The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W5, 2017
26th International CIPA Symposium 2017, 28 August–01 September 2017, Ottawa, Canada

THE MONITORING AND ANALYSIS OF THE CHINESE TRADITIONAL ARCHITECTURE PAINTING DECAY --THE CASE OF JILAN PAVILION IN THE SUMMER PALACE

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KEY WORDS: Heritage Monitoring, Digital Record, Light Environment Stimulation, Painting Protection

ABSTRACT:

The painting is one of the most decorative elements of ancient Chinese architecture and it is sensitive to the natural environment. The outdoor painting is very easily to be affected by the natural environment and its color is easily to decay. In order to study the relationship between the painting decay and the physical environment, the two paintings on both east and west inner eaves of Jilan Pavilion beside the Kunming Lake in Summer Palace are taken as the research objects, because these two paintings are painted at the same period but their decay degrees are greatly different. Since 2013, the research group regularly monitors the color decay of these two paintings. Meanwhile, the physical environment around these two paintings has been monitored. Based on the analysis of the monitor data, it can be seen that the illumination is the major factor that causes the decay of the painting. Meanwhile, by using the ECOTECT software to stimulate the light environment around the Jilan Pavilion, it can be seen that it is the mirror reflection of the lake that causes the result that the illumination of the west eave (face east) is stronger than that of the east eave (face west).

1. INTRODUCTION

The painting is one of the most decorative elements of ancient Chinese architecture, with high historical value and artistic value. Studies have shown that painting is most sensitive to the natural environment, vulnerable to erosion and destruction. (Ohno, 2000) summarized the object color measurement methods and related standards. (Wu, 2003) studied the pigment composition and discoloration reasons of Dunhuang frescoes, and elaborated the process of color change caused by the chemical reaction of pigments with high humidity and strong light environment over time. By the simulation experiment in the laboratory, (Ma, 2009) found that the influence of natural light on the painting is mainly manifested in that strong oxidation of ultraviolet radiation(the short wave radiation) lead to discoloration and pulverization of the painting and the thermal effect of infrared ray(the long wave radiation) lead to cracking, rolling and peeling off of the painting surface. In the same year, (He et al, 2009) found that the optimum relative humidity for preservation of ancient Chinese painting is 55% to 66% and high humidity environment is extremely unfavorable for painting preservation. Simulation studies by (Lin, 2010)on the light environment of Dunhuang Mogao Grottoes cave 237, showed the spatial illuminance distribution in cave 237, and found that the area in which the murals peel and color decays seriously mostly have a high daylight factor. To some extent, it proves the damage of daylight to murals. The fresco located inside the Sistine Chapel known as “Temptations of Christ” by Sandro Botticelli was monitored by (Guarneri et al, 2014)with integrating two techniques, the RGB-ITR hyper-photos and the watershed algorithm for a semi-automatic detection of defects on fresco. This monitoring method is a non-invasive diagnosis of fresco degradation and it contributes to the design and realization of innovative solutions for the restoration and conservation of the paintings. (Liu et al, 2015) further verified that light is the main factor causing the color decay of the paintings, by monitoring the physical environment nears paintings such as temperature, humidity, wind speed and illuminance. (Dang et al, 2015)studied the influence of white LED on the Chinese traditional painting and calligraphy, finding that high-energy and short-wave radiation is the primary factor in color decay.

However, the decay factor considered in most present studies is relatively single, considering only light or humidity. Few studies have taken into account the influence of various external factors on painting synthetically. On the other hand, most studies on color painting monitoring is for indoor movable paintings. There is little research focusing on the decay of color paintings in the complex environment outside the door. In addition, from the previous research, we can know that the influence of the light environment on the painting is obvious. Thus, it is significant to study the light environmental characteristics and its formation process and influential factors for the preserving environmental of color paintings.

