

**Study on Deterioration and Conservation of Brick
Monuments in Polonnaruwa.**



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D. Chandrasiri Chithrananda
April, 2010.

Study on Deterioration and Conservation of Brick Monuments in Polonnaruwa

A thesis presented to the University of Moratuwa, for the Master of Science degree in the Architectural conservation of monuments and sites.



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Declaration

I declare this thesis represents my own work and that it has not been previously included in report submitted to this university or to another institution for a degree, postgraduate diploma or other qualification.

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Abstract

This thesis is presents a study of deterioration and conservation of brick monuments in the ancient city of Polonnaruwa in North central province in Sri Lanka.

The main objective of this research is the study of factors responsible for the deterioration of brick monuments in the old city of polonnaruwa. The study also includes facts such as the history of bricks constructions, technology, and deterioration of brick monuments in Polonanruwa owing to natural, environment and human actions and also the activities connected with conservation.



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Abbreviations

- ASCAR - Archeological Survey of Ceylon Annual Report
EZ - Epigraphiya Zeylanika
HC - Histry of Ceylon (Sinhala Edition)
MV - Mahawansaya (Sinhala Edition)



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Introduction

Polonnaruwa was the second regal capital of Sri Lanka. It was originally formed as the seat of government of chola viceroy in Sri Lanka as therefore followed in chola architecture. Consequently original buildings where of store construction and were replicas of popular religions architecture of south India. However, after liberation in 60 years, to its as well as its architecture reverse, back in Sri Lankan traditions. Consequents it was built with brick constrictions.

0.1. The study

This study is concentrated on examination of brick construction on, their cause of deterioration and conservation methods in the ancient capital of Polonnaruwa. The city of Polonnaruwa is much more significant in brick construction because it is one and the only regal city where large numbers of brick monument are confined in a restricted area.

0.2. Aims and objectives

This study is an attempt to identify courses of decay in selected bricks monuments in the ancient city of polonnaruwa, and to identify possible measures for preservation of them for the posterity. At present since them is not much scientific investigation are involved in identifying courses of deterioration and probable preservation method, these brick monuments are perishing in a rapid faced.

0.3. Scope and limitation

Under this study, examination of deterioration factors and conservation methods of brick monument in entire, Polonnaruwa is an impossible task. There for, studs are limited to four monuments deterioration and conservation factors pertaining to them. They are including Palace of Parakramabahu, Thivanka image house, Lankathilaka image house and Thuparama image house.

0.4. Methodology

Two system of data collection for main parts of the research. One of them is in library reference which gives background information, and the fieldwork which played the major role in this connection. Moreover, on every possible occasion interviews are held with experts at conservation, officials and technicians.

In the case study, all four monuments were subjective to architectural, structural and environments studies.

Data collected two-way, case study was analyzed comparing with each other, with back ground supports from reference.

0.5. Outcome of the research

The first chapter is devoted to the Historic city of Polonnaruwa and its brick monument. This chapter includes history of the city of polonnaruwa and Brick work in the ancient city of Polonnaruwa.

Chapter two deals with and examines the Study of brick monuments in polonnaruwa. This part is a scientific study based on the data we collected out of fieldwork. These data refer to the architecture of the building present state and identification of decay and its underlying causes. In this regard while a selected few monuments have been studied specifically where as other monuments were dealt with at random basis.

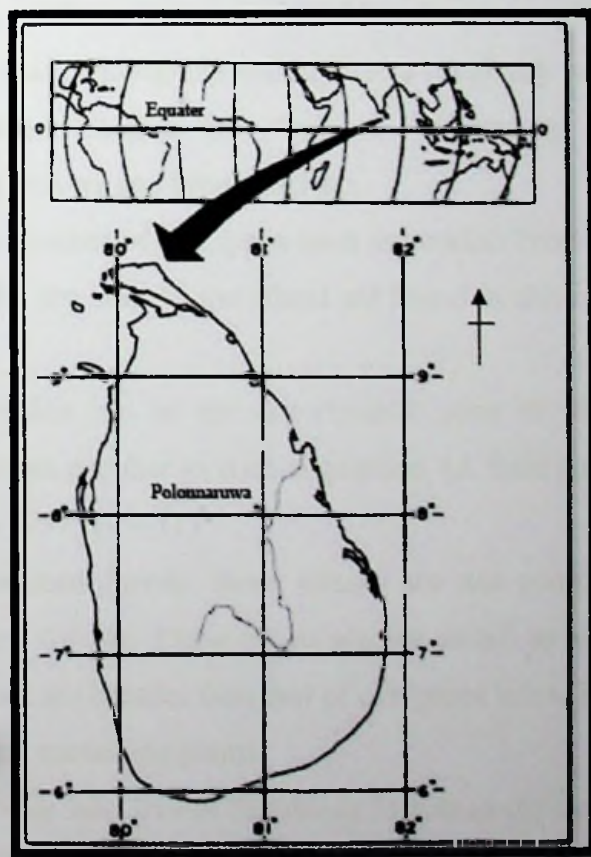
A detailed study in respect of causes of decoy and their activities responsible for the decay of bricks monuments in Polonnaruwa is made in the third chapter.

In the chapter four a detailed account of conservation and proposals regarding brick monuments of Polonnaruwa is given. The first part of the chapter deals with course of deterioration of bricks monument in Polonnaruwa. The next part of the chapter deals with the proposal for conservation of brick monument. And chapters five contain a conclusion.

Chapter-01

Historic city of Polonnaruwa and its brick monument

The old city of Polonnaruwa comprising GS Divisions No 199 Nissankamalla Pedesa and No 198 Ethumalpitiya which belongs to Thamankaduwa Divisional Secretariat of Polonnaruwa District. In the North Central Province lies between $7^{\circ} 54' 57''$ north latitude and $81^{\circ} 00' 02''$ east longitude. The sample selected for the study is a locality of this town some 120 hectare in extent which comprises brick monuments. The thesis presents a comprehensive account of factors leading to deterioration of these monuments and methodologies is adopted so as to preserve them.



