INFLUENCE OF SHELLAC COATING AND ENVIRONMENTAL CONDITIONS ON CONSERVATION OF AJANTA CAVE PAINTINGS

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Introduction

The Ajanta Caves, located in the west-central part of India (20º N, 75º E) along the Wagora river, were constructed between B.C. 2-1 (early phase) and A.D. 6 (later phase) [2]. Overall, this site comprises approximately 30 caves, which have richly decorated wall paintings and sculptures.

The climate in this region is very harsh, as the maximum temperature during the hot season is more than 40 °C, while the relative humidity (RH) is > 80% and < 20% in the rainy and dry seasons, respectively [4]. When they were rediscovered in 1819, the caves were concealed by jungle, infested with bats, and occupied by vagrant plants. Subsequently, several international teams comprised specialists with arts or scientific backgrounds performed conservation work on the Ajanta Caves. At present, the Archaeological Survey of India (ASI) is responsible for conservation and preservation of the site.

The target cave of this study, Cave 2, was constructed in the late phase and contains a *vihara* (Fig. 1). The wall and ceiling of the main hall and shrines in Cave 2 are covered by remaining paintings. Conservation work on this cave was conducted with research cooperation between the National Research Institute for Cultural Properties, Tokyo (NRICPT), and ASI [4]. A deterioration condition survey of the wall paintings was conducted, so as to identify adequate conservation methods and to obtain scientific information on the materials and techniques used to create the paintings. Subsequently, various additional studies were conducted, such as those designed to predict the future deterioration induced by the black substance caused by bat excretion[1] and the influence of the shellac resin layer (applied to the paintings for conservation in the past) on the present condition of the paintings[2].

In the present paper, the deterioration mechanism of the paintings with shellac coatings, related some holes which could be induced by insect, and the influence of the environmental lighting and thermal conditions are discussed, based on a condition survey of the site and using high-resolution digital images.

Conditions of Wall Paintings in Cave 2

Composition of the wall paintings: The paintings in Cave 2 were constructed using several layers (Fig. 2). The paintings have a layer of rough earthen plaster created from plants and having the form of the ballast rock surface, along with layers of fine earthen plaster, ground layer (lime plaster), and paint. During the conservation works conducted in the 1920s, shellac coating (a few~30 μm thickness) was applied to the paintings in order to facilitate easy viewing of the images and to protect them against the harsh external climate conditions. At

present, darkening of the shellac over time is one of the current problems degrading painting visibility [4]. This darkening of the surface is serious at the upper part of the wall and it is possible that the high temperature outside air which is over the point of softening temperature of the shellac resin, over around 30°C, influences to the upper side [5]. Further, some paint layer and earthen plaster has disappeared and small holes are apparent on the surfaces of the shellac-coated paintings, as shown below. This can also be an ongoing problem.

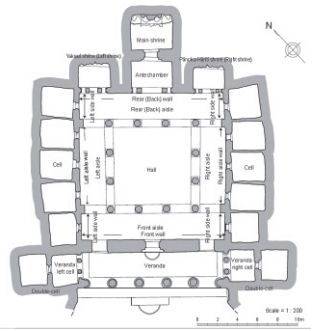

Fig. 1: Plan of Cave 2.

Condition Survey Focusing on Shellac-coated Painting

The condition survey of the shellac-coated paintings was conducted carefully. Small holes with typical sizes of a few millimeters can also be observed on the surfaces of the paintings (Fig. 3a). There are visible white lines of accretions at the same parts. The holes appear in conjunction, as reported previously [4, 1]. The paint layers have disappeared in the vicinity of these holes in the wall painting surface, and some holes are connected to others (Fig. 3b-d).

As regards the areas with shellac coatings, the earthen plaster layer has disappeared, but the shellac-coated paint and lime plaster layers remain (Fig. 3a). An insect (*Ptinidae*) was observed inside the small hole in Fig. 3e in the Cave. As the larvae of that insect family create holes inside earthen plaster, there is a high probability that the presence of these insects is related to the deterioration of the earthen plaster.

Distribution of mural painting deterioration: We examined the wall paintings by focusing on the above mentioned small holes. Fig. 4 shows the areas where the small holes and the white accretions were found. Clearly, the holes are located in the portions of the cave where severe deterioration of the paintings has occurred. There are less holes on the ceilings and upper regions of the walls, while there are more holes on the lower sides of the walls.

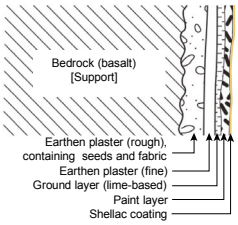

Fig. 2: Structure of the wall paintings

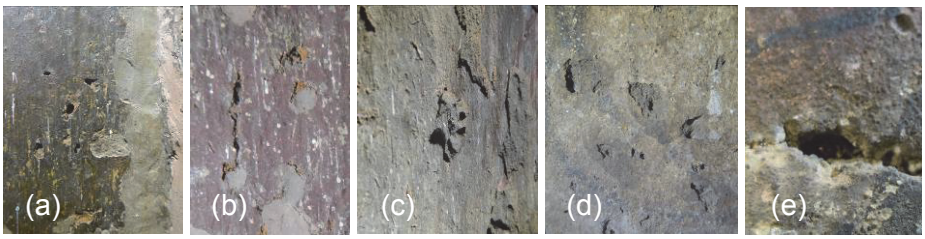

Fig. 3: Condition of the surface of the paintings (a: There are small holes and white accretions on the surface with shellac coating. b, c: The holes connect to others on the inside of the earthen plaster. d: The paint layer around the holes are disappeared in the paintings without shellac coating. e: There was an insect like to *Ptinidae* in the cracks on the paintings.)

