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Deleting of rising damp in the archaeological site of Piazza Armerina through the application of the technology by neutralising electrical charge T.N.C.

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Abstract

The phenomenon of moisture by rising damp is among the major causes of deterioration of masonry and for it the technical literature sets out different types of consolidation among which the engineer evaluates the best approach to resolve the particular problem.

The choice for each building comes from the analysis of the condition of the sites, the system building - environmental conditions and materials that compose the wall texture. The definition of the intervention is then strongly influenced by the historical and artistic value of the building on which you operate: in the event of buildings with historical and artistic value and decorated surfaces it would be unthinkable operate using conventional mechanical work, chemical or evaporative that are incompatibly invasive.

In these conditions the scientific research is testing innovative approaches by application of the "Technology by neutralizing electrical charge " (T.N.C) that offers two benefits: it preserves precious surfaces and, unlike traditional methods, eliminates the phenomenon at the origin regardless of the variables related to the characteristics of materials. The T.N.C., in fact, acts only on the water introducing an electromagnetic field able to neutralize the electrical potential of the flow inside the masonry, eliminating the action of rising damp.

The article analyzes the application case concerning the adoption of the T.N.C. in the archaeological site of Piazza Armerina in Enna, Sicily.

Keywords: Historical Heritage – Rising Damp – Capillary action - Restoration – Charge Neutralization

1. The phenomenon of rising dump moisture

In the context of interventions on the existing buildings with bearing walls structure, it is frequent to find pathologies of degradation related to the phenomenon of rising dump, which is produced by the interaction between the quantity of water present in the foundation soils, or however in contact with the masonry, and the porosity of the stone elements that compose the masonry textures.

The porosity represents the physical characteristic of the stones which is expressed as the ratio between the volume of voids and the total volume and determine their ability to absorb water from the subsoil and to transport it inside the voids by capillary action. It is known that a higher porosity of the stone improves the characteristics of thermal and acoustic insulation thanks to the low heat conductivity of air with values equal to about 0,026W / MK; however, when as a result of capillary water occupies the voids of the stone elements increasing the degree of saturation, there is a significant loss of these characteristics as well as mechanical strength of the blocks masonry.

The rising dump phenomenon is determined, according to the law of Jurin, by the surface tension and size of the stone pores that allow the water, rich in salts, to penetrate into the stone and to be traced back to molecular attraction effect.

After reaching the maximum ascent height, which is a function of the forces of attraction carried out on the fluid by surface tension of the pores, the water migrates outwards for evaporation and depositing

salts contained in it inside the pores. The crystallization of the salts following the evaporation occurs with an increase in volume that produces a stress state inside the blocks masonry with detachment of the protective layers and loss of strength characteristics.

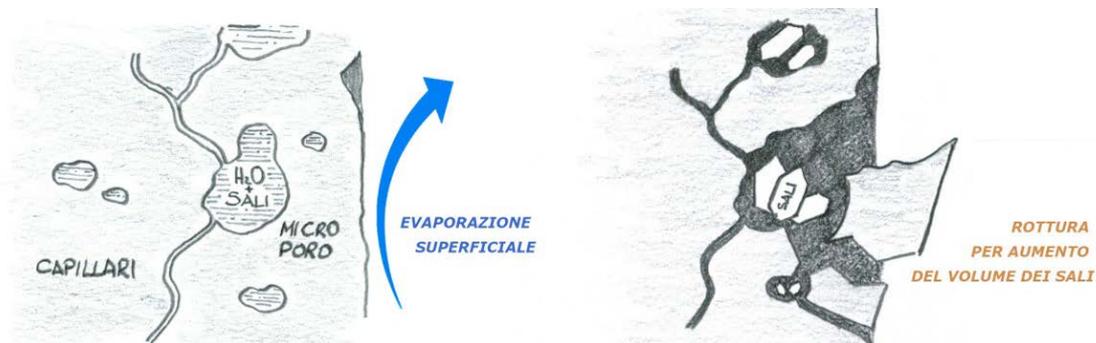


Fig. 1: Deposit of salts in the pores

2. Types of intervention

In order to determine the most valid restoration methods of masonry affected by rising damp is necessary to make the characterization of the building by acquiring a high knowledge of materials, use of building, interaction with the external environment and of more or less important degradation phenomena: the diagnosis phase is the most delicate because a bad analysis of the primary factors can lead to the wrong choice of intervention methods thus worsening rather than solving degradation. Taking a quick glance between traditional interventions suggested from common practice, we can identify:

Mechanical interventions which provide a mechanical cutting and sometimes the removal of material from the wall structure to reduce the contact with the soil or to interpose a layer of waterproof material. Among the best known are the "Koch Method", the "unstitch and stitch" and the mechanical cutting with introduction of stone, metallic or waterproof elements to stop the capillary rise.

Chemical interventions by which we put inside the masonry chemical substances with hydrophobic effect able to occlude the pores and reduce the surface tension of the stone providing a barrier to water ski. The chemical interventions are distinguished, depending on the technique of execution, in "impregnation at slow infusion" and "low injection pressure".

Evaporative interventions that are based on dehumidification of masonry structures due to the increase of the evaporating surface. This type of intervention may be realized through the use of siphons and drains carefully arranged inside the masonry or of macro-porous plasters that improve the volumetric capacity of the porous system by increasing the evaporation surface and delaying the formation of internal stresses following the crystallization of the salts.

Electric interventions that act on the natural electric fields which are activated as a result of the potential difference between the construction materials and the ground. The first interventions of the electric type are based on the principle of electro osmosis: a conductive fluid (water) moves in a porous vehicle under the action of an electric field, from the positive pole (anode) to the negative (cathode). The methods of intervention are therefore been devised in order to cancel the potential difference which determines the water ski or to introduce an external electric field that could reverse the trend. This category includes the active and passive electro-osmosis, the phoresis electro-osmosis and the most modern technology of **Neutralization Charge T.N.C.**

The most suitable choice of restoration depends, as already said, by the specific conditions of the case. However, there are some thoughts that have helped overcome some of the exposed methods.

The intervention with Koch's method, for example, is based on the assumption that the absorption of a masonry is directly proportional to the contact surface between it and the water table and therefore suggests to act by reducing the continuous section of the masonry and replacing with arched structures. The application of the method, however, has shown that the intervention does not affect the quantity of water that is absorbed by the masonry but only on the speed of ascent: the specimens tested in fact have all reached the same level of ascent, although at different times.

The mechanical cutting methods with introduction of waterproof elements don't eliminate the causes of the rise but are aimed only to the realization of a barrier that doesn't allow the water to ascend the layers above but sacrifices those below, determining the consequent reduction of the strength characteristics. Moreover, the realization of a continuous cut at the base of the masonry has a negative effect on dynamic behavior of buildings in seismic zones.

The chemical interventions realize a barrier which unlike the mechanical cutting doesn't affect the static of masonry but similarly to the previous method produces an accumulation of water in the layers below.

Even the evaporative interventions don't act on the absorption of water from the soil, but substantially favor the exchange to the outside, probably also fueling the rise. Furthermore the efficacy of the method depends on the correct placing of the macro-porous plasters and thermo-hygrometric environmental regime, and therefore don't constitute universal methods of intervention.

The limit of the electrical work instead lies in the variability of the factors related to the masonry, the characteristics of the materials that compose the wall structure, the concentration of salts in the water and the degree of humidity, which alter the value of the natural electric potential. Furthermore, the operation is greatly influenced by stray currents in the subsoil. However electrical work paved the way for the development of techniques that intervene on the cause of rising damp from the soil in order to effectively promote a recovery intervention of damp walls. Scientific research has developed an innovative system called "TNC" that intervenes exclusively on the behavior of the water molecule in the natural electric field, excluding the dependence on other factors and establishing the efficacy of intervention, influenced only by chemical and electrical characteristics of water.

3. Intervention on architectonic heritage

The correct choice of the recovery method is even more important when we are working on historical buildings restrictions because it is strongly conditioned by the artistic value of the structures.