Location of Polonnaruwa

Picture - 01

Topography of polonnaruwa is by no means complex. On the whole it is a broad plain. Folded nature of the land with rocks and residual hillocks scattered here and there give this zone a certain amount of topographical variety. To the west of polonnaruwa town parakrama samudra and to the east Mahavali Ganga flow. To speak about heights contour line 140 meters is found near the town and that of 200 is found across the catchment area of parakrama samudra. (1: 50 000 map polonnaruwa, Survey Department of Sri Lanka) There for this zone is an undulating land with an altitude of 140 – 200 meter.

According to the classification of climatic zones in Sri Lanka Polonnaruwa has climatic conditions peculiar to dry zone in the island. As this region receives rainfall only during the north – east monsoon (October – April) and as drought occurs during the south west monsoon i.e. from May to September, this zone is known as dry zone. The average annual rainfall is 1200 – 1800 mm (between 50 – 75 inches) here while temperature increases in the dry season of the year. Throughout the daytime a rough dry wind blows from the south – west. Grass dries out and catches fire. Vegetation withers up. Bushes and hedges die. Thanks turn muddy land. Rivers and brooks dry up.

On the whole a number of soil types such as reddish brown earth and alluvial soils which are common in the dry zone in the island are found in this region. (National Atlas of Sri Lanka 2007ed. 43)

In this region which lies in the dry climatic zone of the island is abundant in evergreen forests and plants peculiar to such vegetation. (A field guide to the Common trees and shrubs of Sri Lanka 1997, 10 – 11)

Unlike wet evergreen forests these forests are not complex. Here the trees are abundant in branches and foliage. These plants are not as tall as evergreen trees. However, the canopies of these trees are broader than that of evergreen trees. There are no plants which grow high. Epiphytes and ascending plants.

Animals of all kinds who live in deciduous forests in dry zone can be found in these regions too. Common small mammals or quadrupeds are common here. They include Spotted deer (*Axis axis ceylonensis*) Elk (*Rusa unicolor*) Wild boar (*Sus scrofa ceylonicus*) Jackal (*Canis aureus lanka*) Mongoose (*Herpestes lanka*) Otter (*Lutra lutra ceylonca*), Palm civet

(*paradoxurus hermat phrodites*) Monkey (*kasi senex*), Bandicoot (*Bandicata malabarica*), Hare (*Lepus negricolis Sinhala*), Porcupine (*Acanthion leucurus*), Dudian pangolin (*Mains crassicaudatus*), Slender loris (*Loris tardigradus*), Ape (*Macaca sinica*) and Rat (*Rattus rattus*). In addition in places turned wild and in reserves belonging to this zone large animals such as Elephant (*Elephas maximus zeylanicus*) can be found. Peacock (*Poavo crisatus*) is the leading bird living in this zone. Moreover, (*Amauromis phoenicurus*), Crane (*Ibis leucocephalus*), Orange minivet (*Oriolus xanthornus*), Hornbill (*Tokus gingalensis shaw*), Wood pecker (*Thereiceryx szeylaniou*), Paradise fly catcher (*Tahitrea paradisi*), Wild fowl (*Gallus lafayetti*), Kingfisher (*Halcyon smyrnenis fusca*), Parrots (*Psittacula calthropae*) and a wide variety of other birds also live here.

Poisonous serpents such as Snake (*Naja naja*), Python (*Vipera russli*), Ceylon krait (*Bungarus caeruleus*), scavengers such as spotted iguana (*varanus salvator*), reptiles, such as Crocodile (*Crocodylus porosus*) *varanus bengalensis* and a wide variety of invertebrates are also found here in large numbers. Among them Butterfly (*Lepidoptera*) and beetles (*septumpunctata*) are found in large numbers.

1.1. History of the city of Polonnaruwa

a). Polonnaruwa During Anuradaghapura period (518 AD-1070 AD)

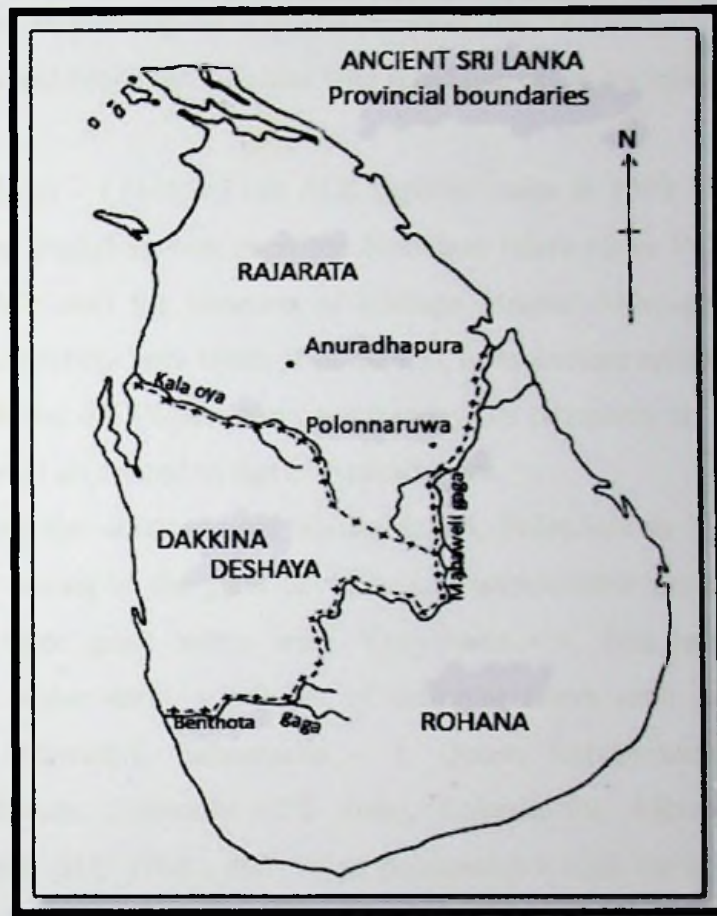
Polonnaruwa period of the history of Sri Lanka commences in the beginning of the 11th century AD and ends in that of the 13th century AD. Anuradapura, the first kingdom of Sri Lanka established in 6th century B.C lasted 1500 years without interruption and was ultimately abandoned in 992 AD or in the 10th year of the reign of king Mahinda - v. (H.C., vol-II 1960 : 332) After that the kingdom was under the authority of Sinhalese, Kerala and Karnataic soldiers. (M.V., 55: 11- 12) Then during the early part of the 11th century Cola seized Anuradhapura and destroyed it. Polonnaruwa was chosen by them as their capital city. It is evident from the earliest Brahmi inscription found in places such as Enderagala, Duwegala, Galkandegama Kanda, Konattegoda, Lunuwaranagala, and Mutugala that Polonnaruwa had been colonized even in the earliest times Bc. (Paranavithana 1970 : 21

