# Decision-making in the intervention on buildings affected by rising damp

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# Dealing with Heritage

## Assessment and Conservation

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# 3 – Decision-making in the intervention on buildings affected by rising damp

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## 3.1 – Introduction

Rising damp, i.e. the capillary rise of water from the ground to the walls of a building, is a well-known and recurrent hazard to heritage buildings. Due to climate changes, its occurrence is expected to increase in the future. The urgency and diffusion of this problem is reflected by the large variety of solutions to tackle rising damp which are available on the market. This wide and differentiated offer, together with the scarce and fragmented scientific information on the effectiveness of these methods, make it difficult (even) for professionals working in the field to choose a suitable intervention on a sound basis.
In this chapter, the different steps in the investigation process for a sound diagnosis of the presence of rising damp are discussed. Moreover, a tool is proposed which can support the choice of a suitable intervention depending on the specific situation.

## 3.2 – The phenomenon of rising damp

The phenomenon of rising damp is more common in old than in new constructions due to the fact that historic buildings often have masonry foundations and lack of a damp-proof course, i.e. a layer hindering the water transport from the ground to the upper part of the structure. The high moisture content deriving from the presence of rising damp does not only create an unpleasant and sometimes unhealthy climate in a building, but it also considerably enhances decay processes in the materials composing the wall, as for example the rotting of wooden beams and salt crystallization [FIG. 3.1]. and/or frost damage to brick and mortar. Unfortunately, due to climate changes (e.g. increased frequency of precipitation events with long and intense rainy periods, increased salinity of ground water), the occurrence and the relevance of rising damp will probably increase in the coming decades (Nijland et al., 2009; Brimblecombe, 2010; Sabbioni et al., 2010; Horowitz et al., 2016).

FIG. 3.1 Salt crystallization damage due to the presence of salts and rising damp, Venice, Italy / Photo: B. Lubelli

The phenomenon of rising damp is quite slow. This means that damage to the building materials and structures may become visible only several years after construction or a restoration intervention. Besides, changes in the groundwater level may also affect the height up to which the water rises in the wall. Additionally, the presence of salt in the masonry may increase the maximum height reached by the rising damp (Hees and Koek, 1996; Hall and Hoff, 2007).

Possible sources of rising damp are:

— ground(water) under the foundations (vertical transport of moisture);
— ground(water) adjacent to the wall (horizontal transport of moisture);
— surface water.

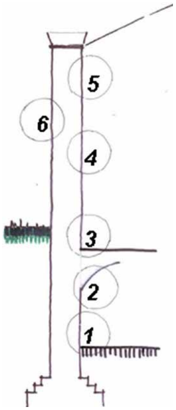
FIG. 3.2 The height of rising damp is generally limited to 1,5-2 meters, Ferrara, Italy / Photo: B. Lubelli

Contrary to what is usually assumed, rising damp from ground water may occur even when the foundations are not in direct contact with groundwater or surface water. In fact, the ground can contain a large amount of water above the groundwater level that has migrated from the groundwater zone to the upper zone by capillarity. When the foundations are in this capillary zone, rising damp may still occur in the wall.

Capillarity is the mechanism governing rising damp in a wall. Capillary forces can transport water from the ground into the wall, countering gravitational forces. Theoretically, water can rise up several metres through capillarity, depending on the pore size of the material. However, the maximum level reached by rising damp in brick and stone masonry is generally limited to 1,5-2 metres in practice, due to resistance to the flow of water, evaporation and the presence of boundaries between materials with different pore sizes (e.g. example mortar and brick) [FIG. 3.2].