In case of decorated surfaces, finishes and masonry with high documentary value, we may rightly exclude all the mechanical interventions involving the removal of material and, in the case of insertion of waterproof barriers, the use of new elements that are incompatible with the original structures.

In the chemical interventions similarly we introduce new materials that interact with the natural stone in order to create a barrier to water rise. In this case the impregnation or injection of the chemical products, which penetrates moving within the capillaries of the stone, determine two unknowns on the result of the intervention: the first relating to the composition of the compound and its interaction with the original materials (stones, mortars and finishes); the other related to the porous structure of the masonry that could lead to accidental impregnation of decorative surfaces, altering the aesthetic and formal characteristics.

Furthermore, after what has been observed, it is clear that both the mechanical and chemical methods don't possess the characteristics of reversibility, recognizability and minimum intervention required to the restoration and therefore cannot be considered in these particular conditions.

The evaporative interventions, however, involve the replacement of entire portions of finishes with macro-porous material. The application of the method is not plausible, because the good practices of restoration of buildings with historical and architectural interest require in each case, the maintenance of the originating materials providing, wherever possible, the consolidation of the existing plaster in place of remaking.

It is evident that the only rehabilitation methods we can apply in these cases are electrical one and among them the innovative "technology of charge neutralization" (TNC), which, as shown by the large experimental campaigns, provides a high level of performance and eliminates the interference with the wall structure, preserving the valuable surfaces and, unlike traditional methods, eliminating the phenomenon at the origin regardless of the variables related to the characteristics of the materials.

4. The technology of charge neutralization T.N.C.

This technology is aimed to eliminate causes of rising damp phenomenon by an intervention that doesn't depend from the type of material, the wall structure, the thermo-hygrometric conditions and the amount of water and salts in the masonry.

The scientific study in support of this method is based on the analysis of the movement of water inside ducts of the wall capillaries and of the factors that influence it: in addition to the action carried out by the surface tension and evaporation the moving of water is strictly influenced by the negative

electrostatic potential that is established, in a natural way, on the inner walls of the capillaries, called "Helmholtz double layer".

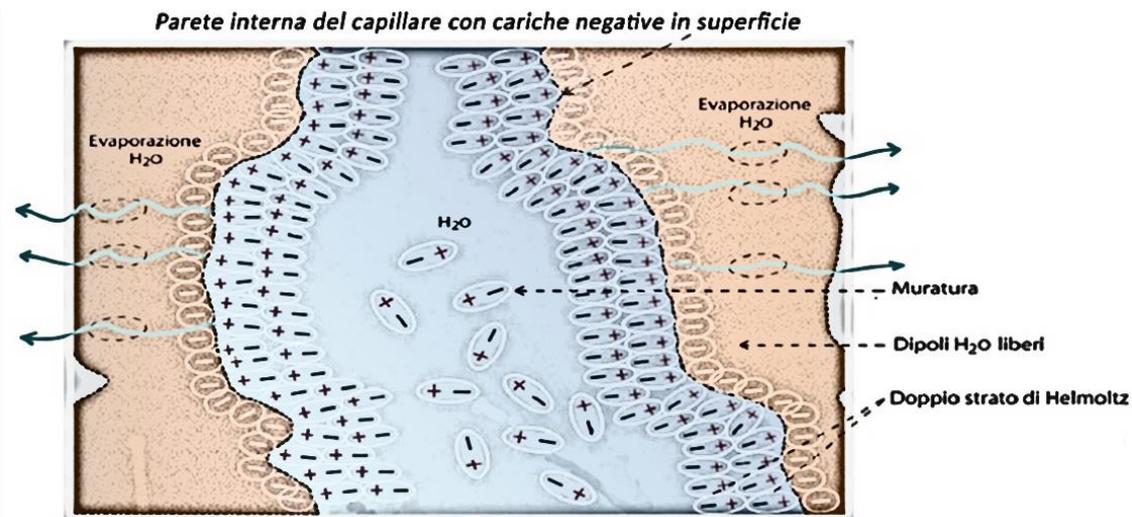


Fig. 2: Schematic representation of the "Helmholtz double layer"

To better understand the mentioned effect we must observe the structure of the materials that compose the masonry to the microscopic scale: most of building materials are characterized by a structure containing silica, a component with a negative electric potential which confers to the inner surfaces of the capillaries the property of attracting water molecules (dipoles): through the electrostatic action carried out dipoles orient themselves with the positive side toward the inner surface of the capillary, configuring a "double layer" defined "Helmholtz double layer".

