Independent Preservation Environment Control for In-Situ Relics in Archaeology Museum

Xilian Luo\textsuperscript{a,b,*}, Qibo Hou\textsuperscript{a}, Zanshe Wang\textsuperscript{a}, Zhaolin Gu\textsuperscript{a}

\textsuperscript{a}School of Human Scelements and Civil Engineering, Xi’an Jiaotong university, No.28, Xianning West Road, Xi’an 710049, P.R.China
\textsuperscript{b}School of Mechanical Engineering, Xi’an Jiaotong university, No.28, Xianning West Road, Xi’an 710049, P.R.China

Abstract

Archaeology museums play an especially important role in protecting unearthed cultural relics from natural weathering caused by the sun, wind and rain and for visitors to understand a certain history. Indoor microclimate conditions in archaeology museums greatly influence the protection of unearthed relics; however, many of the unearthed relics are suffering deteriorations or even ruins owing to improper indoor environment. In this research, a radiant air conditioning system is proposed to implement the local environment control for unearthed relics. The system can satisfy the specified needs of the unearthed relics in preservation environment with very low energy consumption. Moreover, the soil-atmosphere coupling environment trends to be more balance such that the deteriorations caused by non-equilibrium can be greatly delayed.

1. Introduction

Archaeology museums play an especially important role in protecting unearthed cultural relics. However, the unearthed relics are not completely assured the environment in archaeology is suitable for preservation. The properly reservation of relics in long term is still a challenge to the environmental scientists and technologists. Many unearthed relics are suffering serious deteriorations, e.g, the Emperor Qin’s Terra-Cotta Warriors and Horses Museum, a lot of...
relics in the pits have changed appearance since being unearthed owing to the lack of effective environmental management approach [1], [2]. The underground exhibiting hall of Hanyakling Museum, China, opened in 2006, although many technical measures including space division, lighting, radiation heat, ventilation and air conditioning devices have been incorporated, the relics in this new type of archaeology museum are not preserved as good as expected. Slight surface cracking and weathering were found on the pottery figurines. Air pollutants, such as SO2, NOx, were found to have penetrated into the enclosed hall environment [3]. The above problems that the Emperor Qin’s Terra-Cotta Warriors and Horses Museum and Hanyakling Museum faced today are not unique. An investigation, organized by the China’s State Administration of Cultural Heritage, reveals that there are more than 3000 museums in China, among which about 51% of the collections are suffering deteriorations or even ruins owing to improper preservation environment. The creation of a suitable environment for the long-term preservation of relics in archaeology museum is, therefore, becoming an important urgent issue. In order to clarify the particular characteristics of the preservation environment for relics in archaeology, Gu et al. presented the conception of reintegrating the primitive environment and an air curtain system was proposed to implement space division and to prevent the penetration of air pollutants and heat into the pits [3]. Meanwhile, they also pointed out that the establishment of equilibrium between soil and atmospheric environment and mitigation of heat and mass transfer occurring in air-relic-soil system remained are important issues to be faced with in really realizing reintegration of primitive environment.

Here, we present the argument that conflicting demands of visitors and relics on the indoor environmental parameters are essential causes for relics’ deterioration, and that visitors’ and relic preservation environments independent control, reintegration balance between the soil and atmosphere are two strategies to create suitable environment for long-term preservation of unearthed relics in archaeology. Moreover, a radiation tail end air-conditioning system is proposed to implement above targets.

2. Method and materials

2.1. Local environment control system for relic’s area

In an archaeology museum with large and open building layout, such as the Emperor Qin’s Terra-Cotta Warriors and Horses Museum and Hanyakling Museum, the environmental requirements for the optimal preservation of unearthed relics usually do not coincide with those for the visitors to archaeology museum, e.g. the recommended thermal comfort standard for visitor is to maintain the indoor temperature in the range of 24 °C to 28 °C and the relative humidity from 40% to 65% [4]. While the environmental requirements for collections are more complex. Different relics have different optimal internal parameters [5].

In general, the environment control for the visitors’ domain can be easily implemented by the conventional central air conditioning systems that are widely used in public buildings. While for the relic’s preservation domain, quite stringent requirements, e.g., the fluctuation and indoor air flow should be kept as low as possible, are to be considered. In order to implement local environment control and satisfy the specialized needs of the unearthed relics, an experimental system, which is fundamentally consisted of a funerary pit and a local environment control system, is designed and constructed in this research, as shown in Fig. 1. The funerary pit is a rectangular excavation in the ground with dimensions of 4m × 2.8m × 2.2m in length, width and depth respectively. It is noted that the capillary tube radiant panels are paved on the surface of sidewalks. With a hot or cold water flow through the radiant panels, the environment of preservation area within the pits thus could be adjusted to desired parameters. In the experiment, dry bulb temperature of air and soil environment, ceramic brick (represents relics), water in the pipeline system as well as RH and air velocity of air environment are measured to evaluate the performance of the system.