- 25). Further, as there were five tanks called Padaviya, Wahalkada, Kantale, Kawudulla and Minneriya and a good numbers of village tanks built near Mahaweli Ganga and Yan Oya in this region it can be confirmed that there must have been a dense population surrounding polonnaruwa even since early times. Although rulers such as king Silakala (518 – 531 AD) Aggabodhi - III (629 – 639 AD) Aggabodhi- v (607 – 683 AD) and Udaya- I (797 – 801 AD) belonging to the early part of the 6th century AD were ruling the island from Anuradhapura. They were inclined to build second palace as their residence in Polonnaruwa. Further, it seems that work had began at a number of public establishments such as places of worship, hospitals etc, in polonnaruwa during this period. Moreover, the inscriptions belonging to and found in this region also indicate the great importance attached to this place.

As polonnaruwa stood at a central location which enabled them to rule both Ruhuna and the north especially through Dastota and Magantota it is said that very often even troops were stationed in this region since ancient times. Therefore, it seems that Polonnaruwa had been used as a town meant for camping those days. (H.C.,1964:337). Although this city is known as Polonnaruwa today ancient writing indicates that it had several other names in the past. In the ancient times this city was called in Sanskrit as “pulasti Nagara”. Later the city came to be known in pali as Pulati Pura. Ancient Sinhalese inscriptions refer to this city as Pulati Pura. (E.Z ii 1928: 106) Chula vansa very often calls this city Pulasti Nagara (M.V.74: 75). However, the name seems to have regularly developed in to the original Sinhalese word “ Pali naru”. This city has been called as “Polonnaru” in Sigiri Graffiti of the 8th century AD. (Paranawithana. 1956: 143) the name used in middle ages was Polonanru which came to be known as Polonnaruwa today.

The river Mahaweli Ganga is found flowing in the vicinity of Polonnaruwa. Consequently the fords of Mahaweli Ganga facing Polonnaruwa could be easily controlled from Polonnaruwa. The fords along the river (Mahaweli) had to be safeguarded in order to prevent any possible rebellious invasions of Ruhuna launched against Rajarata. Polonnaruwa is an easier place to take such preventive measures. Further, Polonnaruwa lies on this side of the river, namely more interior. So this kind of location also was favorable to guard against any south Indian invasions of the north. The physical location of Polonnaruwa was favorable for the king and his men in such a way that if the enemy destroys strength of fords and

approached land the letter had enough time to leave the city – Polonnaruwa – and flee to Ruhuna. Therefore, Polonnaruwa kingdom was a refuge meant not only for protection from local enemies but also from foreign foes.



Ancient provincial boundaries Sri Lanka

Picture - 02

b). Polonnaruwa as the regal capital

In tenth and eleventh centuries calamities of cola caused against Sri Lanka were at a peak. This was the chief reason for choosing Polonnaruwa as the capital city of Sri Lanka. South Indian colas seized power in the north in 1017 AD, destroyed Anuradapura, and using Polonnaruwa as the capital city ruled the country over half a century till 1070 AD, king Rajendra- i (1014 – 1044 AD) is one of the most remarkable cola rulers who could bring under his control not only the whole of south India and Sri Lanka but also Maldives island,

East Indies archipelago, Malayan peninsula and Java islands. During the above period it seems that Polonnaruwa and the whole island or at least only the north of Sri Lanka were known respect as “Jana Nata Mangalam” and “Mummudi Cola Mandalam” (H.C 1964 : 337) Ancient ruins of archaeological importance show that in Polonnaruwa alone some sixteen Hindu temples had been built by colas who acted like grave enemies of Buddhism.

King Vijayabahu – i (1055- 1110 AD) expelled colas in 1070 AD., seized power and ruled this country. Including him even the Sinhalese rulers chose Polonnaruwa as the capital up to 1215 AD until the invasion of Kalinga Magha. Although the lifespan of Polonaruwa is comparatively very short, it is evident from ancient architectural work and ruins that are found in the old Polonnaruwa town today; its prosperity in the ancient times seems to have been not at all second to that of Anuradapura.