TABLE 3.1 Possible moisture and salt sources

**Internal face of external wall and cellar**




| | MOISTURE SOURCES | SALT SOURCES |
|---|---|---|
| 5 | – Rainwater penetration<br>– Leakage of water transporting element (gutter, down pipe, … ) | – Air (aerosol)<br>– Building materials (brick and/or mortar)<br>– Excrements (birds) |
| 6 | – Rain<br>– Air humidity | – Air (aerosol)<br>– Excrements (birds) |
| 4 | – Rainwater penetration<br>n.b. quality of repointing and mortar joints<br>– Accumulation rain water due to protruding elements etc. in façade (cornice … ) | – Building materials (brick and/or mortar)<br>– Air (aerosol)<br>– Sea water flooding |
| 3 | – Sideward moisture penetration from earth<br>n.b. ground floor below level ground (earth retaining wall)<br>– Surface condensation (thermal bridge / high air humidity) | – Groundwater<br>– De-icing salts<br>– Use (salt storage, stable)<br>– Sea flooding |
| 2 | – Groundwater / Rising damp<br>– Sideward penetration from earth (earth retaining wall), which may be related with rainfall | – Groundwater<br>– Fertilizers (garden)<br>– Garden |
| 1 | – Groundwater / Rising damp<br>– Sideward penetration from earth | – Sea flooding<br>– Use (salt storage, stable) |

*Source: MDCS https://mdcs.monumentenkennis.nl*

There are several methods on the market claiming to solve the problem of rising damp in buildings. However, it is difficult for an owner of a building and/or for the person responsible for its conservation, to take a sound decision on how to tackle rising damp. The reason lies in the fact that, usually, no independent, scientifically-sound investigation is conducted to first assess the actual presence of rising damp and that scientifically validated information on the (long-term) effectiveness of the large variety of intervention methods is lacking. To address this lacuna, an international collaborative research project (JPICH EMERISDA) was set up a few years ago between the Netherlands (TU Delft, the Cultural Heritage Agency of the Netherlands, RCE), Belgium (Belgian Building Research Institute, BBRI) and Italy (University of Ca' Foscari, Consiglio Nazionale delle Ricerche, CNR, and a contractor). In this project a procedure for the assessment of the presence of rising damp was defined and 'standardized' as far as possible and a tool was developed to support the user in the choice of a suitable intervention method. These are described and discussed in the next paragraphs.

## 3.3 – Assessment of the presence of rising damp

From the research carried out in the framework of the EMERISDA project, it emerges that independent and scientifically-based investigation of the actual presence of rising damp from ground water in masonry walls is rare. Often, unreliable investigation techniques or procedures are used and/or investigations are carried out by non-independent parties such as the producer and/or merchant of products or devices against rising damp. In many cases, interventions are carried out without any investigation, but are just based on the visual observation of some symptoms such as moist spots on a wall or a humid indoor climate. However, these symptoms may also be the result of other moisture sources such as a not effective drainage of rain water or the hygroscopic behaviour of salts.

TABLE 3.1 gives an overview of possible moisture sources at the ground floor of a building.

This lack of preliminary investigation may, instead of saving money, result in higher final costs: if the moisture source is not correctly identified, the intervention will in most cases be ineffective.

Therefore, the first step in a decision-making process should be a proper investigation to come to a sound diagnosis of the moisture source. A careful visual survey of the type of damage and its distribution in the wall (e.g. by comparing lower and higher parts of the wall, external and internal walls) is the initial step in this process. It helps in developing a hypothesis on the moisture source and guiding the investigation. The presence of a drainage of rainwater, the existence of a layer of low-absorbing material in the masonry (trasraam) and the possible sideward ingress of water, e.g. in the case of retaining walls, should be checked as well. Also, the depth of the groundwater level is relevant: when the ground water is very deep, rising damp from ground water is unlikely. However, some cases may exist in which the presence of an impermeable layer in the soil, inhibiting the drainage of rain water, can lead to the formation an 'apparent' groundwater level at a higher level, possibly giving place to rising damp in the walls.

The next step in the assessment of the moisture source consists of the validation of the hypothesis, which can be done by measuring the moisture content in the wall. The gravimetric method, i.e. measuring the weight loss of (powder) samples collected from the wall after drying in an oven, is the most reliable method to assess the moisture content and distribution. Non-destructive techniques generally used by consultants in practice, such as capacitance or microwave meters, provide only qualitative results. For a correct diagnosis, the moisture distribution over the wall depth and height should be known: typically, in the case of rising damp, the moisture content in the wall decreases with height and increases with depth. Other aspects to be taken into account are (i) the contribution of hygroscopic salts to the moisture content and (ii) the porosity of the materials (some materials may show low moisture content only because of their low porosity). The reader is referred to the paper by (Lubelli et al., 2018) for a detailed description of the suggested sampling and investigation procedure.

