STUDIES ON THE DETERIORATION, CONSERVATION AND PIGMENT COMPOSITION OF MURAL PAINTINGS IN VIHEAR KOMPONG TRALACH LEU, KOMPONG CHHNANG PROVINCE, CAMBODIA

By
Ms. Sreyleak SOUN

A Thesis Submitted in Partial Fulfillment of the Requirements
for Master of Arts (CONSERVATION OF FINE ART)
Graduate School, Silpakorn University
Academic Year 2019

การศึกษาการเสื่อมสภาพและการอนุรักษ์จิตรกรรมฝาผนังใน Vihear Kompong Tralach LeuในKompong Chhnang province ประเทศกัมพูชา

โดย
Ms.Soun Sreyleak

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรศิลปศาสตรมหาบัณฑิต
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Field of Study	(CONSERVATION OF FINE ART)
Advisor	Assistant Professor Radchada Buntem , Ph.D.

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MS. SREYLEAK SOUN : STUDIES ON THE DETERIORATION, CONSERVATION AND PIGMENT COMPOSITION OF MURAL PAINTINGS IN VIHEAR KOMPONG TRALACH LEU, KOMPONG CHHNANG PROVINCE, CAMBODIA THESIS ADVISOR : ASSISTANT PROFESSOR RADCHADA BUNTEM, Ph.D.

This research aims to study on the deterioration, conservation and pigment composition of mural paintings in Vihear Kompong Tralach Leu. The Vihear was constructed in 1672. While the ancient mural painting in the Vihear was drawn in 1850. The paintings are divided into three different sections, the first on the top ceiling is about Ramayana, the second on the upper part of the wall is about the former life of the Buddha and the third on the lower part of the wall is the Biography of the Buddha. The paintings are suffered from severe deterioration mainly due to humidity. The two-phase conservation has been done eight years ago to reduce the effect of humidity. Before the restoration of the painting is proceeded, the scientific analyses of the pigments and the plaster need to be done. The minute amount of the pigments and plaster from the wall was collected for FT-IR, SEM-EDX and XRD analyses. The spectroscopic studies on the plaster samples showed the similar composition of the old and new plaster indicating the proper preparation of the plaster for the conservation. From the EDX analyses, all pigments contain calcium and silicon. The green and blue colors contain copper while the red-brown contains iron. The golden yellow has sulfur. The calcium found in the paints comes from the plaster on the wall.

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Sreyleak SOUN

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CHAPTER 1

INTRODUCTION

1.1 Statements and Significance of the problems

Kompong Tralach Leu temple with the previous name of Pottish Roskas Ram is in Kompong Chhnang Province, one of the most popular cities for tourism industry and culture in Cambodia. There was a project about the concern for the protection and preservation of the city's urban heritage in 2003 performed by the collaboration between the Municipality of Phnom Penh, UNESCO, and the German Apsara Conservation Project. In Vihear Kompong Tralach Leu which is the place for praying and religious activities, there are ancient and Buddha-related mural paintings.

1.1.1 History of Vihear Kompong Tralach Leu [1]

Vihear Kompong Tralach Leu was constructed in 1672. From previous report, it was claimed that there were five persons building this Vihear. The first person was a monk, called Rous. He built this Vihear using plant leaves. Second was Keo Houk who changed from plant leaves to wood. Roy Roum, the third builder, changed to stone wall. Jim, the fourth person, tried to fix and restore Vihear. The last person, Hong Ruon, used concrete pillars in place of stone pillars in 1847.

Vihear was built on laterite base with 1-meter high. It has brick-concrete piles and rugged wooden roof, designed in the ancient style. The size of Vihear is 7.52 meters wide x 15.53 meters long, 5.73 meters high. It has ancient mural paintings constructed in 1850 by Poach and Chea. These paintings are divided into three different sections, the first on the top ceiling is about Ramayana, the second on the upper part of the wall is about the former life of the Buddha and the third on the lower part of the wall is the Biography of the Buddha.

Figure 1 A map of Kompong Tralach Leu temple

Figure 2 Vihear Kompong Tralach Leu

1.1.2 Conservation and Preservation [1]

The conservation of Vihear Kompong Tralach Leu was divided into two phases as follows:

1.1.2.1 First phase conservation

Besides Angkorian cultural heritage, UNESCO promotes the preservation of the rich and most recent Cambodian Buddhist cultural heritage. In previous years, support was provided for the restoration of the 19th century Kompong Tralach Leu temple, Kompong Chhnang province, a masterpiece of the Khmer Buddhist cultural heritage. This temple is a high level of cultural significance because it is an integral part of the historical development of Kompong Chhnang provinces, and has been a focal point for social and religious activities for many years. The murals represent a significant part of the city's cultural heritage.

This project was performed as the collaborative work between the Municipality of Phnom Penh, UNESCO, and the German Apsara Conservation Project reflecting the general level of concern for the protection and preservation of the city's urban heritage. The project began in October 2002, and the preliminary conservation assessment of the murals was conducted in the first half of 2003. This preliminary assessment was the first stage in the conservation process. The key tasks were undertaken by the German Apsara Conservation Team, with the support from municipality staff as the following details:

a. Taking photographs of the murals, documenting their state of decay and collecting paint and plaster samples
b. Collecting information about the history of the murals, and their iconography
c. Selecting a cleaning test area to assess the effectiveness of basic cleaning agents
d. Strengthening the whole building [2]

1.1.2.2 Second phase conservation

The conservation in the second phase last 6 months, from 2010 to 2011 by Ministry of culture and fine arts. The plan was to renovating the roof of the temple and repairing the wall paintings. For ventilation purpose, the holes on the roof covering with a net were made in order to avoid animal invasion and rainfall running into the interior of the roof (see Figure 3). Moreover, the cracks found in the roof tile caused the rain to flow into the Vihear along the pillar resulting in the break age and deterioration of the pillars. Water and humidity in the Vihear caused the salt precipitation in the wall leading to the deterioration of the painting. To reduce the moisture in the wall, the plaster layer (15 cm above the floor level) was removed with the area of 30 x 60 cm (see Figure 4). The salt adsorption process (Figure 5) using the cellulose fiber was processed to remove the salt precipitates from the wall. The strengthening of the pigments and plaster was also performed using the glue as in Figure 6.

Figure 3 The holes on the roof covering with a net

Figure 4 The removed plaster layer with the area of 30 x 60 cm

Figure 5 The salt adsorption process using the cellulose fiber

Figure 6 The strengthening of the pigments and plaster using glue

The factors causing the deterioration of mural painting are temperature, humidity, pollution, dust, insect nests, excretion of animals and human. A few years ago, during the Khmer Rouge period, this Vihear had been used for the storage of salt and medicines. This caused the severe deterioration to the Vihear and the mural paintings.

As compared to another factors, humidity causes the most severe damage on mural painting like paling, peeling off, softening and powdering of the paint layer, efflorescence of salts, loss of the adhesive properties of the medium, damage to porous building material and vegetation growth a biological factor of deterioration. Sources of humidity are rain, capillary water and air.

Figure 7 Detailed view of Vihear Kompong Tralach Leu

Up to now the conservation in Vihear had been done for 10 years. However, the deterioration of the Vihear is still in progress. The leak of water is still observed from the water stain on the ceiling. The rain water elutes the excretion of bats and birds onto the paintings. According to the pond around the Vihear, ground water adsorbed through the wall plaster causes the salt precipitation in the plaster matrix. The colors of the pigments on the paintings range from red, blue, black, yellow and white. The damage due to paling and peeling off is obviously seen all over the paintings. According to the written report [1], the re-painting and the detailed studies on the pigment compositions have never been done.

1.2 Objectives of the Study

1.2.1 To assess the deterioration condition of the mural painting at Vihear Kompong Tralach Leu

1.2.2 To study on the elemental composition of pigments and plaster used in the wall paintings

1.2.3 To propose on conservation and restoration strategies

1.3 Scopes of Studies

This study focuses on the assessment of mural painting deterioration and elemental composition of the used pigments in Vihear Kompong Tralach Leu, Kompong Chhnang Provinces, in Cambodian.

1.4 Research Outlines

1.4.1 Literature review on the conservation of mural paintings

Review the documents like books, research journals and proceedings relating to the mural painting conservations.

1.4.2 Assessment on the deterioration condition of the mural painting

The condition assessment report was designed and used for giving the deterioration details of the mural paintings in Vihear Kompong Tralach Leu, Kompong Chhnang Province, Cambodia.

1.4.3 Collect the pigments and plaster samples for scientific analyses: FTIR, SEM, EDX and XRD

The pigments and plaster samples were collected at different areas on the paintings and subjected to the scientific analyses like Fourier Transformed Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM)- Energy Dispersive X-ray (EDX) and X-ray Diffraction (XRD). The identity of the pigments and plaster was revealed and used for further studies.

1.4.4 Write-up the thesis

Collect all data, perform analyses and write up research paper(s) and thesis.

1.5 Research Plan

All pigments and plaster samples were collected from the mural paintings at Vihear Kompong Tralach Leu, Kompong Chhnang Province, Cambodia. The analyses were performed in Department of Chemistry, Faculty of Science, Silpakorn University**.** The research period is between August 2019-May 2020.

Research plan	Time (month)									
	1	2	3	4	5	6	7	8	9	10
1. Literature review on the conservation of mural paintings										
2. Assessment on the deterioration condition of the mural painting										
3. Collect the pigments and plaster samples for scientific analyses: FTIR, SEM-EDX and XRD.										
4. Write-up the thesis										

CHAPTER 2

LITERATURA REVIEWS

2.1 Introduction

A mural painting is an artwork drawn on the wall. It can be inside or outside the building. The painting was drawn on the wall made from wood or plaster. The word mural derived from the Latin word “murus” mean wall. A mural painting is a type of painting drawn on surface of wall, ceiling or another permanent surface.

The significance of the murals has important cultural and express the ethos of a group of people in a deep way. Art history is concentrates on culture works created to inform, values and practices into the public eye [3].

2.1.1 History of mural painting

The mural painting has appeared since the beginning of the pre-historic and protohistoric times, the ancient art from of India. The paintings were found in caves or rock walls between 18^{th} and 19^{th} centuries in North and Maharashtra of South India [4] [5].

Murals are the two dissimilar highest quality in Indian traditional painting compared to the ancient world. Frescoes painted on the cave of Ajanta, Ellora, Bagh caves and Sittanvasal are the proof of murals and the oldest one is about 3000 years BC [6].

Deficiencies of preservations along with all types of deterioration and damage consequentially bring a large concern to the present study which is to germinate a protective bio-based gel [7].

The art has undergone many changes in form, style and content but has also witnessed over the centuries, an evolution in its technical execution. Mural paintings are found in the remotest nook and corner of our country; in religious and secular buildings of which many are looked after by Central and State Governments as protected monuments.

a. The influences of history factors in North and North Western India [4]

However, the paintings in rock shelters and pre-historic cages are classified by Selves, several paintings in Mirzapur District of U.P and the later series in the Mahadev Hills in Raigarh, M.P are considered to be in span of 4/6 – 10th century AD. The paintings in Bhimbetka caves (Bhim Baithank) near Bhopal in M.P was prioritized as their prehistoric cultural value around 10,000BC that have been included into many phases and the last one was an interval of 6th and 7th century.