2.2. Monitoring points distribution and measuring instruments

The distribution of the monitoring points is shown in Fig. 2. It is note that the test points of Ta1-Ta5 are arranged along the vertical centre line of the pit to investigate the thermal stratification features. The distances from Ta1 to Ta5 to the bottom of the pit are 0.3m, 0.7m, 1.3m, 1.9m and 2.6m, respectively. Among them, Ta4 can be approximately regarded as the dividing point of the funerary pit area and visitors’ area since its position is close to the upper edge of
the pit and is in parallel with the upper side of the capillary tube radiant panels. While Ta5 is situated at a height of 0.4m higher than the upper edge of the pit to represent record the visitors’ environment temperature and RH. The monitoring positions of T6, T3 and T7 were positioned horizontally to investigate the thermal uniformities at a specific height (h = 1.3m). Meanwhile, a velocity sensor was placed at a height of 0.7 m from the bottom of the pit to measure the air velocity.

Fig. 1. schematic diagram of experimental system. (a) the diagram of the local environment control system.

(b) the funerary pits with capillary tube radiant panels on all around side surfaces
2.3. Description of the experimental cases

Two test cases with radiant air conditioning system turned on or not were performed during Jul.12 to Jul.21, each test case lasted five days, i.e., the system was turned during Jul.12 to Jul.16 and turned off during Jul.17-Jul.21. For each test case, a pre-transition stage with duration of one day was considered between different test conditions, i.e., Jul.12 and Jul.17. The experimental data of these periods are not used to assess the performance of the system since they are not stable test conditions, such that the normal test time for each case is four days.

3. Results and discussion

Marked fluctuations of the temperature and RH could be the main cause of thermal stress rupture on the relic’s surfaces. Researchers have studied the specific environmental specifications[6],[7], to establish the desired steady temperature and humidity for collections in indoor-display museum, e.g. the suggested daily range of air temperature and RH for optimal conservation of cultural relic with organic materials should be less than 1.5 °C and 6%, respectively[6]. Although it is quite difficult to maintain the preservation environment in archaeology museum with large open space layout as stable as that in closed cabin or showcase, and no specifications were made on the allowed fluctuation of the environmental parameters, the stability of the indoor macroclimate parameters is real a critical consideration in implementing long-term preservation of relics in archaeology museum. In additional, the fluctuations of indoor parameters may enhance the heat and mass transfer between the soil and atmosphere environment such that cause relics deterioration.

To verify the performance of the environmental control system, we carried out a series of experimental
investigation during Jul.12 to Jul.21. The daily trend of air temperature and RH, measured at the different heights in the funerary pit for cases with the air conditioning system turned on and off are shown in Fig. 3. The maximum and minimum daily ranges of temperature for test points are listed in Table 1. It is observed that in both cases the temperature fluctuation increases directly with the height of test point. The reason lies in that the soil usually maintains in a relatively constant temperature while the atmospheric environment fluctuates considerably. When the radiant panels system turned on, the radiant panels play a significant role in control pit environment, especially for the area that adjacent to the soil. The fluctuations of Ta1-Ta3 for the test case with system turns on are quite lower than those with system turns off, while at Ta4-Ta5, the temperature fluctuations increase significantly for both cases because these two points are greatly influenced by the visitors’ domain.

When the radiant panel system was switched on (Figure 3a and 3b), the relic preservation pit maintained a steady environment. The daily air temperature variations (Ta1 and Ta2) were kept to no more than 1.8°C, which is very close to the specified value (≤1.5°C) given for appropriate preservation of collections in an indoor-display museum [5]. However, a relatively large fluctuation was observed in the visitor passage (Ta5) because it was greatly influenced by the outdoor environment. When the radiant panel system was switched off (Figure 3c and 3d) the air temperature at the bottom of the pit showed great variations with upper environmental parameters. The daily air temperature variation ranges (Ta1 and Ta2) were much greater when the radiant panel system was switched off than when the system was switched on. The daily variations in RH were also similar to those temperatures under the two monitoring conditions.