## 3.4 – Available solutions

Once the presence of rising damp has been assessed, a choice should be made on whether or not to intervene and by which method. A large range of methods and products against rising damp are available commercially; a recent and comprehensive review can be found in (Franzoni, 2018). Existing methods can be classified as follows:

— *Methods based on a reduction of water flux in ingress:* for example, creation of drains filled with coarse gravel to favour drainage of rainwater, or the application of waterproof membranes along the perimeter of the buildings;
— *Methods based on reduction of the wall sorptivity:* these methods are meant to stop the capillary rise of water above the height of the intervention in the wall. These are the most common methods and include:
— *Mechanical interruption:* a layer of impermeable material, e.g. a lead slab, is inserted in the wall, generally after removing of a joint or of a course of masonry (see e.g. Massari and Massari, 1985) [FIGS. 3.3/3.4];
— *Chemical interruption:* chemical products, meant to fill the pores and/or make them water repellent, are injected (under or without pressure) in a series of holes drilled at a distance of 10-15 cm from each other along a horizontal line in the wall [FIG. 3.5]. The product should spread to form a horizontal layer through the whole section of the masonry, stopping water from rising any higher up the wall [FIG. 3.6];

FIG. 3.3 Mechanical interruption of the wall by the use of plastic sheet, Venice, Italy / Photo: B. L.ubelli

FIG. 3.5 Injection of a liquid product by means of pressure / Photo: B. L.ubelli

FIG. 3.4 Mechanical interruption of the wall by the use undulated steel sheets, Venice, Italy / Photo: R. van Hees

FIG. 3.6 Injection of a liquid product by means impregnation with a product in the form of a cream / Photo: B. L.ubelli