The capillary phenomenon of the rise and the evaporation of the water in correspondence of the wall surface of produce a movement of Helmholtz layer from which it generates a weak electrical differential potential between the soil and the wall with values that vary depending on the rise intensity by 10 ÷ 20 mV (in the case of weak or absent rise) up to 300 ÷ 500 mV (very strong rise).

This evidence shows that the capillary phenomenon is governed by the action of tiny forces of electrical nature.

The technology of charge neutralization T.N.C., therefore, aims to intervene directly on the electrical forces at the origin of the ascent. Such system, having to fight only tiny forces, has much less expensive, in terms of energy, compared to any other traditional system.

The scientific principle behind the method, which aims to eliminate the phenomenon of capillary rise, is based on the application of electro-capillary physical phenomena analyzed in the context of experimental studies of nano-technologies performed by Universities and international Research Institutes since the early 2000s.

In accordance with such experimental studies it is possible to apply an external electromagnetic field to induce changes in the distribution of electric charges at the interface between a conductive liquid (for example a saline solution) and a solid surface (for example an internal wall of a micro capillary). From the physical point of view this effect offers the opportunity to change the flow of the liquid inside the capillary.

The described technology can be easily applied using the devices T.N.C. Domodry® of Leonardo Solutions that represent the weak electromagnetic waves pulse generators capable of neutralizing the electrical potential differential of the capillary flow inside the masonry. The waves produced are suitably modulated in order to be harmless to the human organism.

In simple way we can therefore assert that the T.N.C. can neutralize the water molecules canceling the attraction that the capillaries of the masonry exert because of difference in charge.

The Domodry® device consists of a unit of 28x17x6cm size that is placed inside the building and connected to an electrical outlet. Once in operation it inhibits the capillarity phenomenon, interrupting the ascent of water and neutralizing the water content already present in the masonry which is

gradually kicked out through spontaneous evaporation with variable speed depending on the construction characteristics of the wall, the amount of water initially present and the climatic conditions of the place. At the end of the dehumidification will be enough continue to operate the T.N.C. installation to ensure the maintenance permanently of the equilibrium state (natural hygroscopic damp) reached from the masonry.

