HUMIDITY ANALYSIS AND CONTROL

José Gonçalves

Resume

Humidity is probably the worst enemy of constructions and we can relate its multiple appearances with the majority of degradation processes in traditional buildings. Is also difficult to deal with the real origins of humidity in buildings when some far easier solutions (like hiding their final results) usually achieve a cheaper alternative. The best way to tackle humidity problems is always by preventing its final contact with the building or, when that proves impossible, to conceive a method to reduce that contact with efficient draining systems. The ways to solve this problem are synthesise in this report with examples of practical solutions in traditional buildings and monuments by using ancient techniques that proved particularly well in actual rehabilitation works.

Summary

1 – **Introduction**

Humidity problems in constructions are the worst scenario when the restoration experts came on site for damage evaluation. The causes of degradation are usually disguised with cover material problems which are far easier to deal with in a rehabilitation process. If far simpler to show a new appearance to an ancient surface, or apply an authentic finishing to an old object, than to look for the origin of the damage in that object or artefact. Normally technicians involved in diagnosis and restoration using modern methods and techniques of evaluation tend to create a different approach for the problem and sometimes have not the necessary background to ear what the other have to say about the situation.

Problems relating humidity in constructions are not only the cause for the interaction of these different mentalities but a reason for establishing common principles in modern conservation practice. Is therefore important to study these scenarios for evaluations proposes and modern techniques appliance. The organization of recovered information in work surveys is the basis for the correct evaluation and establishment of protective measures, and that is the aim of this report considering the possible loss of existing patrimony due to bad decisions based on deficient evaluations.

2 – **Construction humidity**

The manifestation of humidity due to the construction is a problem that is apparently overcome by the passage of time and its consequences on the construction behaviour and response. This is not ultimately true because is always possible that the building have been repaired with a modern material using ancient techniques or have suffered from an important alteration in its constitution or organization. That is the example of new floor rehabilitation in which the wood planks had not conveniently dry before application and start to adjust due to water loss (Fig. 1, 2 – Teatro Nacional de São Carlos, Lisbon), or even some mortar application in old surfaces with water transmission inside the walls and consequent moisture migration to their exterior layers. (**Fig. 3** – Teatro Nacional de São Carlos, Lisbon).

The appearance of humidity in the walls or the degradation of the wood on floors are the major consequences of that problem and the repairing solutions are not always easy because usually involve possible substitution of material or moisture control inside the building with all the evident consequences for its inhabitants or visitors. Is much preferable to prevent the problem itself during repairing with simple solutions like interposition of impermeable paper beneath the wood floor before final application of the material or improve the ventilation in certain zones on the repaired walls.

All solutions however need some discussion beforehand with the intervention team because of all the implications

Fig. 1. Humidity in floor

Fig. 2. Damage floor due to humidity

Fig. 3. Construction humidity

on the final aspect of the surfaces or their economic repercussions for the overall budget and management.

3 – **Ground humidity**

Ground humidity is a far worst scenario when it comes to deal with humidity in an existing building that have obviously been subject to alterations or degradation in its environment.

The humidity from the ground beneath the building is always the consequence of hydraulic changes in the foundation that causes the migration of water trough the walls and foundation materials until the water reach the higher levels of the walls inside the building or the floor elements at ground level (**Fig. 4, 5** – Igreja de São Miguel, Lisbon).
A usually alteration in the moisture content of the ground is when the conditions around the building change due to the application of impermeable materials like bituminous surfaces or hydraulic tiles in the area around the exterior walls in a urban intervention. That alteration prevents the water from the rain to infiltrate to the ground in the same way as it used to and may conduct the same water for certain zones on the walls with the known consequences.