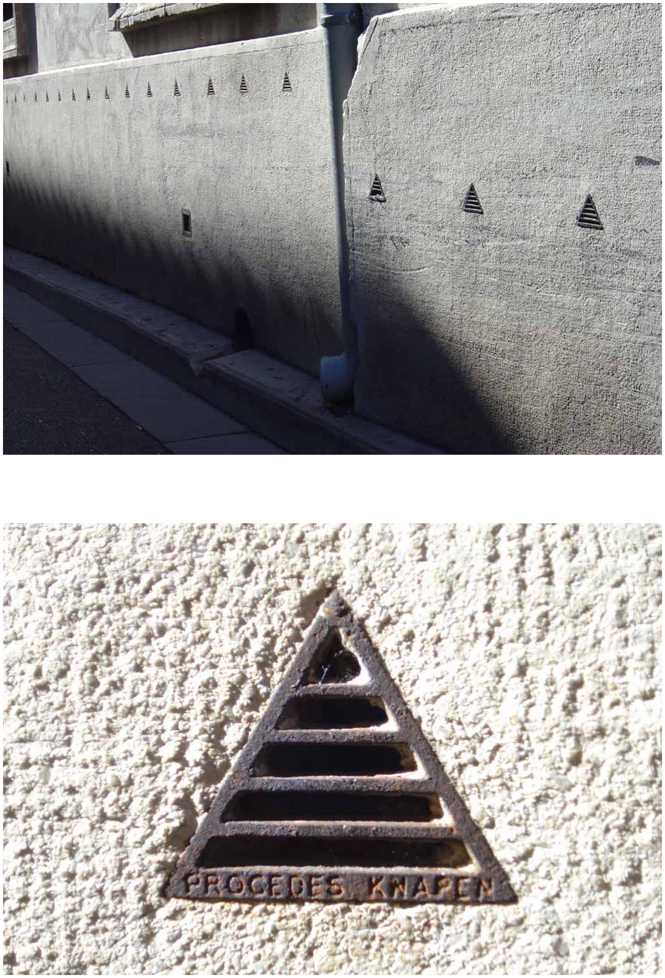



FIG. 3.7 Knapen syphons / Photos: B. L.ubelli

FIG. 3.8 Schrijver system / Photos: B. L.ubelli

- *Methods based on evaporation increase, including:*
  - *Knapen syphons and similar devices, such as Schrijver systeem:* holes are made in the wall and the syphons are placed in them: the hole increases the evaporation surface and it might thus enhance evaporation [FIGS. 3.7/3.8]. As pointed out by Massari in (Massari and Massari, 1985), these systems may help (if not obstructed by debris) only in situations when the wall temperature is slightly lower than, or equal to that of the outside air and when the Relative Humidity (RH) of the outside air is very low. In humid regions, such as in the Netherlands, these systems are generally ineffective. Moreover, drilling a hole in the wall would work similarly (Vos, 1971) and be much cheaper;
  - *Excavation around the perimeter of the building:* the contact between the wet ground and the wall is reduced and at the same time evaporation is allowed. Additionally, mechanical ventilation can be applied, to further increase the drying at the base of the wall (Torres and Peixoto de Freitas, 2007; Guimarães, Delgado and de Freitas, 2016; Torres, 2018);
  - *Special renovation plasters:* these plasters, have generally a high and coarse porosity, which should enable a faster evaporation than traditional plasters;
- *Methods based on electro-kinetic phenomena:* next to devices based on active electro-osmosis (which are difficult to apply in practice), a large variety of devices are present on the market based often on obscure, not scientifically proven 'physical' principles (Lubelli et al., 2016; Vanhellemont et al., 2018);
- *Methods which do not tackle the rising damp, but only its symptoms:* these include veneer walls, the application of tar layers or any other materials impermeable to vapour and the use of special renovation plasters, such as salt accumulating and salt and moisture blocking plasters (Hees et al., 2008).

## 3.5 – Decision process

The large and varied offer of solutions available on the market, the frequent substitution of products (or just their change in name) and the scarcity of scientific and independent information on the subject, make it difficult for professionals and practitioners to choose a suitable method on a sound basis. Choices are more often based on reliance on the seller of the product, than on real knowledge on the effectiveness of the method. Sometimes, the need to respect cultural values and limit the intervention to a minimum has led to institutes for monuments' preservation giving their support to the application of methods of unproven effectiveness only because they are not invasive. The suitability of a method in a specific situation is determined not only by its technical effectiveness, but also by several other aspects, such as:

- *Owner requirements, including:*
  - *available budget:* not only the costs of the interventions in the short term, but also those of maintenance;
  - *function of the building:* e.g. a living space has different requirements in terms of comfort and indoor climate than a store; similarly, in some cases, the occurrence of damage (e.g. peeling of the paint, moist spots) can be acceptable or not, depending on the use of the space.
- *Heritage issues:* as interventions will affect the building and its materiality, issues such as compatibility, retreatability and reversibility of the intervention. Besides, in the case of protected buildings, special legislation exists and restrictions are applied

- *Characteristics of the structure to be treated, including:*
  - *state of conservation of the wall:* some methods, such as mechanical interruption, can be very risky if the structural condition of the wall is poor or the building is located in an earthquake area;
  - *properties (thickness, regularity, finishes) of the wall:* for example, injections of very thick walls can be complicated and mechanical interruption is not easily feasible in masonry with irregular courses. Injections of a masonry with many voids and/or large cracks can only occur once these have been filled, for instance with grouting.

Next to the above-mentioned factors, risks related to the intervention should be considered. For example, after a successful intervention against rising damp the wall will dry. If salts are present, salt crystallization damage will increase directly after the intervention (due to the drying of the wall and the subsequent crystallization of the salts) before stabilizing. It can therefore be wise to wait for a few months after the intervention against rising damp, before re-plastering the wall. An increase of salt damage may also occur in the case of interventions enhancing evaporation when the rising water contains soluble salts. Besides, the presence of a finish retarding or stopping evaporation in the areas where rising damp is still present, will have the risk to displace the problem, moving it higher up the wall or to the other side of the wall. In the case of shared boundary wall, it might be wise to agree on the intervention with the neighbour.

