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Environmental monitoring and microclimatic control strategies in "La Specola" museum of Florence

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ABSTRACT

This work presents the results of the environmental monitoring of some rooms of the "La Specola" Museum in Florence, affected by significant overheating problem in summer mainly due to the absence of efficient solar shadings. The elaboration and analysis of the microclimatic data have been carried out according to the Italian Standard UNI 10829 and the Performance Index of the most important thermo hygrometric parameters has been calculated and assessed. This analysis shows that temperature and RH conditions were not reasonably acceptable for the preservation of the kind of objects exhibited. In order to reduce this problem, solar gain control solutions (shadings and solar control glasses) has been analyzed with a dynamic thermal simulation tool for two sample rooms, as a possible solution to improve architectural integration with the historical context. In order to reduce the risk of damage, the evaluation of different strategies has been expressed in terms of the reduction of energy need for space cooling and in terms of the ability to control dry bulb temperature values. The results can be extended to several historical buildings, where large windows and skylights imply high energy consumption and poor indoor environmental conditions that can cause damage to the artefacts.

1. Introduction

In museums several interactions occur between the indoor environmental conditions and the objects exposed. These interactions, if not properly supervised and limited may cause irreversible process of exhibits degradation.

Microclimate plays a fundamental role in the deterioration process of the exhibit objects that can be strongly affected by the values of temperature and relative humidity (RH) and their time and space fluctuations. Sudden time changes and intense space variations of air temperature and relative humidity are supposed to induce stresses to several materials: this in turn creates cumulative and irreversible alterations of the physical and chemical properties which could accelerate the deterioration process [1].

As a matter of fact, in the last 15 years, the attitude is oriented to preventive conservation, that is a combination of actions directed to reduce the risk of degradation of the exposed object and to identify optimal environmental conditions to show the object in the safest way. It implies both "passive" techniques, aimed to minimize the potential damage to the object from the exhibition environment, and environmental monitoring and management directed to minimize variations of indoor parameters and to reduce impacts from outdoor.

In the absence of a heating, ventilating and air conditioning system, showcases are of key relevance in the conservation and are widely used in not HVAC equipped museums; in general they work as a filter against environmental attacks due to microclimate variations, chemical pollution and action of micro-organism; moreover, they offer a protection against vandalism, robberies and any direct damage that could come from visitors [2–4].

In order to define and asses proper passive techniques of conservation, microclimatic monitoring of museum rooms and showcases is necessary to assess the museum environment suitability to conserve exhibits and to plan any action required to reduce degradation risk [5,6].

Italian and European technical regulations about cultural heritage conservation [7,8] establish guidelines and methods to measure indoor temperature, humidity and lighting level. Especially in historical buildings turned into museums is necessary to carry out a compromise between objects conservation, public fruition and visitors comfort [9].

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Nomenclature

g	solar factor, (dimensionless)
F_s	reduction factor of summer thermal loads, (%)
PI	performance index, (%)
RH	relative humidity, (%)
U	thermal transmittance, (W/m^2 K)
U_g	thermal transmittance of the glass, (W/m^2 K)
U_w	thermal transmittance of the window, (W/m^2 K)
θ	dry bulb temperature, (°C)
$\Delta\theta_{24}$	daily gradient of temperature, (°C)
ΔRH_{24}	daily gradient of relative humidity, (%)
τ_v	light transmittance, (dimensionless)

Main issues related to exposed object deterioration depending on absolute value of temperature and RH as well as their alteration in time can be classified in physical (dimensional and shape variation of objects), chemical (chemical reactions) and microbiological problems for the exhibits (microorganism growth). Depending on the type of object exposed, expansion or contraction due to temperature variation can be relevant as well as those due to RH variation.

In general, even if the optimal microclimatic conditions have been fixed for the most important categories, however it is always difficult to collect information about "the history of deterioration" of the different objects and to therefore establish the importance of the deterioration speed related to the deviation from the optimal established values.

In Italy, many museums are placed in historical buildings and are not equipped with HVAC systems or sealed showcases. In particular, in the Florence district are placed many different museums; most of all (90%) are placed in historical buildings so that their restoration, improvement, safety and accessibility is really difficult to achieve and maintain.

Florence museums conditions are very different and in almost 25% of museums poor conditions are pointed out (possible water infiltration, low windows performances, absence of lighting and solar control systems, poor thermal performance of the building envelope). Widespread are heating systems with radiators or fan coils and 33% of museums is unprovided of any heating system.

