From rest/cons to en/eff: indoor environment and building preservation

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1. Overview
The indoor climate of the historic buildings has been a relevant topic in the field of architectural safeguard in Italy, for the last 30 years.
On one hand, building facilities have been a subject of the restoration project for years. Even though they could be disruptive within a conservation purpose, the national guidelines for the prevention of seismic risk have stigmatized just in 2007 the structural damages to the historical buildings due to the holes and channels made for building facilities. The most advanced projects since the Eighties have tended to minimize the loss of structures and finishes due to the installation of networks and channels. Building facilities were considered a necessary addition to ensure the building usability. This consisted in the fulfilment of environmental parameters (T, RH, lux ...), which the building itself seem to be unable to guarantee. The architectural restoration area has thus treated building facilities, returning to its own field some skills by a neighbouring area, as already was for the structural retrofitting, the building accessibility, the industrial chemistry applied to the polishing and protection of the building finishes (e.g. plasters, varnishing...). It required, in each case, to negotiate judicious compromises among the reduction of the material damage, the recognisability of the addition, the conservation of the historic image of the historic building. It was the research for the most favourable type-solutions. This difficult path, not surprisingly, is illustrated in the 4-volumes “Treaty of architectural restoration,” directed by Giovanni Carbonara [Carbonara, 2001].
On the other hand we have preventive conservation, as it has been developed within the museums area through the definition of the conservation standards. Indoor climate has therefore been considered a specific factor of decay for the artworks and, in the same way, for the finishes and structures of the historic buildings housing the collections. The two instances - usability for people and material conservation - are often opposite, because one requires values of temperature, RH and lighting opposite to the other.

2. Energy efficiency and historical climate
Nowadays the research on the indoor climate of historic buildings follows two main directions. On one hand, the energy behavior of the architectural heritage has been studied in terms of energy efficiency, that is, as an aspect of the general problem of energy sustainability in the construction industry. On the other hand, noted the inadequacy of logic made of parametric requirements mainly oriented to design building plants (see UNI 10829:99, Appendix A), the research is oriented to set the concept of historical climate as encoded by the standard EN 15757:2010. This means to rediscover an attitude prudently able to listen to the particular features of a historic building. This research deals with the multidisciplinary analysis of the know-how - even climatic – one
can recognize in buildings and (art)works which have survived for centuries without an active control of the indoor climate.

3. Analysis and Building Diagnostic
In this direction, the authors present the results of the research carried out at the Laboratory of Analysis and Building Diagnostics at the Politecnico di Milano. Since the efforts to reduce the impacts of the installation, the research now focuses on the evaluation of the indoor environment of the historic buildings. A multidisciplinary approach is employed to deal with the complexity of each case-study from a number of viewpoints. Historical and archival skill are employed to study the building history, including the specific construction history and the history of the building facilities. Building physic skills support the diagnostic investigations on field.

As for materials research, we need a more advanced relationship among the archaeological and historical sciences and the natural sciences. The results of a survey should not be considered as tales on the same object of study, methodologically and substantially separated one from another. On the contrary, they could be considered tools for a mutual and operative verification. The conclusions of the historical research cannot be in conflict with the results of the chemical, physical and mineralogical analysis. We need to find an interpretation sustainable from both points of view. Each research line should point to the highest methodological precision while the results are the more credible the more relevant and numerous disciplines are involved. The results of each discipline regard the correctness of the processes involved and provide a limited information that, even if extensive, is insufficient to know the object. The different disciplinary contributions must establish a dialogue to compose a unified framework, it is necessary to form a wealth of knowledge shared.

In the energy field, the Italian culture is still far from this optimal situation. The building physics has made its way with difficulty in Italy. The building facilities are still designed by mechanical engineers which very often work to adapt the machines to the context. Moreover, in the field of building construction, the machines are often known on the basis of parameters the more elementary as possible, to simplify the calculation, while they are poorly correlated to the existing relationship among the machines, the building and the environment. History and archeology recognize how buildings may document the material conditions in which they were built and used, but rarely know how to support this reading with the use of experimental data. In this way, valuable concepts are lost even when they could be immediately useful for practical decisions (e.g. urban and landscape planning) which can also be much more appropriate to their own purpose, the more numerous and complex are their reference data.