Majority of southern Indian painting from the painting from the cave temple were applied on plaster, prepared walls and rock cut which reflected the practical method of painting proceeds on bare rock by using ochre or white colours within varieties of contents, looks and materials used. The results, however in the executed-on rock laid over with a mud plaster in 2rd century B.C and continued to 6th and 7th century A.D. In the post A janta Baghera, the Buddhist painter who in his ageless devotion to the Buddhist who in the ageless devotion to the Buddha completed his work in the remoter of the Himalayas in Arunachal Pradesh, in Ladakh, Jammu and Kashmira in Tabo valley of Lahul and spiti district of Himachal Pradesh and also district Dhar by utilizing similar procedure following the Ajanata period.

Difference from rock cut caves of Ajanta and Bagh, the paintings in Ladakh and spiti valley are done on mud plaster and lime ground. Although the common pigments that the form and line of the Himalayan paintings in Ajanta Bagh display a vastly various style and form, the Buddhist painter has to use it unless the same palette. Whether it is Himalayas, Northern plains, or the plateau like regions of North India following the hiatus kept on coming again with the advent of the Muslim intrusion of India in the 13th century and those are in other classical temple arts of North India got a severe impact. In the 15th century and later on, the art resuscitated as far as the paintings are solicitude much ground was arrogated by miniatures in which the Persian Safavid School was informed and wall paintings passed to the back. Wealthy classes and particular Jains for temples in Gujarat and Rajasthan performed as an illustrator of manuscripts commissioned from Hindu painting culture.

The methods of the latter's execution distinguish from wall paintings according to the carrier, by the way there are many materials employed in both. A large number of pigment and binding media, for instance, found a place in these both techniques. Due to the weakness of the Moghul Court in the second half of the 17th century A.D. the wall paintings in Rajasthan initially came into sight in relatively free from dangerous places like place temples in the Royal Rajput Forts, meanwhile alongside the art of miniature painting started to grow vigorously. It is a false perception that wall painting was regulated by the Moghul idiom and gained through what is known as the Rajaput style, whether it was paintings in miniature or on walls. Resurgence of the art of wall painting in North India gave a certain impression on the outside of defensive structure in which Akbar and Jahangir treasured as the evidence of murals on their forts, places.

b. Techniques of mural painting

In order to conduct a mural painting whether on walls of caves, structural or walls of places were based extremely on Indian developed techniques that constituted of three fundamental layers and attached to the ground of pigment layers. The pigment layer, which obtains the picture and support on the wall, may be rock surface in a crave or structural on that serves as carriers are rough or unsmooth. This unevenness benefits the 'tooth' to hold the plaster on the surface. This unsmooth surface has to be made uniform with layers of plaster in consecutive stage of fineness in which generally one layer of rough plaster followed by one another of plaster. Either ground or plaster is a composition to apply on the surface material of a wall or building in a form of plastic mass made from certain materials with water letting the mass set by drying, carbonation or hydration. The setting elements of plaster normally combine with clay which results from drying, lime which receives from carbonation, gypsum and pozzolana which are provided by hydration [8].

Clay, live stone, lime and shells, in powdered form serve as the ground substances, are different mixtures for rough plaster. The organic materials like gum, glue, pulled out from barks are effectively adhesive for some particles. It is demanded to be more conservative for fine plaster layer's preparation as it is the layer on which the pigments are linked up with picture. 'Shilparatna' propose an assortment of conch

Oyster shells or white clay with gum of neem or calcium hydroxide and coconut water. Its reaction results from saturation with carbon dioxide of slake lime that becomes Carbonate as a final product. Mural paintings have been lime washed since 17th until the beginning of 19th century. In contrast, A few paintings in vaults were never lime washed, for example at Taby and Floda, painted by medieval painter names Albertus Pictor. A plaster base is known as ground of varied thickness is Laid on support, whereas the ground may compromise of one or more layers. Strengthened ground plays an enormous role for the whole mural and determine mural's character, whether it is fresco or tempera. The mural painting is comported plaster with the ratio of 1:2 from lime and sand. In addition, a combination of egg yolk, vinegar, oil colours is taken in dry plaster [8].

In the early middle of 19th century painting of murals in tempera was claimed to be the prominent supporter, even so it occurs that Italian process Buono had appeared to be recognized to the Indian, especially Rajput painter. The process of fresco Buono which involves painting on wet lime plaster was struggling due to unproductiveness of climate state, nevertheless Indian painters had their own version that varies from a standard to address on a wall in several then Layers, each fasten properly to eliminate the cracks and joints the entire wideness of a quarter to half inch. Lime plaster and prepared milk of lime were applied to wet wall, at the same time several coats were applied by rubbing the stone each time and the final one followed by smoothening with an agate stone to generate an unbroken glaze surface which later acquired pigment arranged in water with a gum medium and from time to time glue if there happens to be needed in pigment, especially black. A little protein in the form of curds in the slaying of lime is essential in advance of milk lime, also the polished white plaster wall related to the plaster prepared for Buono fresco but the alikeness ceases there and the painting could probably be finalized both on wet and dry ground using a binder. Finally, on account of this beating and polishing the painting could be wiped by cloth or limited washing with water to remove the dust and dirt. It is believed that the pigment can be gained by a layer of lime which caused by beating and polishing [4].

In the 1420s, Wat Ratcha Burana in Ayutthaya was a master piece of long-lasting fresco technique from Chinese artisans, according to the Thai research. What

is more, the walls of the lower crypt of this ‘chedi’ were occupied with paintings, including various scenes formerly thought to symbolize a series of Jataka tales prior to the final ten and found in 1957. There was a chaos time as the original murals were lost when the structure broke down, but duplication from the compositions were based on this tragedy. There are two styles in evidence; one team painted rows of hieratic Buddhas with disciples, and another composed the Jataka murals regarded as demonstration of narrative wall paintings superior to the 18th century. The ceiling, with a big roan and shape of medallion consists of common central bands and flowers dedicated distich similarities to paintings found at Ajanta in India. Monochromatic colors were utilized. In 1959, another exploration brought about depictions of celestial being which would be differentiated to stone engravings at Wat Si chum in Sukhothai [9].

c. Dyes used in mural painting

There are more than 450 plants that used for the coloring of textiles, drugs and cosmetics in India. By the way, the non-toxic plants are also exerted in food products and some make as medicine as well. Moreover, there are many more plants have been exploited. Therefore, there have a few precise techniques about the synthetic dyes in [10].

The origin of the color materials such as terracotta, chalk, red ochre and yellow ochre with animal fat were exerted as the mural painting in ancient India. The colors were applied to different kinds of material. The white originated from lime, black originated from carbon soot of lamps, and also the red and yellow came from minerals. Moreover, the blue originated from indigo ferra and deep red from lac [11].

To sum up, mural painting in India is the one of the ancient arts which, from the pre-historic and protohistoric time on the cave or rock wall in 19th century, and there’re who the first of knowing to apply the different kinds of colors materials on mural painting. So, it’s clearly with the most important history in Indian that related to the religion and culture in Cambodia by showing the paint on walls to talk about the life of Buddha and Ramaker in the old Buddhist monasteries.

An ancient Cambodia was influenced by the two religions from Indian such as, Buddhism and Hinduism. Buddhism in Cambodia is influenced two points from Indian. Mahayana Buddhism flourished strongly in the late 12th to 13th century, in

ruling Jayavarman VII. As have known that, there are many evidences which have been demonstrated through temples that dedicated to Mahayana Buddhism. The history of Buddhism was influence by ancient people in Cambodia to show on wall paint such as, Buddhist or Novel. Actually, to be purposed of knowledge of worship that showing about life of Buddha etc. After Angkor period Mahayana was converted to Theravada Buddhism. Theravada Buddhism has been linked to Buddhism in Lanka, while Lanka was a major Theravada Buddhist center, while bringing the Buddha's story to the Buddha was changed appearance. However, historians and religion of India and Cambodia were painted on wall paint by showing about life of Buddha and Ramaker in old Buddhist monasteries until nowadays. Which, to show about the story that related to India and Cambodia.

2.1.2 Mural painting in Cambodia

In Cambodia, there're many origins of insight for Buddhist mural "murals are paintings created on walls "murus in Latin, therefore murals" accomplish an arranged level surface on that a painting of the matter to be painted is created. The surface is commonly rock like and arid, the specialized name of "dry fresco mural" thought the most ordinary are commonly the life of Buddha and last ten Jataka tales. In the other Vihear, many parts from each are commonly contained, constantly with short recognizing message, even though in some conditions, sure situations may take up one filled wall, like the defeat of Mara, the Buddha supplying his first sermon, the descent from Tavatimsa Heaven, or the MahaParimrvna. In specifically, the wall later than shrine, from fundamental part to the ceiling, in most case full with a huge scenery of the first Sermon, when observed in old monasteries by Giteau, the describing of the Dream of Maya was barely represented [12], which is opposite to what could be seen recently, as this view is now regularly described in the murals.

In the past, the artists seemingly had some component of religious comprehension or agreement. Nevertheless, they had yet to obey rigidly the command of the promoters and concurrently maintain their artwork in correspondence with the religious memorial coming after appointing iconographic codes. Any evidence of egocentric painting, or what we might deal with the style of an artist, could be ascribed to various understanding of the content and to the painter's capability to contribute a specific atmosphere or context [13].

Function of murals [13]. In aspect of the quick social reversals in Cambodia society, the attainable reason for bedecking monasteries and particularly, for the addition of Buddhist narratives, have to be searched in some details. In this revere, different functions of the murals can be distinguished.

a. The prayer functions

The perceptible narratives decorating the walls and plaster of Vihara comprise a prayer to the Buddha, to his life and his abundant previous lives in examination of the truth. The narrative description completely changes the Vihara into a demonstration of his mission, an impression of Buddhist cosmology (theory of the universe) and the Vihara's identification with him. Through, the construction turns the living presence of the Buddha. For this reason, it's a widely held view that all Viharas from the start must have been decorated with some decorations, making it real value as a representation of the Buddha.

b. The didactic function

The murals are determined to educate and admonish devotes over the visual contributing of the teachings of the Buddha or Bodhisattvas. The murals inform, lead and stimulate by demonstrating scenes of religious history and moral worth. For those who have been thought the image of elephant, drew white and a man pouring water in front of beggars, is adequate to flash the narrative of the beginning of the Vessantara Jatake with its symbolism of great goodness and compassion. Each character activities are identified in the light of the content it symbolizes, as a usual procedure that had been making it's easy by closeness with the oral attitude and display theatre accomplishment, show performance of the "Sbek Thom".

c. The symbolic function

Mural painting is purpose of existence to the Buddha and his teachings in the Vihara. Symbolically, the Buddha as recognizable for the monks and the worshippers share the lives. Consequently, in this manifestation the stories are not certainly meant to produce a story are not the mind of the witness and the images are not "read" analytical way or even looked at, and nor arrange in a mental narrative "this would be in line with the old tradition important discussed by Robert Brown in which the murals in ancient Buddhist pillar had the function of showing the Buddha's presence in his form and teaching [14]. In 8^{th} century release of the Chedi Chula Pathom in

Thailand, in which there was no struggle to create a fictional, but directly to make clear of the Buddha is presence, hence, making the monument expressive. Even at Borobudur, where the equivalence between text and photo is almost complete and establish to reflect the story nature of the lexical text, the optical images of the specific the Buddhist nature of the monument as a demonstration of the Buddha and his teaching they're surrender their teaching slightly through their contact with the worshippers.

d. The merit making function

In Cambodia, At the same time the Buddhist clergy and the Buddhist monastery are sweeping to specific case in Vihear and be new to attract attention. In old murals in Vihear are not good supremacy need to be changed. Indirectly, it's more useful to assemble a new Vihear with new mural paintings. Absolutely, it must affectation wealth to attract wealth. The benefactor of murals is public display of their names and amount gave to serve a tangible "receipt" of the endowment and a "guarantee" of benefit gaining.

