Thermal performance of an underground museum in Turkey

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ABSTRACT

This study examines the thermal behavior of an underground space via the analysis of ancient underground dwellings and computer simulation. The analysis of the cave dwellings was done to observe their thermal performance so as to validate the hypothesis of thermal stability due to the great mass of the surrounding soil. The computer simulation was performed to model the situation of a museum which differs from a cave dwelling. The present work looks at three main objectives which are conservation of archaeological objects, appropriate display of the collection and comfort, using passive design techniques, aiming to promote alternative building methods for the preservation of our environment. The result is a design proposal of a local archaeological museum in the village of Sahmuratli, Turkey. Conclusions drawn from this analysis are an attempt to inform conservators and architects in preserving the artifacts while preserving our environment.

1. INTRODUCTION

The topic of this paper is inscribed within a cultural context focusing on the conservation of artifacts and their display within museum spaces. The significance of our cultural heritage dictates the need for its conservation, which is about communicating its cultural value to society in the present and in the future. This study focuses on the first aspect involved in the field of conservation, which is the control of the environment to control the decay of artifacts and materials.

One of the problems is that over the last decades, the control of the environment within the museums has been achieved by means of air conditioning systems and artificial lighting, converting the museums in 'conservation machines' (Hahlert, 2004) while ignoring the impact that this has on CO_2 emissions, global warming an climate change.

A more sustainable approach regarding conservation has arisen (Cassar, 1995) emphasizing the importance of the relation between conservation and the environment, stating that heritage protection cannot imply the deterioration of the environment and calls the heritage sector to be aware of passive means of environmental control and more retained use of energy systems and materials. She stresses the role of the building as the first line of defense against environmental instability, for which the building should respond only gradually to changes in external climate and internal heat gains, and mentions that buildings constructed wholly underground have improved stability.

A local archaeological museum was proposed in the village of Sahmuratli, Turkey, for the preservation and display of the recently excavated artifiacts belonging to the Iron Age city of Kerkenes.

The climate of the Central Anatolian region is characterized by cold winters and warm summers with wide diurnal fluctuations in temperature and relative humidity. Mean year air temperature is 10.6^{o}C, mean year relative humidity is 80%. A special environmental condition of the region includes humid nights reaching a relative humidity of 100% every early morning during the whole year.

The hypothesis that an underground building seems to enhance stability led the present study to the observation of the thermal conditions inside ancient underground spaces and based on the approach of Cassar, to the proposal of an underground archaeological museum for the preservation of a local collection in Central Anatolia, Turkey.

Different authors have monitored the thermal conditions inside ancient underground dwellings.

Recent research (Krarti, 1997) revealed that Golany monitored the thermal performance of a vernacular dwelling with a sunken courtyard in Matmata, Tunisia and showed that, whilst the maximum dry-bulb temperature in the sunken courtyard was around 43°C in mid summer, the temperature of the room facing the courtyard was nearly stable at about 25°C, 18°C cooler. The temperature swing during the 24 hours period was only 1°C inside the facing rooms, while the courtyard temperature swing was 10°C. Other studies (Matsumoto et al., 1996) show the thermal performance of a vernacular subterranean dwelling in Brhlovce, Slovakia revealing that in July the maximum outside air temperature was around 27°C whilst the temperature of the unoccupied south-facing room was relatively stable at about 18°C, 9°C cooler.

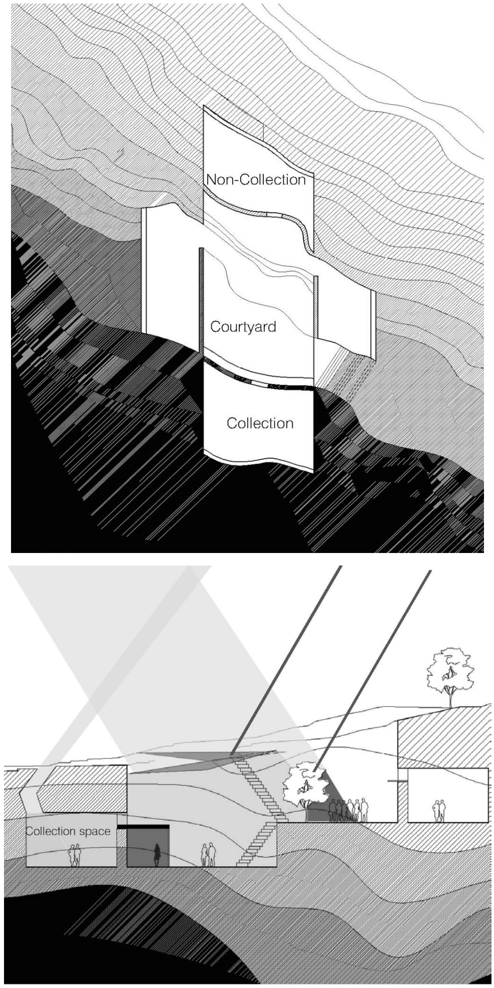
The internal temperature swing during the 24 hours period was about 2°C, while the ambient temperature swing was 14°C.