Notwithstanding the uninterrupted hostile action, Polonnaruwa kingdom produced excellent work of art owing to the great devotion and unbelievable perseverance of three great rulers. These three great rulers were Vijayabahu - i, Prakaramabahu – i and Nissankamalla. In the mean time, a number of different rulers such as Jayabahu - iii, Codaganga, Queen Lilawathie, Sahsamalla – i, Queen Kalyanawathie, Dharmasola, Anikanga Maha Adipada, Lilawathi (2nd time), Lokeshwara, Lilawathie (3rd time), Parakrama Pandu etc. (H.C 1964 : 807) ruled polonnaruwa until the invasion of kalinga Magha in 1215 AD. However, these rulers were unable to do a sufficient service due to political unrest. King Vijayabahu -i, taking advantage of a rebellion occurred in Cola country in 1070 AD, expelled Colas from this island and seized Polonnaruwa which hitherto had been named Jananathapuram and controlled by Colas, named the kingdom as Vijayarajapura and ruled the country for about 53 years(1055 – 1110 AD). Thus he put an end to the Cola power in this country (M.V 59: 259) Vijayabahu – i performed his task in a manner as he hoped would not allow any repetition of Cola invasion in future. Accordingly he first of all made provision so as to safeguard the coastal region. He got a tall, strong brick wall built around Polonnaruwa his capital city. Then he had broad, long moat constructed around the wall. (M.V 60:2,3). A temple of the tooth to the north of the place and some new Buddhist temples within the city were erected. The large Elahara canal which supplied water to Minneriya Tank and the associated place called Elahera itself were offered to these temples for their

maintenance.(M.V 60 : 2-5) The king also reconstructed a good number of tanks, dams and monasteries.

The king Vijayabahu was under obligation of the performance of the great task, namely the restoration of agriculture and irrigation work which had been come to a standstill and of Buddhism which had been neglected both for about fifty three years. Unfortunately owing to riots and fights that took place in his reign the above task of his could not be fulfilled as he wished. Two of these riots were brought about by his own high ranking officials while the other one was by Tamils living here. King Vijayabahu wouldn't construct any new irrigation work. Yet he which were destroyed by colas. One of his services of significance is repairing breaches and damages caused to Elahara canal which supplied water to Minneriya, Kavudulu and kantale tanks.

Higher ordination was restored by obtaining higher ordained bhikkus from Burma in order to restore Buddhism which had hitherto been declined (M.V 60:2-3) king Vijayabahu the great made a great effort to create a prosperous state in every respect. But he could not restore the entire country because it was a century old destruction colas brought about before his ascending the throne.

The scheme of architecture of king parakramabahu the great who succeeded Vijayabahu the great was the first step taken to transform the city suitable for a kingdom. It was during his reign that palaces, temples, parks and ponds erected according to a plan. He extended the walls of the old city and also increased their height.(H.C 1972: 438) But the extent referred to in the chronicles is obviously not only the area covered by walls. It can be an exaggeration to some extent. According to archaeological factors already discovered polonnaruwa town is about 120 hectare in extent. The area of the old inner city which is long in shape is about 1000 hectare in extent. This area is covered by a huge brick wall. Then the rampart may have been extended from north to south some 1.6 Km and east to west some 0.8 Km.

The castle stood in the south corner of the area covered by the rampart. Within the fortress stood seven storied palace. In the garden of the palace there were accessories of the palace too. One of them included the large reception hall meant for the polite visit to the king. There was a pleasant park called Nandana uyana in it too. Further, there were four

attractive ponds. Between the palace ground and Parakrama samudraya "Deepaudyana" or Deepa uyana stood. In it also were a number of fine buildings. Moreover, king perakumba got 14 gates of the Polonnaruw rampart erected. (H.C. 1972:438). Queen of Parakramabahu the great Subhadrawathie, and other queen of the king Raupwathi got the Pabbalu Vehera built. (M.V 70:139-149) Numerous monasteries for bhikkus were built by this king too. On the city boundary Jethavanaramaya was built to north of the fortress. (M.V 78:32-34) 8 precious three storied mansions were erected surrounding the establishments of Segiriya of polonnaruwa. During the reign of this ruler a great number of religious buildings such as Uttararamaya, Kapilaya, Isipathanaya, Alahana parivena etc. were constructed brick has been the material mostly used to erect those buildings furthermore, during this period a minister called Mahendra, a man who won the confidence of the king, had a mansion with a Chandra sala built and offered to the tooth. The building now known as Thuparamaya may be the construction referred to here. (M.V 73:138 and 334 - 342). In addition during his reign a canal known as Akasha Ganga (M.V 79:27-29) and huge tanks and irrigation work such as Parakrama Samudraya were built. Hence it is clear that the reign of this king seems to be an extremely prosperous period in the history of Sri Lanka in economic, social and cultural aspects.

Another important ruler who headed the kingdom of Polonnaruwa was king Nissankamalla. He ruled the country for 9 years from 1187 - 1196 AD. (H.C 1972:807) There was no other king in Sri Lanka similar to Nissankamalla. Because he was the only ruler who did his best to win the heart of his subjects. During his 9 year old reign (M.V.80:25) no foreign enemy invaded Sri Lanka. In addition, even the internal political state of affairs in the country seems peaceful in nature. This ruler made a great deal of travel and tours in many parts of the country. (H.C 1972:489) Unlike other kings he sat up a large number of inscriptions wherein he referred to his tours, achievements, and constructions etc. in them. At the foot of Topa wewa his palace and the council hall was built further, Nissanka Lata Mandapaya and the Hetadageya taken as the temple of the tooth built at the sacred square in Polonnaruwa are attributed to Nissankamalla.(H.C1972:490) Moreover, Ran Koth Dagaba one of the largest stupas in Polonnaruwa is one of his constructions (M.V.,80:18). King Nissankamalla like his predecessors and both successors acted always in accordance with the wishes of the sangha and the institutions of sangha. It is said that he reconciled three

sects and expelled immoral bhikkus from the order. (EZ.i :34,ii:81-82).His reign was very short, namely only a years. Phenomenon of his religious and worldly labor becomes more significant because all that effort he achieved within a very short span of life (H.C 1972:490). With the death of king Nissankamalla political condition of the island become confused. Although weak rules were able to ascend the throne with the support of the powerful men behind them their reigns were very short (H.C 972:480).