4. First the building
The negotiation of the parameters and current models for the interpretation of existing buildings is therefore a scarcely interesting exercise. Perhaps it is no coincidence that the cogency and the scope of these parameters decreased. Their reliability is increasingly the subject of discussion and even their own
scientific foundation. On the other hand the most advanced research do not get tired of recommending preventive measure of the thermal and RH behaviour of each building. Only on this basis it makes sense to determine whether a correction (passive or active) of the indoor climate is or is not appropriate. Only in this way it is possible to establish the extent of this fix and the way to implement it, for example by increasing the insulation of the building envelope or installing new machines.

For example, the work undertaken in 2003 for the Neues Museum in Berlin, although foresaw to change temperature and humidity within very narrow limits, and the subsequent formation of a complete HVAC system, already were based on a detailed study of the indoor environment of each room and of each significant building component. Instead of defining a priori the operating conditions through the calculation procedures and parameters defined by the rules, this study was carried out with a dynamic models based on data actually observed [Thiele, 2009]. This allowed to maintain, even with additions, wooden windows survived to the war, allowed to keep in use the large radiators of the early XX century, integrating them with the new system. This analytical approach was refined based on a large multi-year experience of survey campaigns of the indoor climate. The reference data of these experiences have been available since the eighties [Künzel, 2007, pp. 67-68], especially for large religious buildings like the Cathedral in Ulm. Interestingly, for example, the behaviour of these large masonry buildings is often similar. The main differences are substantially proportional to the different trends of the external climate.

5. Indoor environment and decay
The monitoring of the indoor climate of the St. Andrea Basilica in Mantua has been ongoing for six years. The monitoring campaign started prior to the restoration of the internal wall paintings, to characterize the environmental conditions necessary for the development of specific degradation. As the chemical and mineralogical survey has helped to describe the materials constituting the paintings and the ways in which the paints are degraded, so the monitoring of the internal climate serves to describe the environmental conditions that, over time, have favored the degradation of materials and that after the restoration will be finished, will accelerate the new decay. This is very important in the case of S. Andrea, considering the difficult conditions in the city of Mantua (the town was built on an area obtained by reclaiming marshy ground and is surrounded by three lakes). In addition, the Basilica of St. Andrea is constructed entirely of brick masonry and mortar of great depth and also the roof is made of masonry. The Basilica is therefore a building with high thermal inertia, where the sudden changes in the prevailing weather conditions do not affect the indoor climate, while seasonal variations affect the interior very slowly. The monitoring has sought in particular to quantify the risk of condensation on the surfaces decorated. This condition is especially critical for the conservation of the paintings that are made with preparations containing clay and organic matter. These materials are hygroscopic and they easily decay when exposed to condensation. Given the large size of the building, we have
combined the environmental mapping (useful for describing the distribution of temperature and RH inside the Basilica) with spot measurements carried out for long periods in the areas most exposed to risk [Camuffo, Fassina, Havermans, 2010, pp. 14-16].

The results show that the greatest risk is concentrated in the late spring, when the warm, moist air enters the outside of the Basilica, depositing the vapor on the surfaces of the walls that remain cold until late summer. In these cases, the condensation is very likely. On the other hand, the measurements show that the large mass of air and the great mass of the walls of the Basilica are equipped with large thermal inertia. For this reason, it is impossible to think of “correct” the internal climate of the Basilica on the basis of parameters established a priori as those which are still prescribed by the Italian standard for the conservation of paintings (10-24° C, 55-65% RH). This would necessarily determine great masonry work to install HVAC powerful machines. The result would also be disastrous because this great building, which has been preserved for over 200 years, would be expected to abruptly change the historical climate to which it has been slowly accustomed. This would have serious consequences for the conservation of decorated surfaces inside (cracks, craquelure, saline migration...), which are the interface between the internal environment and structure. The intervention in the internal climate, based on its accurate survey, must tend to reduce the conditions of greatest risk, smooth the peaks of the trends, to develop local solutions to the most dangerous
situations for the conservation of decorated surfaces or greater hardship for people [Camuffo, 2000, pp. 62-73].