On the edge of the section from the Buddhist art in India was leadership in Cambodia. Historical of Buddha painted on wall form Indian to Cambodia view the point in Cambodia society has been changed and there're similarities between the styles that show about the Buddhist art in Khmer on caves in old Buddhist monasteries. Actually, the wall painting in Cambodia was shown about the biography and former life of the Buddha such as, traditional music, circus performance of arts, activity in the market and crafts on the mural painting like ancient traditional style on wall painting in Vihear Kompong Tralach Leu, Kompong Chhnang Province in Cambodia.

2.1.3 Mural painting in Vihear Kompong Tralach [15]

The monastery of Vihear Kompong Tralach Leu is located about 45 kilometers to the northwest of Phom Penh and can be reached from National Road No. 5. A large medallion on the Vihear's western wall is inscribed with the date 1925, presumably referring to its construction or decoration, while the nearby old salesman has a plaque dated 1922, showing that both were constructed towards the end of the reign of King Sisowath I. The monastery is active but with few monks. Most of the

buildings are dilapidated, especially the old wooden Vihear and houses serving as the residences for the monks. The monastery was occupied by the Khmer Rouge soldiers from 1975 to 1979, causing extensive damage, as the Vihear was used for boiling and disinfecting gauzes in large cauldrons for wounded soldiers Figure 8.

Figure 8 Vihear Kompong Tralach Leu

The most attractive murals on the wall of Vihear were found everywhere in Cambodia. They are probably the only remaining classic of a particular painting style such as delicate, human and refined. Base on the examine by Giteau in the 1960 until 1970, while the best of the classic ancient mural paintings were conserved in Cambodia, the murals of Vihear Kompong Tralach Leu perform the meeting point of Aristocratic and Provincial styles. These paintings of Vihear Kompong Tralach Leu along with those of Vihear Sisowatg Ratanaram through the expert artist Tep Nimit Mak are the only lasting examples of an old style that can be called “classical” with a delicate historical and refined design. Beside a culture and art narrative opinion it implies essential that necessity intervention be collected to combine and conserve these exquisite murals that have been under estimated for far too long. Scenes from the Life of the Buddha are described high on the walls as with the most traditional visual historical in Buddhist monasteries, as long as the Jataka tales involve a lower position between the windows. Since it’s further the scope of this book to explain in the detail the marvelous murals to be discovered here, consideration will be paid only to a few of the most attractive and noteworthy panels Figure 9 and 10.

Figure 9 A mural painting in Vihear Kompong Tralach Leu, A full mural panel showing the descent from Tavatimsa Heaven, within a cosmological setting, from the life of the Buddha.

Figure 10 A mural painting in Vihear Kompong Tralach Leu. Detail of a mural depicting the Vidhurapandita Jataka, showing the ogre Punnaka being enchanted by the dance of Irandati.

a. The cosmological panel

A part of the western wall in Vihear defined with art of the Trai Phum where the Buddha came down from Tavatimsa Heaven to initiate the doctrine with his mother. The line of blue and thick red background of the backstory are simple, that offering to Buddhist narratives present the will power and glamorisations with the people and the Buddha.

b. The life of the Buddha

In this story style of the panel illustrate several events from the Buddha life are extremely notable Figure 11. The allegory maturation was along without broadly. The backstory of the Great Departure was appeared at rocky landscape with Prince Siddhartha gets out his horse Kanthaka and his Liege Channa, who kneels opposite in his tension. Then the allegory is continuing movement with Channa is crying on the horse that is dying of sadness. In the bottom of the panel, Channa has been going away to get back Siddhartha's gold crown to his father. The allegory changes to the right and fairly high than before occasion painting the cutting of the Hair Figure 12, and under this, Indra come from the heavens to get the hair in a gold casket.

Figure 11 Vihear Kompong Tralach Leu. A mural from the life of the Buddha showing perspective with multiple vanishing points.

Figure 12 The cutting of the Hair: Siddhartha cuts his long hair, using his left hand, under the watchful eye of Indra to the right.

c. Vessantara's coronation

From the first part of the end of Vessantara Jataka backstory, Vessantara was being appointed king. He was sits in a hieratic, angular pose with royal blade, Ta Prohm in his arms, dressed in gold and green with crown jewel Figure 13 and 14. This tale is very similar to the formal figure to cut into cowhide of the Sbek Thom. People who are staying around him are welcome to the event altogether with jugglers, acrobats, dancers, musicians and local people, starting off the airspace of happiness and delight Figure 15.

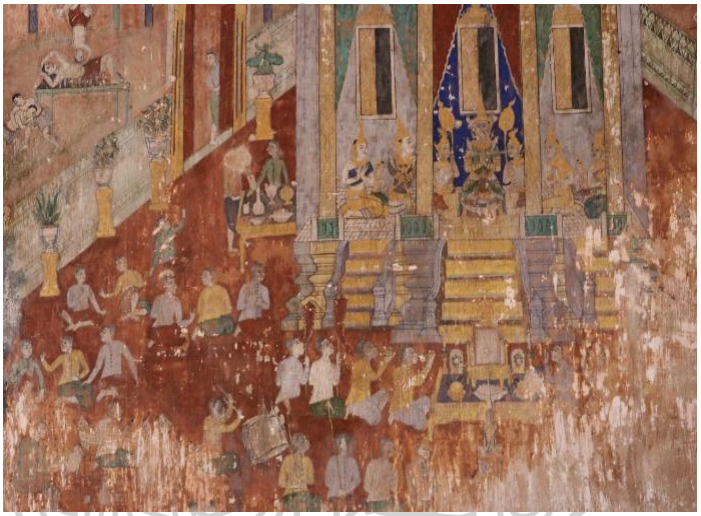


Figure 13 Vessantara Jataka is shown in his royal palace being appointed king. He sits in a hieratic, symmetrical pose, with the royal sword, Ta Prohm, in his arms, dressed in gold and green with royal regalia.

Figure 14 Vessantara Jataka: The coronation of Prince Vessantara.

Figure 15 People are celebrating the event including jugglers, acrobats, dancers, musicians and local people, creating an atmosphere of joy and excitement.

d. Other Jataka scenes

The fascinating and infrequent are the tale of an occasion from the Maha Ummaggaa Jataka, when Mahosadha helps the princess to dress before fleeing though underground to avoid capture by the evil Culani. One more painting is showing fluid and evolution is that of the Candakumara Jataka, in which of the young prince is shown waiting calmly at the involvement to be relinquish enclosed to his wife and courtiers, as Indra arises in the sky striking down the ceremonial umbrellas by disordering and terminus the reparation.

Figure 16 The young prince is shown waiting calmly at the stake to be sacrificed surrounded by his wife and courtiers, as Indra appears in the sky striking down the ceremonial umbrellas, there by disrupting and terminating the sacrifice.

e. Scenes of daily life

The painting shows the most interesting scenes of daily life that talk place in the market with local people and foreigners are busy in looking for alcoholic drinks, the busy small shop with women sell cloth and another ironmonger. At the right site, the customer is holding a sword as a result of locksmith handmade job. At the front of, a man helping other by replacing a horseshoe Figure 17.

Figure 17 A mural painting in Vihear Kompong Tralach Leu, Scenes of daily life looking for alcoholic drinks; in the background in a small shop, are ironmongers and women sell cloth; to the right a locksmith is working diligently for a customer holding a sword; in front a man is replacing a horseshoe with the help of another.

f. Ceiling and other decorations

Vihear Kompong Tralach Leu is also painted on ceiling and walls. Regrettably, the panels have pounded extensive damage from acid rain insertion and only a few views are clear, such as the one with a kinnra ‘male kinnari’ of huge moiety compared to the many devatas flying in the sky.

Yaksha was painted at the doorjambs of the window shutters, that protector or kinnari standing on animals, like tigers, elephants, and nag as. At the top of the wall

between the huge panels and the veer ceiling is a clerestory with kneeling gods and devatas against a Prussian blue background Figure 18 and 19.

Figure 18 A mural painting in Vihear to showing on the ceiling is painted with a scene from the Rama Epic showing Viradha attempting to abduct Sita, while Rama and Lakshmana are clasped in his feet.

Figure 19 A mural painting in Vihear with a scene from Vessantara Jataka: The eight Brahmins ride away on the white elephant received from Vessantara, while the distressed local villagers are complaining in anger.

2.2 Techniques of mural painting in Cambodia

According to [16] one publication, Nafilyan, it stated that ancient mural paintings in Cambodia involved complicated processes and required tremendous efforts in making it starting from preparing the walls, mixing the paints and finally dealing with the complexity of gold leaf. It was quite surprised that these techniques used by

Cambodia were similar to India manual starting from the wall preparation, using the similar organic for undercoating and using the same type of pigments. This information was provided from an expert in restoration and it was included India publication, which was published in 1957 by Sri Gunasighe at the Presse Univeristaire de France. These ancient mural painting techniques are described herein [15].

2.2.1 Preparation of the base [15]

In the past, the wall was carefully prepared so it would be in the best possible condition for receiving the primer, which formed the base for the colours. The wall was rendered neutral, free from salts, allowing for a solid adhesion of the primer.

The primer base on which the paint was applied consisted of one or two layers of lime mortar or plaster, 2. 3 mm thick. The colour was generally white, but it may have been slightly orangey yellow depending on the mixture of the composing particles. Afterwards, the wall was polished with a brick or stone to obtain a totally smooth surface. Then, the lime in the plaster had to be neutralized in a two-step process, since the lime could cause chemical reactions with the paint layers.

First the wall was distempered or whitewashed with solution of ‘mlou phnom’ (mountain betel). The distempering solution was made by dissolving in water a paste obtained from the leaves of the mlou phnom, well mixed and filtered. Ordinary piper betel, which was cheaper, was also used. The wall was then washed two or three times with this solution. This was followed by a test of the results with a layer of white paint; if it became yellow, it was necessary to repeat the application of the betel solution until the white paint did not turn yellow.

In the second step, the wall was whitewashed with a specially prepared mixture in order to completely neutralize the lime. The application of the whitewash was made with a ball of white cloth about the size of a first, never with brushes. There were different ways to create the solution, including:

1. a seed, locally called ‘krakas’, was ground and rubbed together to form small pellets. The pellets were boiled until a jelly was obtained, then passed

through a sieve. Finally, a filtered clay solution was mixed with the krakas jelly, in the proportions of one third clay water to two thirds jelly;

2. A mixture based on tamarind seeds (Tamarinds indica) and made in a similar fashion to the krakas jelly.
3. A mixture based on the bark of 'krapul bay', soaked for a time in water, and then mixed with an equal amount of glutinous rice flour.

