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ScienceDirect

Energy Procedia 76 (2015) 40 – 48

Energy Procedia

European Geosciences Union General Assembly 2015, EGU

Division Energy, Resources & Environment, ERE

Thermographic mapping of a complex vernacular settlement: the case study of Casalnuovo District within the Sassi of Matera (Italy)

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Abstract

The research focuses on an abandoned area within the Casalnuovo District, situated in the south of the city, probably the place of the future Demoethnoanthropological Museum. It is known today that the particular shape of the area is made up of settlements mainly in cave.
Since the evaluation of the historical buildings conservation state using destructive techniques should be avoided to prevent the integrity of the cultural heritage, the development of non-destructive techniques is very important. For this reason, an appropriate cognitive apparatus has been set up for the entire technical process, first of all making use of infrared thermography.

Peer-review under responsibility of the GFZ German Research Centre for Geosciences

Keywords: survey; preservation; historic heritage; non-destructive techniques; energy evaluation

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Peer-review under responsibility of the GFZ German Research Centre for Geosciences
doi:10.1016/j.egypro.2015.07.840

1. Introduction

Small communities like Matera survived in extreme situations by practicing accurate methods of resources proper management, behaviors and forms of subsistence, assimilating different skills and worldviews.

At the outskirts of the great empires, they developed and spread local knowledge and were centers of technological, social and spiritual innovation. Facing difficult situations, they allowed the construction of exchange and communications networks, the knowledge and cultures transmission, facilitating the spread of new ideas and techniques. The cities, according to the different available materials, earth, wood or stone, have in common the use of the places whose essence is not development and unlimited growth, but slow and gradual adaptation [1].

In the Lucan city there have been favorable and stable conditions that have allowed the development of an architectural language, juxtaposition of materials, spaces interpenetration and volumes conformation, thus creating a unique urban phenomenon (figs.1,2). The distribution of similar building artifacts in symbiotic unity with the connective texture of limestone, led to a spontaneous figurative harmonious balance between man and nature that characterizes the building and the distribution techniques and morphological solutions [2].

Fig. 1. The left limit of the Casalnuovo District

Fig. 2. A typical part of the Casalnuovo District

2. The sustainable regeneration of the historical heritage

The rising cost of fossil fuels, climate change and the disruption of the natural balance, have clearly demonstrated the need to act on several fronts, to put in place a process of sustainable development. The involvement in that sense of the architectural heritage is derived from the analysis of energy consumption, which has shown that the current conditions of the buildings allow wide margins for improvement. Regulations on energy, in continuous evolution, have become more and more stringent in recent years.

In a scenario like the one of Matera, you have to develop a strategy that attempts to combine the needs of the architectural heritage protection with the efficiency and thermal comfort standards. To this end, the study of the potential and performance of the historic artifacts in terms of the spatial configuration and environmental compatibility, in addition to the thermographic survey, useful for diagnosis of diseases and the casing deterioration, and to the steady-state and dynamic simulations, it is essential to develop a hypothesis of material, technological and energy regeneration of the area.

A very important issue, linked to the relationship between building and environment, concerns in Europe - but not only - just the recovery of existing buildings.

According to data by CRESME [3], at the beginning of this millennium, the recovery involved, with 124.037 billion, 42.7% of building production, while the only ordinary maintenance concerned, with 50.53 billion, 17.4%. In total, recovery in the broad sense constituted the 60.1% of the total market. It is expected today the continued growth of the sector, reaching almost 80% in 2020. The issue of improving performance - especially energy - plays an important part in this sector in strong expansion, supported in recent years by fiscal incentives.

If you take into consideration the Italian situation - but the same thing could be extended to other international contexts - the building heritage, built from scratch in the second half of the twentieth century, it is a large part of the total housing stock.

During their functioning life these buildings consume energy - mainly in terms of fuel for air conditioning - in quantities that would decrease considerably with energy improvements interventions. A few years ago the average energy needs of Italian buildings was almost 300 kWh/m^2 per year, compared with 200 in Germany and 60 in Sweden. Now, after the recent normative predispositions this quantity has dropped, but still about 30% of the final energy consumed in Italy comes from buildings and these energy consumptions are responsible for 28% of CO_2 national emissions.