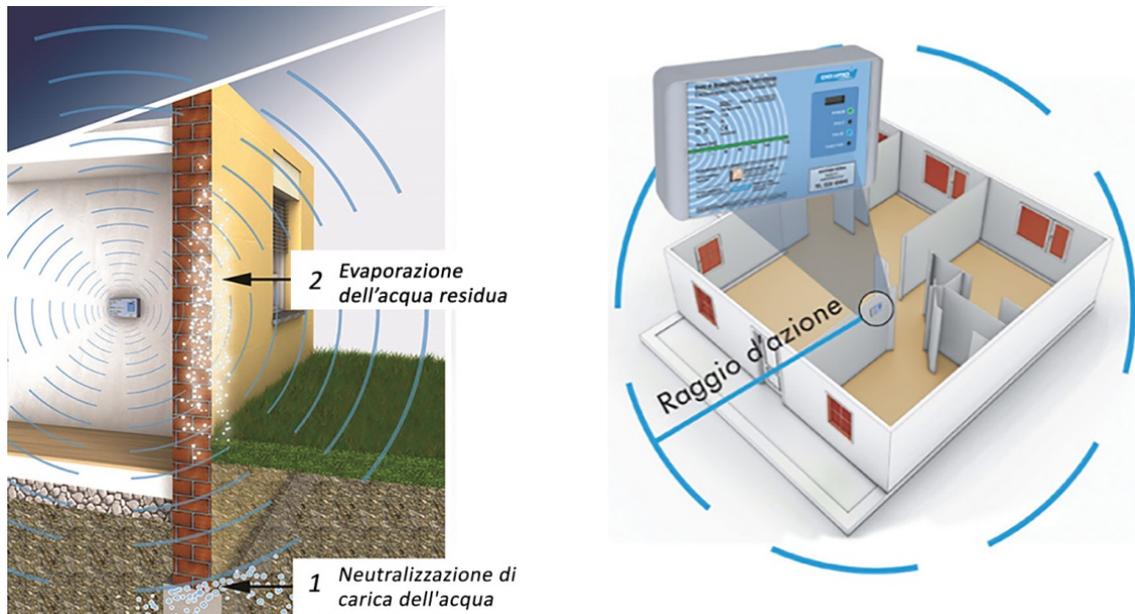


Fig. 3: Working principle of T.N.C. Domodry®

The Domodry® devices act in a spherical action field with variable radius - in relation to the device model - from a minimum of 6m up to a maximum of 15m, ensuring the dehumidification of all the structures (walls, partitions, floors, etc.).

The pulses generated from the device are far less than those with a normal household appliance and therefore are totally harmless to people and animals. This characteristic has allowed to obtain for the device the certification of "bio-built".

The charge neutralization system Domodry® stands for maximum versatility, thanks to the possibility to adapt to buildings of any type and size, and for minimal invasiveness that make it an optimal method of intervention in the conservation of historical and artistic heritage.

5. The case of archaeological site of Piazza Armerina

In order to determine the efficiency of the charge-neutralization technology, Leonardo Solutions has implemented various installations, in collaboration with University and other institutions, for the collection of experimental data that have been evaluated by analyzing the changes of the water content in the masonry in the course of time in different areas subject to the action of the system.

The experiments were conducted in buildings very different both for materials and construction techniques both for the historical and architectural value.

To verify the efficacy of the innovative technology and the complete lack of invasiveness of the method in the context of the architectural heritage, an experiment was carried out by the installation of charge-neutralizing devices in the ruins of the "Villa Romana del Casale" Piazza Armerina (Enna, Sicily).

The Villa, considered an example of representation mansion of the Roman period, became part of the World Heritage Site of Unesco since 1997.

According to some experts, the structure was built in the late imperial period by the will of a Roman governor or probably commissioned by the Emperor himself. To increase the value of the building there are polychrome mosaics whose construction is attributed to African mosaic workers and the rich collection of wall paintings that decorated the exterior and the interior of the residence environments.

The architecture is developed with three main bodies that are oriented each according to its own axis around the large rectangular room with peristyle and the central basin.



Fig. 4: Photo from the archive of the Regional Museum of the Villa Romana del Casale in Piazza Armerina. Author: Mario Noto



Fig. 5: Central peristyle discovered with the excavations led in the '50s

Archaeological excavations of the Villa were performed since the 30s of the twentieth century, on the basis of the survey conducted at the beginning of the previous century that had led to light part of the ruins and mosaic floors.

After World War II, thanks to the actions financed by the Sicilian Region and the “Cassa del Mezzogiorno”, almost all archaeological works have been completed.

The great discoveries led under the direction of Gino Vinicio Gentili were followed by the competition for the design of the new covers. The winning project, by the architect Franco Minissi, involved the construction of steel structures with closings in plastic slabs. This solution caused an alteration of temperature and humidity conditions on the wall faces helping create of rising damp phenomena that have caused a serious deterioration of the mosaic carpet.

During the modern excavations promoted by the University La Sapienza of Rome, the Museum of the Villa del Casale and the Commission for the Architectural and Landscape Heritage of Enna, have been found more remains of an ancient village of the Middle Ages in the south of the archaeological site area.

View to achieving the consolidation of masonry structures the Villa has been subject to a testing campaign Domodry® installed in December 2012.

