solution remains saturated when more water is absorbed in the solution.

- This experiment may be repeated with the same samples under a much lower RH, for instance around 70 or 80%. By using a saturated NaCl-solution, one obtains 75% RH. With a saturated KCl-solution, one obtains 85% RH.

Presentation of the results

- The results should be presented as mentioned in DL 2.3:
- Per zone and per depth, one vertical profile, indicating both MC and HMC, in order to easily evaluate the humidity situation: contribution of actual humidity (presence of rising damp), hygroscopic moisture, or both.

Frequency of the sampling.

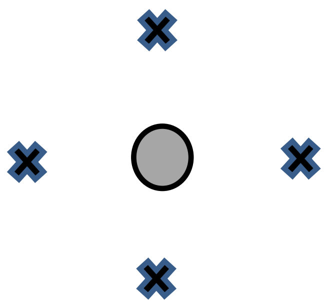
- Each campaign should be repeated every 6 months, unless this is considered to be too invasive for the monument under investigation. Within the project we then have the initial situation, followed by 3 campaigns after the treatments. This should be sufficient to evaluate the evolution of the humidity situation.
- At each campaign, the sampling zone should remain as close as possible to the centre of the test zone. The presence of an older borehole does not seem to influence a lot the humidity around that borehole if the hole has been properly closed (e.g. with a stopper or with mortar) after sampling. So in order to compare results from subsequent test campaigns, the new samples should be taken as close as possible to the older samples.

4. Capacitance/resistance moisture meters

As these methods are to be considered as indicative, even though useful, methods, we consider them as optional in the project. However, in order to evaluate their reliability, these measurements might prove useful.

Proposition:

- 4 measurement around each borehole (the sampling holes from the determination of MC and HMC, see point 3 above). The average value of these 4 measurements is the final result.
- The results should be expressed as a vertical profile, per test zone, such as with the MC- and HMC-measurements, and compared to the vertical profiles measured according to the MC and HMC-measurements.



5. Monitoring of RH in boreholes

This method will not be employed in all zones, but it is a method that will be tested in order to verify if this method may be suitable for a permanent monitoring of the drying process.

At several heights in a test zone, a hole is drilled, to a depth of 20 cm. a probe is inserted, that measures every 10 minutes the RH in the hole. This curve will be compared to the MC and HMC in order to see a possible correlation between the two measurements.

6. Infrared thermography

This method may prove to be a fast indication of the spatial distribution of humidity problems in walls:

- Humidity in walls causes a larger thermal conductivity in these walls. When the walls separate cold and warm spaces, there should be an influence on the surface temperature of the walls.
- Humidity evaporates, and thus extracts warmth from the wall, causing the wall to cool down. This could be visible on a thermal image, as long as the humidity is evaporating from the surface. When the ‘evaporation front’ lies under the

surface of the masonry, it is less likely that the cooling effect will be visible at the surface..

- Measurements at each campaign might prove the practical usefulness of the method.

7. Microwave

The measurement of microwave might be a useful method to evaluate the drying process of the wall. The heterogeneity of masonry might cause important interferences with the measurements.

Possibility to perform microwave measurements in each brick composing the masonry, not only nearby the sampling holes.

8. Porosity measurement

On bulk samples of the wall, the porosity of the materials, combined with the MC-measurements, could be an indication of the saturation degree of the walls, and an explanation of the spatial distribution of the humidity in the wall.

9. Sclerometric test.

The presence of humidity in materials might influence the mechanic properties of materials. For instance, the capillary forces cause a ‘compression’ force on the materials, causing the materials to behave more stiff. As different materials behave differently under the mechanical action of such a sclerometer, it is difficult to extract exact quantitative data. The method should be merely considered as indicative and comparative (measurements on exactly the same location on the masonry surface in order to monitor the drying process).

Possibility to perform sclerometric tests like in point 4 (capacitance/resistance measurements, in 4 points around each sampling hole).

10. Ion chromatography

The salt content and types of salts may give an explanation about the drying behaviour and the hygroscopic water uptake. Based on the results of the HMC of samples, a selection of the most hygroscopic samples may be tested with ion chromatography.

11. Conductivity

A conductivity measurement of samples mixed with water is another indication of the salt content of the samples, and might prove useful to explain anomalies in drying behaviour of walls, and of HMC. It should be kept in mind that some materials, such as mortars and limestones, contain lightly soluble components, that might influence the conductivity.

12. Colouring the water that is being absorbed by the wall.

This method should only be used with the scale models, as the addition of colour in walls might prove to be irreversible. It is a variation of other methods, in which markers (such as rubidiumcarbonate) are injected into the wall, after which is evaluated in what direction this marker diffuses into the wall.

- The water in which the scale models are standing are coloured with a colouring agent. In order to be sure that the size of the molecules is not affecting the absorption of the colouring agent into the wall, it might be recommended to use colouring agents with small molecules, or ions. An example might be $CuCl_2$, which is highly soluble in water, and gives a vivid blue colour to the water.

- This test should be carried out at the very end of the test campaigns on the scale models, as the colouring agent (or the salt) might influence the drying behaviour of the wall. For instance, $CuCl_2$ is highly hygroscopic, which will influence without any doubt the drying of the masonry.

- The height at which the colour rises into the wall may be an indication of the effectiveness of the treatment.