Periods of reign of the kings of Polonaruwa.

Serial No.	Name of ruler	Period of reign A.D	Total period of reign in years /month/day
1	Vijayabahu-iI	1055 – 1110	55
02	Jayabahu- i	1110 – 1111	01
03	Vikramabahu –i	1111 – 1132	21
04	Gajabahu –ii	1132 – 1153	21
05	Parakramabahu –i	1153 - 1186	33
06	Vijayabahu – i	1186 – 1187	01
07	Nissankamalla	1187-1196	09
08	Vickramabahu –i	1196 -	1 month
09	Chodaganaga	1196 – 1197	9 months
10	Leelawathie	1197 – 1200	3
11	Sahassamalla	1200 – 1202	2
12	Kalayanawathie	1202 – 1208	06
13	Dharmashoka	1208 – 1209	01
14	Anikanga maha adipada	1209	40 days
15	Leelawathie(2 nd time)	1209 – 1210	01
16	Lakeshwara	12010 – 1211	9 month
17	Leelawathie (3 rd time)	1211 – 1212	7 month

Source: (Mahavansaya. 2004.79-80 Chapter & History of Ceylon (Sinhala Translation) 1972. 807 p)

Table-1

Even the data given above (table -1) show that every ruler who succeeded following king Nissankamalla could not reign longer than him. Therefore, the period following Nissankamalla, the kingdom of polonnaruwa declined more and more in economic, social and cultural aspects. Towards the end of Polonnaruwa kingdom, a pandyan prince called Parakaramapandu invaded Sri Lanka, expelled both queen Lilawathie who was on throne for the third time and her commander Parakrama, and grabbed kingship of the Polonnaruwa city. In the third year of his reign, an enemy called magha from Kalinga, invaded Sri Lanka with troops comprising 24000 soldiers and captured the kingdom of polonnaruwa.

As it is described in the second part of the great chronic this Kalingayan called Magha, accompanying an army of 24000 (soldiers) landed on Sri Lanka, seized camps, broke dagobas, had Tamils taken monasteries pirivenas and sanctuaries as dwelling, destroyed noblemen, cut hands and feet of the rich and grabbed their wealth, made the country Sri Lanka like a burning house, made Tamil army rob villages, ruled the country for 21 years (1215 - 1236 AD)

With the cruel invasion and rule of Sri Lanka by Kalinga Magha, Sri Lanka lost all its fortune. Many Buddhist architectural creations were lost, and ended up in ruin. People who resided in Rajarata migrated to the south- west region country. The whole of Rajarata, ancient cities of Anuradapura and Polonnaruwa become uninhabited region. The whole civilization with its fortune was buried in forest. Due to breach, abundance, and tide of the jungle all monuments were destroyed.

c) Polonnaruwa during latter part of history

Polonnaruwa was a highly prosperous kingdom before destroyed by the cruelest ruler Magha. All the prosperity so far brought about by Sinhalese kings was ruthlessly burned by him. Our legend Mahavamsa states this destruction... "Magha the cruelest ruler, born in Kalinga clan, head of twenty four thousand soldiers crashed here from Kalinga desha conquered Lanka deepa. Like a forest fire Magha burned Lanka kingdom. Many a rich personages was tortured and many Stupas were destroyed. Giant stupas like Rathnawali were brought down and invaluable Buddha relics made disappeared. Thereafter city of Pulasti was sieged round and arrested King Parakum Pandi, whose eyes were taken out. All the invaluable riches like pearls, gems were taken forcibly.

Next Kalinga Magha made Army General Manabharana as heir to the Lanka throne. Thus he surrendered the country and lived in Polonnaruwa. This ruler of land, Mahipala made populion believe heresy, made people of four castes to mix among them. All property, villages, fields, houses, temples, servants, cattle etc. belong to Sinhalese, handed over to Kerala men. Many temples, Pirivenas and Devalas were handed over to army captains. He thus acquired immense sins with taking of wealth belonging Lord Buddha, Dhamma and Sangha and was heading towards hell. King Magha ruled Lanka in this cruel way for twenty one long years (M. V. 80:56-79).

During those 21 years Magha rule Sinhalese society became degenerated. Treasure hunters inflicted further destruction to all archaeological buildings. All the ancient brick monuments in Polonnaruwa which are in our study field were also subjected to annihilation during this cruel reign.

This ruthless regime was defeated by King Parakkramabhahu - II of Dambadeniya (1236-1270 A.D.) who invaded Polonnaruwa city and chased out Kalinga Magha (Mahavamsa 83:27-35). Thereafter this King embarked on the giant task of re-construction of what the great damage inflicted to this country by Cholas. But King Parakkramabhahu fell ill in 1258 A.D. and bestowed his eldest son Vijayabahu in 1262 A.D. this task which he could not complete (H.C. 1972:592). Prince Vijayabahu thereafter came to Polonnaruwa and embarked on conservation work (H.C. 1972:595).

Mahavansa describes the sad state of Polonnaruwa at the arrival there of Prince Vijayabahu thus, "We will build well our old kingdom. They discussed each other to re- build Pulasthipura with its palaces, image houses, Viharas, Pirivena, Stupas, congregation hall, Devalas etc. on some of which were covered with weed, bushes, and some othesr fall down due to decayed columns. Some another works crumbled down by heavy walls which were cracked from top to bottom and some are inclined to be fallen due to non – support... Alas!.. Some another bend with weaknesses and decay like old men. Some other have broken roofs, some have broken tiles. In some other, walls and columns remain. Some others with broken doors, door arches and some other with broken stairs etc. Some foundations of houses only visible..." (M.V. 88:90-102).

