Original article

Investigation on the interaction between the outdoor environment and the indoor microclimate of a historical library

Massimo Andretta [a,*], Floriana Coppola [a], Leonardo Seccia [b,1]

[a] School of Science, Alma Mater, University of Bologna, Ravenna Campus, Via dell'Agricoltura, 5, 48123 Ravenna (RA), Italy
[b] School of Engineering and Architecture, Department of Mathematics and CAI-Lab–Archeo-Engineering Laboratory–Alma Mater, University of Bologna, Via Fontanelle 40, 47121 Forlì (FC), Italy

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ABSTRACT

In recent years, the study of the indoor microclimate has assumed increasing importance, both in relation to the health of people living in confined environments for a considerable part of their time, both for the problems associated with the conservation of works of art and cultural heritage housed in museums, galleries and libraries. In this paper, we present the results of a measurement campaign carried out in two periods of the year, which can be considered "extreme" from the meteo-climatic point of view, in the Classense Library located in the city of Ravenna (Italy). This is a famous Italian historical library that houses many books of great value. The campaigns took place one in the summer period (from July 22nd to August 6th 2014) and another one in winter (from 15th December to 30th December 2014). During these measurements campaigns, we have characterized different and heterogeneous indoor environments. The internal pollutants concentrations and thermo-hygrometric data have been compared with the external ones, obtained from nearby measuring points. In this way, we have been able to determine the Indoor/Outdoor ratio (I/O ratio) of the pollutants concentrations. From these data and from the estimated air exchange rate, the pollutants deposition velocities have been calculated, too. The building has no air conditioning systems and our experimental data show that it is characterized by a relatively low rate of air exchange and a high thermal inertia. We have also compared the analysed microclimatic data with the specific values recommended by different norms and standards, in order to verify the conditions of preservation of the precious texts. Finally, we have applied a mathematical model to study the indoor pollutants concentrations, in order to confirm that the correlations between the outdoor and the indoor pollutants levels can be explained in terms of the building characteristics. The results of the model application fit well the experimental data and the consequent theoretical estimates made in this work; in fact, they are consistent with very low values of air exchange ratio of the building. These results can be used to define a specific "Performance Index" (PI) of the building, expressed as the percentage of time in which the microclimatic parameters of the library (i.e. the thermo-hygrometric values) do not match the recommended values. Furthermore, they can also provide a first step, based on experimental data, for the development, in close collaboration with the conservation scientists, of a methodology for risk assessment, specifically to be used for cultural heritage housed in museums, galleries and archives.

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1. Research aims

In this work, we have measured the thermo-hygrometric data and the NO_2 and O_3 outdoor concentrations in many inner rooms of an ancient historical Italian Library. Our aims were threefold: the first one was to correlate the indoor microclimate of the Library with the outdoor climate conditions. The second one was to compare the monitored microclimatic data with the specific values recommended by different norms and standards; this can be considered the first step in verifying the conditions of the cultural property. Finally, we have applied a mathematical model to study the indoor pollutants concentrations, in order to confirm that the correlations between the outdoor and the indoor pollutants levels can be explained in terms of the building walls characteristics, e.g. their ventilation and air exchange rates. The results of this study will allow us to develop a Performance Index of the building [1,2], that can also represents a basis for a future development of a risk

* Corresponding author. Tel.: +39 0544 937301; mobile: +39 330 488921; fax: +39 0544 937303.
E-mail addresses: massimo.andretta@unibo.it (M. Andretta), coppola.floriana@gmail.com (F. Coppola), leonardo.seccia@unibo.it (L. Seccia).
[1] Tel.: +39 0543 374452; fax: +39 0543 374477.

assessment methodology, to be developed with the support of the conservation scientists, for the works of art exhibited in museums or in historical libraries.

2. Introduction

Over the last decades, the problem of the microclimate monitoring and control for cultural heritage has assumed increasing importance as a result of many factors: e.g. the wide variety of works of art exhibited in museums or housed in the historical libraries, the increasing number of visitors of the places of art, the different materials composing the cultural goods and the great importance of these objects which represent rare or, in many cases, unique examples of the human art [1–5].

Nowadays it is well known that the microclimate conditions and the indoor pollutants concentrations, as well as their place and time changes, play a relevant role in the deterioration processes of the different constituents of the works of art.

These issues are both a local and an international problem, despite that in the last 30 years the emissions of air pollution have decreased considerably, at least in some countries. Nevertheless, low concentration of air pollutants can produce rather limited direct effects on the materials, but if we consider the over long periods of their exposition, more severe effects may occur [6]. Different researches have investigated the inner environmental conditions of several type of buildings, from the art galleries, to the museums, churches, libraries [6–14].