In particular, with regard to the field of study of this work, it is useful to highlight how the attention to face and try to solve the enormous current environmental issues, find a prominent place in the important communication from the Commission on Thematic Strategy on the Urban Environment, in which sustainable building is identified as one of the four fundamental pillars of the European Public Administrations sustainability policies and also how, as we can read in the Third European Ministerial Conference on sustainable housing, it is necessary make existing buildings more sustainable, by retrofitting or renovation according to sustainability criteria. Improving the energy efficiency of existing buildings is one of the systems with the best ratio cost / performance in order to meet the commitments assumed under the Kyoto Protocol adopted in the field of climate change.

The adaptation of the old building stock by insulation works could reduce CO_2 emissions from buildings and related energy costs by 42-46%.

The renovation is more complex than the construction of new buildings, because different solutions depending on the buildings are necessary, and it is even more complex in the case of property subject to protection, but the sustainable renovation has several environmental advantages over demolition and reconstruction, such as the conservation of energy and materials already present. In addition, the renovation and regeneration of historic buildings and areas contribute to create in local communities a sense of pride and awareness of their heritage.

Since the EU Directive of 2002 on the energy use in buildings (2002/91/EC) we have reached even in Italy the development of intervention methods more careful to the reduction of energy consumption and to the mandatory certification of buildings energy performance.

The issue of how to combine sustainability and historical buildings so was finally felt as fundamental and, with the intent to promote the energy efficient use in the Cultural Heritage, the MiBACT (Ministry of Heritage and Culture and Tourism) is in the process of issuing National guidelines on the subject, thanks to the collaboration with the AiCARR (Italian Association for Air Conditioning Heating and Refrigeration).

It is therefore sought to identify consistent and correct methods of intervention to improve energy performances, in combination with environmental ones, all in accordance with the sustainable principles both in terms of materials quality, healthy environments, attention to a proper use of natural resources (water, soil, raw materials, etc.), both of historical and artistic heritage in terms of material compatibility, less invasive interventions and applied technologies, compliance with the conservation criteria, etc.

Primary and fundamental element of this excursus was to put as the basis of the action choices on historic constructions in terms of energy and environmental performance, a new, complex and innovative methodological approach, able to combine conservative respect with a unified and synergetic vision of the historic building structure in its relations with the natural, man-made suburban or urban surrounding.

3. The energy monitoring and the evaluation of thermal, physical and chemical conditions

Specifically about the heritage object of this work, the most delicate and difficult case is clearly the extreme one concerning situations of decay and neglect.

This is the case of the area 22 of Casalnuovo District, which subsequently to the displacement of the inhabitants, within a few years, has seen triggering a series of terminal events: infiltration of water from the roof surface, collapse of the roof structures, involvement of the vertical structures until its transformation into a ruin.

This case histories actually unfortunately concerns large areas of the national territory and raises dramatic problems about the possibility of permanence of a “minor” heritage but that in many cases, primarily as Matera, presents characteristics of material culture and great historic and symbolic significance and that we have to completely recover by adapting the housing typologies to contemporary standards of habitability, health and hygiene.

We are just in front to an urban context of great historical value, which has taken a suggestive aspect, constituted precisely not only by monumental buildings, but especially by artifacts of “minor” constructions that can be treated as decorative elements of a great facade represented by the Sassi context: any work on these buildings will have to be aimed at the protection of the unicum represented by the ancient districts [4].

It should be recalled that the study of artistic, historic, archaeological, architectural and environmental emergencies, is the prerequisite necessary for all forms of heritage programming and protection in the territory.

For this reason the thermal mapping of the site, through the survey of quantitative data, regarding the temperature, and qualitative data, about the humidity, was used to develop a valuable framework concerning the chemical-physical and biological degradation of the dwellings in the Sassi area.

Thermography is a technique of analysis that allows rapid identification of defects; for an accurate mapping it can be integrated by means of other methods such as the thermal anemometer for measuring the air velocity entering from the joints, the blower door test that verify the air tightness, by artificially causing a pressure jump through the casing, and the thermohygrometer for the relative air humidity and temperature.

In particular, the term thermal mapping means a process of monitoring and capture of the buildings thermal anomalies through the use of infrared digital sensors (thermography), aimed at defining judgments about the building envelope quality and related energy losses [5].

With the outdoor thermographic survey campaign, the radiations in the infrared range emitted by buildings are recorded; then, on the basis of these and surfaces emissivity, temperatures are calculated and represented in a scale of “false color”. The final product of the processing performed by thermal camera depends on the distance between the object to be detected and the camera itself and on the angle of the instrument focal length. Thus we have worked in a different way inside and outside of the historic artifacts.