Fig. 4. Ground Humidity

The solution, in this case, is an easy one. All we have to do is dig a water barrier around the exterior walls of the building and, with the application of water proof solutions like polyethylene membranes or geo textile materials to block the access of water in its way to reach the outer layers of the walls. This solution must be completed with an efficient method of conducting the water to an existing draining system, with convenient drilled tubes placed in the lower level of the water barrier and the use of small rock sand to facilitate the water migration to the draining tubes (**Fig. 6, 7, 8**; Drawings 1, 2 – Capela de São Sebastião, Moita).
Another situation comes with the presence of water around

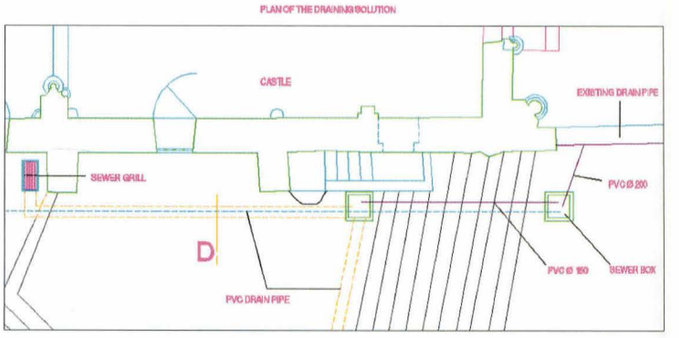
Fig. 5. Damages due to gound humidity

the exterior walls in a sub level of the building with no access on the outside, like the above mentioned situation. In this case one must seriously consider a construction of a second wall on the inside with an efficient draining system in the space between the two walls.

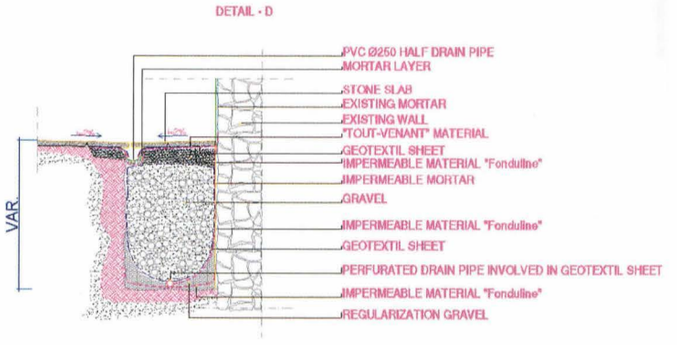
Fig. 6. Geo textil on draining solution

Fig. 7. Draining solution materials

Fig. 8 . Sewer Box of draining solution



Drain Detail -1



Drain Detail -2

A third solution could be achieved with the use of a chemical solution of silicone resins, or other water repellent product, injected with a pump system in predetermined holes on a level below the affected zones of the walls.

Each of these solutions must be used with great care due to the obvious difficulty in an exact determination of the water origin and its future effect on the building. Some of the mentioned techniques also involve the use of expensive machinery and equipment so a carefully planed intervention must be carried and each solution conveniently adapt to the building because of its singularities or specifications.

4 – **Rain humidity**

Rain humidity if perhaps the first preoccupation in the design phases of the intervention and can be, by that reason, one of the only reasons for water prevention systems to exist. That is not obviously correct and a global study of this problem can be achieved with the consideration of all elements of the exterior enclose of the building.

4.1 – **Exterior walls**

Exterior walls are the first element in a building where humidity related damages are best perceived in a visual inspection or survey. Normally, considering the permeable materials of walls constitution, the visual aspect of humidity in the interior of an element, signifies that the entire wall is humid and a special protective treatment must be applied.
Also the great thicknesses of monument walls, with heterogeneous materials and sometimes problems of structural origins, facilitate the water migration trough dangerous regions where its presence is a major handicap to building preservation and interior protection.

The water migration inside a wall is not only a cause for major alarm and concern due to the consequences for the existing materials but also because of the long time effect of salts dissolution and future crystallization in the outer layers of the walls that causes the premature degradation of the element (**Fig. 9** – Edificio do Café Barreiro, Barreiro).

All solutions based in mortar applications must be conveniently study and adapt considering the existing elements and materials in the walls. Also, modern composites namely hydraulic products, cement materials and non expansive solutions should carefully chosen or alternatively a lime based mortar with a limited portion of Portland cement can be applied with a limited risk for the existing walls. That is an option to each case as there is no universal solution for all historical buildings and monuments.

