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Conservation and restoration of Ta Prohm temple

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ABSTRACT: The region of Angkor has been inscribed in the World Heritage List in 1992. Spread over an area of 400 sq.km, the Angkor World Heritage Site is marked with splendid structures constructed by the Khmer rulers from the 9th to the 15th century. The rulers of this Khmer civilization constructed many temples including the famous temple of Angkor Wat, the royal city of Angkor, palaces, historic water structures, embankments and irrigation canals. One such temple is the Buddhist monastic complex of Ta Prohm constructed in 1186 AD by Jayavarman VII, as a citadel of Rajavihara (the royal monastery) for his mother. The conservation and restoration of this temple complex has been undertaken by the Archaeological Survey of India. This temple complex is located in a dense forest, in Cambodia. Huge trees are seen growing on top of several structures; such vegetation has disturbed the structural stability of several components of this temple. There are more than 150 species of trees in the temple complex. But subsequently the trees intertwining with the monuments depict a symbiotic relationship one supporting the other. Visitors throng this temple complex to visualize this rare coexistence of the trees and the monument, hence it is commonly known as the "Tree temple". The conservation strategy aims to protect both the natural and the built heritage, thereby safeguarding the authenticity and the integrity of this monument. Studies of the trees has been undertaken by the botanists and scientists, to understand the growth of the trees, their life spans and load transmitted by the trees on the structures. Ground Penetrating Radar studies have been undertaken to understand the movement of the roots below the surface of the soil. The structural failure of the various components of the temple is attributed to action of the vegetation, human vandalism, weathering, foundation movements. Finite element modeling technique has been used to understand the structural behavior of the corbelled vaults of Ta Prohm. Engineers and other experts have undertaken foundation analysis, and the deficiencies in the foundations have been identified. The unstable sandstone blocks of the temple have been supported by means of a temporary supporting systems comprising of wooden props.

The temple is flooded up to 1 m for some days during the wet season. The problem of stagnating water is primarily due to randomly scattered sandstone blocks which act as little bunds and obstruct the flow of water. The existence of the ancient drainage outlets inside the temple is not visible as they have been silted up or blocked. Studies have been conducted to understand the hydrology of the site. A multidisciplinary integrated scientific approach has been adopted to conserve and protect the distinct uniqueness of this outstanding monument in the World Heritage Site of Angkor.

1 INTRODUCTION

This paper is based on the conservation project undertaken by Archaeological Survey of India, for protecting and restoring the Ta Prohm temple in the Angkor World Heritage Site. This paper highlights in brief the conservation approach adopted for the protecting the authenticity and integrity of this unique monument in the Angkor World Heritage Site.

The archaeological site of Angkor, occupying an area of approximately 400 sq.km, is located in the mainland of South–East Asia. This site was inscribed in the World Heritage List in 1992. One of the most unique temples in this World Heritage site is the Ta Prohm temple. It is one of the largest 12th century Buddhist monastic-complex enclosed within an area of 1105 m × 663.00 m. This temple was originally known as Rajavihara (Royal Monastery), later it was given the name of *Ta* Prohm, *Ta* means Ancestor, *Prohm* means Brahma the Hindu God of creation. This temple is of outstanding value and portrays a unique harmonious coexistence of the trees and the built heritage.

A Sanskrit inscription on a stone found inside the temple states that this temple was built by Jayavarman VII, as a citadel of Rajavihara, for his mother in AD 1186.The additions in the temple complex continued till the end of the thirteenth century. This temple functioned as a mini city. The area between the outer enclosure wall and the fourth enclosure supported a population of 12 640 residents, other than the monks.

This temple is extremely significant as a "Tree temple". It has been left in its natural ruinous state

overgrown with trees. The forest has grown unchecked which creates an air of mystique that Ta Prohm is famous for. The visitors throng the temple complex to visualize the unique coexistence of the trees and the built heritage of the temple. Different species of matured and young trees, some standing on the ground and some on the walls and roofs of the various structures are seen in the temple. The most commonly found species is "Tetrameles nudiflora" locally known as sponge tree which stands on the various structures in the temple. There are one hundred and fifty trees of thirty different species standing in the various locations in the temple.

2 GEOGRAPHICAL CONTEXT

Cambodia is a large depressed basin lying between 102° E and 103° E and 10° N and 15° N covering an area of 181,040 square kilometers. The entire region comprises of three zones, the northern zone, central zone and the southern zone. The northern zone is occupied by the Kulen Mountains. Central zone is an alluvial plain that is occupied by the Angkor World Heritage Site having temple – complexes, moats, reservoirs and canals. The southern zone is the Tonle Sap Lake, which serves as a discharge area for the drainage system and for dispersing water from the temple complexes of the heritage site. The Kulen Mountains in the North formed the source of water for the canals, moats, reservoirs of the ancient city. The sandstone for the monuments in the region was obtained from the quarries in the Kulen Mountains. It was on these hills that Jayavarman II founded the Khmer Empire in the 9th century.