For the indoor thermographic survey we acquired salient excerpts of the walls, representative of the state of surfaces conservation; for the outdoor thermographic survey, instead we had to perform a lot of photo shots, and therefore different thermal infrared images.

Logically, this also influences the image spatial resolution (the shorter the distance, the greater the spatial resolution).

From an instrumental point of view the images were taken using the same thermal imaging camera, for both the exterior and interior, that is an infrared camera Fluke Ti32 model with FPA (Focal Plane Array) micro bolometer detector operating in the long wave spectral band between 8 and 14 microns. As regards the spatial resolution of the acquisition system, the FPA is equipped with a matrix of sensitive elements of dimensions 320 (H) x 240 (V) with a view field of 23.0 °(H) x 17.0 °(V) and is capable of producing a minimum thermal resolution less than or equal to 0.45 °C with a precision of the measured temperature equal to ± 2 °C in the temperature range comprised within 100 °C (the measurable temperature range is between -20 °C and 600 °C).

An acquisition system of this kind offers, in addition to a remarkable handiness, a spatial resolution that allows to investigate an area of size 314 x 309 mm at a shooting distance of 250 m.

From a methodological point of view the images were taken using the solar source as thermal stimulus analyzing qualitatively the transitory that passively is created inside the wall thanks to the combined effect of solar radiation and spontaneous thermal-physical processes affecting the frontier of the historic artifacts (fig.3).

Another very important thing to note is that it is not possible to modify the machine focus, and then in case of blurred photos it is necessary to repeat the analysis.

It is also necessary to underline that the acquired thermogram refers to a very specific moment and represents the thermal response of the building exclusively linked to the acquisition time.

Inside certain problems do not arise and we therefore more easily proceeded through a thermographic survey of the surfaces with the same thermal camera, but we found great difficulty in simultaneous acquisition of the images in the infrared and visible field, because of the poor lighting conditions. The thermal images were then subjected to a similar process of post-production, but it was not necessary to resort to operations of photos mosaicking [6].

The results of the analysis (figs.4-9) show that the internal temperatures are constant and are around 16-17 °C, while the relative humidity is around 80%: limit conditions which obviously may lead to a distorted interpretation of the data.

In any case it is absolutely clear that there are several reasons that lead to the formation of humidity inside such environments, with situations that present contextually an overlap of different types. The moisture therefore, due to infiltration or condensation or capillary rise, seems to interest in a widespread and uniform way all the masonry walls, with some points certainly more damaged than others. There are many thermal bridges, associated with change of the material that exists between the facade and the excavated part of the house and with the inclusion of posthumous dividing walls.

The most evident disease is the alveolization caused by the internal circulation of moisture and from its evaporation from the stone surface, which determines the crystallization of soluble salts contained in it.

Another phenomenon of degradation is the washing away of the stone caused by the rain water, slightly acidic, which, dissolving the calcium carbonate, causes an increase of the surface porosity.

The repaired surfaces (so we refer to the internal ones) are subject, however, to the night condensation that, depositing the suspended particulate in the air, produces black crusts.

The gray-black color is due to the prevailing microbiological alteration; a phenomenon which affects above all the surfaces exposed to the north. The most common micro-organisms are the “blue algae”: in addition to these, in many cases, there is also the development of lichens, and these two factors, together, may constitute an important cause of degradation of the finishing. surface layers

The data obtained from the research and the study of the buildings surfaces allowed to make some observations on the facades maintenance over time:

- they were rarely left without surface protection;
- the surface finishing was made with a very thin plaster called “scialbo” or with a finishing plaster coat of 2-3 mm thickness;
- the materials used for finishing were lime and “tufina” with, sometimes, brick dust;
- the lime application can delay the resumption of the attack of algae after cleaning;
- the maintenance system based on layers of finishing plaster coat or lime can only delay, and not prevent, the process of alveolization, absorbing phenomenon of crystallization of the salts, with progressive disintegration;
- a slowdown in the alveolization process can be achieved by filling the cavity with a porous material (brick or tufa stone) tied with lime mortar.

Fig. 3. (a), (b) Some moments of the thermografic survey.