2.2.2 The pigment [15]

Many colors were derived from original materials like the yellow from ochre, white from sells or kaolin, a fine clay, and black from charcoal. Green was excerpt from the pigment cobble together from pepper leaves, filtrate and left to dry into a powder or acquire from malachite imported from China. Red was produced from the gains of 'Champou Lak' (a Variety of Jamboc, of the Myrtacea family), by crushing, boiling filtered, and then atomizing to acquire. Cinnabar was obtained by a dense tone of vermillion or scarlet, and blue pigments from China was made from lapis lazuli. Before Khmer Rouge many mural paintings were examined that no chemical analysis.

2.2.3 Preparation of the paints [15]

The intended design of painting could commence by first outline in red or black after the offset of the lime. Many paints were quite complex inn pre parathion by some of the powders were imported from China, and others were acquired from the preparation of powders as defining above. Cambodian artists arrange the paints in two ways by these powders:

1. The well-known local trees like 'Snay' (strellus asperolus) and 'Rovea' of the (chrey kroem) diluted with powders. Nevertheless, scientific names are uncharted. At that time, Albumen (egg-white) was dropped to mix with those powders.
2. The mixture of the powders in a solution of resin of 'Krasaing', previously a few albumens was added to dilute with water.

2.3 Deterioration of Mural Paintings

There was a study on the deterioration factors facing mural paintings in El Sakakeny palace, Egypt [17]. This palace was built for Habib El Sakakeny Pasha in 1897. The palace is famous for its decoration and the mural paintings on ceils or walls. There are mural paintings in a Rococo style exist in a love chamber on the first floor of the palace (Figure 20). They suffered from many deterioration factors as following:

1. Raising of groundwater through the walls of the basement due to the palace location on a dried lake called Karaga (Figure 20 (a))
2. Daily sunlight exposure due to the huge windows (Figure 20 (b) and (c))
3. Electric light as the palace being used as an office for curators (Figure 2.13 (d), (e) and (f))

The most vital factors on mural painting deterioration are **salts** in the rising ground water and the **daily sunlight**. The wet-dry-wet cycle due to ground water and sunlight causes the salt polymerization and the salt growth resulting in the detachments of paint layers as being shown in Figure 20 (c). The two scientific methods used for salt analyses are X-ray diffraction and Scanning Electron Microscopy – Energy Dispersive X-ray (SEM-EDX). The results from both techniques confirmed the existence of halite (NaCl) as the main component in the salt.

Figure 20 The deterioration factors facing El Sakakeny palace [16], (a) The ground water in the external walls, (b) the huge window in El Sakakeny palace, (c) The sun light affects the mural painting in front of the huge window causing detachment of the paint layers, (d) The modern paints, (e) The random electricity as the lamp is touching the wall causing detachment of

the paint layer, (f) The chairs and desk for the too many curators inside the palace.

The conservation on the mural paintings in this palace was suggested. They can be protected by covering with flat glass (Figure 21). This method was widely used in tombs in Luxor and Aswan to prevent visitors from touching the painted layers. It also cut off all the harmful radiations.

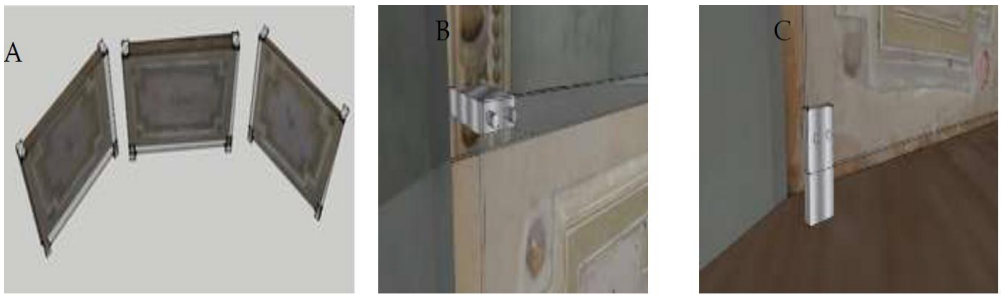


Figure 21 (a) The final view of the special glass on mural paintings, (b) and (c) The shape of the nails which used in the installation of the glass to the wall [17].

After there was studying on the deterioration factors facing mural paintings in El Sakakeny palace, Egypt. They continued to focus on analytical study of the materials used in mural paintings in the love chamber of El Sakakeny palace also. During this century, several mural paintings were executed on the ceilings and walls of several rooms in a style that differed from the usual oriental one used in Egypt [18]. In the stratigraphic study as following:

-The first layer of rough coating, applied on the wall support of limestone, is a mortar composed of a mixture of hydrated lime (calcium hydroxide) and coarse sand.

- The second layer consists of zincate and gypsum.

- The third layer is the pictorial layer, made of pigments, the medium being applied in several coatings with a brush [19].

In this study, three mural paintings were fully investigated (Figure 22). Besides gaining technical information about this type of painting, the purpose of this research was to acquire knowledge about both the organic and inorganic materials used. The

study comprised the examination of the pigments, media and ground layer [20]. In the conservation state of the paintings to analyses of these paintings were carried out during restoration treatment. From the visual inspection and cross section images, the condition of the paintings is poor, with weakness in the paint layers, which is the most apparent deterioration phenomenon (Figure 23 A-F). There are several areas of the pictorial layer that have become detached, with chromatic alterations around the missing parts, grease and soot spots, and detachment of decorative elements.

Figure 22 The three mural paintings in El Sakakeny Palace showing sampling points on the damage on the ceiling

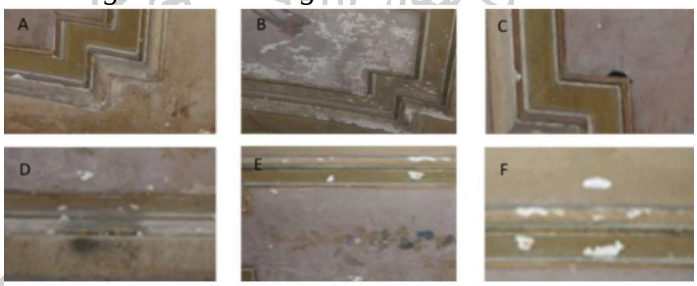


Figure 23 Condition assessment of the mural paintings [21], (A) detachment of decorative elements, (B) loss in paint layers, (C-D) soot and grease spots, (E) blistering, (F) cracks.

The four scientific methods, optical microscope (OM), X-ray diffraction (XRD), scanning electron microscope coupled with energy dispersive X-ray (SEM-EDX) and Fourier transform infrared-attenuated total reflectance (FTIR-ATR), were used for material analyses. The results from OM technique showed that the sample of black color was composed mainly of fine to medium-grained quartz, iron oxides applied as a layer on the ground layer; the reddish brown contained black spots; the blue color was of a powdery consistency, the deep green color was applied in multilayers as was the golden green color (Figure 24 (A-F) [21].

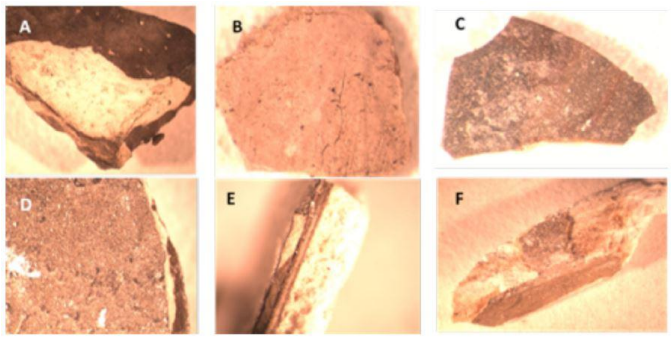


Figure 24 Optical microscopy sh ows structure of paintings [21], (A) crystals of the ground are large and seem to be homogenous, (B) red color mixed with a percentage of fine black color and there are cracks on the paint layer, (C) blue color has a powdery consistency, (D) flecks of white and black appear in the deep green color, (E) the layers of the deep green color, (F) the irregularly applied golden color.

The XRD results showed that the pigments used in the painting were common in that period. The red color is hematite, the yellow is litharge, the green is malachite, the blue is wollastonite, the golden color is gold oxide and the black color is magnetite. The reddish brown consists of hematite mixed with azurite while the light green color is a mixture of litharge with malachite and calcite. The SEM-EDX analyses showed the presence of halite crystals (the salt was evidenced by XRD) on the surface and in plaster matrix, together with calcite crystals homogenously ligated to large-sized quartz crystals. The FTIR-ATR analyses evidenced that the linseed oil was used as the medium in the paintings even if the animal glue was used in the gold color [21]. From the scientific results, it was claimed that the main cause of deterioration and detachment of the painting layers was due to the growth of halite crystals.

There was another interesting result from the analyses of pigments used in the 16th C. wall painting in the church of Agios Sozomenos in Galata, Cyprus [22]. This church possesses two schemes of post-Byzantine wall paintings, which are important to the history of Cypriot mural decoration during the Venetian period. The paintings are dated back to 1513 and are signed by the artist Symeon Axenti. Those on the exterior north wall are totally different from the interior scheme in both style and

technique. Moreover, more severe damages like localized flaking, white film covering and pigment alterations were apparently observed (see Figure 25). The alteration of the blue-green pigment from the exterior north wall's painting of the Last Judgement (Figure 25 (c) was characterized in cross-section by polarized light microscope and micro-FTIR, followed by Raman microscopy and Gas Chromatography Mass Spectrometry technique. The results showed the presence of copper oxalate and calcium oxalate in the pigment as well as casein as the binder of the paintings. It was claimed that the presence of the oxalates was from the degradation of binding media (proteins and other organic materials) according to the attack of oxalic acid produced by lichens on calcium and other carbonates [23] Copper oxalate has never been used as an artist pigment. In addition, the use of naturally occurring mineral Moolooite, CuC_2O_4-$4H_2O$ [24, 25] is quite unlikely due to the rare production. Therefore, copper oxalate was referenced to be the degraded product of copper mineral [26]. The presence of calcium oxalate is responsible for the white film on the wall surface. However, the recrystallization of calcium carbonate was previously reported to form the white insoluble film on the wall painting [27].

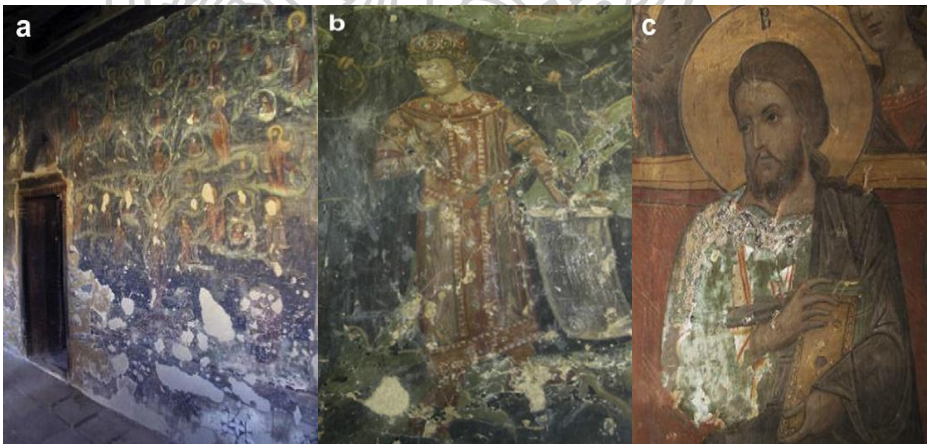


Figure 25 Galata, Cyprus. Agios Sozomenos Church, exterior north wall, (a) Tree of Jesse. Early 16th century, (b) an intractable white film is present on much of the painting's surface, as is seen here in a detail of a figure from the Tree of Jesse, (c) an Apostle from the upper tier of the Last Judgement, early 16th century, a sample was taken from the flaking green paint on the upper left of the figure's drapery.