The Siem Reap river is the largest perennial river with a catchment area of 670 sq km which flows through Lake Tonle Sap. This river has changed its course; it presently flows on the western side of the Ta Prohm Temple. The Khmer rulers were extremely sensitive to the hydrology of the area. Location of the capital of the Khmer rulers was such that Angkor was never exposed to floods because it was built at an elevated terrain. Major floods were restricted upstream near the North Baray area. The water structures such as, embankments and Barrays were constructed in the east–west direction and they were effective in flood control. The Eastern and Western Baray are two major reservoirs in the Angkor heritage area.

A topographical survey of the site has shown that the ground levels inside the site vary from 24.5 m to 26.5 m. Generally the slope is from the center of the temple towards the moat. A ridge line exists at an elevation of 24.5 m between the Siem Reap River and Ta Prohm temple. Historically it is seen that Jayavarman II who established the Angkor Empire located his capital in military strategic position such that his kingdom which was located at the north of the lake and upstream of the river, could be accessed only through river tributary of Tonle Sap Lake. It is due to its perfect location that the Angkor Empire existed for more than 600 years.

A major part of the country is covered under the tropical evergreen forest that encircles the Tonle Sap lake, Savanna grass is on the coast. In these rain forests, trees are as tall as 30 m–40 m. Some of them even reach a height of 70–80 m. Ta Prohm Temple is located in such a dense forest where the trees have enveloped the structures over the centuries. The temple-complex is dominated by different species of matured/young trees.

3 HISTORICAL BACKGROUND

The History of Angkor region can be divided into three distinct periods: Pre Angkor era, Angkor era and post Angkor era. This temple was built by Jayavarman VII,[1] one of the greatest rulers of the Angkor era who reigned from AD 1181 to 1219.

3.1 *Pre Angkor Era – From the 1st century to the 8th century*

During Neolithic age, there were large settlements of people living in this region whose origins were unknown but their existence is known from the finding of ceramics and stone tools. From the Chinese chronicles of the second century it is known that a state called "Funan" emerged around 1st century, in southern coast of Cambodia along the Mekong Delta. During this period there was trade between the Southern kingdoms of India and the state of "Funan". Cambodia was a staging post along the trade route between India and China. It is during this period that a very strong influence of Indian culture and religion gradually made its impact on the people of Cambodia. The Indian settlement of Funan was founded in the third century AD. Legend says that a marriage took place between a Brahmin or a Chola king called Kaundinya from South India, and the Princess Soma, daughter of a *Naga* king, who inhabited the waters. According to the legend, the *Naga* king consumed the waters that covered the land, built a capital and gave it to the couple, naming it *Kambuja* (the origin of the present day name of Cambodia). Kaundinya is believed to have founded the Funanese kingdom, with Hinduism as the predominant religion.

In the fifth century, Sanskrit was adopted as a language at court, giving birth to a writing system and the early inscriptions. The Khmer rulers without abandoning their own customs and traditions adopted what they needed of the Indian religions: Hinduism and Buddhism. The stability of Funan was undermined by civil wars, and the creation of new states (upper and lower Chenla). The foundation of Angkor Empire was laid by Jayavarman II. In AD 802, Jayavarman II crowned

himself for the second time, which marked as a starting point of the Khmer Civilization and the birth of the Angkor Empire.

3.2 *The Angkor Era – From AD 834 to 1431 AD*

The Angkor era reflects the most glorious period of Cambodian history, during which the Khmer empire was consolidated and reached its peak in terms of cultural and artistic achievements. The Angkor Wat complex covering an area of about 200 square kilometers was constructed during this period. The first dynasty of Angkor was founded by Jayavarman II (AD 802–850) and the inscriptions give names of twenty-eight kings who succeeded him during the Angkor period. One of the greatest rulers of this empire was Jayavarman VII (AD1181–1219) who was a devout Buddhist of the Mahayana sect. He was a great builder and he built the new capital of Angkor Thom. At the center of Angkor Thom is the Bayon, the state temple . . . As a Buddhist Monarch he was a major patron of the Sangha, the community of monks. He built mini cities like Ta Prohm (temple- monastery), Preah Khan, and Banteay Chamar[1]. The reign of Jayavarman VII was marked as the peak period of the Angkor Empire as well as of the Khmer Civilization, which began to decline gradually after the death of this king in AD1219. The architectural endeavors of Jayavarman VII are seen all over his vast empire. In AD 1431, the Thai army attacked Angkor. This marked the end of Angkor Empire