As far as the museum is concerned, the greater advantage of underground spaces is the thermal stability, which is essential in a museum space, suggesting that the approach of building underground could be adopted for a new museum.

2. METHOD

Because the nature of a museum is not the same as an ancient dwelling due to the fact that the spaces and the activities are different, a design for the museum space was proposed (Figs. 1 and 2), which then was used to simulate the thermal conditions inside the museum.

A sunken courtyard was proposed with four underground spaces facing it, the collection space facing north in order to avoid direct solar radiation onto the artifacts. The non collection spaces were places around the sunken courtyard facing the other three facades of the courtyard. One of the main advantages of a sunken courtyard is that it creates a microclimate which can be modified by shading it and by incorporating vegetation in it. Shading devices were placed above the courtyard also to reduce the illuminance into the collection space. Deciduous trees were to be planted at the center of the courtyard so as to provide cooler shaded areas for the visitors. Concerning the illuminance inside the collection space, some design considerations were proposed in order to create a more even internal illuminance for the appropriate display of the artifacts. An upper window was placed along the façade facing the courtyard and a light well was introduced in the roof at the back of the room. The results derived from the computer simulations are not presented in this paper, con-



Figures 1 and 2: Plan and longitudinal section of the proposed museum.

sidering that the results derived from the thermal simulations are more important for the scope of this conference.

The massive thermal mass of the surrounding soil was expected to generate a stable internal environment suitable for the preservation of the artifacts. In order to corroborate this hypothesis, computer simulations were performed for the proposed model.

Thermal simulations were performed using A-Tas software. Two different digital models were simulated in order to validate the results, due to the fact that A-Tas software is not designed to simulate the effect of the surrounding soil of underground spaces.

The simulations were expected to show two main outputs: Firstly, the thermal indoor conditions and secondly, the effect of internal heat sources on the internal conditions (considering a wide variation of internal heat gains due to the visitors entering and leaving the collection area).

The results to be described were firstly for three days in June and secondly for one full summer day comparing the internal environment inside the collection space with the ambient. The effect of occupancy heat gains was shown in the latter. Simulated variables included resultant temperature and relative humidity.

The results discussed are for the collection space only, due to the importance of the environment within this space compared to the other museum spaces.

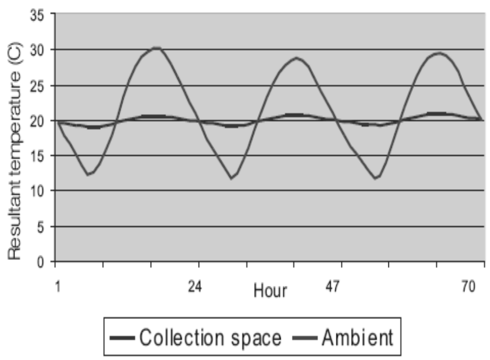
3. THERMAL PERFORMANCE OF THE SIMULATED SPACE

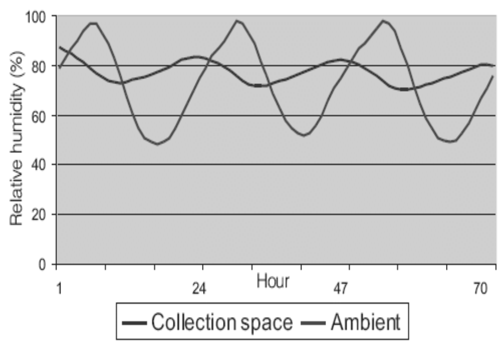
The results from the two different models appeared to be nearly identical, indicating that both models were valid to use for the thermal simulations. The internal environment of both models is shown in the simulations performed for three days in June.