2.4 Conservation of Mural Paintings

Cambodian and Thailand are an accient city, culture, arts and history. In Southeast Asian countries are in deteriorated states due to deteriminer like pollution, animal excretion, heat, humidity and human. Moreover, the water from humidity make a severe damage to the cultural heritage [28].

2.4.1 Damage due to humidity [28]

The cause of humidity, water in the atmosphere as following from:

1. Rain

Rain is the source of humidity. It affects on the wall of the building and creation of the damage on the wall and lack of the protection. To avoid direct relative to the rain, it expands the roof after cover the building.

2. Capillary water

The water was remained in the soil after gravitational water is appearing in the form of a film in the soil grain. The water can raise to a height of two to five meter in the old building materials that it's a cause's capillary water drained out.

To protect mural paintings from this capillary effect, must be following on:

To apply the metal sheets to the wall, mix the damp proof solvent in the concrete and apply to the original floor foundation of the building and inject silicone solution into the wall.

3. Humidity in the air

This will condense on the surface walls. The air circulation can be made by making holes on the wall.

2.4.2 Techniques of conservation

The condition assessment, on the techniques and characteristic on the paintings must also be performed before to the conservation by material analyses and its should be following on the common conservation processes on murals. [28].

1. Cleaning

The preliminary examinations have been performed, to cleaning process is the first step in conservation and dust removal by using soft brush to follow on neat surface , treatment by using moist cotton wool and the proper cleaning solvent or solution are carry out. Moreover, the weak area like paint-detached part, the fixation by a proper glue must be done before cleaning process. In 1982, a group of international specialists from (ICCROM) suggested to the following cleaning techniques on: to use of wet Chaing-Mai paper to soften detached paint flakes and gently press them back into the correct place. Moreover, to using the paper pulp soaked with ammonium carbonate solution or other reagent for cleaning Thai tempera painting without causing abrasion.

2. Fixation

The two common glues used for fixation of the paint flake on the mural paintings are Paraloid B-72 and cellulose nitrate. Paraloid B-72 is a durable and non-yellowing acrylic resin which is melted in ethanol, acetone, xylenes, and toluene [29]. It can be used as a consolidate which is stronger and harder than polyvinyl acetate. Paraloid B-72 film is too circumstance and tolerates high stress and strain. Unlike cellulose nitrate, Paraloid B-72 does not need additives like plasticizers to stabilize its durability. While cellulose nitrate (also called nitrocellulose, guncotton, flash paper, cotton, and flash string) is a highly flammable compound formed by nitration reaction of cellulose [30]. It was used as a film base in photography, X-ray films and motion-picture films. In conservation, it is used as an adhesive for ceramics and glass [31]. In mural painting, Paraloid B-72 is used for curing the separate paint by injecting under the paint layer. Cellulose nitrate, suitable for the paintings with thick ground layers, must be injected beneath the ground layer in order to avoid the trace left on the painting.

3. Consolidation

After consolidating, cleaning and fixing on the painting surface. Especially, the tropical-climate countries in Southeast Asia. The consolidating agents, the

mixture of polyvinyl alcohol and lime is wonderful used for injecting into hollow area to consolidate the ground layers.

4. Filling the lacunae

Clean the lacunae, to make a rough surface and fill with lime mortar.

5. Protective coating is the final treatment to retard further surface deterioration.

The coating must be thin, and glossy-free, durable (not becoming yellowish or brownish) and removable.

One example of mural painting conservation using the above-mentioned processes [32] was found in Thailand at Wat Prasert Suthawas, an old temple which dated back to Ayutthaya period. The Ordination Hall, a religious building in Thai-Chinese style architecture, is the only monument in Thailand having Chinese ink mural painting scenes form Chinese Chronicle "The Three Kingdoms". This temple has been registered as a national monument by the Fine Arts Department since 1995. The stone inscriptions on the interior wall of the Ordination Hall is a combination of Chinese and Thai architecture [33]. The building condition was in severely deteriorated conditions as in the following on:

a. The damage of roof tiles and roof structure due to the rainwater

b. Rainwater penetration into the mural

c. The deterioration of the wall and inner wood pillar due to underground water, rising damp caused deterioration to walls, paintings and into wood pillar.

d. Weathering of wooden doors, windows, stucco decorations at gables, above window and door frames, plaster on walls and the dais of the Buddha's image.

e. The deterioration of the terrace within the into boundary walls due to flood in rainy season and lost parts was done by repairing of the damaged and lost parts. The instead materials used must have the same color, texture and size as the original ones. The techniques applied to repair roof, ornamental stuccos, walls,

door frames, door panels, window and base on the Buddha's image and into boundary walls are traditional. The restoration as follows detail on:

1. The roof stuccos were fixed by using the mixture of slaked lime, animal glue, and sand molasses, followed by coating with lime paper paste
2. Gable decoration with ceramics in Chinese style was restored by cleaning, and attaching the new ceramics to the damaged and lost parts with epoxy resin adhesive
3. The roof structure was fixed by replacing the damaged parts with the new wood having similar properties to the original
4. The brick wall was repaired by removing the damaged plaster, followed by replacing with new plaster made from slaked lime, sand and coating with lime paper paste
5. The outdoor panel were newly decorated with gilded red lacquer
6. The restoration of stucco was performed as follows: fixing the original loosing pieces of stucco with epoxy resin, instead some lost parts of the stucco with new stucco made of slaked lime, sand, animal glue, molasses cleaning the stucco surface by brushing with detergent or ammonium carbonate solution, spraying the surfaces of the stucco with sodium benzalkonium chloride solution to prevent algal and plant growth, coating the stucco surface with silicone resin to prevent the water adsorption
7. The building was leveled with new concrete floor paved with terracotta tiles
8. Water drainage and flood prevention system were provided by sumps, pump and gutters.

2.5 Scientific Analyses

2.5.1 Fourier Transformed Infrared Spectroscopy (FTIR)

This technique uses IR light (with the wave number of 4000-400 cm^{-1}) to characterize the samples. Pass the IR light through the sample and measure the intensity of transmitted IR as compared to incident IR (see Figure 26).

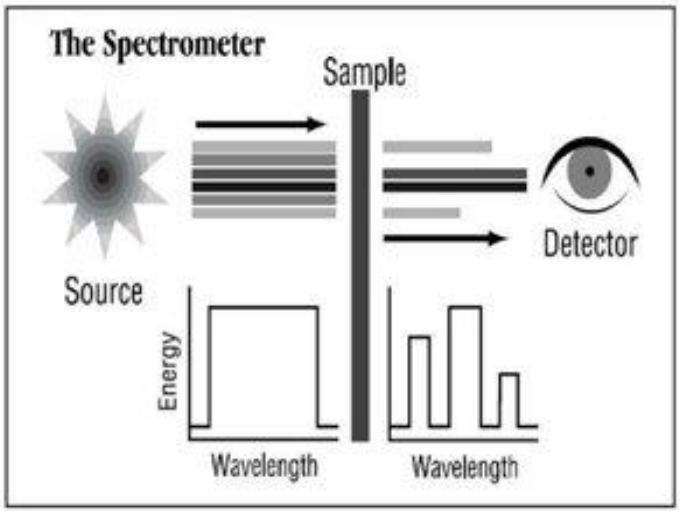


Figure 26 The instrument scheme of IR spectrometer [32, 34]

The absorbance and transmittance can be calculated as follows:

Transmittance percentage (%T) = (I/I_0) x 100

Absorbance = 2- log (%T)

Each sample can differently absorb IR light at certain wavelengths depending on the functional group existing in the molecule. The IR vibrational frequencies or wave number absorbed by certain functional groups are shown in Figure 27.

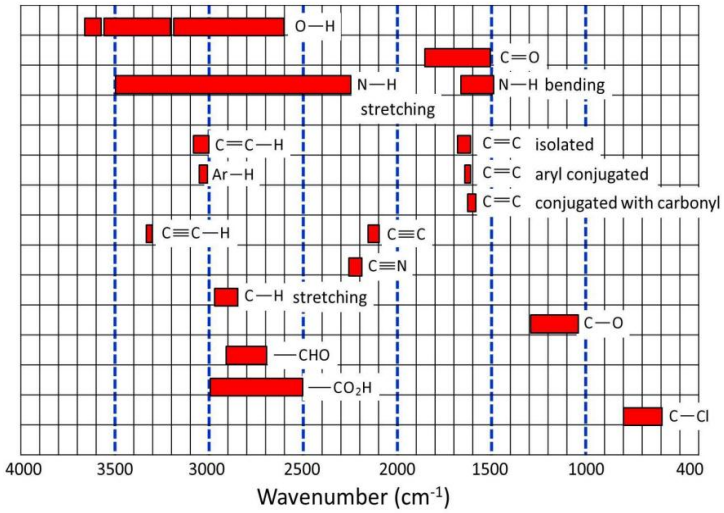
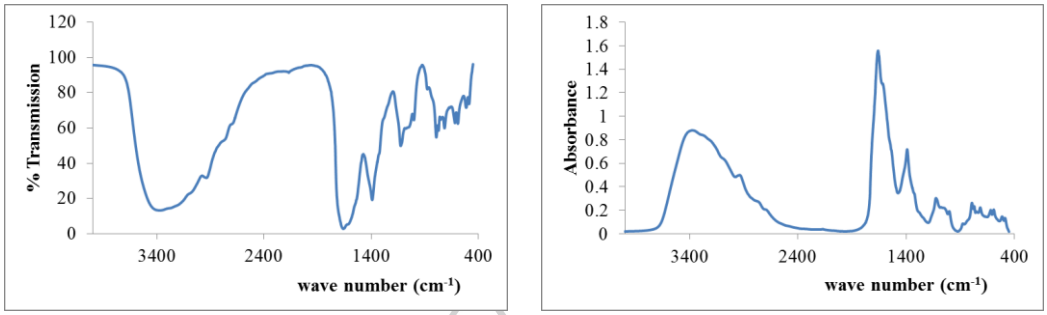


Figure 27 The IR vibrational frequencies for certain functional groups [34]

The IR spectrum is the plot of the transmission percentage (%T) or absorbance against wave number (cm^{-1}) as in Figure 28 (a) and (b).



(a) (b)

Figure 28 The IR spectrum of silicon protein in (a) transmittance (percentage) and (b) absorbance modes

The FTIR has been used as the characterization technique for pigments and plaster used in ancient mural paintings [35, 36]. The types of binders and source of plaster and mortars were revealed by this technique.

