Carcer-Tullianum in the Forum Romanum in Rome: a preliminary microclimate investigation

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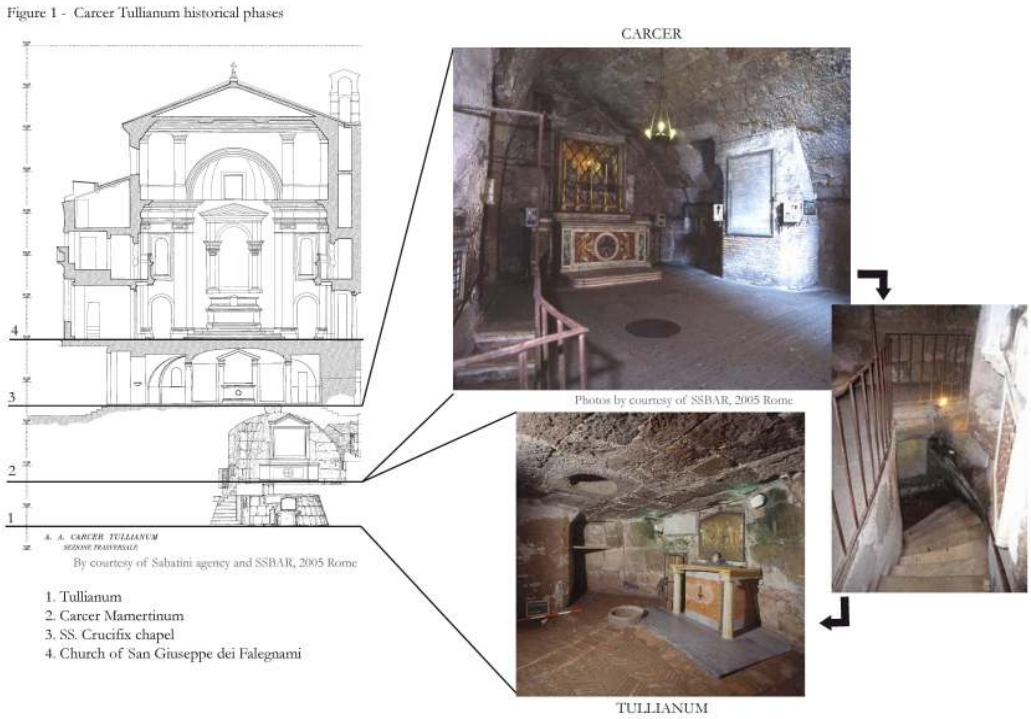
Abstract

The Carcer-Tullianum is one of the oldest prisons in Rome. It is located on the east side of the Campitoline Hill in the Forum Romanum. It consists of two levels. The lower called the "Tullianum" chamber, the upper the "Carcer".
This study is a preliminary analysis of the meteorological conditions characterising the microclimate of both chambers. The data collected from 15 to 28 April 2010 was used to determine whether the place is affected by inadequate environmental conditions.

Introduction

The Carcer-Tullianum, one of the oldest roman prisons, is located on the east side of the Campitoline Hill in the Forum Romanum. It consists of two levels. The lower called the "Tullianum" chamber (with a small pit inside), and a upper level, the actual "Carcer", (Fig.1).



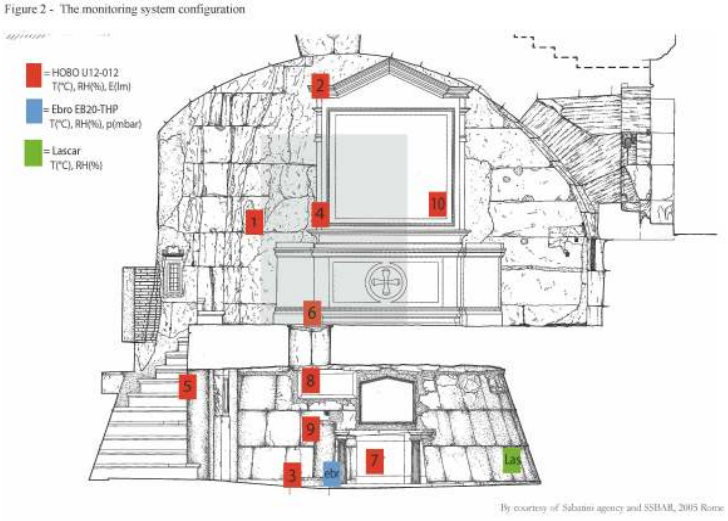
The former level existed before the upper, the newer being added to convert the building into a prison. These chambers were connected through a passage used to lower prisoners into the jail. The Tullianum was built around the 4th century BC while the Carcer dates back to 3-2nd century BC. Presently the Carcer is below ground level.
Both sites are hypogenous structures although the upper level is connected to the outside by a grating door.