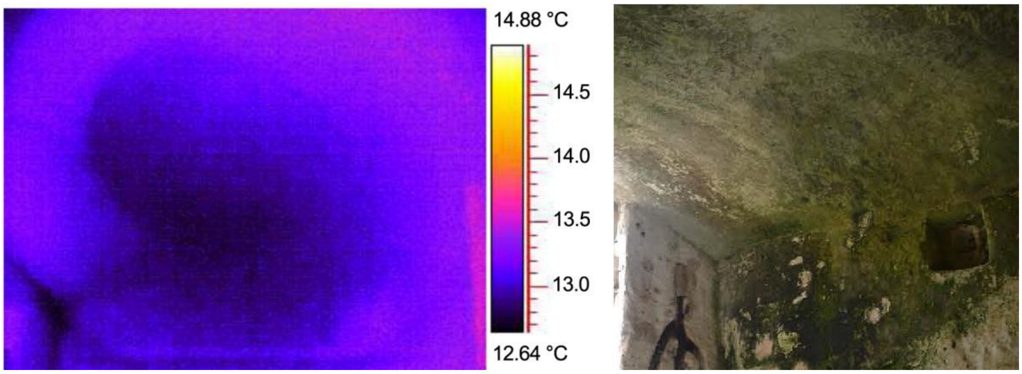

Fig. 4. Presence of moisture due to infiltration.

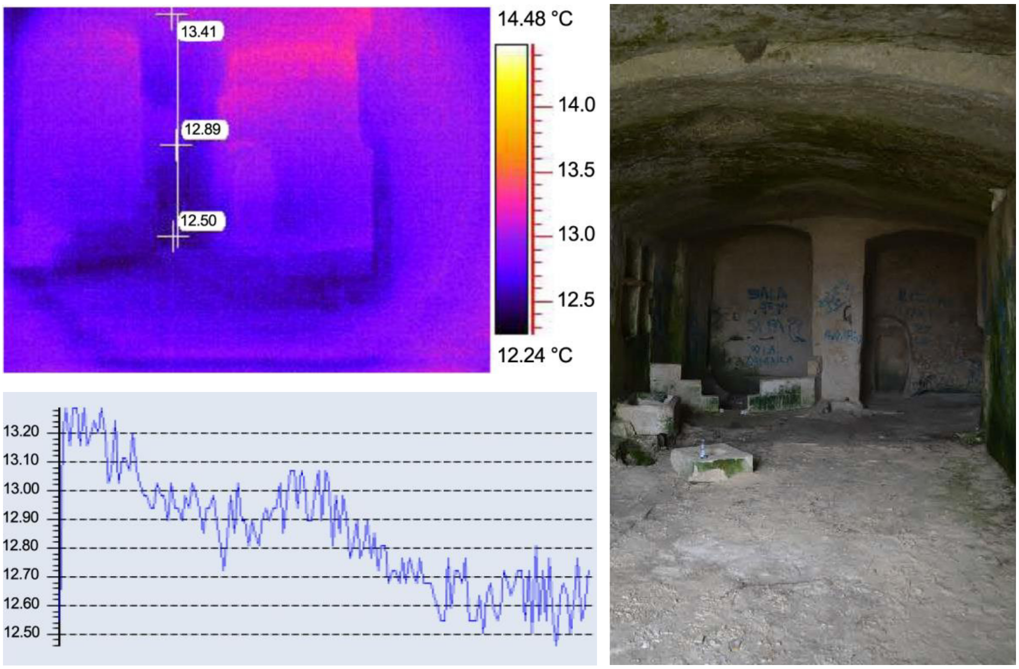

Fig. 5. Presence of moisture due to capillary rise with a temperature gradient equal to 0.7 °C.

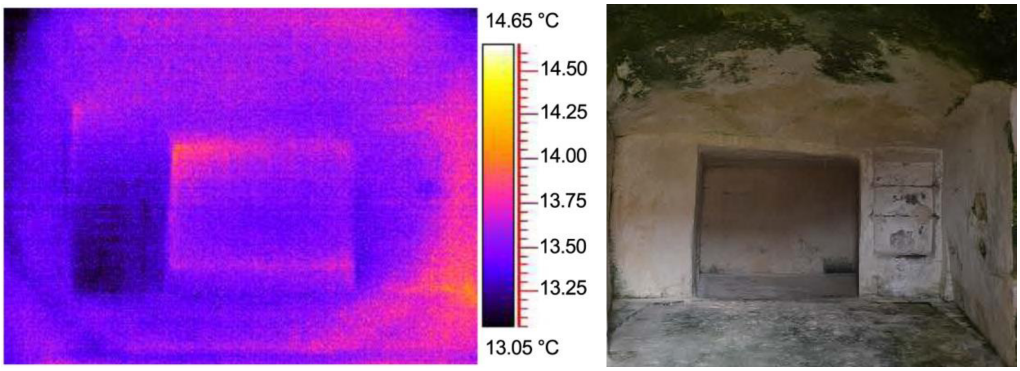

Fig. 6. Presence of moisture due to condensation.