In order to support professionals in choosing a suitable intervention, a decision support tool has been developed as part the recent EMERISDA research project in which all aspects involved in the decision are considered: requirements of the owner and user of the building, technical aspects, legislative issues as well as issues related to the cultural value of the buildings [TABLE 3.2] (Lubelli et al., 2018). When using the system, the user is asked to answer questions on the different subjects and, for each possible intervention, the consequences are reported: the severity of the risks is visualized with orange and red cells; a green cell means that the method does not pose a specific risk [FIG 3.9]. The user can thus become aware of advantages, limitations and risks of each technique, compare the different intervention methods and select the most appropriate one for the specific situation. Besides, the tool helps to make clear the relevance of each aspect to all parties involved in a conservation/renovation project, supporting thereby the achievement of an agreement. The approach proposed might be considered as a kind of pilot, and it can eventually be used for other decision-making processes, also of more complex nature.

TABLE 3.2 Scheme of the structure of the prototype of a decision support tool

| SITUATION | SOLUTIONS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Based on reduction of water flux in ingress | Based on stopping/ reducing water transport higher up in the wall | | Based on evaporation increase | | | Based on electrokinetic phenomena | | | Additional/ alternative methods, treat symptoms | | | | | | |
| | Sub-soil drains | Mechanical interruption | Chemical damp-proofing | Knapen Siphons & similar | Wall base ventilation | Thermal methods | Active electro-osmosis | Passive electro-osmosis | 'Electro-kybernetic' and similar methods | Take no action | Veneer walls, tiles and impermeable layers | Salt blocking plasters | Salt accumulating plasters | Salt transporting plasters | Air Conditioning and/or dehumidification of air |
| Owner requirements | | | | | | | | | | | | | | | | |
| Heritage issues | | | | | | | | | | | | | | | | |
| Wall characterics | | | | | | | | | | | | | | | | |
| Moisture and salt content/damage | | | | | | | | | | | | | | | | |

| | working principle > | Based on stopping/reducing water transport higher up in the wall | | Based on evaporation increase | | |
|---|---|---|---|---|---|---|
| | | These methods are supposed to reduce rising damp by making water transport through the wall more difficult or even impossible. | | These methods are supposed to reduce rising damp by increasing evaporation of the water already present in the wall. The source of the moisture is not altered. | | |
| situation v | solution > | Mechanical interruption | Chemical damp-proofing | Knapen Siphons & Schrijver stones | Wall base ventilation | Thermal methods |
| Owner requirements: Is it acceptable to have to do maintenance to keep the method working? | Yes | OK; no maintenance is required. | OK; no maintenance is required. | OK. Expect to have to clean the openings evey so often, so the airflow is not blocked. | OK. In case of active ventilation, the devices might need maintenance. | OK; depending on heating method, device might need maintenance. |
| Do I need to stop rising damp completely? | Yes | OK; rising damp is completely stopped above the level of the interruption. | Attention: the effectiveness of this method depends on several factors. It is advised to check the effectiveness 6-12 months after the intervention. | Risk: this method is not meant to stop rising damp completely but to reduce the MC in the wall. The effectiveness of this method is low. | Risk: this method is not meant to stop rising damp completely but to reduce the MC in the wall. The effectiveness of this method is low. | Risk: this method is not meant to stop rising damp completely but to reduce the MC in the wall. The effectiveness of this method is low. |
| Do you have a large budget available for this intervention (initial costs + operation + maintenance)? | No | Risk; very high initial costs but no running costs or maintenance. | OK; moderate initial costs but no running costs or maintenance. | OK; moderate initial costs and no running costs or maintenance. | Attention; apart from initial costs, take into account the running costs for the mechanical ventilation devices. | Risk; apart from high initial costs, expect high running costs as well. |
| Is it acceptable if you cannot use the room for some time while/after the intervention is carried out? | Yes | OK; keep in mind that the intervention is quite rigorous. | OK; be aware that, depending on the product/solvent, you may not be able to use the room for a few weeks. | OK; the intervention does not take long to carry out. | OK; the intervention is on the outside and the wall is not affected. | OK; depends on the chosen method. |

Manual | 1. Likeliness | 2. Confirm | 3. Techniques | 4. Risks | A. Attachments

FIG. 3.9 Screen shot of a section of the decision support tool prototype (the colour of the cell indicates the capability of a certain method to fulfil the requirement specified in the question)