6. Monitoring a “historical” indoor climate
Another example is useful for explaining how the indoor climate of the historic buildings were well controlled in the past, and as both the general choices of project (for example, the arrangement and the size of the rooms, the distribution of functions) and the particular choices (for example the interior finishes, the use of internal and external shutters, the curtains) were well oriented to the control of temperature and relative humidity. The indoor climate of the Palazzina Gonzaga nel Bosco della Fontana in Marmirolo, near Mantua is being monitored for more than two years. Monitoring started with an aim of preventive conservation, after restoration work carried out on the interior walls decorated. The monitoring tools should therefore be considered first and foremost as a diagnostic permanent, able to quickly identify the indoor climate conditions are potentially harmful to the conservation of the wall paintings inside. Given the current use of the building and the specific humidity of the region, the greatest risks are represented by the cold winters and high humidity, and by condensation on the interior surfaces that, at the end of spring, is common in masonry buildings without heating, especially when the doors and windows are opened after a long time and when people are present. The special design of the floor plan indicates a precise attention to the functional aspects in the design of this building for recreation and fun of hunting. The rectangle of the layout is arranged with perfect inclination of about 15° to the axis EW. The rooms are arranged in a double symmetry, around the large loggia. This design is well explained in relation to the use temporary and seasonal where this building was intended. In addition, the lodge was originally closed by a masonry wall and large glass windows that were removed during the restoration of the twentieth century, based on an imaginative reconstruction of the original project dating back to late sixteenth century. The monitoring results of the internal climate confirm the “climatic” functioning of this small building, based on the control of solar radiation. The sun was used to warm some rooms used during the cold season. In summer, however, were used rooms facing towards the North-East, shadier and cooler. In this way, the environmental measures specify the results and confirm the hypotheses already developed throughout the historical and archival research [Mirandola, Solera, 2012]. The “archeological” study of the building, provides further confirmation. For example it was possible to detect the remains of the ancient windows that closed the wide loggia that, in this way, was usable as a large living room also in wintertime.

In addition to assess the conditions of use (indoor comfort) and the consequences in terms of preventive conservation (degradation due to specific conditions of indoor climate) the research on the indoor climate of the Palazzina Gonzaga nel Bosco della Fontana suggested topics to discuss the construction history of the building along four centuries. This is an example of a multi-disciplinary use of the tools for the indoor climate control within the archaeological study of a historic building, next to the archival research, architectural
7. Indoor climate and building facilities
A similar problem we have in the Villa Reale in Milan, now hosting the Gallery of Modern Art. In this case a neoclassical building designed as a luxury residence (a villa, of course) was transformed into a public art gallery [Fratelli, 2010]. The shutters have been removed from the southern facade of the building, perhaps because in contrast to the strict neoclassical design of this facade. This fact leads to a significant change in the internal climate because the solar radiation is no longer controlled in the side of the building in which it is greater (curiously, in fact, the shutters have been preserved on the northern facade). The alteration of the indoor climate (sudden rise in temperature and drop in RH) induces serious consequences both for the conservation of the paintings of the gallery, and for the preservation of the historic building finishes, such as the rich wooden floors.

The results of the monitoring performed for the past four years, allow to quantify the serious consequences on the indoor climate conditions due to the lack of the shutters of the southern façade, especially during the summer. The shutters existed in that position since the end of the eighteenth century and were also used to improve the air heating system (even this system is partially original and consistently expanded during the nineteenth century) which does not have, especially after the most recent changes, an adequate adjustment system. The monitoring of the indoor climate is mainly aimed at describing the anomalies of this system and the consequences for the historical building and the paintings of the gallery. The results form a database very useful to guide the improvement project and to check the results.