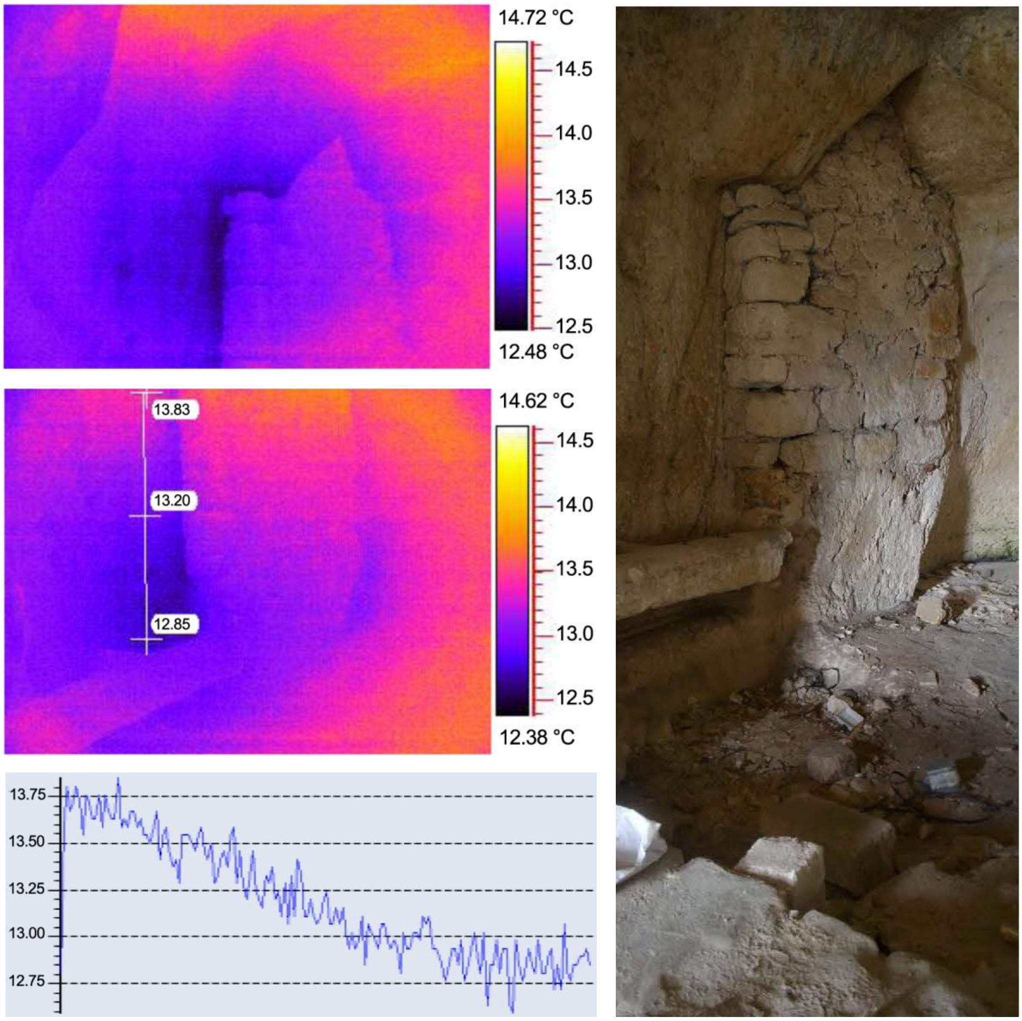

Fig. 7. Presence of moisture due to capillary rise with a temperature gradient equal to 1 °C.

