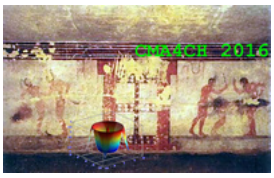
CMA4CH 2016, Mediterraneum Meeting
Straightforward approach in Cultural Heritage and Environment studies - Multivariate Analysis and Chemometry
6th ed., Rome, Italy, Europe, 18-20 December 2016



Microclimatic Measurements and Whole-building Dynamic Simulation of a Semi-confined Paleontological Site: La Polledrara di Cecanibbio (Rome)

F. Frasca[1], A.M. Siani[2], C. Cornaro[3]
[1]Sapienza Università di Roma, Dept. of Earth Sciences, P.le A. Moro 2, 00185 Rome, Italy; [2]Sapienza Università di Roma, Dept. of Physics, P.le A. Moro 2, 00185 Rome, Italy; [3]Università degli Studi di Roma "Tor Vergata", Dept of Enterprise Engineering, Via del Politecnico 1, 00133 Rome, Italy;

Abstract

The paper describes a preliminary analysis of the thermal behaviour of a paleontological site, La Polledrara di Cecanibbio (Rome), using on-site measurements and a building thermal dynamic simulation. Even though the building envelope of the paleontological site is a modern structure, commercial whole-building simulation software is not fully tested in semi-confined environments, e.g. when indoor environmental conditions are strongly affected by the external forcing. The calibration of the model, which is the crucial phase of the simulation process, will be performed using only hourly indoor temperature measurements and varying thermo-physical properties of external walls and the soil floor. The preliminary results of simulated thermal behaviour will be compared with measured data using the Taylor Diagram. Nevertheless, a semi-automatic calibration of the model is required to identify the most proper settings of thermal-physical properties of building components.

Introduction

Recently the whole-building dynamic simulation has become a useful tool in preventive climate control actions in buildings which preserve cultural artefacts. However, the existing software have been developed to model modern buildings having regular geometries and for which the thermo-physical properties of building materials are well known. In historical and archaeological buildings, the simulation codes do not include materials of these structures in their library and in the case of semi-confined environments the performance of these codes has not been thoroughly investigated.

This paper introduces a study to assess the performance of IDA Indoor Climate and Energy (IDA ICE), a whole-building dynamic simulation software, applied to a semi-confined site such as the paleontological site "La Polledrara di Cecanibbio" (Lat.41.9, Long. 12.3). The building is located about 15 km NW of Rome (Italy) in a rural area. The building envelope is placed directly on the soil covering an excavated area of 900 m^2, where many valuable faunal remains from Middle Pleistocene are preserved [1]. The site suffers from biological degradation mainly because indoor environment is affected by soil hygrometric conditions.

The thermal behaviour of La Polledrara has been investigated using both on-site measurements and simulated values. Hourly indoor temperature measurements were used to calibrate the model varying thickness (s), thermal conductance (λ_w) of external walls and thermal conductance (λ_s) of the soil. Even though indoor climate is stable during the years, many dry episodes are experienced in winter and fall. The external wall, i.e. a double skin insulated panel, facilitates the exchange between internal and external temperatures mainly in the midday after the maximum exposure to solar radiation provoking RH drops.

Materials & Methods

The indoor air temperature (T) and relative humidity (RH) parameters were analysed from January 2009 till December 2013 (the monitoring campaign is still in operation), with an acquisition and recording time set to 30 minutes. T sensor is a platinum resistance thermometer Pt100 1/3 DIN (accuracy 0.3°C), while RH sensor is a film capacitor "Rotronic" C94 (accuracy 1.5%), both connected to a datalogger CR 1000. Before applying exploratory data analysis (EDA), the quality of the T-RH series was carried out using the Continuity Index (CI) and the Completeness Index (CoI) [2].

To apply the thermal dynamic simulation, first the physical model of the building was built. Then the outdoor climate behaviour was studied using the outdoor T-RH data monitored at La Polledrara and the wind and solar radiation data monitored at the meteorological station *ESTER* (Energia Solare TEst e Ricerca) belonging to *Università degli Studi di Roma "Tor Vergata"*.