In this building, the problems of preservation both of the artworks on display, both of the precious interior finishes (which makes it impossible any kind of typical duct air treatment) must be harmonized with the control of energy consumption. On the one hand we must take advantage of the characteristics of the building and its historic facilities, avoiding to design a new plant layouts. On the other hand it is possible to point to target values of temperature and RH with wider ranges than those indicated by the Italian standard and that experience has shown to be compatibles with the conservation of the artworks. This has a local evidence because the measurements were performed both in the rooms where the heating system is in operation, both in the storages where there is not any kind of plant. In these deposits, we found the indoor climate conditions much more suited to the preservation of the works compared to those found in the rooms normally heated [Del Curto, Luciani, Manfredi, Valisi, 2013, pp. 237-8].

8. Historical climate and Construction History
For the design of possible improvements, in-depth knowledge of the historical building facilities is crucial. To recognize the traces of historical plants, to understand how they worked, keep and implement them, measure the effects of changes implemented, are assets which constitute a full and current integration between safeguard and sustainability. A corpus of experiences is
now forming among survey and documentary research [Landi, 2011]. This includes, in its own right, the older plants in the construction history field. The construction history also includes the wide area relating to comfort and energy management, according to a research line which is already consistent in Europe [Carvais, Guillerme, Nègre, Sakarovitch, 2012]. The study and updating through the most popular English-language publications is necessary but not sufficient. We must seek a systematic relationship with groups and research centers of different linguistic and cultural spaces in major literary languages. Especially when they are based on a great tradition and they rely on large pools of readers, they may express complex and articulated results, even in the field of experimental sciences. This research has many debts towards the French-speaking area, towards its innovative approaches to the study of the techniques, the many possible ways for the study of the industrial revolution, the pervasiveness of its culture since the Modern Age. Even the German-speaking area is very important. The cutting-edge research in the field of sustainability comes from there. The same can be said for the early experiments of radiant systems wall [GROßESCHMIDT, 2004] - and particularly their use for the protection of historic buildings - an option that often is neither intended nor practiced even in its own Country.

9. Architectural conservation and building facilities
The monitoring of the internal climate of the Palazzo Pallavicino in Cremona is aimed at improving the economy and efficiency of wall radiant heating system installed during the last general restoration of the building. The idea of the restoration project based on the relationship between project systems and architectural design (the idea that, after all, motivates the path and fields of interest described so far) is mainly due to the reflections developed in the cultural space of the German language. Already in the nineteenth century and
then in a radical way with modernity, the relationship between building fac-
ilities and masonry, the way of sort ducts and users has forced designers to
produce designs that sort the elements of an increasing complexity of the
buildings. The application “retroactive” to the historic buildings of this way of
designing that identifies, sorts and contains networks and users, which in this
ordering and rationalizing may measure the distance and the diversity (and on
the basis of this data reconstructs the relationships), it has nothing in common
with the staging of the technology, which plays on the easy category of the
contrast [Carbonara, 2011].
To order, you need to know, if not in detail, at least in principle, the logic of
what you order. This means employ, from another point of view, the same
model verification plural borrowed from the archeology. To know the principles
also means to go back to basics, follow the developments not just referring in
the evolution of techniques and artifacts, but also in the use and perception
of the users, in social life, in the ways in which it determines the changes and
it is conditioned by them. It is no accident that one of the greatest scholar of
comparative literature [Schivelbusch, 1983] has chosen a technical issue, the
evolution of the lighting between the eighteenth and nineteenth century, as a
path to grasp the radical changes in the way of the production and in the social
equilibriums. However, this same story refers to the relationship between the
objects seen as a resource, as a documentary source and narrative, in other
words, refers to the substance itself of the safeguard.

Notes
1 Direttiva del Presidente del Consiglio dei Ministri per la valutazione e la riduzione
del rischio sismico del patrimonio culturale con riferimento alle norme tecniche per le
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