The Summer Palace was built in the late Qing Dynasty. December 2, 1998, the Summer Palace was included in the World Heritage List by United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Committee. Its architectural paintings almost cover all the ancient Chinese architectural painting types, like dragons pattern, tangent circle pattern, Suzhou-style decorative painting and so on, (Yuan, 2009). As the safest and most complete royal garden ever preserved, the Summer Palace reflects the superb craftsmanship and drawing level of Chinese ancient architectural painting. The paintings in the Summer Palace contain all the categories in the official style of the Qing Dynasty, with a clear and complete development history. These architectural paintings contain rich historical information. Their painting content, drawing

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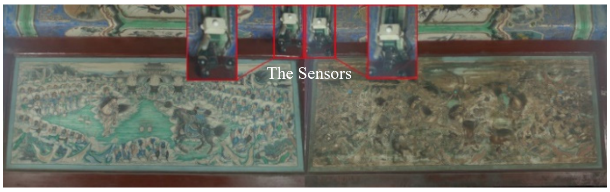
techniques and specifications can be regarded as a precious intangible cultural heritage. Especially the Long Corridor in the Summer Palace, total length of 728 meters and total of 273 bays, are painted with more than 14,000 pieces of color painting, covering include, character stories, landscapes, flowers and birds, ancient architecture and other themes. It can be considered as a "gene" library of classical Chinese oil painting.

Two typical paintings (As shown in Figure 1) on both east and west inner eaves of Jilan Pavilion are chosen as research objects by this paper. As a typical representative of the Long Corridor painting, they are in the complex natural environment of the Summer Palace. And the current preservation states of the two paintings are very different, though they were redrawn at the same time. The decay degree of the west painting is much more serious than that of the east painting. See detail in Figure 1 (The picture is taken on November 7th, 2016). The research on the two paintings can provide a basis for the protection of the Long Corridor paintings and even the protection of entire Summer Palace paintings. It may also serve as a reference for relevant research.



a b

Figure 1. The east painting (a) and the west painting(b)

In order to study the painting's decay principle, affecting factors and the reason causing the serious color fading of the west painting, the color information of the two paintings was regularly monitored from August 2013 and the micro environment was continuously monitored from May 2014. By analyzing the monitoring data, it is found that the illumination intensity of the west side is stronger than that of the east side, which is the main reason for the rapid color fading of the painting on the west side. But according to the general view in architecture, the illumination intensity of east side(face west) should be stronger than west side(face east) illumination, because the solar radiation in the afternoon is stronger than that in the morning. The actual monitoring data are inconsistent with the conventional view. For studying and analyzing the cause of this abnormal condition, the light environment around Jilan Pavilion is simulated with ECOTECT software and filed surveys are also beneficial.

2. THE MONITOR OF THE COLOR DECAY

Since 2013, the color information of the two paintings on both sides of Jilan Pavilion have been monitored quarterly. We mainly use the on-site monitoring method and the monitoring work is carried out at night, when there is no interference from other light sources. Firstly, the painting will be illuminated by the D65 standard light source. Then, the color coordinates will be measured with the 2D Color Analyzer CA-2000. The color coordinate is based on the CIE1931xyY color space. We select nine typical sampling spots on the painting. The color coordinates x, y and the luminance value Y of each spot are extracted from the original data. Every spot covers 10 pixels and the values of x, y and Y for each spot are the average of the values for its 10 pixels. By comparing the color data between different spots and different monitoring cycles, it is found that the luminance value Y varies greatly between different monitoring cycles, which is related to uncontrollable factors such as the supply voltage of D65 and the environmental temperature. This is a measuring error and it is too large not be ignored. While in the CIE1931xyY space, the color coordinates x and y are relatively independent with the Y value. That is to say the error does not affect x and y. So, in the subsequent analysis, only x and y are considered. By analyzing the data of x and y, we can know that:

The change of color coordinates in winter is larger than that in summer.

The change of color coordinates in the monitoring period is small.

The change of color coordinates does not show obvious trend.