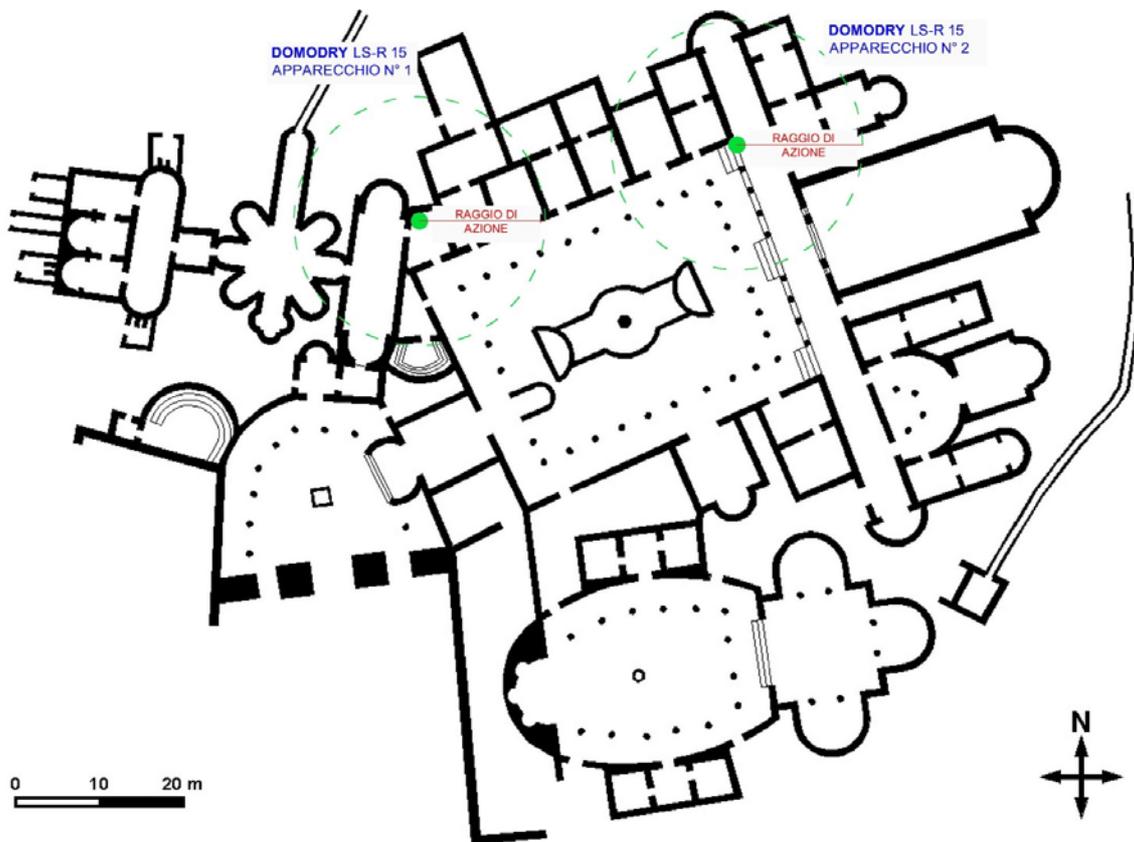


Fig. 6: Installation diagram of the devices

The evaluation of the results was performed using the following survey methodology:

- Measuring of water content in the walls, carried out with the method given by the UNI 11085;
- IR thermographic mapping of the internal surfaces of the building

Measurements were repeated in three sessions for each installation:

1. The first during the installation of the system;
2. The second during the drying step;
3. The third at the end of it

The first device was installed at the Circus Salon or Gymnasium.



