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New Concept of Historical Indoor Microclimate - Learning from the Past for a More Sustainable Future

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Abstract

Historical architecture is a long time studied subject in Europe. We know building techniques, materials and problems linked to the decay about most of it, and even solution for the restoration project, depending on the goal of the restoration itself and the intended usage. A less studied aspect of Historical architecture is their historic microclimates: researches currently carried on in the Department of Architecture of Università di Bologna aim specifically to study this field of architecture, considering it highly relevant to accomplish the goals of any restoration intervention. Thanks to monitoring campaigns, we have data related to three distinct buildings, different in their construction times, typology, location and techniques used. These data show that historical microclimates guaranteed by these architectures are surprisingly overlapping to the parameters considered, nowadays, appropriate to conserve them and the historical patrimony they contain.

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Keywords: Historical building; historical microclimate; decay of materials; preservation;

Monitoring, moreover, allowed developing the analysis further, from survey to simulation. This way it was possible to verify the effects of minimal variations in the architecture characteristics, such as opening or closing a window, covering an open yard, or else, removing a cover, reducing the source of light etc. All of these interventions have significant effect on the microclimate of buildings and can improve the conservation status of architecture, sometimes to such an extent that costlier and invasive restorations become unnecessary.

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1. Introduction

Knowledge about restoration increased much since Viollet-le-Duc and Ruskin times, with an increased number of study cases and theoretical approaches, and in disciplines and disciplinary sectors as well, such as History of Architecture and Chemistry of Materials. In this field, though, one of the most neglected subject concerns a non-material characteristic of architecture: Historical Indoor Microclimate, i.e. internal climatic conditions. Strategies to control microclimate within spaces are born in the dawn of times, along with architecture itself, such as the first braziers to cook, heat and protect our ancestors' caves. Techniques evolved until the modern HVAC (Heating, Ventilation and Air-Condition System) that are able to modify the internal microclimate of buildings independently from the outer space. In historical buildings, mostly built before 20th century and of HVAC introduction, indoor microclimate conditions were strictly dependent on the architectural, technological and local techniques used to build them. This means that each architecture is characterized by a specific Historic Indoor Microclimate (HIM). Thus the internal microclimate of each building was strictly connected to the specificities of its territory and architectural traditions. Restoration is performed in Europe for about two centuries and developed in this time an incredibly detailed attention to material facts of physical parts of buildings –such as masonries, floors and finishing. Every restoration project stems nowadays from detailed researches on history from archives, from bibliographic and iconographic analyses and architectonic surveys, obtained thanks to electronic instruments, physical and chemical analyses of the materials and structural evaluations. Within these researches, though, microclimatic analyses are often forgotten. Thanks to these, however, highly interesting data can be collected with reasonable costs and timings, as it happens with the previously cited analyses, and more effective restorations can be thus achieved.

2. The concept of Historic Indoor Microclimate (HIM)

2.1. HIM evolution and history

The definition of Historic Indoor Microclimate (HIM), as reported in here, is strictly related to the study of evolution and history of indoor microclimate in buildings, along with the variation of: A. Physical characteristics of the architecture, such as its geometry and shape, in one hand, changing as the building was enlarged, partially demolished, etc. Or, in the other hand, as the presence of proto-plants such as stoves and fireplaces, or, later, proper plants (Heating Ventilation and Air-Conditioning - HVAC); B. Cultural characteristics that have an effect on the historic microclimate and on the building itself, as use of clothes, functions, habits and rituals of the inhabitants and even energy sources.

Indoor microclimate has been studied within scientific literature [8] and physical characteristics and instruments have been defined for it, especially in the heritage field [1]. Study cases have been analysed [2, 3], in particular for museums [9, 10, 11, 14], norms have been elaborated [4, 5], as well as specific indexes for the heritage field [12, 13]. HVAC have an historical role, as it has been described in other studies from our group [6, 7, 8, 15].