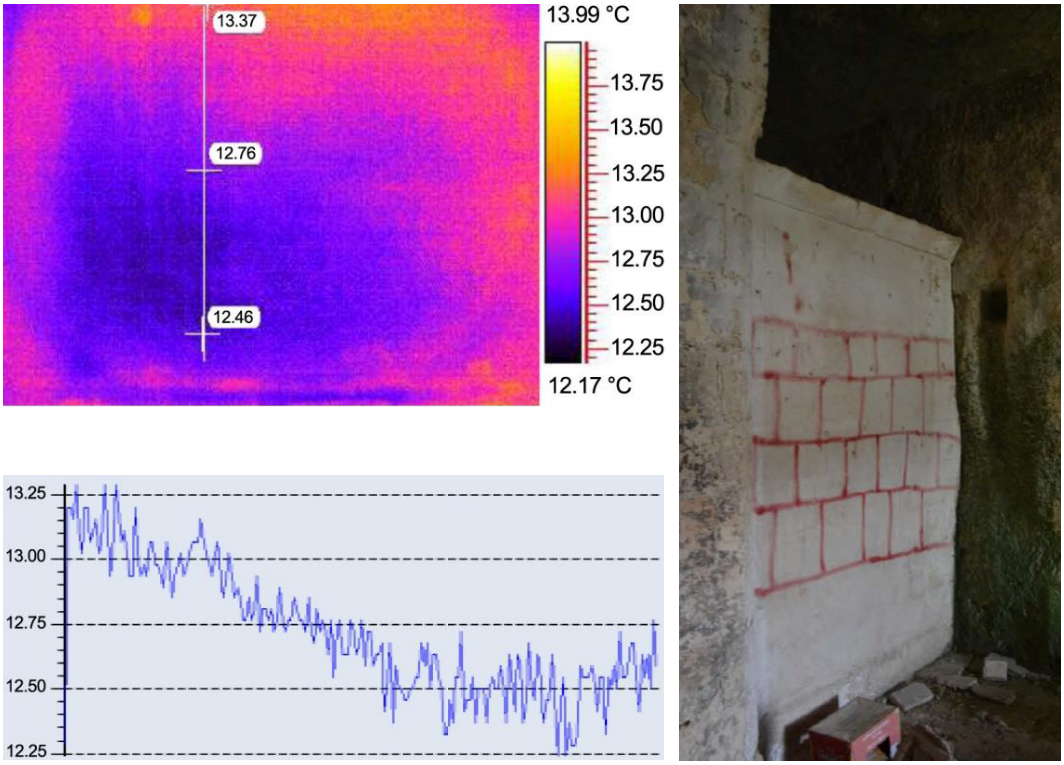

Fig. 8. Presence of moisture due to capillary rise with a temperature gradient equal to 1 °C.

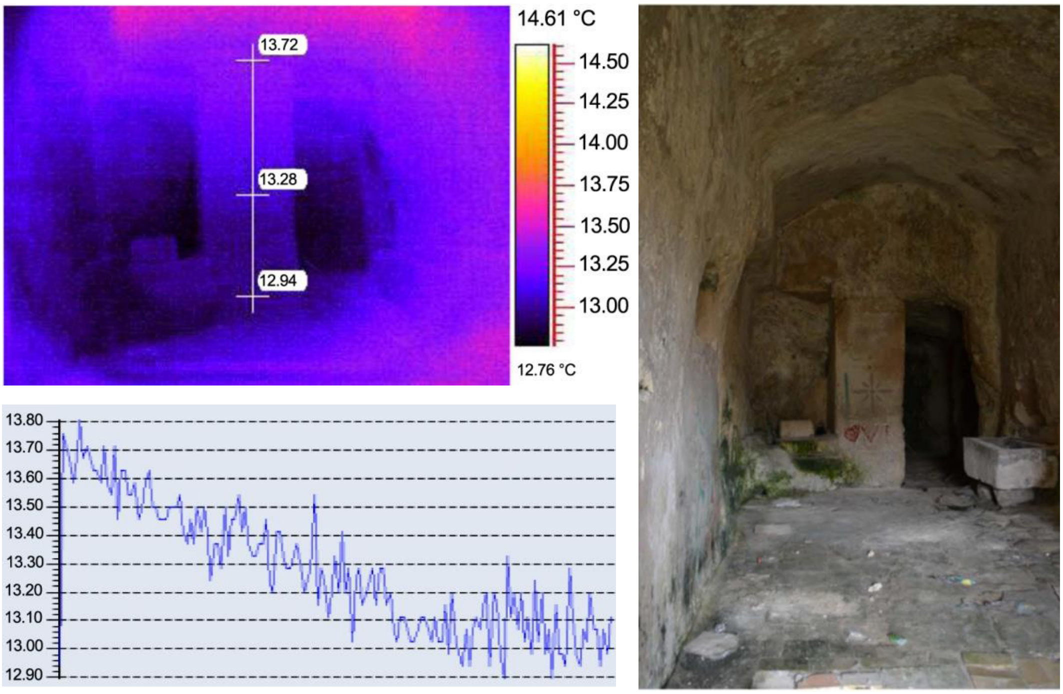

Fig. 9. Presence of moisture due to capillary rise with a temperature gradient equal to 0.9 °C.