Fig. 7: Installation of the first device

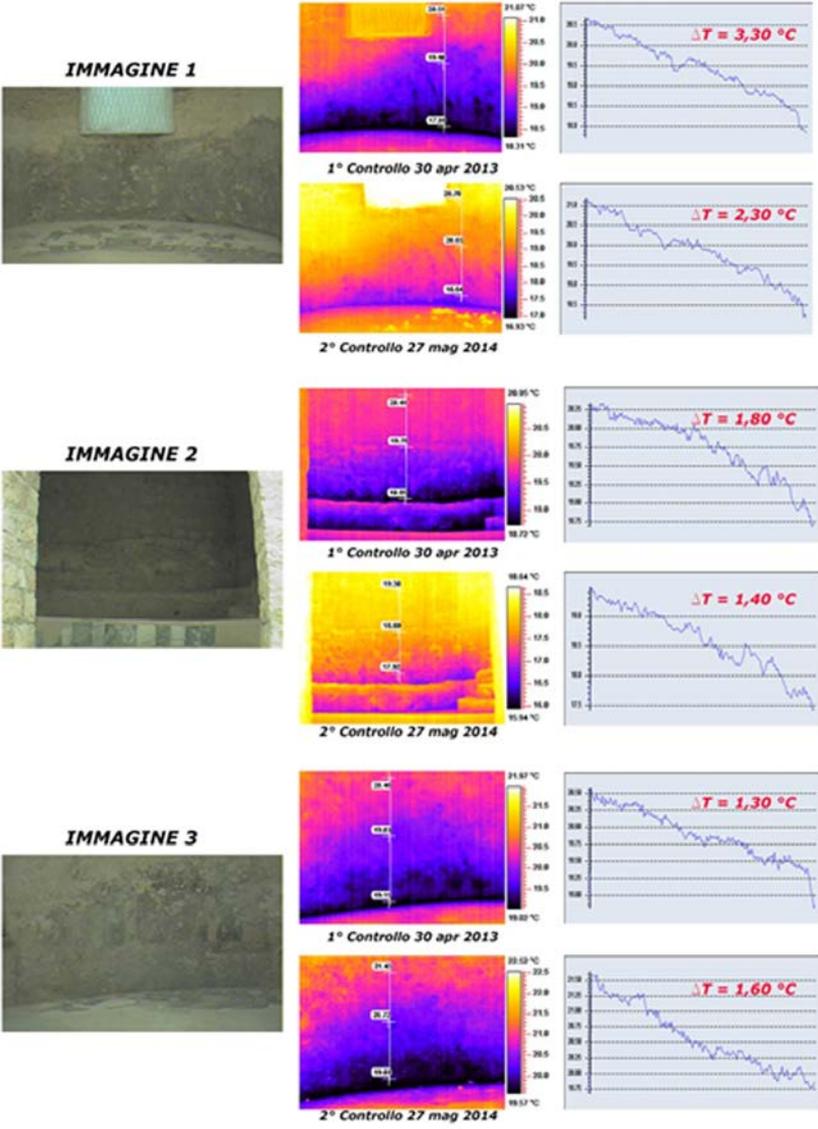


Fig. 8: Measurements repeated in three sessions

The second device was installed at the rooms in the north of the large rectangular peristyle.