Fig. 4: Distribution of the small hales and white accretions on the paintings of the left aisle wall.

Insect-induced holes: According to the previous reports [4], the small holes are widespread in all areas of the Ajanta Caves. In this study, we observed the distribution of the small holes in Cave 2 (Fig. 4). Further, during the condition survey of the surfaces, an insect (might be *Ptinidae*) was observed in one of the small holes. According to reports on the conservation of Cave 17, several small insects such as *Silverfish*[3] and *Ptinidae*[4] are identified using bio traps and they distributed throughout that cave [1]. As noted above, because *Ptinidae* larvae usually create holes in bio materials [3], there is possibility that they cause deterioration of the earthen plaster. Usually, these insects lives under darker and moderate condition.

Lighting and Thermal Environmental Conditions

Thermal Environment: In the rainy season, the air temperature in the cave is 25-30 °C, with more than 60%RH [4, 6]. As the inside temperature of the earthen plaster remains moderate and the humidity is over 60%RH, being almost identical to the condition of the air inside the cave [5], this constitutes a suitable insect habitat [3]. Thus, preservation measures to protect against insect-induced damage should be adopted in the rainy season. Because the temperature and humidity distributions inside the cave are relatively small, the influence of the thermal environment on the distribution of the deterioration features, such as the small holes, may also be small.

Lighting Environment: In order to assess the lighting conditions, we simulated the illuminance of the cave interior using the DIALux computer program [7]. The reflection ratios of the wall, floor, and ceilings were assumed to be 20%. Fig. 5 shows the result obtained for the case in which the sun was positioned at the top of the sky and the sunlight diffusion was high.

Hence, it is apparent that direct sunlight does not enter the cave, except in the case where the sun is positioned at lower 15° and south west in the evening. While the diffused sunlight can enter the cave through the three openings on the west side (Fig. 1), where it can reflect on the floor and walls and weakly illuminate the paintings. The lighting conditions on the front aisle or the back sides of the pilasters are lower than 3 lx and slightly weak in comparison with the surroundings. The areas in which the deterioration involving the small holes is observed correspond to the areas with low illumination. Although the lighting conditions may be one of the factors influencing the distribution of the deterioration features, such as the small holes, this effect cannot sufficiently explain their vertical distribution. Other factors, such as the insect behavior, also have an influence.

Mechanism of Deterioration

The deterioration in the form of small hales and plaster loss may be caused by insects. As

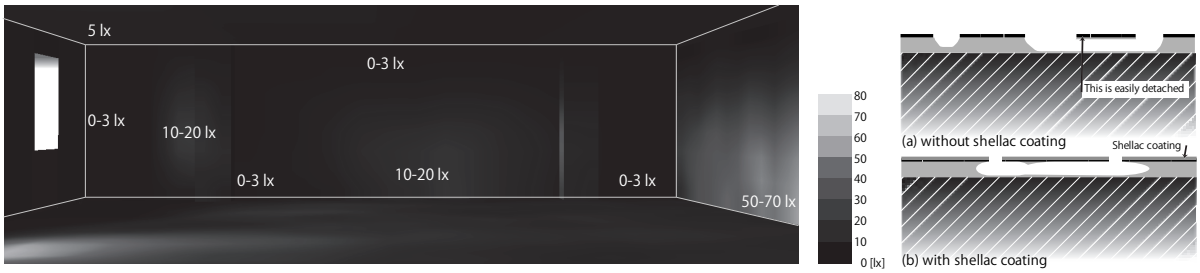

Fig. 5: Illuminance distribution on the paintings of the left aisle wall. The *vihala* and shrines are not considered. The places where there are small holes are located under 3 lx.

Fig. 6 Mechanism of the deterioration (a: without shellac layer, b: with shellac layer)

regards the paintings without shellac coatings, once the earthen plaster has disappeared, the lime plaster and paint layer (which is harder than the earthen plaster) cannot remain in place for a long period of time. Indeed, it can be detached easily under minimal impact. Thus, the disappearance of the earthen plaster can be directly linked to detachment of the lime plaster and paint layers (Fig. 6a). However, it is possible for a shellac-coated paint layer to remain in place even if the underlying earthen plaster disappears (Fig. 6b). From the above analysis, it is apparent that one of the causes of the earthen plaster deterioration and the paint-layer detachment is the presence of insects. However, the shellac layer prevents the paint layers from detaching from the surface.

Conclusion

In this paper, we considered the deterioration mechanism of the wall paintings in Cave 2, Ajanta. Detailed observations of the surface were conducted both in the field and using high-resolution digital images. In addition, the influences of shellac coatings and insects on the deterioration were also analyzed. We suggested some larvae such as *Ptinidae* create the holes in the earthen plaster, and the deterioration is found under the low illuminance condition. Thus the insects' deterioration can be influenced by rather the lighting environment than the thermal environment. The shellac coatings might prevent the paint layer from being detached.

Notes

1. Scientific research fund, no. 24501261.
2. Scientific research fund, no. 25350396.
3. Silverfish have lengths of approximately 10 mm. They damage surfaces, but do not create holes. They require humid and moderate conditions in darkness, and are active at night [3].
4. Mature and larval Ptinidae have sizes of 2.5–3 and 5 mm, respectively. The larvae create holes as habitats, thereby damaging the mud plaster [3].

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