2. Description of "La Specola" museum of Florence

One of the most important museum of Florence is "La Specola", situated in Palazzo Torrigiani; it can be considered the first European scientific museum opened to the public. It was inaugurated, under the name of Royal Museum of Physics and Natural History, on February 21, 1775, at the wish of Peter Leopold of Lorraine, Grand Duke of Tuscany, who had expressly ordered the reorganization of the Medici collections. The first director of the museum, Felice Fontana, initially organized the museum based on the existing scientific material inventoried in 1763 by Giovanni Targioni Tozzetti, and then continued to enrich it with new acquisitions. At the same time, a collection of anatomical wax models was created, which illustrate the entire human body in all its details. The Museum has always been known as "La Specola" because of the presence in the building of a small tower used as an astronomical observatory, established in 1789 and operative for almost a century. "La Specola" zoological collections are rich, but only a small portion of the over three million specimens is visible to the public; the rest constitutes research material for specialists. Most of the specimens displayed in the halls date to between the second half of the 1800s and the first decades of the 1900s, and almost all of them were collected during scientific expeditions organize by the Museum. The Museum is open from Thursday to Sunday (01/10–31/05: 09.30–16.30; 01/06-30/09: 10.30–17.30). On Monday ordinary maintenance is carried out. Inside "La Specola" Museum are collected objects with different conservative requirements; the rooms contain showcases, of great historic and artistic value, in which very different specimen are exposed, such as: Diorama, Protozoa, Mollusca, Insects, Worms, Echinoderms, Carnivores, "Count of Turin" hunting trophies, Rodents, Cetaceans, Monkeys, Birds, Reptiles, Fishes, Anatomic waxes, etc.

In particular, anatomical waxes are mostly vulnerable to high temperature values while wooden showcases particularly suffer from temporal RH variations that can cause their dimensional alterations. For their safe exhibition, anatomical waxes are securely coupled to showcases so any shift of the wooden support structure have repercussions on the exposed object and can cause its damage. For this reason, when the first temperature control system has been installed in the wax section, many conservative problems occurred, first of all the showcases dimensional variations, caused by the decrement of RH values lower than the values the showcases get historically accustomed. This phenomenon provoked the breaking both of the showcases veneer and of the parts of the waxes connected to the showcases because of their different water vapor adsorption. Since then, the showcases and the exhibit waxes have been restored and now are balanced with the new microclimatic environment.

As for the zoological exhibits, they are particularly sensible to high temperature values that can cause biological growth and activate putrefaction. RH variations are particularly important for the mammals exhibited that have an inner filling made of gypsum instead of straw; this filling presents a different behavior then the animal skin and can cause its break due to high temperatures that determine a quick and uncontrolled reduction of RH values in summer periods.

"La Specola" is a non air conditioned museum; only in the waxes section (rooms XXV–XXXIV) a heat pump system with ceiling fan coils was installed in the'80s to maintain indoor temperature between 20 and 22 °C; air temperature control system consist of simply thermostat placed in every room. Artificial lighting in the Museum is guaranteed by discharge lamps that are turned on for all the opening hours; in some rooms there is also artificial lighting inside showcases (discharge lamps and LED).

3. Environmental monitoring campaign: analysis, results and discussion

An experimental monitoring system has been installed in the Zoology "La Specola" Section of the Natural History Museum of Florence in order to investigate and control the indoor microclimatic conditions as well as to point out damage causes for the objects exposed (Fig.1). Fixed data loggers (resolution: 01 °C/0.1%; accuracy: ±0.5 °C/ ± 2%) has been used in the Museum to collect values of dry bulb temperature (θ) and relative humidity with fifteen-minute time step. The loggers, placed in 16 rooms and inside 4 representative showcases, send the signal every 15 min to a master connected to a PC thanks to a LAN network so that the system can immediately collect the measures, even when great distances are involved. Recordings of each data logger are displayed in the bookshop's PC and in the museum manager's PC, in order to perform a real time control of the measured environmental parameters. The external data logger, protected from the solar radiation, is located in an internal courtyard. As for the conservation, optimal parameters can be defined both by the curators and by technical documents and UNI standards, such as DM 10.05.2001 [10], UNI 10829 [7] and UNI EN 15757 [8]; these parameters can be defined on the basis of the climatic history of the exhibits, their material and structural characteristics. Thanks to important new indexes such as "cumulative