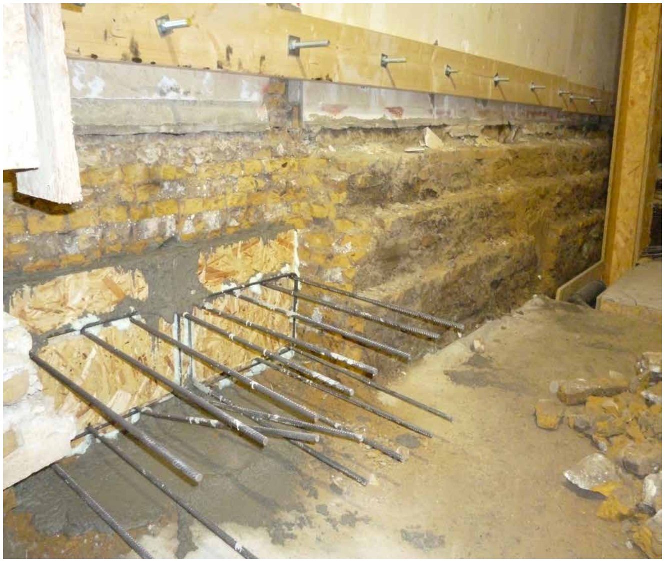


FIG. 3.10 Huis Nolet, basement: reinforcement for insertion of concrete floor (December 2016) / Photo: B. L.ubelli

FIG. 3.11 Huis Nolet, basement: temporary support of the wall during insertion of concrete floor (December 2016) / Photo: B. L.ubelli

## Huis Nolet in Schiedam

In the renovation of Huis Nolet, a mansion in Schiedam, the Netherlands, dating back to the beginning of the 19th century, the restoration architect decided to carry out a mechanical interruption in order to tackle rising damp in the basement of the building, despite the high costs and difficulties of this type of intervention.

The reason for choosing a mechanical interruption of the wall, despite the difficulties in execution and the high costs, was mainly the need for a definitive solution. Moreover, the execution of extensive renovation works, including the reinforcement of the foundations and the addition of a concrete floor in the basement, made it possible to carry out the mechanical cut in the walls with a relatively small additional effort. A concrete floor, originally planned to be inserted into the perimetral walls of the buildings at intervals of 50 cm, was made through the entire section of the wall [FIGS. 3.10/3.11]. The part of the walls in contact with the ground was protected with an impermeable layer in order to avoid sideward penetration of water. In this way an effective intervention against rising damp was obtained with relatively limited additional costs. This shows that for each situation a bespoke approach is required, defined by considering all aspects: even a complex and expensive intervention, such as mechanical interruption, may become feasible and suitable in specific situations.

FIG. 3.12 Interior of the Elleboog church: water used to extinguish a fire had accumulated on the concrete floor and risen up in the wall, leading to a moisture content distribution similar to that observed in the presence of rising damp from groundwater / Photo: B. L.ubelli

FIG. 3.13 Excavation of the ground around the foundation of the church and sampling, at different depths and heights in the wall along a vertical profile, for the measurement of the moisture content and distribution / Photo: B. L.ubelli

## Elleboog church Amersfoort

A sound diagnosis of the moisture source is necessary prior to an intervention against rising damp. A small investment in preliminary research can save large investments in unnecessary and/or unsuccessful interventions. This is shown by the example of the Elleboogkerk in Amersfoort, the Netherlands. A fire destroyed the roof of the church. The fire was extinguished, and, after some time, a new roof was built and the walls were plastered again. A few weeks after the application, the plaster showed damage in the form of spalling. The Dutch independent research organisation TNO was asked to investigate the cause of the damage (Lubelli and Hees, 2012). During a first investigation of the moisture content in the wall, the lower part of the masonry was found to be very wet, suggesting the presence of rising damp from groundwater [FIG. 3.12]. A further investigation of the groundwater level and of the moisture content in the soil, clarified that rising damp from groundwater was indeed present, but only up to a low height in the wall [FIG. 3.13]. The high moisture content (MC) measured in the wall in the interior of the church was not due to rising damp from ground water, but to the capillary rise of water used to extinguish the fire, which had accumulated on the concrete floor of the church. No intervention against rising damp was thus necessary; after 6 months the walls were dry enough to be safely plastered.

Rising damp in wall / Photo: B. Lubelli

Exfoliation of brick / Photo: B. Lubelli