For the outdoor architectural painting color measurement, there are still no mature measurement methods and instruments in the world. The monitoring method used by this paper also has many shortcomings. It still need to be improved in order to obtain more accurate color coordinates and luminance data.

3. THE MICRO-ENVIRONMENT MONITORING AND CORRELATION ANALYSIS

The micro environment near the two paintings on west and east side of Jilan Pavilion has been monitored continually since May 2014, so as to find the relationship between micro environment and painting decay. The monitoring indexes include temperature, humidity, wind speed and illuminance. The monitoring equipment is installed in the upper left corner and the upper right corner of the painting, as shown in figure 1.

By comparing the monitoring data of temperature(Figure 2), humidity(Figure 3), illuminance(Figure 4) and wind speed(Figure 5) in the whole year of 2016, it is found that the temperature and humidity on both sides are basically the same. Although there is a small difference in wind speed, but the magnitude of the whole year is very small. While the illumination of the west side is significantly larger than the east side, and coupled with the analysis made by Ma J and Liu G, it can be found out that the light is the main factor affecting the decay of ancient architecture painting.

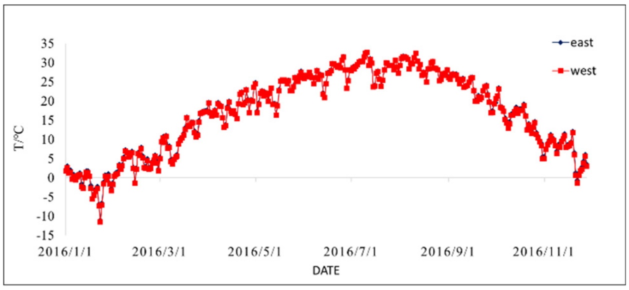


Figure 2. Temperature comparison diagram

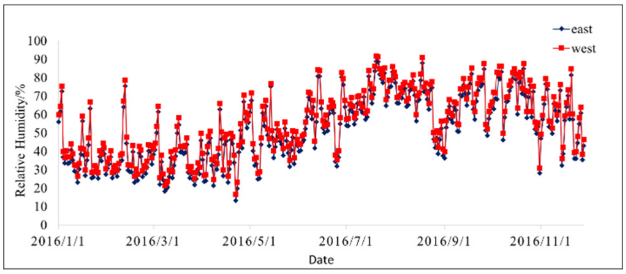


Figure 3: Relative humidity comparison diagram

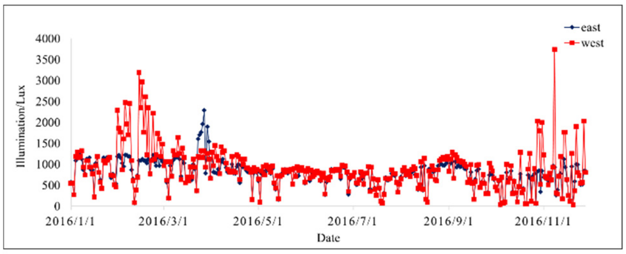


Figure 4: Illuminance comparison diagram

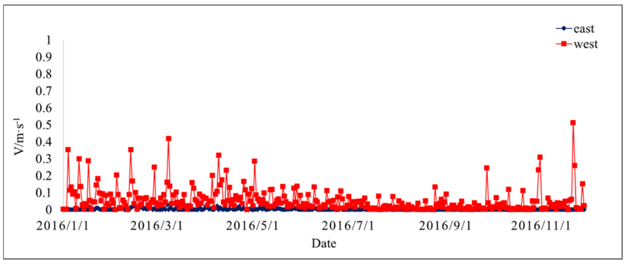


Figure 5: Wind speed comparison diagram

As can be seen from Figure 4, the illuminance on the west side in the winter is obviously larger than that on the east side. While the illuminance of east side is basically consistent with that of west side from April and October. Through on-site investigation and the plan of the Summer Palace, we can know that there is the Kunming Lake in the 6 meters south of the Jilan Pavilion. And as the painting is located at the inner eaves of Jilan Pavilion, it cannot be directly illuminated by the sun light. So according to the amplitude and change trend of the illumination curve, as well as the surrounding terrain, the following inference can be drawn: Although the direct sunlight cannot reach the painting, it can be reflected to the painting through the Kunming Lake(shown in Figure 6).