2.2. HIM and its articulation in different concepts

Historic Indoor Microclimate (HIM), as a product of the interaction between two main parameters T/RH (Temperature and Relative Humidity) with some other (air speed; solar radiation…) is to be studied specifically, being a multidisciplinary research concerning many areas of interest: from artefact conservation, to comfort, Building Physics, architecture, down to history of culture. HIM could be divided into: A. *Original Indoor Microclimate (OIM)*: which is the historically original microclimate, that characterizing the building at the beginning. This can be simulated and studied thanks to the historic, climatic and architectural data, and on the historical information on the period of construction of the building. The knowledge of OIM is relevant to speculate on the possible reinstatement of the original microclimate, which is very often that which ensure the best conservation of the building itself; B. *Subsequential Indoor Microclimate (SIM)*: as the microclimate present in historic times in the building, consequent to variations in the building. Variations as additions, covering etc. can be deduced from historic and architectural data as well as on researches on the phases of construction of the building, including plants. C. *Actual Indoor Microclimate (AIM)*: contemporary microclimate, determined by the state of the building in present times. This can be recorded with instruments placed in loco during the monitoring phase and the data can be used during a modelling phase and even

be validated. Two main methods are applied to perform these studies: research into historic archives and Building Simulation within Virtual Environmental Building. This latter study method creates a virtual model of the building based on its original configuration, with no addition nor successive modifications and use it to simulate the past microclimate of buildings. The results obtained with this method allow to understand the characteristics of the original indoor microclimate and use this information to develop considerations useful to restoration project.

3. Some results from our case-studies

The three monitored buildings are similar in the length of their lives, but time acted on them in very different ways. First, the Malatestiana Library in Cesena is still today in the same conditions as it was handed in by the builders in the XV century, even in the management of indoor microclimate. Second, the Santuario del Valinotto in Carignano is nowadays in a similar state to that of XVII century, apart from the sophisticated system that was closing the windows, which is unusable. Third, villa Petraia in Florence (which was detailed examined in *Villa La Petraia: historic indoor microclimate. Effects and permanent changes* by Signorelli L. and Fabbri K. in this volume), where the original situation is completely modified by the covering of an originally open internal courtyard.

3.1. Malatestiana Library in Cesena, Italy

The Malatestiana Library was built in the second half of XV century to host and preserve, as it is still doing today, manuscripts and books. The project was realized by a protorenaissance architect, Matteo Nuti, pupil of Leon Battista Alberti. The building has no HVAC and the monitoring is relative to the period between March and October 2013.

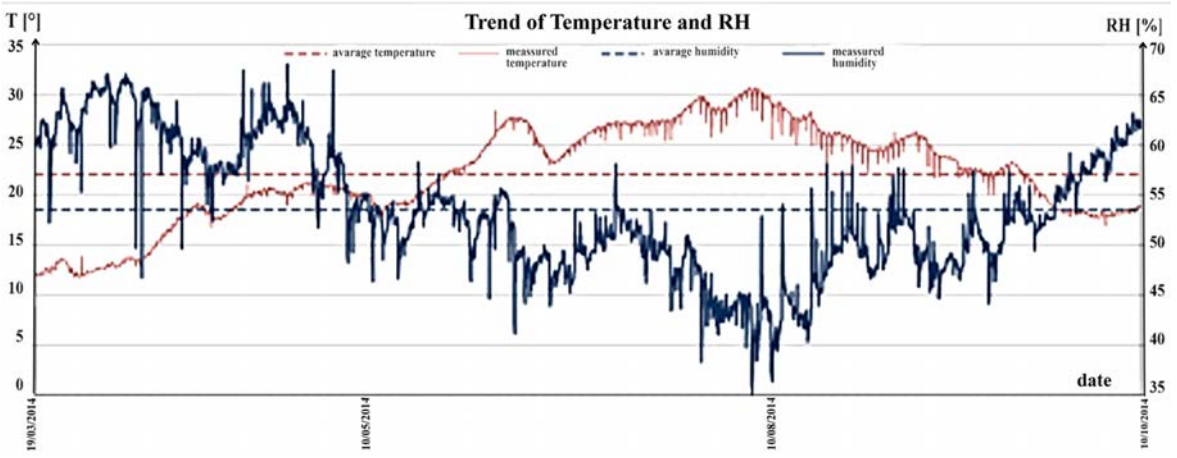

Fig. 1 – Malatestiana Library Trend of Air temperature (in °C) and Relative Humidity (RH in percentage) compared with average values, from 19th March to 10th October 2014.