Polonnaruwa city thus destroyed had been taken to task by King Parakkramabahu - II and the conservation works began in this way. This is the first conservation programme ever carried out in Polonnaruwa.

..... "Gathered the cabinet of ministers, all the Lankan people were deployed, craftsmen workers like iron workers, Carpenters, smiths, potters, load lifters and carries, stone masons, coolies servants and implements, bellowing skin, hammer, anvil etc. sharp saws, adze, battons, mammoties, mats. Baskets etc. great wealth was bestowed unto the further king along with army...." (M.V. 88:103-110).

Prince Vijayabahu with the reception of these resources and army of workers made all the monasteries, tanks and anicuts to be repaired and re- constructed. These re-construction tasks belong to our study of conservation of brick monument entirely. This conservation is in progress is detailed in Mahawansa this way.

..... "Thereafter the King built Pulathisipura with attractive ramparts, many monasteries, devalas, various mansions, numerous roadways, well planned with four gravest, pretty junctions etc...." (M.V. 88:116-120).

This conservation programme was the first and last giant conservation effected by Sinhalese kings in Polonnaruwa. Gradually people deserted Polonnaruwa along with the change of kingdom towards southwest part of Sri Lanka. Then the forest took over and covered the city of Polonnaruwa and all its brick monuments.

d). Rediscovery of Polnnaruwa

The kingdom of polonnaruwa which become a part of the jungle with its residents leaving it for the south – west region of the country, once again becomes an object of people's attention in the month October 1817, (only after six and a quarter centuries) during the British colonial rule of Sri Lanka. A British army official travelling from Bintenna to Minneriya, in the month October 1817, saw some letters inscribed on a stone near Kopari Lake, some 1/2 miles away from the village Kaduruwela. But neither he nor any Sinhalese could understand the meaning of the letters. A little distance away from the lake on the left were some ruins and the inscription in question perhaps may have had some connection with those ruins.

When lieutenant M.H. Pagan was on his way in 1820 from Batticalowa on foot taking a group of soldiers belonging to the 2nd regiment of his Majesty's army he took rest at Topari. There he saw some stone pillars standing out of the main road. Then he went in to the jungle with an elderly village who guided him. There he saw a circular red construction covered with the creepers of an Indian banyan tree.

It is clear from these accounts that Polonnaruwa which was abandoned by Sinhalese some 625 years ago was rediscovered perhaps by Pagan. J.H. Burch (Ceylon Civil Service) Laithan R.W. Stewart was the first two men perhaps who went to Polonnaruwa and photographed the ruins, in 1886. (Alahana Parivena Polonnaruwa first Architectural Conservation Report, 1981-1992:23). Major Fobes examined the ruins and discovered Lankathilakaya in 1831. Sir Emerson Tennent who became very active went to Thopari in July 1848. The bund of the tank was on our way and the tank was found shrunk and was covered with Iluk grass.

In 1851 Sir Samuel Baker his brother Lieutenant V. Braker, Peliser and Ktuvarthi Verti (later Sir Wan Cliffs) did hunting in this region. They also have left a description of Polonnaruwa. After that Buros 1886, Bell 1893-1912, Ayton 1912-1913, Hocart 1921-1929, Paranawithana 1940-1952 and others visited this place. (First Conservation Report 1981, Alahana Parivena, Polonnaruwa, 1992:23) They explored, excavated, conserved and offered Polonnaruwa city back to the nation.

After the archaeological explorations were begun in 1890 under the Commissioner H.C.P. Bell. His attention on Polonnaruwa was directed in 1893.

A meaningful excavation was carried on in 1910-1911 years. But many projects begun by him were completed in 1952. Sri Lanka archaeological authorities could only clean up the monuments which were scattered about and giant size remains of buildings etc.

The Indian government under the Colonial rule had begun archaeological research in 1861. By the end of 19th Century, research expectations and plans were well executed. Although certain archaeological findings were made, it took another 30 years for Sri Lanka to follow up Indian way of progress in this regard.

In the beginning what happened in Sri Lanka was to photograph and report on the archaeological surveys affected in Anuradhapura, Polonnaruwa and other areas. During the then British governor Sir Hercules Robinson, a person named Lotan had taken a lot of finest photographs of major ancient buildings in Anuradhapura and Polonnaruwa (H. A.D. 1993:03). An excellent opinion of deterioration on the Polonnaruwa monuments could be obtained from these photographs.



Ancient photographs of Watadage, Thivankaya, Thuparamaya.

Picture - 03

Further various persons have written many books on Polonnaruwa monuments with illustrations as seen by them. This information is also very useful for us to obtain a picture of these monuments, their ancient grandeur and lately of dilapidated condition.

Sir James Emerson Tennent's book on Ceylon in 1859 wherein page 97 gives an illustration of supposed Thivanka Image House. This illustration depicts the monument been hidden by growing trees and creepers (Tennent.J.E. 1856:97).



Ancient photographs of Thuparamaya image house.

Picture - 04

C.F. Gorgon Cumming had written a book by the name "Two Happy Years in Ceylon" wherein given an account of towns in Ceylon, he had found including ancient Polonnaruwa city with its ancient ruins. A detailed account of these ruins and their present appearances with illustrations had been given by it.



Ancient photographs of Watadage, Lankathilaka image house.

Picture - 05

In the book "Ruined Cities", illustrations of Galvihara, Rankoth Vihara, Seven storied palace, Royal palace, Lankathilaka (Jethavana Vihara), Watadage etc. have been made. By these we can understand how far these monuments have been destroyed due to neglect for several centuries and also how largely the bushes, weeds and trees grown on them.