The RH monitored at the test point Ta1 for the case that the HVAC system turned off is also very stable and approximately to 100%, reflect that the underground soil has high soil water content and specific heat capacity, and the primitive environment has not yet destroyed unearthed relics due to excavation, and the relics were exposed to the exhibiting hall environment for only a short time [3].
Fig. 3. Vertical profile of the indoor air temperature and RH at five levels (0.3m, 0.7m, 1.3m, 1.9m and 2.6m) in and overhead the experimental funerary pit. (a, b) temperature and RH distribution at different test positions for the test case that radiant air conditioning system turned on. (c, d) temperature and RH distribution at different test positions for the test case that radiant air conditioning system turned off.

Table 2. Mean value of the air temperature and its daily range (°C), and average RH (%)

<table>
<thead>
<tr>
<th>Monitoring points</th>
<th>Ta1</th>
<th>Ta2</th>
<th>Ta3</th>
<th>Ta4</th>
<th>Ta5</th>
</tr>
</thead>
<tbody>
<tr>
<td>system switched on</td>
<td>21.4</td>
<td>21.9</td>
<td>23.4</td>
<td>26.7</td>
<td>28.5</td>
</tr>
<tr>
<td>Average temperature</td>
<td>1.5</td>
<td>1.8</td>
<td>3.2</td>
<td>7.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Mean daily range of temperature</td>
<td>97</td>
<td>94</td>
<td>81</td>
<td>61</td>
<td>52</td>
</tr>
<tr>
<td>Mean daily range of RH</td>
<td>8</td>
<td>14</td>
<td>24</td>
<td>42</td>
<td>52</td>
</tr>
<tr>
<td>system switched off</td>
<td>25.5</td>
<td>26.5</td>
<td>28.5</td>
<td>30.4</td>
<td>31.7</td>
</tr>
<tr>
<td>Average temperature</td>
<td>2.7</td>
<td>3.9</td>
<td>6.3</td>
<td>8.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Mean daily range of temperature</td>
<td>94</td>
<td>94</td>
<td>70</td>
<td>54</td>
<td>48</td>
</tr>
<tr>
<td>Mean daily range of RH</td>
<td>8</td>
<td>19</td>
<td>26</td>
<td>28</td>
<td>31</td>
</tr>
</tbody>
</table>

The horizontal distributions of temperature and RH at the same height of 1.3m (T6, T3 and T7 in Figure 2) are shown in Fig. 4a and Fig. 4c, respectively. Consistent value of both temperature and RH were illustrated at the three monitoring positions (Ta6, Ta3 and T7) and thus indicating that the operation of the radiant panel system is an effective way to sustain a uniform spatial distribution of pit environmental conditions.

![Fig. 4. Temperature and RH distributions along the horizontal centreline of the funerary pit at the height of 1.3m.](image)

(a) distribution of temperature. (b) distribution of RH.

Generally, the heating and cooling process by traditional fan-driven HVAC systems create intensive higher air velocities, such that the heat and mass transfer between soil and atmosphere will be significantly enhanced. The air velocity at the height $z=1.3m$ with the radiant system turned on and off are shown in Fig.5a and Fig.5b, respectively. The average velocities for these two cases are 0.014m/s and 0.015m/s, respectively. As can be seen that in this study, the air movement intensified by the radiant cooling system is statistically insignificant, this because on the one hand the cooling process may cause a slightly natural convection that will intensify the air movement, but on the other hand, the cooling process was implemented by the way of radiation instead of air supply.
Fig. 5. Variation of air velocity with time. (a) Profile of air velocity in the pits for the test case that radiant air conditioning system turned on. (b) Profile of air velocity in the pits for the test case that radiant air conditioning system turned off.

4. Conclusions

At present, the targets of indoor microclimate control for archaeology museum are still confined to create specific indoor parameters. Archeologists and museum staff desire to preserve the unearthed relics for a long-term through this kind of environmental control. We proved that above understanding on environmental control for archaeology museum is biased and incomplete from the point of view of conflicting demands on indoor environment. Thus we propose the environment control targets to satisfy visitors’ thermal requirements cannot provide a suitable environment for unearthed relics at the same time. The visitors’ environment and relics preserved environment should be controlled independent according to their individual needs and operating hours.

The radiant air conditioning system is quite effective in implementing local environment control for preservation area: a relative large area adjacent to the unearthed soil and relics can be maintained in a stable state, the temperature fluctuations are confined no bigger than 1.8°C, which is only half of that of the control system turns off. The local environment control system is also very helpful in energy saving since during the nighttime only a very small part of the large space exhibiting hall needs to be control.

Acknowledgement

This study was supported by the National Natural Science Foundation of China (under Grant No.51306150), State Administration of Cultural Heritage (Under Grant No.2013-YB-HT-014), China Postdoctoral Science Foundation (Under Grant No.2014M552454) and the Shaanxi Provincial Natural Science Foundation (2014 Jm2-5071).

References