Figure 6: The plan around Jilan Pavilion

In summer, because of the higher solar altitude angle, the light is reflected to the lake's edge(shown in Figure 7), so that the illuminance on both sides in the summer is almost the same and both value is relatively small. While in winter, the solar altitude angle is relatively small, so sunlight will be reflected from the lake surface to the pavilion(shown in Figure 7). But the lake shoreline on the west side protrudes to the lake, it is not conducive for the light reflection. Therefore, the light illumination on the west is stronger than that on the east.

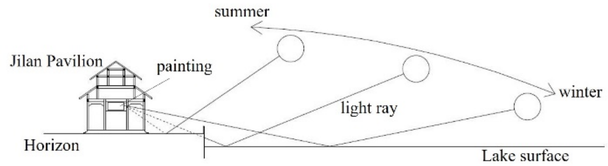


Figure 7: sunlight reflection diagram

4. LIGHT ENVIRONMENT ANALYSIS AND STIMULATION

In order to confirm the inference in the section 3, the ECOTECT software is used to simulate the light environment near the Jilan Pavilion. The simulation contents and results are shown below.

The annual total sunlight hours at the painting position is calculated by transforming the painting into an analysis grid. The results are shown in Figures 8 and 9. Different colors present different value of total sunlight hours. The color is closer to the yellow, the value is greater. It shows all value at east painting is 0, that is to say there is no sunlight being reflected to the east painting throughout a year. However the value at west painting is between 100 to 180, indicating that sunlight can be reflected to the west painting by the lake surface for around 150 hours throughout a year.

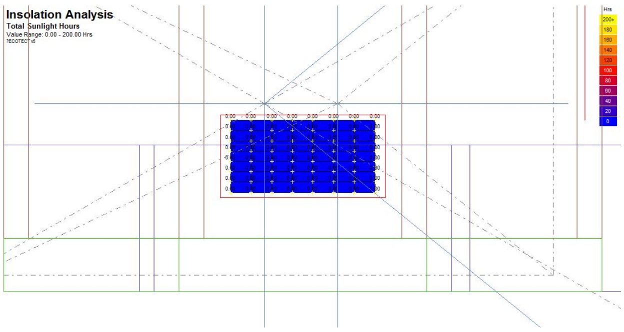


Figure 8: Annual total sunlight hours at east painting

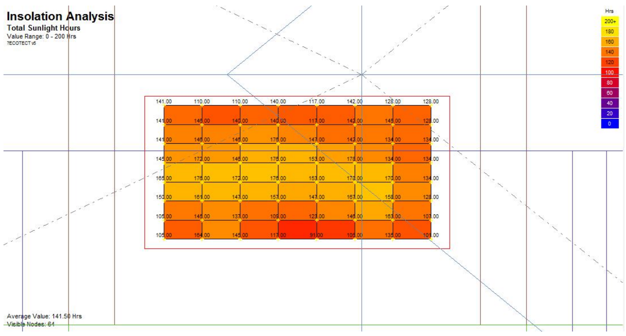


Figure 9: Annual total sunlight hours at west painting

Then, the annual solar shading percentage is calculated by the software in the form of sun-path diagram. The results are shown in Figure 10 and 11. The solar shading percentage means the same area percentage of the painting is shielded from the solar reflected light. When the solar path is in the black area, the sun is completely obscured and the painting is totally in the shadow. On the contrary, when the solar path is in the gray region, the painting is partly exposed to the solar reflected light. We can see from Figure 10, for the east painting, the solar path is entirely in the black, indicating that no sunlight can reach to the east painting by reflecting. But for the west painting, seen in the Figure 11, the solar path is in the gray after sunrise in In November, December, January and February, that is to say sunlight can be reflected to the west painting at these times. These results are consistent with the above results.