For three days in summer, the internal temperatures appeared to be about 10°C lower than the ambient maximum temperatures in summer. The internal temperature fluctuation of 4°C throughout the three days, compared to the ambient temperature fluctuation of about 18°C (Fig. 3), showed the ability of the building to act as a climatic buffer. The internal constant temperature of about 20°C appeared to be the ideal for the preservation of the artifacts (Cassar, 1995).

The internal RH of about 80% (Fig. 4), appeared to be higher than the required by the artifacts. However, the internal RH fluctuation of about 10% compared to the ambient that was 50% was significant because the most important aspect for the preservation of artifacts is the environmental stability more than a specific temperature or RH value (Cassar, 1995). The nearly stable environment derived from the simulated space showed the effect that the surrounding soil has on the internal environment. The high RH could have been reduced through ventilation during the day when the ambient RH was about 50% (Fig. 4).

In order to compare the results from an unoccupied space and an occupied space with visitors entering and leaving the building, a one day simulation was performed with and without occupancy heat gains.

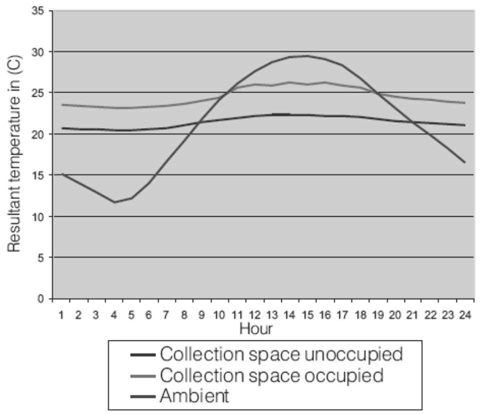


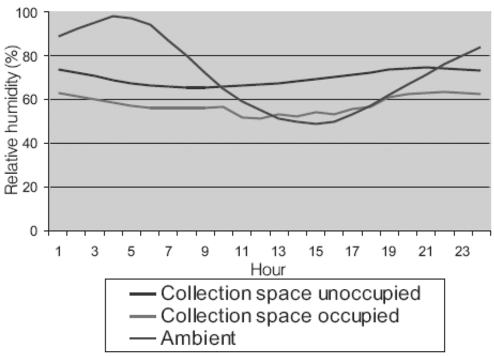


Figures 3 and 4: Resultant temperature and relative humidity in the internal collection space of both models compared to the ambient for three days in June.

For one full day on the 20th of June (Figs. 5 and 6), the internal simulated environment appeared to be nearly stable compared to the ambient conditions. The internal temperature swing was only of 4°C and the relative humidity of 10%, compared to the ambient swings which were of 18°C and 50% respectively.

An interesting aspect of the results presented is the fact that the internal environment was greatly affected by the visitors due to their metabolic heat. When the space was occupied, the internal resultant temperature was higher than without occupancy (Fig. 5) at about 25°C which helped the RH to drop to about 60% (Fig. 6). Despite the effect of the visitors inside the collection space, the internal environment was rather stable compared to the external conditions.





Figures 5 and 6: Resultant temperature and relative humidity in the collection space and in the courtyard, compared to the ambient for one full day on the 20th of June.

4. CONCLUSIONS

The present work aimed to create an internal environment that was suitable both for the artifacts as well as for the visitors, given the importance of preserving and displaying our cultural heritage while preserving our environment.

The results derived from the simulations seemed to corroborate the statement of Cassar that an underground building enhances stability in the internal thermal environment, therefore is suitable for new collection spaces.

The interest of simulating an internal environment through the use of computer modeling was not only to show a nearly stable environment achieved by means of coupling the building with the surrounding soil, but more importantly to promote such an alternative building method to the new museum spaces in which the stability of the environment required for the preservation of artifacts is achieved through passive means without the use of air conditioning. This study proposes a new architectural scheme for the museum building not particularly in Central Anatolia, Turkey but in every region and climate. It is an attempt to emphasize the importance of preserving our environment to all architects involved in the field of conservation and more specifically to the heritage sector, hoping that it would inspire new ideas of museum design as a measure of sustainable conservation.

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