For this reason, any preservation assessment, development of pragmatic strategy and policies of museums, galleries, and archives management cannot ignore a comprehensive study of the microclimatic parameters and of their mutual interrelationship with the outdoor conditions. In fact, any anomalous environmental parameter or its sudden change may induce stresses on the different materials, which can produce irreversible alterations of their chemical and physical properties and, in turn, increase the rate of the deterioration process and cause a damage to the artefacts [15].

The need to define quality levels of indoor microclimatic parameters, compatible with the preservation of the different artefacts has led, in recent years, to the release of several international standards and national laws on this subject. In particular, for this work, we have made explicit reference to the following standards and norms: UNI 10586 [16], UNI 10829 [17] and the Italian Ministerial Decree May 10th 2001 [18]. We have also taken in consideration the guidelines reported in the Canadian Conservation Institute document [15] and in the EN 15251 [19].

The activities described in this paper are aimed at achieving two different but strictly interconnected objectives: the analysis of the microclimate of three rooms of the Classense Library of Ravenna and the study of the correlation between the measured indoor parameters and the corresponding outdoor values (i.e. the relationship between indoor and outdoor climate).

The Classense Library, object of this research, is an Italian historical library, famous all over the world for its history and for its books of great value, located in the city of Ravenna (Italy). The building of the Library is an historic building of the XVI century, with the walls of fire brick [20,21].

For this research, a detailed monitoring plan has been developed and it has affected three inner rooms of the Classense Library: the Hall of the Holy Fathers (*Sala Santi Padri*, in Italian), the Dante Hall (*Sala Dantesca*, in Italian) and the Great Hall (*Aula Magna*, in Italian). The choice that has been made has been dictated, in particular, by the possibility to analyze heterogeneous indoor environments, each different from the others for geometry, use and attendance. The indoor measurements have been compared with the outdoor ones, in order to determine some peculiarities of the

building (such as, for example: the so called "I/O ratio", i.e. the ratio of the indoor/outdoor pollutants concentrations, the ventilation rate and the pollutants deposition velocities in the inner rooms). The outdoor data have been obtained from two measuring points: one point located just nearby the Classense Library and, another one, represented by one of the air quality monitoring stations of the Regional Environmental Protection Agency (ARPA-RER), Provincial Section of Ravenna [22,23]. In detail, the microclimate has been monitored in three rooms of the Library, during a measurement campaign carried out in the summer period (from July 22nd to August 6th 2014) and in the winter one (from 15th December to 30th December 2014). The monitoring has been focused on the following thermo-hygrometric parameters: temperature (T), relative humidity (RH) and their daily excursions (ΔT_{24} and ΔRH_{24}).

The choice of the time interval is linked to the aims of the monitoring: here, we would present a preliminary study of an historical library positioned in urban area. Thus, the UNI 10829 norm describes two alternatives: the first one requires an analysis of thermo-hygrometric conditions in order to advise contingent intervention strategy; it is needed to carry out the monitoring throughout a year. The second one, to control the thermo-hygrometric data trend at a specific period, in which it is possible to record problems linked to particular conditions; in this case, it is needed to carry out the monitoring during that time interval, in any case for a period of time equal or greater than 15 days [17]. So, to fulfil our goals, though a longer period of measures would be preferable, at least from a general point of view and for a more fundamental approach, for several contingent reasons (e.g. the availability of the rooms for the measurement campaigns), in this work, also according to the above mentioned principles, we have monitored the environmental conditions of the sites of interest, during the two seasons (Summer and Winter) that can represent the "worst cases" from the meteorological point of view, both for a period of two weeks. This strategy can be considered also in accordance with the criteria of "macro-scale risk assessment" reported by some authors [15]. However, starting from the preliminary results described in this paper, it could be possible to carry out a longer monitoring campaign, with a future research project, focused to a more detailed characterization of the preventive conservation for the cultural heritage, housed in the Library.

We have also measured the indoor and the outdoor concentrations of the following gaseous pollutants: NO_2 and O_3, which can be considered key gaseous pollutants for this kind of heritage building in Ravenna [15].

In order to confirm that the estimated correlations between the outdoor and the indoor pollutants levels can be explained in terms of the building walls, its ventilation characteristics and interior finishes, we have also applied a mathematical model to study the indoor pollutants concentrations on the base of the respective outdoor concentrations. This model, implemented in the IMPACT SW [24–27], has been developed by the University College of London, Institute for Sustainable Heritage (UCL-CSH) [28]. It has been specifically implemented for helping conservators, conservation scientists and other professionals in museums, galleries, historic houses, libraries and archives dealing with the issue of pollution damage to collections. The application of the IMPACT model has provided results which fit well the experimental data and the consequent theoretical estimates made in this work, consistent with very low values of air exchange ratio of the building.

3. Material and methods

The monitoring in the rooms of the Classense Library has been performed in order to take into account the relationships, the incidence and the variability between the outdoor values of the