2.5.2 Scanning Electron Microscopy-Energy Dispersive X-ray

When electrons strike on the sample surface, the followings are generated (see Figure 29):

1. Secondary electron creating SEM image
2. Backscattered electron (BSE) creating BSE image with contrast giving the information on the atomic number differences
3. Characteristic X-ray or energy dispersive X-ray giving the detailed information on elemental composition
4. Cathodoluminescence giving the information on the electronic structure and the chemical composition
5. Auger electron

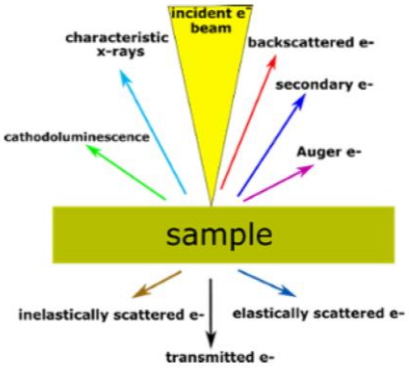
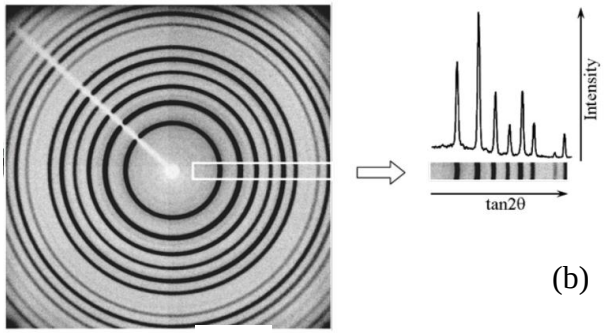


Figure 29 Electron-Matter Interaction [37]

SEM-EDX has been used to identify the detailed elemental compositions of the pigments and plaster used in wall paintings [38, 39].

2.5.3 X-ray Diffraction

The compound with well-ordered arrangement of atoms has a characteristic crystallographic form and can be analyzed by X-ray diffraction. The atoms in a crystal are arranged in a periodic array and can diffract X-ray. Due to the similarity of the X-ray wavelength and the distance between atoms, the scattered X-rays can be combined both constructively and destructively to produce a characteristic diffraction pattern depending on the crystal type. The diffraction pattern, presented in Figure 30 (a), can be calculated and transformed into the plot of peak intensity and two theta (degree) as in Figure 30 (b) [40]. This technique has been used to identify the pigments and plaster in the wall paintings [41, 42].



(b)

(a)

Figure 30 (a) X-ray diffraction pattern depending on the crystal type, (b) the plot of peak intensity and two theta (degree)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Assessment on the deterioration condition of the mural paintings

This study focuses on condition assessment of deterioration, damage on painting in Vihear Kompong Tralach Leu, Kompong Tralach Province, Cambodian.

3.1.1 Condition assessment report

The condition assessment report has been constructed as in the following table:

Condition assessment on mural paintings	
Category	**Details**
1. Place	
2. Environment characteristics and management	
3. Date of construction	
4. Artists	
5. Techniques	
6. Dimensions and story of the paintings	
7. Evidences of the previous conservation and responsible institution	
8. Conditions of the painting	
9. Inspection Notes	
10. Examined by	

3.1.2 Overview of the mural paintings in Vihear Kompong Tralach Leu,Kompong Tralach Province

Photograph and draw maps of Vihear Kompong Tralach Leu, Kompong Tralach Province both outside and inside. The photos and maps outside and inside of the Vihear are presented in Figure 31 and Figure 32 respectively. While the sampling areas for the pigments and plaster were selected from the lower parts of the southern, northern and western walls as shown in Figure 33, 34 and 35 respectively. The painting is about the biography of the Buddha.

Figure 31 Vihear Kompong Tralach Leu (outside)

Figure 32 Plan of Vihear Kompong Tralach Leu (outside)

Figure 33 Vihear Kompong Tralach Leu (inside)

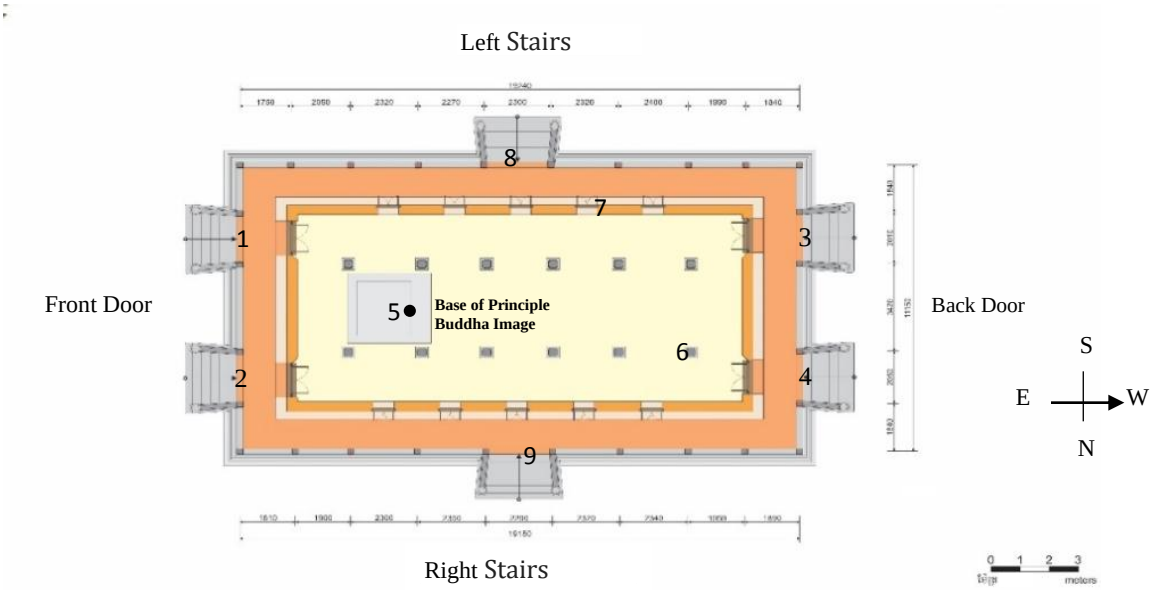
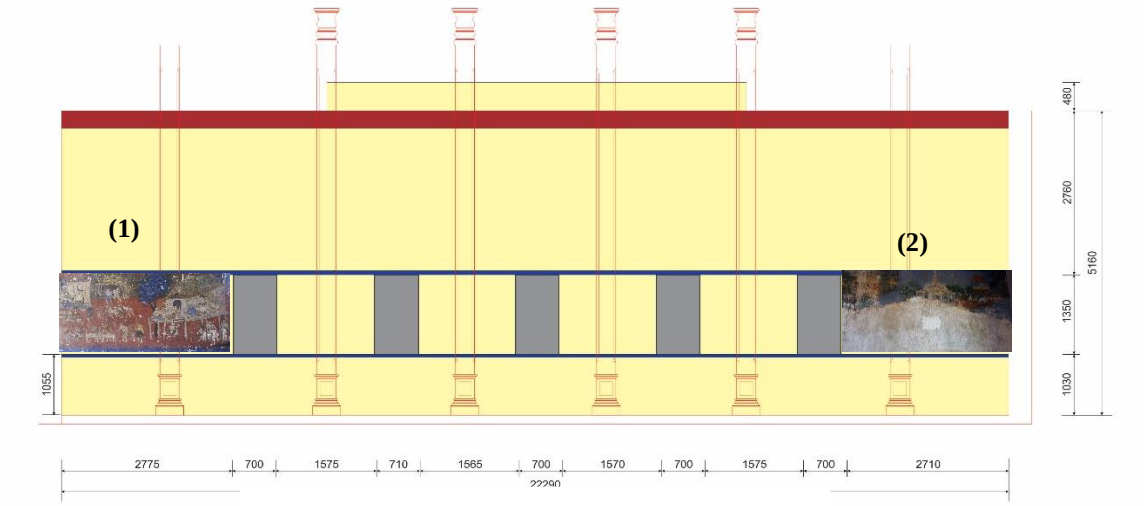
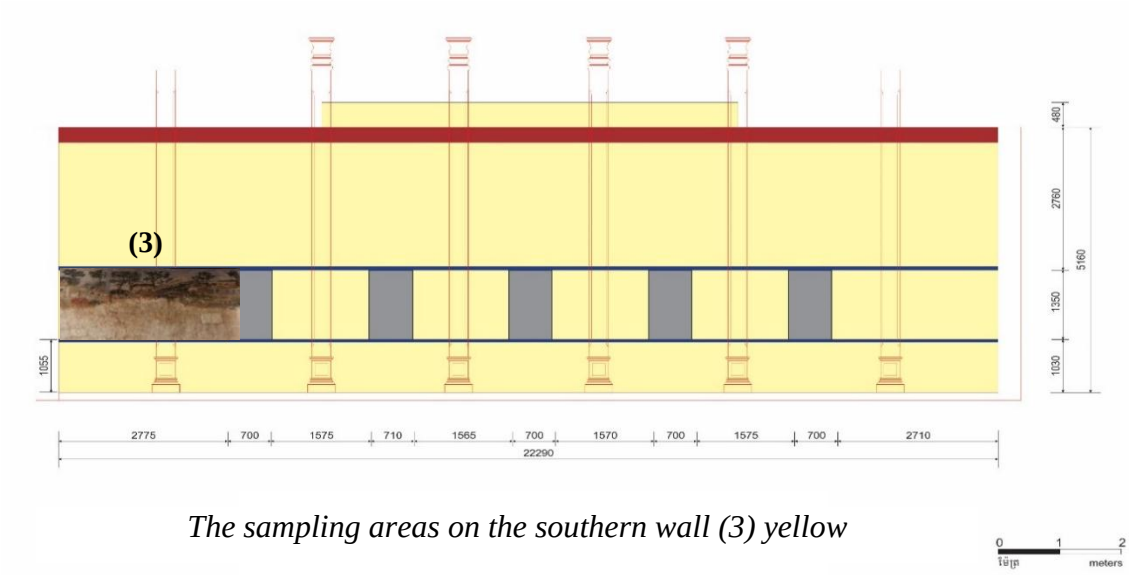


Figure 34 Plan in Vihear Kompong Tralach Leu (inside) showing the location of front doors (1,2), back doors (3,4), Buddha statue base (5), columns or pillars (6), windows (7), stairs (8, 9)



Plan of mural painting from northern wall

Figure 35 The sampling areas on the northern wall (1) red and (2) blue



The sampling areas on the southern wall (3) yellow

Figure 36 The sampling areas on the southern wall (3) yellow

Plan of mural painting from western wall

Figure 37 The three sampling areas was collected on the western wall (4) navy blue, (5) green, and (6) black

3.2 Collect the pigments and plaster samples

Collect the pigments and plaster as details below:

3.2.1 Collect the pigments: (1) red and (2) blue (northern wall), (3) yellow (southern wall), (4) navy blue, (5) green, and (6) black (western wall) from the selected sampling area using cotton buds as shown in Figure 38.