3.3 *Post Angkor Era – From AD 1431 to 2000 AD*

After being seized by the Thai army in AD 1431, it appeared that the Angkor Empire entered a dark period as there are rarely any inscriptions found in later centuries. Later the city of Angkor lost its importance and the capital was shifted from Angkor to Srei Santhor. The region of Angkor was rediscovered by the West through the accounts of Portuguese trader Diogo do Couto (dating1585 to 1588 AD) and the accounts of French botanist Henri Mouhot which were published in French in AD 1863 and in English in AD 1868.

4 DESCRIPTION

The temple is concentric in plan and has five rectangular enclosures and entrances on all the four directions. A moat is provided around the fourth enclosure, with a causeway along the east-west axis. There is another moat between the third and the fourth enclosure. The temple is built of dry sand stone masonry with laterite core in the foundation and has corbelled vaulted roof over the galleries and entrances. The temple is decorated with Apsara figures, Naga canopies besides mythological figures and detailed carvings.

Ta Prohm temple reflects the characteristics of the Mahayana Buddhism prevalent during the reign of Jayavarman VII. These temples differed from the previous temple mountain structures in their emphasis on a horizontal layout at the same level. The architectural layout is complex, with numerous structures including interconnected galleries, shrines and pavilions. Ta Prohm temple with its multiple shrines and structures placed along a linear axis is a typical example of the temples constructed during the Angkorean period. The prinicipal decorative features seen in these temples are the images of Bodhisattva, identified by the small seated Buddha at the base of the crown, carved on the walls of the temple. Another distinct feature predominantly seen in the temples belonging to this style of architecture is the four faces of Avalokiteshvara sculpted on the towers of the entrance gopuras. The sculptures and reliefs in the temple complex reveal the myths and legends associated with the Mahayana Buddhism. Episodes from the life of Buddha which emphasized his teachings and images of the Bodhisattvas are seen in the temple complex.

The main deity in the central shrine at Ta Prohm temple is "Prajnaparamita", "Perfection of Wisdom" personified by the Mother of Buddha. The other shrines present in the temple complex housed the image of the Jayamangalartha Deva, the guru of Jayavarman VII and the northern shrine housed the image of Jayakirtideva, Jayaverman VII's elder brother[1]. Ta Prohm temple also served as a monastery. Sandstone was the principal material used for the construction of the various structures during the Angkor period; occasionally it was combined with laterite. In general, the masonry construction has horizontal bed joints, with an average height of 340 mm in each layer. Laterite was also used for the enclosure walls, and for retaining walls at the base. Laterite stone was also principally used for the construction of foundations and plinths, and as core material within thick sandstone walls.

The ruinous state of the temple can be attributed to various factors. The following issues need to be addressed:

a. Issues of Structural Stability mainly due to action of vegetation, human vandalism, weathering and foundation movement
b. Issues of water stagnation
c. Decay caused due to neglect and lack of maintenance.

5 CONSERVATION STRATEGY

A multidisciplinary integrated approach has been adopted to protect and conserve this unique cultural resource of the Angkor World Heritage Site. The conservation strategy revolves around the basic concept of trying to conserve both the natural and built heritage

and ensure its sustainability. The unique co-existence of the trees and the built form needs to be preserved and there should be a continuity of the legacy in the shape and form it has come down to us.

5.1 *The approach*

Principles for conservation and restoration of the Ta Prohm temple complex are framed around the concept of preservation and restoration as advocated in the Venice Charter and Nara Document of Authenticity. The local community has a strong association with the numerous trees in the temple complex, hence protecting this component of intangible heritage forms the basis of all conservation works.

The conservation strategy aims to:

a. protect and conserve the tangible and intangible heritage of the temple complex
b. preserve the authenticity and integrity of the temple complex
c. protect and preserve the natural and built heritage of the site and ensure its sustainability
d. make the site more accessible and provide for the safety of the visitors
e. prepare a comprehensive information database of this cultural resource which will guide future interventions
f. to enable transfer of skills and encourage local participation

Principles guiding the conservation and restoration work:

- Interventions will be minimum and shall be undertaken to improve the structural integrity of the cultural resource.
- No hypothetical restoration will be carried out.
- New stones, wherever required, will be dressed and carved to match with the original, but at the same time should be identifiable on close look.
- No historical evidences will be damaged in the process of conservation.
- All interventions shall be undertaken in consultation with ICC (UNESCO) and APSARA Authority.
- The stipulated methodology of UNESCO shall be adopted.
- All interventions will be carried out under the supervision of trained, experienced archaeological conservation professionals.
- All interventions will be completely documented so as to facilitate future interventions.