In the VII-VIIIth century AD, both, Carcer and Tullianum assumed a religious character. The seventeenth century church of S. Giuseppe dei Falegnami was built on top, as shown in Fig.1. During the last restoration, in 2010, two frescoes, dated between the XI and the XIV century, were discovered in the upper level. This finding triggered interest in the control of the environment to secure its preservation.
To determine the indoor environmental conditions before it opened to the public, and to determine whether the place may suffer from inadequate conditions, microclimate parameters such as air temperature, relative humidity, lighting, air composition (O_2, CO_2, CO) and air pressure, were monitored from 15 to 28 of April 2010.
A statistical analysis was performed first to evaluate the quality of data. Then the data set was analysed in accordance with the Italian Standard UNI 10829 (1999)[1] and the recent European Normative [2]. In addition, the Performance Index [3] was determined to verify the favourable thermo-hygrometric conditions.

Materials & Methods

The monitoring system consisted of fifteen data-logger equipped with a thermo-hygrometer and a lighting sensors: 5 Hobo sensors installed in the Carcer, 5 Hobo sensors and 1 EBRO and 1 Lascar installed in the Tullianum, and 3 Hobo sensors in a small, narrow opening from the Tullianum towards the outside (not considered in this analysis). The monitoring system configuration is shown in Fig. 2.

Figure 2 - The monitoring system configuration



The technical features of the instruments used for microclimate monitoring are reported in Table 1.

Table 1 - Technical features of instruments used for microclimate monitoring.

Model	HOBO U12-012			EBRO EB20-THP			LASCAR	
Manufacturer	Onset USA			Ebro GmbH			Lascar	
Parameters	T(°C)	RH(%)	E(lm)	T(°C)	RH(%)	p(mbar)	T(°C)	RH(%)
Accuracy	±0.35	±2.5	-	±0.5	±3.0	±5.0	±1.0	±3.5

The acquisition time was set to 10 minutes for all the loggers.
Outdoor air temperature and relative humidity data have been provided by CRA-CMA Rome meteorological station (Collegio Romano), which is in the vicinity of the site. Both were also used to study the influence of outdoor climate on the internal environment.

The investigation analysed the data set of the period 15 - 28 April 2010. The collected data was first checked to identify possible spikes or anomalous values. Then the indoor temperature (T) and relative humidity (RH) data were analysed assuming the acceptable safety range of 19°C<T<24°C and 40%<RH<60% for porous stone conservation [1].
Later the microclimate quality was evaluated using the "performance index" [3], which expresses the percentage of time in which the above parameters do not match the requirements fixed by the normative.
A non-parametric approach to the statistical investigation was taken and the strength of the relationship between the environmental parameters (both indoor and outdoor) was investigated using Spearman's Rank correlation with a large correlation defined as 0.50 or more [4].

Results

The Box plots summarize the temperature and relative humidity conditions for Carcer (Figs 3-4) and for Tullianum (Figs.5 - 6).
The top and the bottom of the boxes represent respectively the upper and the lower quartiles (a measure of the dispersion of data), while the line inside every box depicts the median. The whiskers show minimum and maximum values except for the outliers, which are drawn as circles (beyond 3 times the IQR).