This research demonstrates that the Malatestiana Library has its own specific microclimate, which is the same historical microclimate that, since XV Century, has permitted and is still permitting the conservation of the wooden plutea, of the parchment manuscripts. The results of the research show the Malatestiana Library as a unique model for microclimate: thanks to its typological, material and architectural characteristics, the built architecture preserves its historical microclimate, most likely the same that the Library had when it was just built. In this case, the Historic Indoor Microclimate, HIM, corresponds to the Actual Indoor Microclimate, AIM. Furthermore the absence of any HVAC system is not negatively affecting the manuscript conservation. Hence, it's easily understandable that Nuti's project was thought with the goal to protect the Library and its contents. This outcome of Renaissance architectural knowledge is an architecture that maintains high efficiency level with very low expenses. The machine for the conservation and consultation of the manuscripts, built more than five centuries ago, is still functional and operative,

with costs that are still very low, related to routine architectural maintenance and to the management of window opening, which is the main, wisely done, work that maintains the perfect indoor microclimate of the Library.

3.2. Santuario del Valinotto in Carignano, Italy

The sanctuary is one of the most interesting examples of Piedmontese baroque and resulting from the project of Bernardo Vittone, pupil of Juvarra and Guarini. The map shows a hexagonal central disposition, with deep recesses, and a generally complex layout, with windows in the back of diaphragms and a significant vertical development. The church has a single opening, about 23m tall and 9m wide. The building has no HVAC plant and the monitoring was done from January to June 2015.