Fig. 9. Loss of paint due to imcompatibility of materials

However must be considered the execution of at least two layers, following the first consolidation (or in some cases reinforced) layer, with mortar compatible materials, preventing the migration of water, or in other cases, allowing water migration to the exterior of the wall.

Special care must be taken also with the use of modern water repellent painting systems that, as well as preventing the water passage to the inner layers of the walls, prevent the migration of the water vapour to the exterior, and, consequently became non adherent to the wall and fall after some time (**Fig. 10** – Edifício do Café Barreiro, Barreiro). In this case, lime based inks are preferably a better option for ancient walls because allow a certain hydraulic equilibrium in both sides of the element, exposed to climatic conditions.

4.2 – **Horizontal construction elements**

Horizontal construction elements formed with ceramic tiles or terraced floor tiles represent the principal problem in dealing with water access to buildings and monuments.

Fig.10. Salt migration for exterior

The singularities of the respective draining elements like pipes, gutters and all sorts of accessories related with water conduction to inferior levels of the building are a major concern in humidity prevention design and the solutions should be reached from the first sketches of the project until the final phase of construction.
Is therefore of great significance the rehabilitation of all the horizontal elements that support the draining systems, like trusses, ceiling beans or structural frames, because its deformation or collapse leads to water problems in the building and the future loss of the remaining elements (**Fig. 11** – Convento de São Francisco, Tomar).
There are some ways to prevent this problem and normally

involves the interposition of a water barrier material underneath the cover elements with no alteration of the final aspect of the building. These solutions are relatively easy to adjust to existing structures and modern water proof materials are generally of great quality in humidity prevention if all the actions concerning its maintenance are taken along the way (**Fig. 12, 13** – Convento de São

Fig. 11. Damage on structure due to infiltration

Francisco, Tomar).

Is also necessary to think of all the exterior parts of the building elements like chimneys, salient walls, ventilation pipes, joints between buildings or dilatation joints in which case special isolation elements and connections must be considered in water prevention systems.
Modern methods are based in water proof painting systems

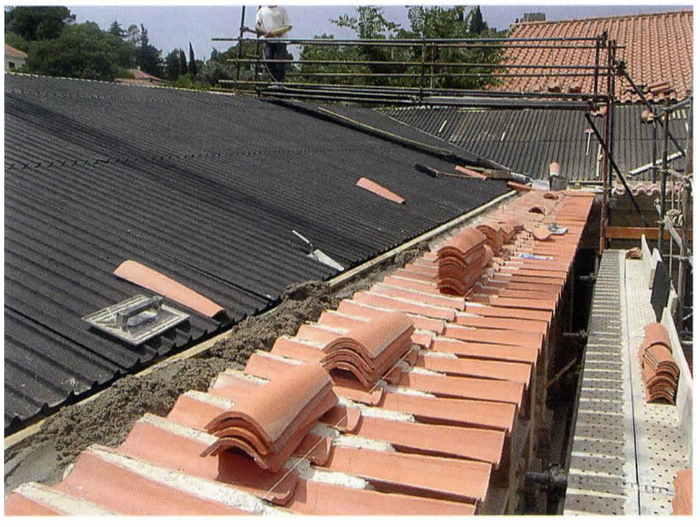


Fig. 12. Rain water protective elements

easily applied with normal brushes and other tolls in which a good adhesion is achieved with satisfactory results in rehabilitation programs.
Is interesting to compare the value of all water prevention systems with the loss of the building and its interior valuable pieces due to water damage or humidity related problems. Is a far better solution to prevent things to happen than to repair what went wrong in building design or maintenance.

Fig. 13. Rain water protective element

4.3 - **Window frames**

All the exterior elements in a façade are singular points in which humidity problems can occur if there is that possibility. Window frames in historical buildings represent a problem itself because its materials, like wood and iron, have some characteristics that change due to climatic exposition and that alteration can bring humidity problems to the interior of the building.