Figure 3 - Carcer T Boxplot

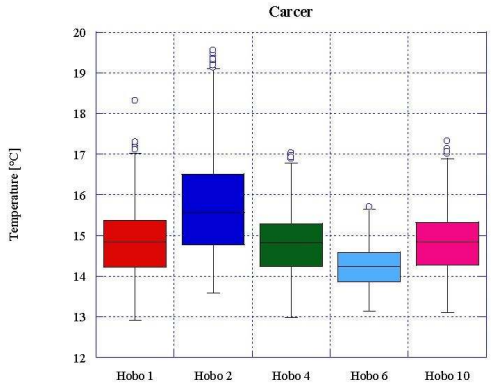


Figure 4 - Carcer RH box plot

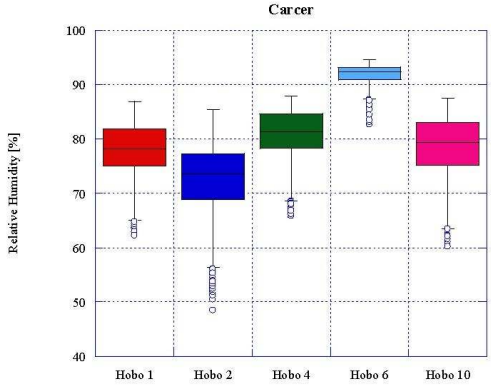


Figure 5 - Tullianum T boxplot

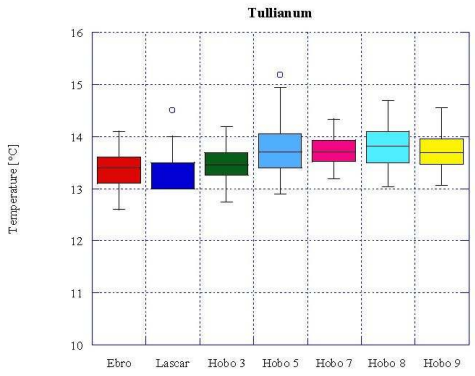
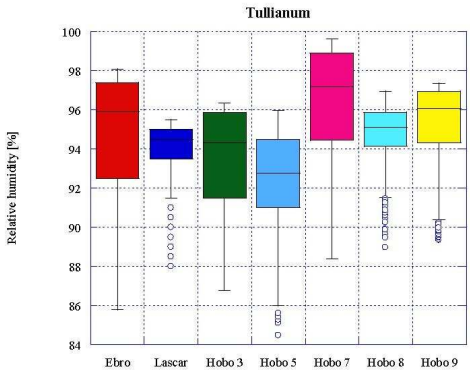


Figure 6 - Tullianum RH boxplot



As shown by the diagrams in Figs. 3-6, there is no significant difference in both, temperatures and humidity values, (except RH of Hobo 6) among the sensors within each site. In the Carcer a larger variability of T the Hobo 2 can be detected (Fig.3) probably due to natural ventilation through the open entrance door. Furthermore, Hobo 6 (located close to the cavity) has the higher RH values (Fig.4) since it could be affected by climate in Tullianum.

The Box plots show that most of T and RH values are outside the safety range suggested by the normative 10829.
Tullianum shows low temperature variability (Fig.5), while the RH values are around above 80% as expected for hypogenous structures.
The Performance Index (PI) was determined taking into account the relative frequency distribution and cumulated frequency of the T and RH and the safety range provided by [1]. The PI was calculated as the percentage of the time in which both T and RH are within the safety interval.
The Figs. 7-8 show that most of T and RH values are outside the safety range (the square in the graphs is related to 19°C<T<24°C vs 40%<RH<60%), for both Carcer and Tullianum.

Figure 7 - Carcer Performance Index (%)