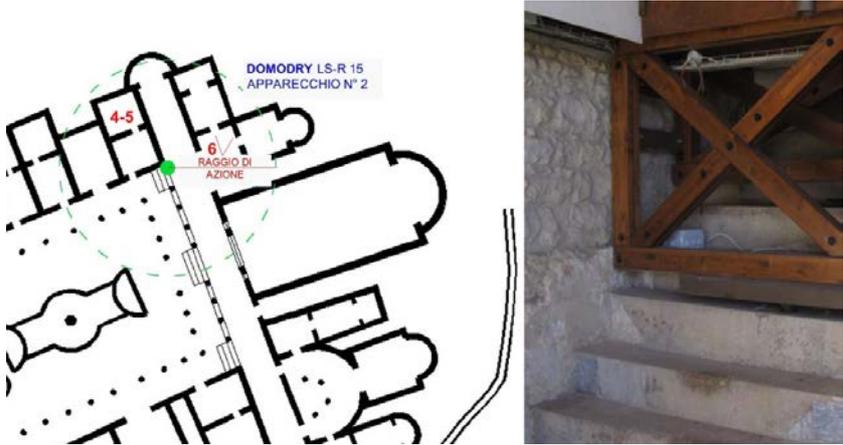


Fig. 9: Installation of the second device

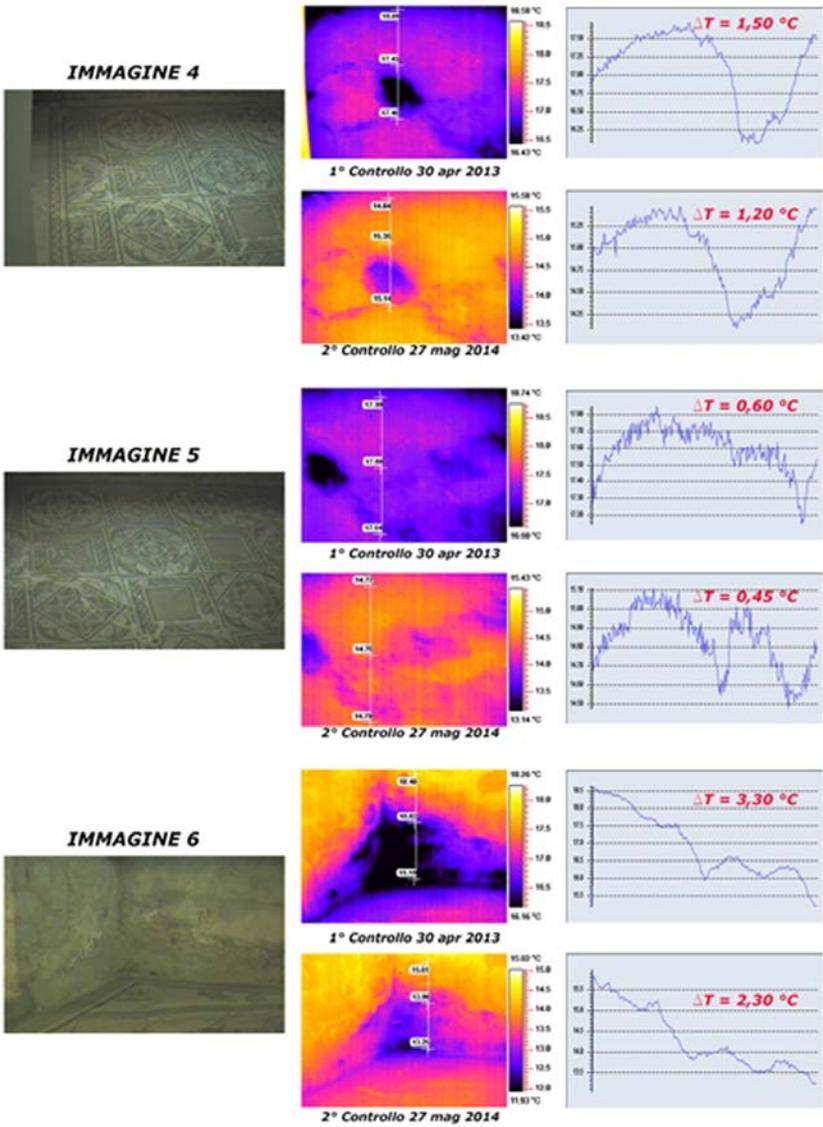


Fig. 10: Measurements repeated in three sessions

Through the comparison of the data provided by measuring of water content with thermographic images of the masonry section, it has been possible define the parameters to extrapolate a good approximation of the value of water content in portions of masonry not directly investigated, comparing the relative thermal images, so as to appropriately limit the number of invasive samples.

In addition on some of the samples taken in the first measurement session, it was determined the content of soluble salts by ionic chromatography, in order to evaluate the extent and the status of the masonry degradation.

The Architect Rosa Oliva, Director of the Regional Museum of the Villa Romana del Casale in Piazza Armerina, has checked that the surveys carried out on site during the first two years after activation of dry out damp masonry indicate positive results in terms of reduction of the initial content of water in the masonry.

The thermographic analysis of last May 2015, made about two and half years after the Domodry® system installation of , confirmed that the capillary phenomenon was shut down in all areas covered by the action of devices, and also revealed a drastic reduction of the pre-existing masonry damp, both at the level of the floor mosaics, both mainly of masonry walls.

Thanks to the excellent results obtained the Museum Management is determined to extend the installation of devices in total archaeological monument area.

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