The major problems related with the presence of water in these elements are the attacks by insects or other bugs, in the case of wood, and the corrosion problems, in the case of iron. Both put a delicate problem in water prevention analysis because the maintenance of existing materials in exterior widows and doors of historical buildings, are generally imposed as a preliminary condition and so an easy method for its rehabilitation must be achieved.

Protective elements in monument windows and doors have obviously been subject to exterior actions along the life of the building and some importance due to that fact they had had. The substitution of these elements must made with identical materials and using the same techniques as the original ones. The intervention should be programmed to achieve a good integration of materials and building awareness because no other solution could be easily justifiable.
Generally is far cheaper to build identical new elements in a window and door frame rehabilitation program then to treat existing ones in site, even if the degradation is not prohibitively significant. The first question is to know whether treatment products and methodology are well tested in similar conservative processes, considering the risk of future degradation due to the same phenomena.

The second one is to evaluate the degradation level of the element and to compare between its integral substitution value and the restoration value with all the factors involved.

That can be achieved for a particular case not meaning that the same result can be achieved for a different one.

5 – **Humidity from damage installations**

Installations in historical buildings are not generally original due to the evolution of our necessities in the building fruition process. The number of different installations inside an existing monument is a consequence of the historical value of that monument as a cultural object and a signal of its importance for the visiting public.

One can assume the risk of a small water leakage in a fire security pipe system but obviously not the risk of loosing the monument because the fire security system inexistence. The same applies to bathroom water systems or draining pipe systems as mentioned before.

Another completely different problem is some existing systems that have suffered from bad interventions in previous alteration processes or pretence reparations with non adequate materials as mixing modern techniques with ancient concepts (**Fig. 14** – Teatro Nacional de São Carlos, Lisbon).
That is the case of modern materials like plastic tubes in hot water supply systems that need a considerable dilatation space when applied in existing walls which have not been devised to receive those elements. In this case, a special technical duct should be considered and all the systems easily placed there for conservation and maintenance purposes.

Fig. 14. Water suply pipes with leakes

The problems related with new installations or new supply systems should similarly be considered and all the materials carefully chosen to prevent future problems due to the presence of water sometimes in different places of the building.

6 – **Condensation humidity**

Humidity problems related with condensation phenomena are generally of great difficulty to solve and even, in cases where its occurrence is considered as natural, to assume as a problem.

Condensation derives of the fact that air, in contact with cold environments turn into water, damaging the support material that was supposed to stay dry. This is apparently easy to solve applying insulation materials on the walls or by heating the interior of the zones where this occurrence is significant. The problem derives of the fact that with any changes in the moisture degree of the place, for example in kitchens, bathrooms or rooms with great number or people, the dryness capacity of the interior air is easily achieved and all the remaining moisture turn into water, with the known consequences for the material surfaces (**Fig. 15** – Igreja de São Miguel, Lisbon).

Is also possible to ventilate the places where condensation problems are expect to happen, and allowing a certain amount of water to evaporate before its concentration is perceived or generate any damage. That is not always possible because monuments and traditional buildings are not usually easily adapted to modern ventilation systems.

Fig. 15. Efect of condensation water

Is this case, it must be considered small ventilation systems or strategically placed openings functioning according to convection laws and exploring existing air movements to permit a certain evaporation capacity and reducing the risk of condensations.

In the majority of situations, however, construction systems itself can accommodate the water level increase using exterior walls stiffness to allow a certain moisture

infiltration and adjusting ventilation conditions to climatic environment with air permeable doors and window frames, using traditional materials like iron or wood (**Fig. 16** – Universidade da Beira Interior, Covilhã). In this case, application of modern materials such as aluminium and PVC should be considered only in a limited scale.

Author:
José Gonçalves, Civil Engineer,
National Monument and Building Conservation Department
josegoncalves@drml.dgemn.pt

Fig. 16. Iron frame doors allowing some air penetration