Painting of Sathmahal prasada, Watadage, Lankathilaka

Picture - 06

Henry .W. Cave wrote a book "Ruined Cities of Ceylon" in 1896 in which he records detail obtained from the visits made to the ancient ruined cities in Ceylon. Chapter- VII of this book provides an account of old Polonnaruwa city with its old monuments with photographs,

revealing clear and comprehensive description including Jethavanarama, Lankathilaka, Palace, Thuparama, Seven storied palace etc.

These photographs could be tallied with sketches and illustrations drawn by those early writers e.g. Emerson Tennent- Ceylon, 1859 and H.W.Cave- Ruined Cities of Ceylon, 1896, Illustrations and photographs produced in these books. Some study could be made on these monuments on the differences shown after 37 years of short. A large scale clearing of lands and removing of trees and bushes were carried out. Only small weed to be seen.

On the instruction of Sir W.M. Gregory a person by the name Capper had launched a full scale survey on Stupas known to that day in Anuradhapura in 1873. Height of giant Dagobas and other scales had been calculated. In 1877, on the recommendation by J. Furguson, Mr.Smithier had drawn detailed plans on sales of more important ruins in Anuradhapura. This type of exploration to certain extent did not take place at the sometime. Attention on Polonnaruwa was paid in later years.

Under the orders of Sir A.M. Gordon, S.M. Barrow's government agent 1884-1885 some limited and useful explorations were carried out in Anuradhapura and in Polonnaruwa (H. A.D. 1999:03). Mr. H.C.P. Bell of Ceylon civil service was appointed as Archaeology Commissioner in February 1890 (H.A.D.1999:03). Archaeological survey done for the first time in Polonnaruwa in May 1900, ended in September same year. Bell describes thus: Pulatisipura or Kalingapura is still largely under jungle. But structures of markings of not only main roads of this city, but also of buildings are to be seen even today (H. A.D.1999:03).

These monuments were partly cleared under the orders of the government and then photographed by Mr. Lotan. These photos show large growth of vegetation on monuments, and roofs, walls stairs were subjected to crumbling, cracking, crashing and to the rain. These ruins are scattered about 5 miles on the side of a dam of large tank of the circumference of 10 or 12 miles. On the order of Sir A.M. Gordon, Thamankaduwe Dissawe had carried out useful clearing and exploration duties in Polonnaruwe in 1885-1886 (H. A.D.1999:27).

At the first stages of excavation done in Polonnaruwa, first identifications were ruins of Nisshanka Malla Palace, Royal court areas. In 1903 a group of Sinhalese labourers fully

cleared bushes and forests of the west side half of the city which was rounded up by rampart fortifications. They also marked ancient road ways (H. A.D.1999:30). During the years 1900-1901, the land portion of about 22 1/2 acres bulging into Topawewa was excavated for ruins of buildings bathing places, sluice gates etc. (H. A.D.1999:30).

25 acre land inside the city was fortified by ramparts. As such the land belongs to Polonnaruwa city including inner city and cape (H. A.D.1999:30).

E). Polonnaruwa as an archaeological reserve

Polonnaruwa was declared an archaeological reserve by ordinance number 728 of 23 October 1914. 2413 Acres and Perches 13.46 of land belonging to Polonnaruwa had been declared as an archaeological reserve (ASCAR, 1927:28). Scattered places of ruins had been cleared first and then cleared the jungle in between to have the archaeological site free. Accordingly the length from North to South is about a miles of a land full of historical monuments could be seen. Borders of the land are; Galvihara to the North, highway to the North near Demalamahaseya to the East, road running around the fort to other villages nearby Mahaweli river and Galewela to the South and the West wall of the fort and city to the West (ASCAR,1910-11:502-526).

Small gang of workers were employed in the regular service of maintenance of Polonnaruwa ruins during the financial year 1921/1922 (ASCAR,1921: 226).Selected trees removable from reserves should have been removed with utmost care. "Such trees harmful to the ruins were cut down and removed away said Bell in his reports (ASCAR, 1910-1911:503-527). After these clearings the archaeological site of Polonnaruwa appeared like a well planned park" thus Bell admired (ASCAR, 1910-1911:503-527). Mr. Hocart once admitted that it was too late for them to remove these trees considering the damage occurred to the ruins by growth of trees. Some ruins had been crushed beneath the large fallen trees. Hocart knew that Rankoth Vehera and Kiri Vehera were also threatened by giant trees and their roots (H.A.D.1999:50). Mr. S. B. Barrows engaged in the task of removing trees from the reserve areas, in 1885. But it cannot be seen such an event taking place up to the financial year 1910-1911. Only the weed and bushes were removed intermittently. According to the report 1910-



1911 of Bell, there had not been any uprooting of dangerous trees. Large roots had destroyed Stupas in Polonnaruwa (ASCAR. 1911-1912:102-186). Some of the ruins were being decayed due to pilgrims and tourists lighting lamps and making bon fires on and around ruins. Hocart records such an incident. Certain insane woman lived at Utthara Vihara. She lighted fires in it that required Government Agent of North Central to evict her. Pilgrims continued to light oil lamps and candles destroying statues and carvings. Suitable steps have been taken to remedy this. A printed pamphlet explaining the damage done to the ruins by ignorance has been distributed among pilgrims (ASCAR .1926-1927:01-05). Bell has launched explorations during 1910-1911 and 1911-1912 on many ruins like Polonnaruwa Kirivehera, Jethavana Vihara or the Lankathillaka, Thuparama, Nishshankalatha Mandapa, Seven storied palace, Pothgulvehara, Galvihara, Royal Palace, Watadage, Baddha sima Malaka, Gopala Pabbhatha, Wall of Daladha Maluwa and the ruins near Thopa wewa areas.