4. Conclusions

The type of direct analysis described in this paper is the crucial first step to structure a proper recovery process, especially in existing buildings. It allows to show the presence of moisture in the walls that produces the physical degradation of the materials, the increase of the thermal conductivity of them and hygrothermal discomfort in rooms. The invitation, however, is to proceed also through indirect analysis to simulate the environmental conditions and, in this regard, it is appropriate to reflect on the model calculations. The thermohygrometric simulations under steady state conditions allow to investigate only partially the real performance of the buildings, as they start from the assumption that the cyclic variation of the temperature and the contribution due to solar radiation can be neglected, for which the climate data used are highly aggregated .

The simulations carried out in dynamic regime however, allow a much more realistic and complete analysis, because they allow to assess in detail the contributions the thermal inertia of the housing and the natural or the mechanical ventilation, which have an impact on thermohygrometric performance in winter and summer conditions.

An important problem that arises in dealing with an energy analysis of existing buildings (especially historical) is given by the poor availability and reliability of data concerning the essential parameters for the assessment of their performance, such as, for example, thermal transmittance of the walls and performance of the plants, so you need to proceed with extreme caution after having obtained experimentally the thermal-physical properties of materials and the individual components that constitute the building envelope (conductivity and heat capacity, thermal conductivity, etc.). But in the case of Sassi of Matera in [7], the authors determined the sandstone thermal conductivity as a function of absolute humidity. These results, together with the thermographic analysis and energy simulations described in [8], [9], [10] allow a sufficient evaluation of energy and thermohygrometric behavior of the Sassi of Matera buildings.

References

[1] Laureano P. Matera. La sfida della memoria. Architettura della fusione. *Lettera Internazionale* 2013;118:44-47.

[2] Cardinale T., Pavia L., Zucchi G. The city of Matera and the Sassi: smart places with a Dantean attraction. In: Schrenk M., Vasily V. Popovich V., Zeile P., Elisei P., editors. *Proceedings of 19th International Conference on Urban Planning and Regional Development in the Information Society GeoMultimedia, Real Corp* 2014: 665-674.

[3] Centro Ricerche Economiche Sociali di Mercato per l'Edilizia e il Territorio.

[4] Cardinale T., Valva R., Lucarelli M.. The integrated survey for excavated architectures: the complex of Casalnuovo District within the World Heritage Site "Sassi" (Matera, Italy). In D. González-Aguilera, F. Remondino, J. Boehm, T. Kersten, T. Fuse, editors. *Proceedings of 3D-Arch 2015-3D Virtual Reconstruction and Visualization of Complex Architectures, ISPRS Archives XL-5/W4*; 2015: 403-409.

[5] Condotta M. Energy Web. *Conoscenza condivisa, intelligenza collettiva e nuove tecnologie per il contenimento dei consumi energetici a scala urbana*. Tesi di Dottorato. IUAV; 2014.

[6] Mannina M. *Contributi della geomatica nella salvaguardia e gestione dei beni culturali.* Tesi di Dottorato. Alma Mater Studiorum – Università di Bologna; 2012.

[7] Cardinale N., Guida A., Ruggiero F. Thermo-Hygrometric evaluations in the recovery of rocky buildings of the "Sassi of Matera" (Italy). *Journal of Thermal Environment and Buidings* 24; 2001: 1-14.

[8] Cardinale N., Rospi G., Stazi A. 2010. "Energy and microclimatic performance of restored hypogeus building in south Italy: the Sassi district of Matera". *Building and Environment*, 37: 94-106.

[9] Cardinale T., Cardinale N., Colapietro D., Fatiguso F. Evaluation of the efficacy of traditional recovery interventions in historical buildings. A new selection methodology. *Energy Procedia* 40; 2013: 515-524.

[10] Cardinale N., Rospi G., Stefanizzi P. Energy and microclimatic performance of Mediterranean vernacular buildings: The Sassi district of Matera and the Trulli district of Alberobello. *Building and Environment* 59; 2013: 590-598.