5.2 *Methodology*

The technique of "Anastylosis" is being followed in undertaking the conservation and restoration works. This technique involves reassembling of the existing dismembered parts. Initially the site is dividing into bays and detail documentation including inventory of the stones and other architectural members lying in the site in their original state is undertaken. The task of careful dismantling of loose, dislodged sand stone blocks and other architectural members of the heritage structure is also undertaken. Then the dismantled stones are numbered and stacked in respective bays of the stack yard with the help of cranes up to 100.00 m. At specified locations excavation or scientific clearance of earth deposit is also carried out. This task includes retrieving floor and drainage system. Subsequently a trial assembly of the various architectural elements like the semi vault and vault, walls etc, is undertaken prior to the final reassembling. This process enables to understand the missing stones and the other missing elements. These missing stones and elements are to be carved out of matching material and then reassembled. Finally all the architectural members and stones are reassembled in their original location.

A multidisciplinary and integrated approach has been adopted for conserving this temple. Professionals and experts from the fields of archeology, history, epigraphy, structural engineering, hydrology, geology, geo-technology, arboriculture, botany and architecture are working together to understand the complexities of the site and evolve a most appropriate conservation strategy for this monument.

Prior to undertaking conservation works on site, detailed technical studies and investigation have been undertaken which include the structural analysis of the temple, the geotechnical studies, hydrology study, Ground Penetration Radar (GPR) studies and arboriculture studies. Complete documentation of the temple has been accomplished using the technique of laser scanning.

Presently five locations in the temple complex have been proposed for undertaking the conservation and restoration works. To facilitate visitor circulation and ensure the safety of the visitors nine locations in the temple complex have been proposed for temporary reversible structural interventions.

The temporary reversible interventions are being designed to support the dangerously perched stone and prevent the collapse of the structure due to tree root action. These supports are in the form of props and trusses designed to counteract the various forces acting on the built form.

Engineers and experts from Indian Institute of Technology, Madras conducted studies and investigations pertaining structural stability of the various components of the temple and soil mechanics. Hydrology and civil engineers from Water and Power Consultancy Services (WAPCOS) were involved in understanding the hydrology of the area and causes for water stagnation in the temple complex. Scientists from Forest Research Institute, Dehradun are presently involved in arboriculture studies and investigation related to the numerous trees in the temple complex.

5.3 *Structural analysis of the temple*

The conservation of Ta Prohm Temple is very complex in nature due to the site conditions. The structural issues of concern at Ta Prohm are related to the damage caused to the various sandstone and laterite stone masonry structures which undergo relative displacements with the passage of time.

The stone blocks that were originally placed closely together with no gaps have moved apart, which has resulted in a loss of structural integrity. At many locations, the roof portions of the vaulted galleries have collapsed, and the walls and pillars too have given way. There are several critical locations where the stones are precariously perched and are in danger of imminent collapse. There are many reasons that can be attributed to the structural failures visible at Ta Prohm.

The primary causes for failure appear to be:

(i) Foundation movements caused by the escape of sand fill from the plinth regions and
(ii) Action of trees and tree roots on the structure and foundation.

The various structural elements at Ta Prohm may be broadly categorized as follows:

- Corbelled Vaults
- Vaulted Galleries – Intermediate Segments
- Vaulted Galleries – Corner Segments
- Vaulted Galleries – Middle Segments
- Towers
- Entrance Pavilions (Fourth Enclosure)
- Entrance Pavilions (Fifth Enclosure)
- Laterite Compound Walls
- Post and Lintel Constructions
- Foundations
- Pillars Other Structures.

5.4 *The geotechnical studies*

The geotechnical studies were undertaken by the experts from Indian Institute of Technology Madras. The surface soil was investigated through a few trial pits and by extracting soil samples up to a depth of about 4 m from the present ground level. This was undertaken for preliminary assessment of the surface soil conditions. Five trial-pits adjacent to the plinth walls of some structures within the temple complex were excavated to understand the soil strata conditions at the foundation level. Soil samples were collected from the pits, and the tests were conducted at Geotechnical Engineering Laboratory at IIT Madras.

Based on the soil classification tests, the foundation soil formation was found to be almost uniform within the temple complex. Further, the foundation soils samples are dominated with fine sand/silt size materials. The plasticity characteristics of the foundation soils were found to be increasing with increase in depth.

Considering dry density of the foundation and the weight of the structure, it is expected that the structure might have undergone excessive post construction settlement/differential settlement.