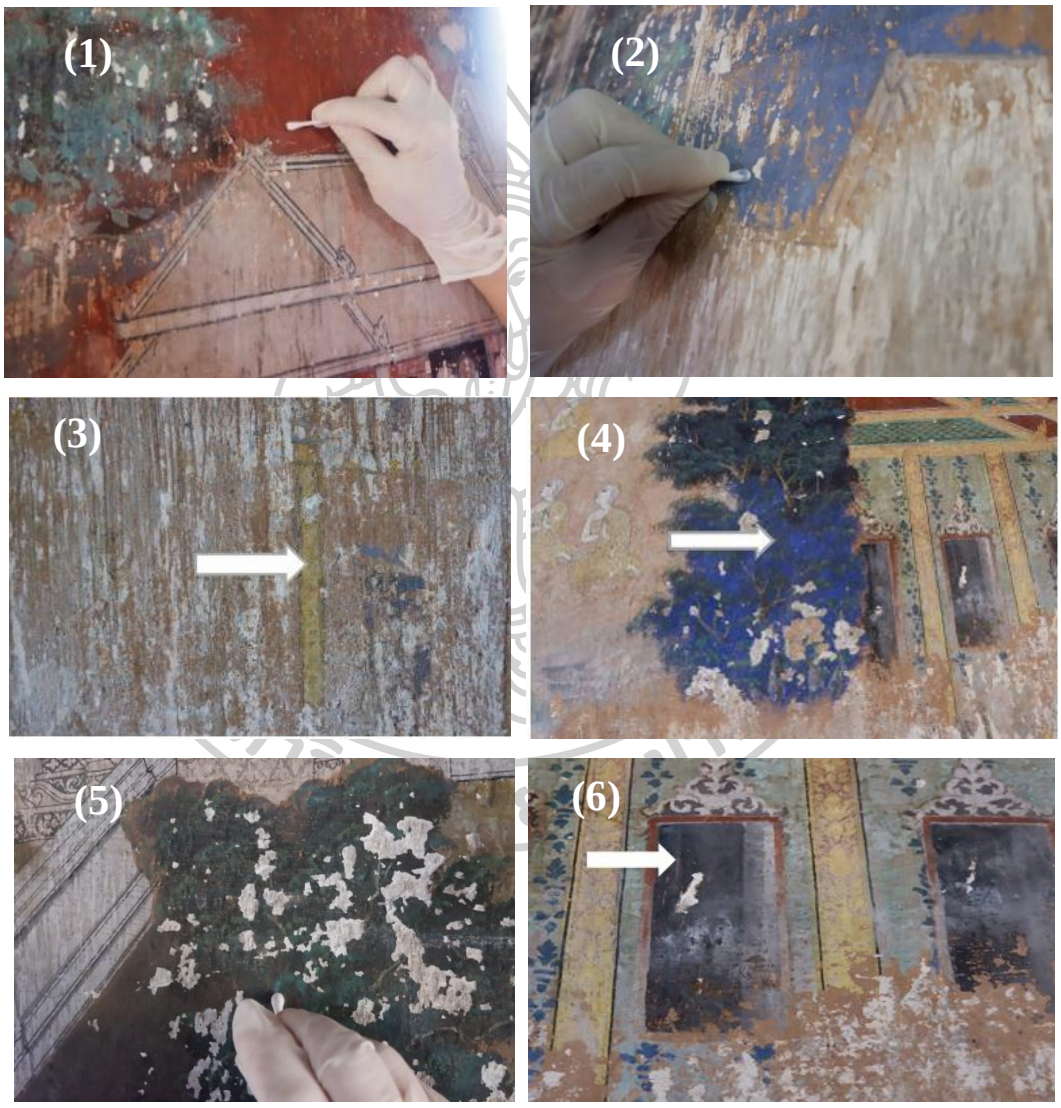
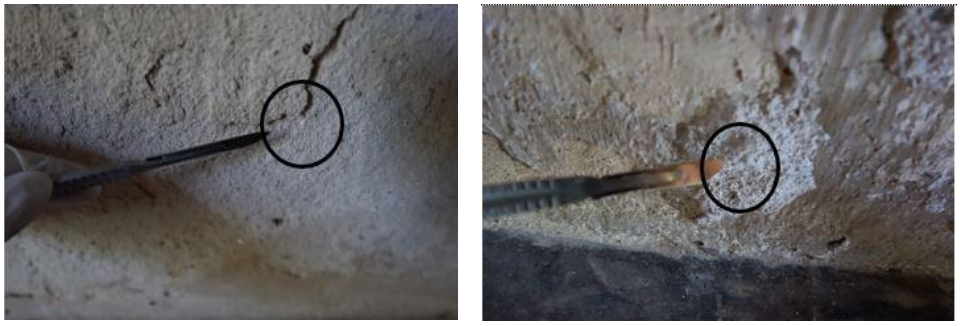


Figure 38 Collect the pigments from the selected areas on wall painting: (1) red and (2) blue (northern wall), (3) yellow (southern wall), (4) navy blue, (5) green, and (6) black (western wall)

3.2.2 Collect old and new plasters on wall by using scalpels as shown in



a. Old plaster b. New plaster

Figure 39 Collect (a) old and (b) new plaster from the wall

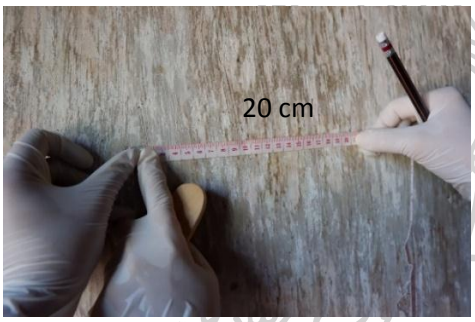
3.3 Salt adsorption

The salt adsorption was performed using wet Sa-paper in order to follow up the condition of the mural paintings in the Vihear after being conserved 10 years ago. The salt adsorption was performed as follows:

1. The 54 cm x 80 cm Sa-paper, made in Thailand, was shredded into small pieces as in the following figure:

2. The small pieces of Sa-paper were soaked in water for 3- 4 hours to complete water adsorption in Sa-paper.


3. Mark the area of 20 cm x 20 cm on the wall as in the following figure:



4. The soaked Sa-paper was attached on to the three marked areas as the detail below:





5. After 3 days, the dry Sa-paper was detached softly using scalpel. Keep the Sa-paper in Zip-locked plastic back for the scientific analyses.



3.4 Scientific analyses: FTIR, SEM-EDX and XRD

3.4.1 Fourier Transform Infrared Spectroscopy (FTIR)

The old and new plasters were analyzed by Spectrum 100 FT-IR spectrophotometer (Perkin Elmer) in both transmittance and reflectanc modes. The funcional group analyses on each sample are recorded.

Figure 40 The Fourier Transform Infrared Spectroscopy (FTIR) spectrometer

3.4.2 Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX)

The pigments, plaster and Sa-paper were analyzed by a JSM-6610 LV scanning electron microscope associated with X-max^N, Oxford Instrument EDX microprobe. The surface morphology and the elemental compositions of all samples are recorded.

3.4.3 X-ray diffraction

The plasters samples were analyzed by a Miniflex II, Rigaku diffractometer operating with Cu Kα radiation (λ = 1.5406 Å). The measured 2θ is in a range between 5º and 70º.

3.5 Conservation method of the mural painting in Vihear Kompong Tralach Leu, Kompong Chhnang Province, Cambodia

From conservation report was divided into two phases in the first half of 2003, this preliminary assessment was the first stage in the conservation process. Taking photographs of the murals, documenting their state of decay, collecting paint, plaster samples, information about the history of the murals, and their iconography. The last stage is selecting a cleaning test area to assess the effectiveness of basic cleaning agents and strengthening the whole building [2]. The conservation in the second phase last 6 months, from 2010 to 2011. On the basis of the damage assessment as the following to conservation step for the mural paintings were carried out: renovating the roof, repairing the wall painting and ventilation the holes on the roof covering with a net were made in order to avoid animal invasion and rainfall running into the interior of the roof. On another hand, the cracks found in the roof tile caused the rain to flow into the Vihear along the pillar resulting in the breakage and deterioration of the pillars. Water and humidity in the Vihear caused the salt precipitation in the wall leading to the deterioration of the painting. To reduce the moisture in the wall, the plaster layer was removed with the area. The salt adsorption precipitates from the wall and strengthening of the pigment and plaster was also performed using the glue. Up to now the conservation in Vihear had been done for 10 years.

According to the pond around the Vihear, the colors of the pigments on the paintings range from red, blue, black, yellow and white. The damage due to the

written report [1], the re-painting and the detailed studies on the pigment compositions have never been done. This study focuses on condition assessment of deterioration, damage on paintings in Vihear. On the basis of the damage assessment the following conservation steps for the mural painting were carried out: collect the pigments and plaster samples for scientific analyses (FTIR, SEM-EDX and XRD) by using cotton buds and the salt adsorption was performed using wet Sa-paper in order to follow up the condition of the mural paintings in Vihear after being conserved 10 years ago.

It corresponds to another mural painting in Wedding Hall of Mary Girgis (Saint George) was built in 684. The Wedding Hall on mural paintings were various damaged in the painted layer and underneath support cannot control cohesion and divided into many pieces. The most important causes of the environmental condition such as the effects of the groundwater, the presence of salts, the humidity and cracks on mortar. The aims of this study is to characterize the components of the pictorial surface which consists of pigments, the binding media and the plaster. Its support and introduce the conservation project of the mural painting which was carried out in Wedding Hall during 2004 until 2014. After the material characterization, the conservation and restoration of the mural paintings, which including cleaning, injection grouting and fixation of the paint layer on filling of the support gaps with mortar, consolidation, restoration and completion of lost parts, were carried out [43].

CHAPTER 4

Results and discussion

4.1 Assessment on the deterioration condition of the mural paintings

This study focuses on condition assessment of deterioration, damage on painting in Vihear Kompong Tralach Leu, Kompong Tralach Province, Cambodia.

4.1.1 Condition assessment report

The condition assessment report has been constructed as in the following table:

Condition assessment on mural paintings	
Category	**Details**
1. Place	Vihear Kompong Tralach Leu, Kompong Chhnang province, Cambodia.
2. Environment characteristics and management	Vihear was built on laterite base with 1meter high. It has brick-concrete piles and rugged wooden roof, designed in the ancient style. - the size of Vihear is 7.52 meters wide x 15.53 meters long, 5.73 meters high. - is one of the most popular cities for tourism industry and culture in Cambodia.
3. Date of construction	1672
4. Artists	Poach and Chea
5. Techniques	Water Colours on mural painting

6. Dimensions and story of the paintings	These paintings are divided into three different sections: - The first on the top ceiling is about Ramayana - The second on the upper part of the wall is about the former life of the Buddha - Third on the lower part of the wall is the Biography of the Buddha.
7. Evidences of the previous conservation and responsible institution	The conservation of Vihear Kompong Tralach Leu was divided into two phases as follows: a. Preservation of the city's urban heritage in 2003 performed by the collaboration between the Municipality of Phnom Penh, UNESCO, and the German Apsara Conservation Project, support from municipality staff as the following details: - taking photographs of the murals - documenting their state of decay and collecting paint and plaster samples - collecting information about the history of the murals, and their iconography - selecting a cleaning test area to assess the effectiveness of basic cleaning agents, and strengthening the whole building. b. The conservation in the second phase last 6 months, in 2010 by Ministry of culture and Fine Arts. The plan was to renovating the roof of the temple and repairing the wall paintings.

8. Conditions of the painting	1. Collection of documents data 2. Collect the pigments and plaster samples for scientific analyses: FTIR, SEM-EDX and XRD
9. Inspection Notes	-
10. Examined by	(13 until 16 / 10 / 2018)

4.2 Characterization of the pigments

The pigments were subjected for EDX analysis and the data were tabulated in Table 1. All pigments contain Ca and Si which are the plaster components. The plaster is unavoidably found in paint layer due to the painting technique. For the fresco painting technique, the paint layer was normally applied on the wet plaster. The colorant element(s) in each pigment is listed as follows: Fe and Cu in red-brown, Cu in blue and green, Pb and S in yellow. From previous research, the possible colorants in each pigment are proposed as follows: Fe_2O_3 in red-brown [44], Cu $(C_2H_3O_2).3Cu(AsO_2)_2$ [45] in green and malachite $(Cu_2[(OH)_2, CO_3]$ or azurite $(Cu_3[(OH)/ CO_3]_2)$ in blue [44]. In the case of yellow, the explicit identification of the colorant cannot be made. The presence of Pb in red and blue pigments possibly came from the white lead $(2PbCO_3 \cdot Pb(OH)_2)$ [39]which was used as the white pigment.