The key factor to take advantages from simulation model and to avoid that simulated variables are far from actual values is an accurate calibration of the model using measured and simulated data. In this study, a preliminary calibration was performed using hourly indoor T monitored from September till December 2013. The results were analysed using the Taylor Diagram, which allows determining the degree of agreement between measured data, taken as reference values, and simulated data in terms of their correlation (R), root-mean-square difference (RMSD) and standard deviation (SD) [3].

Results

Both T and RH series resulted of high-quality (CI=1 and CoI=0.96), and hence suitable for exploratory data analysis. It was found that there is no significant seasonal difference in the T and RH series. The outliers found in the RH series are associated with low values occurring especially in winter and fall in the hourly intervals of 13-16 and 17-20 as shown in Fig 1.

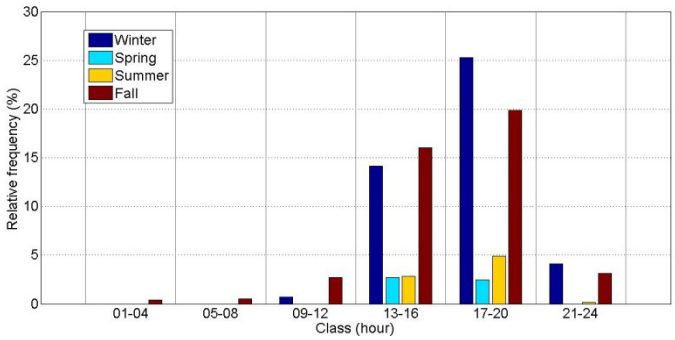


Fig. 1; Frequency distributions of the RH outliers below Q1-(1.5*IQR), which are associated with dry episodes. The graph refers to year 2011.

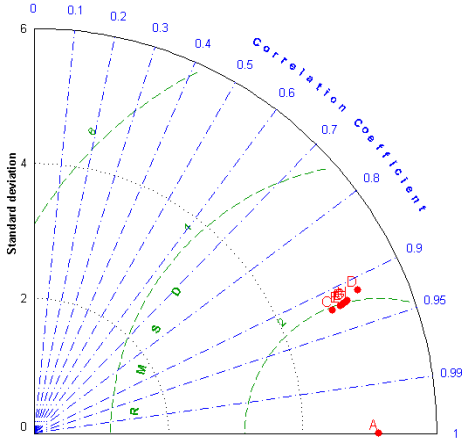


Fig. 2; Taylor Diagram of simulations carried out from September till December 2013. A is reference temperature, letters from B to H are tests temperature.

Fig. 2 shows the Taylor diagram. Each simulation, corresponding to different values of the thermal conductance of insulated component (polyurethane) of the external walls, is indicated as a point on the diagram, while the reference (A) is plotted along the abscissa. In the initial model (B) λ_w=0.035 W/(m K), while in the following simulations (from C to H) λ_w has been varied between 0.001-0.090 W/(m K). Simulated and reference data are highly correlated (R=0.92) and their highest difference (RMSD=2.15°C) has been found when λ_w is overestimated (simulation D with λ_w =0.090 W/(m K)). No difference in simulation data is shown varying λ_s, but further investigations are required taking into account the density and thermal capacity of soil.

Conclusions

The thermal behaviour of the building envelope that shelters the site of La Polledrara di Cecanibbio has been investigated using a long-term microclimatic monitoring campaign coupled with a whole building simulation model calibrated using hourly indoor air temperature profile. The method proposed allows better understanding the behaviour of the envelope interacting with the remains preserved and it could also be used to test new solutions of conservation related to the microclimate conditions. Although the procedure has been applied to a specific case it will be used in the future as a general approach for Cultural Heritage investigation and preservation.

References

1) A.P. Anzidei, G.M. Bulgarelli, et al., Ongoing research at the late Middle Pleistocene site of La Polledrara di Cecanibbio (central Italy), with emphasis on human-elephant relationships, *Quatern Int*, vol(255), (2012) 171-187
2) F. Frasca, A.M. Siani, G.R. Casale, et al., Assessment of indoor climate of Mogila Abbey in Kraków (Poland) and the application of the analogues method to predict microclimate indoor conditions, *Environ Sci Pollut R*, (2016) 1-13
3) K.E. Taylor, Summarizing multiple aspects of model performance in a single diagram, *J Geophys Res-Atmos*, vol(106(D7)), (2001) 7183-7192.