Since the plasticity index of the foundation soil is found to increase with increase in depths, the soil formation might have under gone shrinkage and swelling during dry and wet seasons respectively. Depending upon the intensity of volume reduction and increment, the structures, might have encountered with excessive settlement/ vertical cracks/ structural failures.

5.5 *Monitoring systems*

In Ta Prohm temple complex it is seen that as the tree grows, it will exert an increasing pressure on the dry stone masonry. These forces will further increase during the period of high wind velocity. In order to understand the effect of these various forces on this unique tree structure combination, it is necessary to incorporate suitable monitoring systems. The data obtained from such monitoring gadgets will be useful in the structural analysis of the temple structures and will help in implementing appropriate conservation measures.

We need to study structural displacements and rotational displacements as an effect of:

- Environmental parameters
- Ground/foundation movements and
- Tree structure interactions.

Effect of various forces such as horizontal & vertical displacements, rotation, inclination and environmental parameters (temperature, humidity, moisture) are required to be monitored over a period of time (approximately six months). An effective and reliable way to monitor the structures in order to get accurate data is to monitor the structures using remote instrumentation, the outputs of which can be calibrated to get the required data.

Most effective monitoring systems are being installed in the temple.

Another most difficult and challenging aspect of restoration task relates to construction planning, with special attention to material handling. The appropriate use of cranes is envisaged for this purpose.

5.6 *Hydrology study*

It was observed that during the rainy season, the water level in the moat closer to the north-eastern side is higher by about 1 m than the water in the other moats. Also the rain water accumulated in the temple-complex does not get drained and keeps standing for 3 to 4 days. The temple complex experiences standing water up to 1 m and up to floor levels of most of the structures. The moat in the northern side, at present, gets the water from the inundated canal which has breached at

many places. From this point the water gushes through a drain (pipe culvert) and enters the ponds, moat and the eastern gate side. The other moat gets the water from the rain. Unfortunately due to heavy silting and tree growth the traditional drainage system cannot be revived. The studies undertaken to understand the hydrology of the area of Ta Prohm Temple were initiated in January 2004 by Water and Power Consultancy Services (India) Limited (WAPCOS).

The studies undertaken by experts from this organization include the topographical survey of the area, hydrological study, metrological study, flood control and drainage study, and hydro-geological studies.

The aim of this study is to prevent flooding of the moat around the temple complex and prevent water stagnation inside the temple complex and provide adequate drainage management.

5.7 *Ground penetrating radar survey*

Ground penetration radar is a geo-physical method that produces a continuous cross-sectional profile or records sub-surface features, without drilling, probing, or digging. It operates by transmitting pulses of ultra high frequency radio waves (micro-wave electromagnetic energy) down into the ground through a transducer or antenna. Transmitted energy is reflected from various buried objects or distinct contacts between different earth materials. The antenna then receives the reflected waves and stores them in the digital control unit, which registers the reflections against two-way travel time in nanoseconds and then amplifies the signals. The depth of penetration is also determined by the GPR antenna used.

This technique was used in this temple complex to understand the movement of tree roots under the soil.

Along all the GPR survey lines, a large number of tree roots were encountered.

Most of the tree roots are located at a shallow depth. Out of about 2200 roots encountered, 98% are located within a depth of 1 m from the ground surface. No root deeper than 2 m was found. The GPR could penetrate to a depth of about 3 m from ground surface.

According to the GPR Survey it is seen that there is very little possibility of any roots being present between 2 m to 3 m from the ground surface.

5.8 *Arboriculture studies*

A detailed analytical study of the trees in the temple complex was undertaken with their orientation; classification and documentation of trees by the Horticultural department of Archaeological Survey of India Inventories of all the trees were prepared and identified on the site.

It is seen that the seeds dropped on the temples grow into small trees, which then start to develop grow their roots to the ground not only for nutrition but also for anchorage. When these trees grow bigger, the roots increase in volume, move the stones apart, causing damage to walls, vaulted roofs and foundations. Trees are as tall as 30–40 m, some could even reach 70–80 m and their canopies are also quite wide and big.

A long-term tree and ecosystem conservation strategy will be formulated once these studies are underway. These studies will also provide vital information on the tree growth characteristics, their life span and conservation. In the meanwhile it is recommended that there should be no disturbance to the existing biotic ecosystem in and around the temple including the trees. Conservation of the built form should be done without disturbing the trees and the tree roots.

There is also a need to put in place a system for monitoring the biodiversity and ecosystem including the trees in the Ta Prohm complex. On-field training to the personnel of local authorities of and Forest Department etc. is proposed by the Indian scientists for the conservation of trees along with the monument.

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