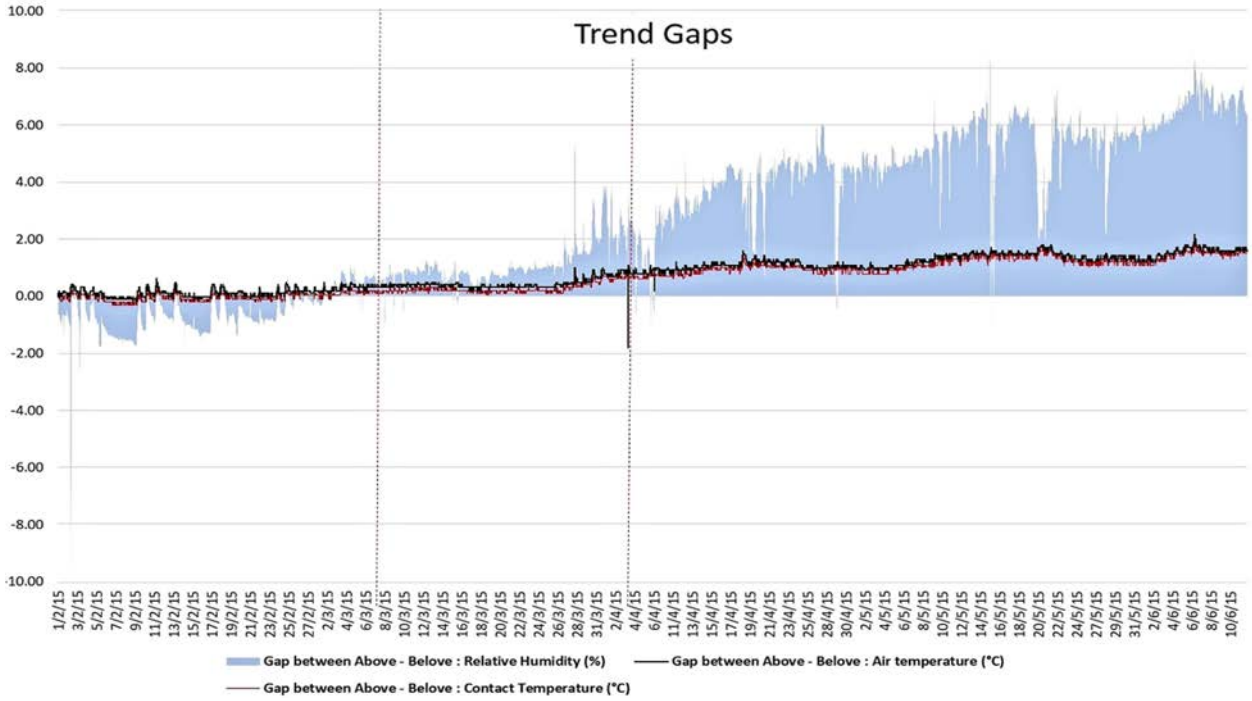

Fig. 2 – Comparison of the trends of the gaps between the upper and lower probe, relative to air temperature, contact one and relative humidity.

Figure 2 shows the trends in the difference of air temperature, contact one and relative humidity between the probes placed at different levels. Humidity appears to be constant until March, while temperature keeps constant until April. The difference between the probes, a proxy of air stratification and movement, increases with internal temperature during spring, but the phenomenon does not appear strictly dependent on external temperature, otherwise there wouldn't be any difference between upper and lower levels. It is, instead, linked to the structure of the architecture itself, to the stratification of the air in the upper level because of the absence of constantly opened windows to "remove" the excess heat caused by convective motions and to the solar radiations heating the upper part of the building and the roof. Humidity, as the vapour content, does not appear connected to external phenomena. The overall high values are probably strictly linked to the Actual Indoor Microclimate, AIM, and constitute a problem for conservation. This situation probably depends on the loss in functionality of the system of openings present on the architectural body that cannot be opened. Modelling analyses, currently carried out, show a substantial improvement in response to the opening of these windows, pointing out how Historic Indoor Microclimate HIM was more adequate to the conservation of the complex.

3.3. Villa La Petraia in Florence, Italy

The Villa, which belonged among others to the famous family that ruled over Florence, the Medici, is attributed to Buontalenti. Its two stories, plus one below the ground, developed around a central courtyard, covered in 1872, on a hill over Florence. In the building was installed a heating system that is nowadays not working. The results of this study, currently elaborated, show the consequences of the covering, that changed deeply the original microclimate of the Villa and creates risks to the conservation of the historical and artistic heritage in there contained (Actual Indoor Microclimate, AIM). The modelling aims at evaluating the benefits of the reactivation of the openings of the covering, recreating an Historic Indoor Microclimate (HIM), and of a possible protection from solar radiations, that is a Virtual Indoor Microclimate.

4. Conclusion

HIM is relevant for the knowledge concerning architectures because, when coupled with other historic data, it helps to understand role and function of many historic architectures. HIM could give interesting contributions for the conservation of architecture and it is to be considered as relevant as the structural data or the physic-material ones. Knowledge of Historic Indoor Microclimate allows to evaluate the effects of microclimatic changes related to decay and to give suggestion on how to better preserve the architecture. With respect to this, the corpus of data concerning internal microclimate results to be so relevant to understand the mechanisms of decay of the materials of buildings that, in our opinion, it shouldn't be neglected. Restoration is the last step to be used; as highlighted by Cesare Brandi and Giovanni Urbani, it should be considered extreme. Restoration should be adopted as a solution only in those cases where the degree of decay of the building is such that no other conservation strategy is feasible. Taking into account HIM is one of these elements of preventive care that, when resources are limited, could prevent the need of a restoration. The authors in here believe that HIM should be in the future a central study subject to researchers dealing with historic architecture. This because HIM helps to define strategies to enhance knowledge, conservation and fruition of architecture itself and because it is an intangible heritage to study and preserve in its own right.

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