Table 1 EDX data of all pigments

Element	Atomic %			
	Red-brown	Green	Blue	Yellow
Mg	-	-	2.12	2.56
Al	5.21	-	4.99	4.81
Si	5.30	0.51	2.67	4.68
S	-	-	-	26.35
Pb	5.57	-	37.26	7.40
Cl	-	7.93	34.86	5.32
K	3.65	2.00	-	-
Ca	29.29	15.65	9.23	26.28
Fe	44.13	-	-	-
Ba	-	-	-	20.36
Cu	6.85	38.93	8.87	2.25
As	-	34.97	-	-

4.3 Characterization of the plasters

4.3.1 Attenuated Total Reflectance Fourier Transformed Infrared Spectroscopy (ATR-FTIR)

The similar IR spectra of old and new plasters were shown in the Figure 41. The band at 1795 cm^{-1} was assigned to the C=O groups of carbonate ions [46]. The characteristic bands of calcite phase were observed at 1444 cm^{-1} (ν_3), 875 cm^{-1} (ν_2) and 713 cm^{-1} (ν_4), corresponding to the internal vibration modes of carbonate ions [47]. The broad band at 1081 cm^{-1} was assigned to Si-O stretching of silica.

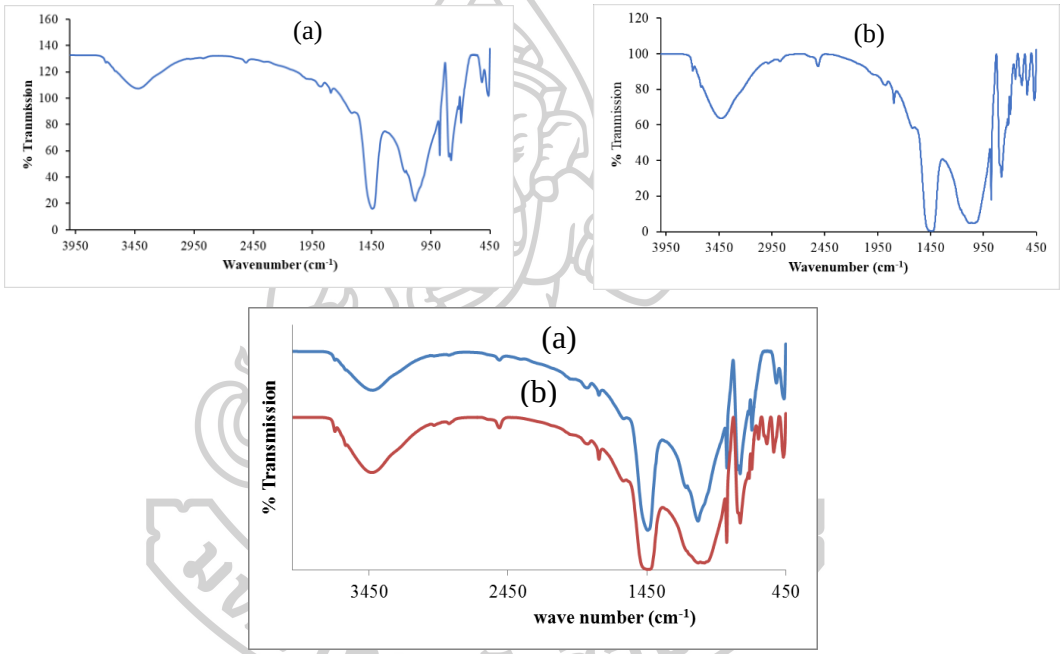


Figure 41 FT-IR spectrum of the sampling (a) old plaster and (b) new plaster

4.3.2 X-ray Diffraction (XRD)

The presence of quartz (SiO_2), mullite (aluminosilicate with two possible formulas: $3Al_2O_32SiO_2$ or $2Al_2O_3SiO_2$) and calcite ($CaCO_3$) was observed in the diffraction patterns [48] [49] of old and new plaster as in Figure 42.

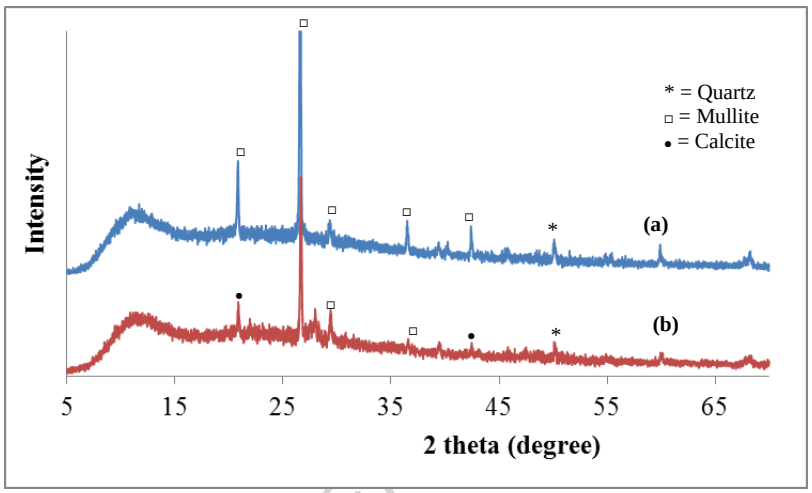


Figure 42 XRD of (a) old plaster (b) new plaster

4.3.3 Techniques Scanning Electron Microscopy-Energy Dispersive Spectrometry (SEM-EDS)

The SEM images of old and new plasters are presented in Figure 43. They both have similar morphology showing the powdery phase and smooth solid phase. Each phase in the plaster was further analyzed by EDX as the data summarized in Table 2. The presence of Ca and C evidenced the existence of $CaCO_3$ while Si, Al and O confirmed the existence of Quartz and Mullite. These analyses show that the new plaster used in the previous conservation is similar in the components to the old plaster.

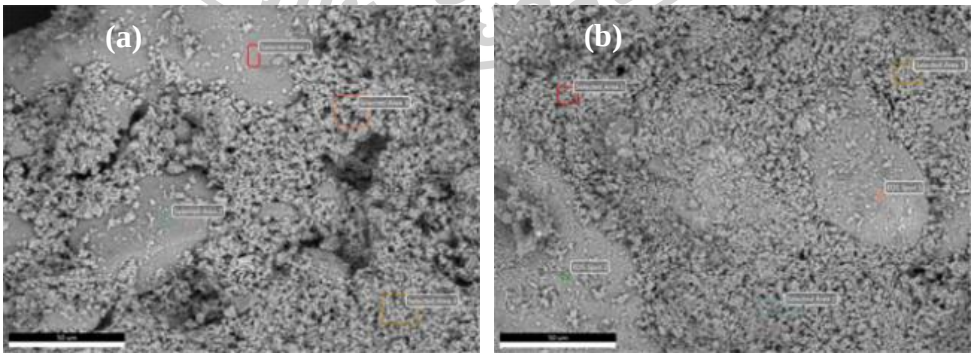


Figure 43 SEM-EDX of (a) old and (b) new plaster

Table 2 EDX data of old and new plasters

Element	Atomic %			
	Old plaster		New plaster	
	Smooth phase	Powdery phase	Smooth phase	Powdery phase
C	18.73	13.06	8.74	13.57
O	52.54	65.48	54.88	64.24
Na	-		7.22	-
Mg	1.06	1.26	-	1.14
Al	0.82	0.62	8.56	1.15
Si	23.77	1.88	17.19	2.27
Ca	3.08	0.47	3.41	17.62

4.4 Conservation method of the mural painting in Vihear Kompong Tralach Leu, Kompong Chhnang Province, Cambodia

According to the above analysis, the paintings are suffered from severing deterioration mainly due to humidity. The two-phase conservations have been done ten years ago to reduce the effect of humidity and to reduce the moisture in the wall, the plaster layer was removed with the area. The salt adsorption process using the cellulose fiber was processed to remove the salt precipitates from the wall. Before the restoration of the painting is proceeded, the scientific analyses of the pigments and the plaster need to be done. The salt adsorption was performed using wet Sa-paper in order to follow up the condition of the mural paintings in Vihear after being conserved 10 years ago. After removing the layers, the salt adsorption hasn't been found and this cause a good solution in Vihear by to reducing the moisture in the wall, the plaster layer was removed with the area. The minute amount of the pigments and plaster from the wall was collected for FT-IR, SEM-EDX and XRD analyses. Base on the results from the EDX analyses, all pigments contain calcium and silicon which are the plaster components. The green and blue colors contain copper while the red-brown contains iron. The golden yellow has sulfur. The calcium found in the paints comes from the plaster on the wall. The plaster samples showed the similar composition of the old and new plaster indicating the proper preparation of the plaster for the conservation. The elemental identifications of the pigments used in the mural paintings of the Vihear Kompong Tralach Leu are mineral compounds which were commonly used in the ancient mural paintings.

CHAPTER 5

CONCLUSION AND SUGGESTION

This research aims to study on the deterioration, conservation and pigment composition of mural paintings in Vihear Kompong Tralach Leu, Kompong Chhnang province, Cambodia. The condition assessment report has been constructed as in the following: Vihear was constructed in 1672, one of the most popular cities for tourism industry and culture in Cambodia. In Vihear, there are ancient and Buddha-related mural paintings which are divided into three different sections. The first on the top ceiling is about Ramayana, the second on the upper part of the wall is about the former life of the Buddha and the third on the lower part of the wall is the Biography of the Buddha. The paintings being drawn in 1850 are suffered from severe deterioration mainly due to humidity and capillary water. The two-phase conservation has been done ten years ago to reduce the effect of humidity and water. After removing the layers, the salt adsorption hasn't been found and this cause a good solution in Vihear by reducing the moisture in the wall, the plaster layer was removed with the area. However, the scientific analyses on plaster and pigments have not been done yet. The Characterization on pigments and plaster need to be done before the restoration of the paintings is proceeded. The detailed composition of the plaster and pigments gives the important information in choosing the proper materials for painting conservation. The characterization techniques like IR spectroscopy, Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX) and X-ray Diffraction have been used for analyzing materials used in mural paintings. In this research, the plaster and pigments on the wall were collected for FT-IR, SEM-EDX and XRD analyses. The result of the salt adsorption was completed with a good solution in Vihear by to reducing the moisture in the wall, the plaster layer was removed with the area. The spectroscopic studies on the plaster samples showed the similar composition of the old and new plaster indicating the proper preparation of the plaster for the conservation. The elemental identifications of the pigments used in the mural paintings of the Vihear Kompong Tralach Leu are mineral compounds which were commonly used in the ancient mural paintings.

Suggestion for conservation step should be following:

1. Protecting the mural painting from tourism without touching. Moreover, defending from the kid by casting the net over windows.
2. The model studies on the deterioration of the plaster due to water and heat. The detailed composition from scientific analyses will be used to prepare the plaster paste. The paste is solidified into the square shaped and dried at room temperature. The factors affecting the deterioration of the plaster like water and heat are studies.

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[1-54]

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