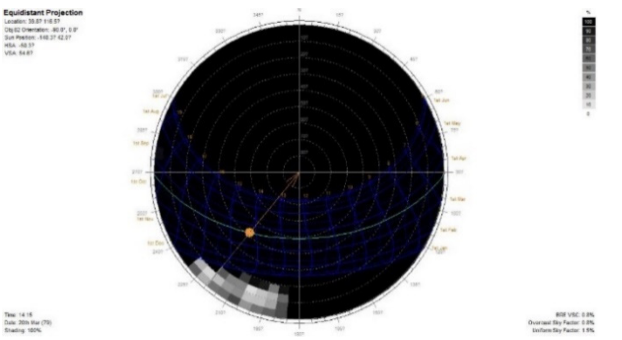


Figure 10: Annual solar shading percentage sun-path diagram at east painting

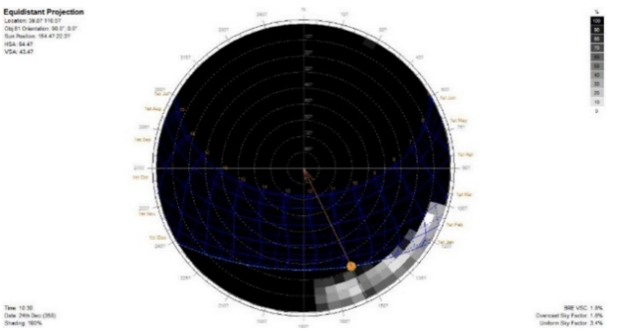


Figure 11: Annual solar shading percentage sun-path diagram at west painting

In the further analysis, we extract the shading percentage data of the two paintings on June 21, 2016 and November 27, 2016 and the illumination monitoring data on the two days. Then we draw the curves that show these data changing over time in the whole day, shown in Figure 12(Solar shading percentage on June 21), Figure 13(Illuminance monitoring data on June 21), Figure 14(Solar shading percentage on November 27) and Figure 15(Illuminance monitoring data on November 27).

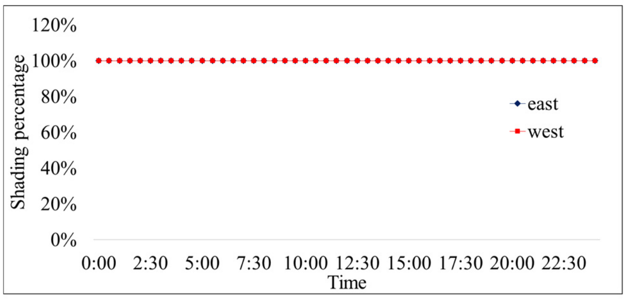


Figure 12. Solar shading percentage on June 21, 2016

On June 21, 2016, the shading percentage is 100% all day long for both east and west, shown in Figure 12. And Figure 13 shows that the illuminance monitoring data at both sides on that day has the same variation trend. The value is relatively small. And the curves are smooth without catastrophe points. All these features reflect the two paintings are in the shadow, without sunlight or reflected light reaching. This is consistent with the result shown by Figure 12.

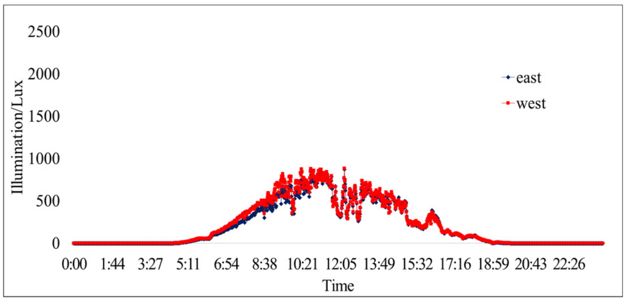


Figure 13. Illuminance monitoring data on June 21, 2016

On November 27, 2016, the shading percentage (Figure 14) and illuminance monitoring data (Figure 15) for east side are almost the same with the day June 21, 2016. However, for the west side, the shading percentage is not 100% from 7:30 to 8:30. In this time, the sunlight can be reflected to the west side painting. Then according to Figure 15, a mutation appears from 7:30 to 8:30 on the illumination curve for west side and the value becomes lager in this time. While in the other time, the illumination is the same with east side.