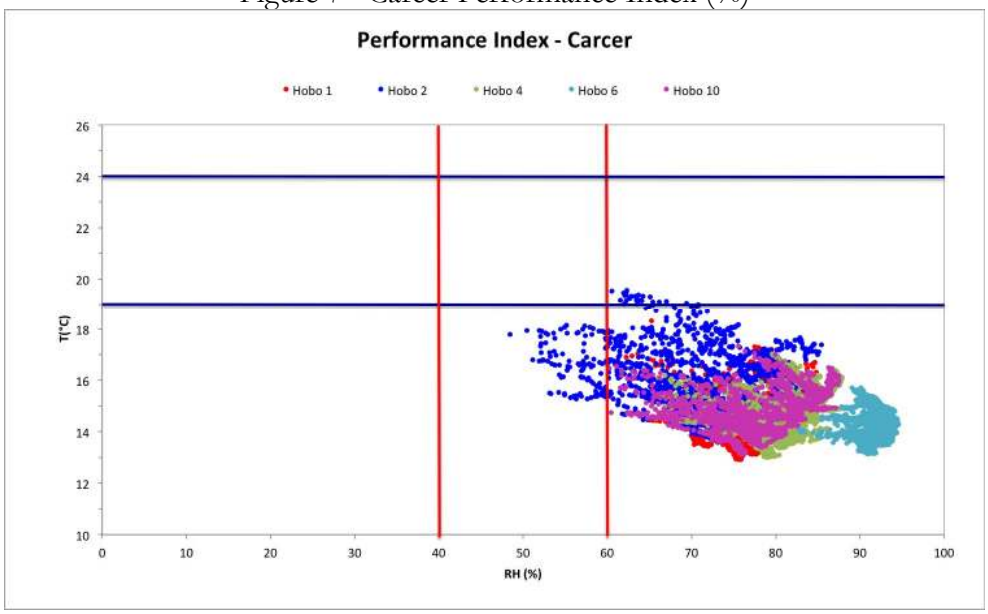
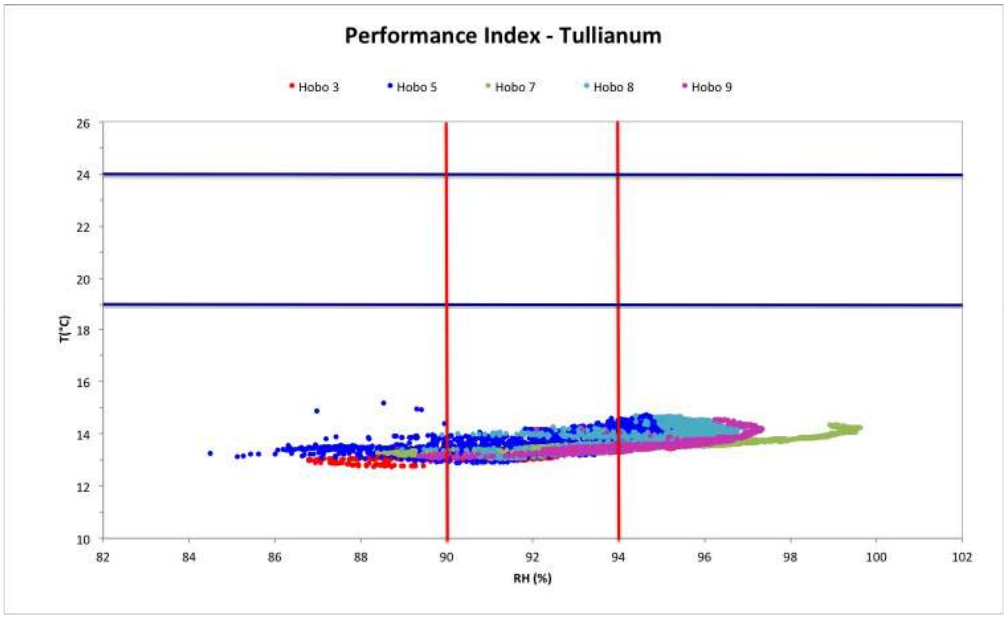


Figure 8 - Tullianum Performance Index (%)



The PI values are reported in Table 3. It can be noticed the PIs tend to be zero for every Hobos while for the Hobo 2 PI it is very low (7.1%).

Table 3 - Carcer and Tullianum Performance Index (PI)

CARCER		TULLIANUM	
Sensor	**$PI_{T\&RH}$ (%)**	**Sensor**	**$PI_{T\&RH}$ (%)**
Hobo 1	0.00	Hobo 3	0.00
Hobo 2	7.09	Hobo 5	0.00
Hobo 4	0.00	Hobo 7	0.00
Hobo 6	0.00	Hobo 8	0.00
Hobo 10	0.00	Hobo 9	0.00

The strength of the relationship between indoor and outdoor T and RH values was investigated using the Spearman Rank correlation (ρs) for non-parametric data. The range for a weak correlation was defined as zero to 0.29; a moderate correlation from 0.30 to 0.49; and a large correlation was defined as 0.50 or greater [4].
The Carcer shows a large correlation between the internal T and external RH, with a ρs max=0.93 for the Hobo 2, while the correlation between the indoor T and RH is moderate, with ρs max=0.38 for the Hobo4.
The Tullianum shows a large correlation between the indoor T and outdoor RH, with a ρs max=0.52 for the Hobo 5, and between the indoor T and RH, with ρs max=0.98 for the Hobo7, while the correlation between the indoor and outdoor RH is moderate, with ρs max=0.35 for the Hobo 8.

Conclusions

This work studied the indoor environmental conditions of the Carcer-Tullianum, for the period 15 - 28 April 2010, using some statistical analysis and the Performance Index that is a synthetic indicator of microclimate quality. Temperatures and humidity conditions do not appear to be within the acceptable range suggested by the UNI 10829. The observed low temperatures and high humidity could be considered critical for the conservation of both sites.
In addition, the correlation between indoor and outdoor parameters indicates a strong sensitivity of the Carcer to outdoors changes.
Further analysis is needed, with a longer time series of data, to determine a new safety range on the basis of the frequent thermo-hygrometric cycles in accordance with the recent European Normative EN 15757 (2010)[2], and to investigate the nature of the outliers in order to identify the most critical events occurred during that period.

Acknowledgements

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References

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