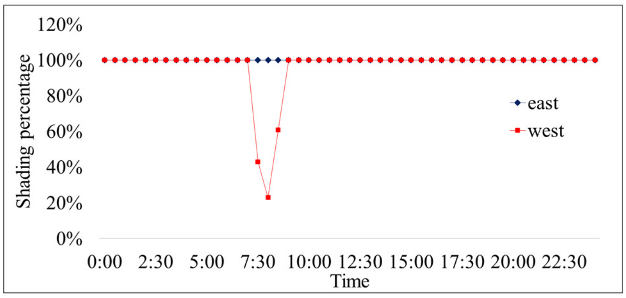


Figure 14. Solar shading percentage on November 27, 2016

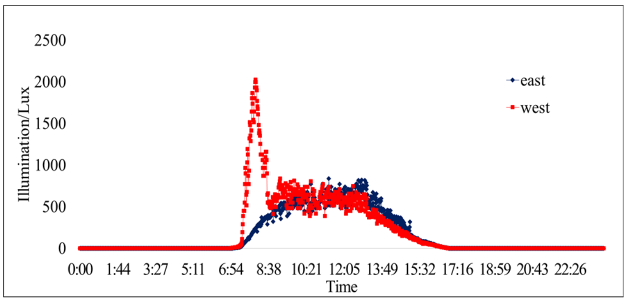


Figure 15. Illuminance monitoring data on November 27, 2016

From the above discussions and analysis, it is can be seen that, the monitoring data is highly consistent with the simulation results. To a certain degree, the previous inference in the section 3 is proved to be correct. And we can draw the following conclusions.

There is no direct sunlight at both west and east side painting in the whole year. But the sunlight can be reflected to the painting by the surface of Kunming Lake, which is in the south of the pavilion. In summer, because of the higher solar altitude angle, the light is reflected to the lake's edge, rather than the painting, so that the illuminance on both sides in the summer is almost the same and the value is relatively small. While in winter, the solar altitude angle is relatively small, so the sunlight can be reflected from the lake surface to the pavilion. That causes the strong intensity of illumination at west painting in the winter morning. But because of the protuberance of the lake shoreline on the west side, the reflection to the east side that should happen in the winter afternoon does not take place. Therefore, the light illumination on the west is stronger than that on the east in winter, but they are the same in summer. The east painting has the same illumination variation trend in the whole year. But the west painting has stronger intensity of illumination in winter morning than other time.

5. CONCLUSION

Different light environment is the main factor that cause different decay degrees of the two paintings on east and west inner eaves of Jilan Pavilion in Summer Palace. Although sunlight cannot reach to the two paintings directly, it can be reflected to the painting through the Kunming Lake surface. Because of high solar altitude angle, the sunlight cannot be reflected to the painting in summer or at noon, so that the change of color coordinates in winter is larger than that in summer. The surrounding terrain prevents sunlight from being reflected to the east painting, so that preservation state of east painting is much better than that of west painting.

In summary, ancient architectural painting under the outdoor environment is vulnerable to erosion and color decay. The color measurement methods and instruments for this kind of cultural objects still need improved. Light is the main factor affecting the painting decay. And the light environment around the painting will be affected by its surrounding buildings, vegetation, water, terrain and other comprehensive factors. Illumination monitoring and environment simulation by software, like ECOTECT, are effective methods to study the light protection for the painting.

ACKNOWLEDGEMENTS (OPTIONAL)

This work is partially supported by the Management Office of the Summer Palace.

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