At the times of excavation, this Thupa was up to the third Pesa walalu submerged with ruins and broken parts. Much of the ruins could be removed away from Dagoba by June 1910. Wonderfully "Tun Mahal Pesawa had been protected as though by the same ruins.



Ancient photographs of Kirivehera

Picture - 07

Therefore only a small part had to be conserved. Yet all four "Wahalkadas" had been badly destroyed. There appeared small stalls to offer flowers on both sides of each Wahalkada. The state of the other parts of the Stupa and the sacrileges inflicted by treasure hunters, along

with the measurements of various parts of Stupa etc., make his aforesaid report very highly important (ASCAR. 1910-1912:50, 45, 05, 28, 29).

An important excavation launched in 1910 was found at Jethavanarama. Bell has recorded the pre conditions existed before excavation and the process of excavation at the conclusion of excavation, venture in his report (ASCAR 1910-1911:507, 508; 32, 33).

As per the description of this report the building was utterly dilapidated. Only a half of back side wall to the North and West had been left. Wall parts between the entrance hall and the chamber house too had been crumbled down. Walls had been isolated. Very small aperture only remained at the entrance hall due to falling out of inner and outside plasters. It was very dangerous relative to the thickness and height. These conditions could be seen on the south wall as well as on north wall. The entrance door was high as the columns and the connection between walls was wholly destroyed. They were in precarious condition. Everywhere there were dangers openings, blasts on all brick walls. Hence the excavations should have been done with utmost care and risk.



Ancient photographs of Lankathilaka

Picture - 08

About hundred days between 25 July to November excavation work was carried on and the results were very satisfactory. In the excavation process it had to dispose rubbish ahead of

conservation effort. Numerous archaeological artifacts have been found there. Bell has written in his excavation report including a finest on the architecture of it. This building also named as Jethavanaramaya of which there are stone inscriptions aiding to identify Lankathilaka Vihara (H.A.D.1999:60).

Two masons were deployed to do repair works of the entrance hall of Jethavanarama Vihara. Several walls were about to be collapsed and in a very dangerous condition. Vertically existed crevices were filled in and walls made strong. Treasure hunters had broken the seat of the giant Buddha statue. That has been repaired and feet and the rings were strengthened. The doors of entrance hall and chamber house had high stairs resulting water accumulation inside. Therefore a small gutter was cut through the stone stair at the base of door frame and let water drain out (ASCAR. 1910-1911:516/40).

Bell was further able to assess the archaeological importance during the survey continued in the next financial year. He warned that he could not forecast what part at what time, requiring immediate repairs to save the building. First Bell began conservation in northern door entrance hall (H.A.D.1999:60). Crashed down parts of Jethavanarama Southern wall were repaired during financial year 1920-1921. These works were carried on with the theories introduced by Bell. Assistant Architect in the Public Work Department and Mr. W.M. Fernando who was in charge of Polonnaruwa helped the aforesaid repair work. Strengthening of the foundation of the southwest wall, repair of large crevice in the west wall, reconstruction of existing lower parts due to over weight of upper parts, filling of cavities and holes developed due to weather and other factors etc were all effected. Hocart reported that although much of the new work effected they were not much changed from the existing works (ASCAR. 1920-1921:07).

Several restorations were done inside of Viharageya and on corridor walls. Several parts of the robe of Buddha statue have been strengthened. Although it was prepared to put a cemented floor it was abandoned due to the presence of coal mixed floor, beneath the layer of lime mixed existing floor. Several of repairs affected the floor level variations needing to repair water drains accordingly. The concrete floor of Viharage front was strengthened with suitable coloured cement. However Hocart was not so satisfactory with that (ASCAR. 1920-1921:07).

Ireton has done some repair work here. Staircases, Korawakgal and Muragal were re-fixed. Entrance hall floor was fully cemented to prevent water seepage. Outer side of the south east wall which was on the verge of destruction had been walled up to the height of about 12 feet and slanted towards the existing wall. The crevice enlarged up to one foot crosswise has been filled with cement. The wall behind the Buddha statue was cracked towards south west and the gap was filled to join two walls together. Cavities developed here and there in the statue filled up with cement. Wall of the entrance pavilion had a broken part of 6x8 feet has been repaired with lime plaster and bricks. Crevices which were in the north east were extremely dangerous and he was not sure of achieving full strength with the restoration, said Ireton (ASCAR 1912-1913:652/656).

Northern wall of outside Vihara remained intact and attractive. But the brick walls on both sides of the arch and the door with stairs had been mostly destroyed. Also upper frame of the door had been cracked. A flat iron was laid to harden the soil mass. However only six feet high part could be repaired (ASCAR 1911-1912:984/58).

Following restorations and conservations works were launched by him during July to September 1912. Northern wall of the entrance hall has been repaired to full height and width. Parts of east wall of chamber house connected with north and south walls of entrance hall have been repaired. North wall of the chamber house crumbled down to window level. Bell understood that nothing could be done except to strengthen its top and did it as he thought. However, south wall of chamber house had been remained intact, except small defects. Although it was necessary to put cement to the entrance hall floor and chamber house floor Bell was able to do so, only a part of it (ASCAR. 1910-1912:1016-1017/90-91).

Bell has launched explorations and excavations on the north door pavilion of the Polonnaruwa Fort. Royal palace within the fortress and the Prince Pond and had produced a very valuable report (ASCAR 1911-1912:978/52).

Excavations were carried on in the large area situated to the south and south east of Jethavanarama premises. Baddha Sima palace and several normal ruins belong to this part excavated during July to October 1912. Bell has included in his report, Archaeology of

Baddha Sima palace and factors of helping to its identification (ASCAR. 1911-1912:1008-1010/82-84).

All the soil and ruined parts piled up around Rankoth Vehera had been removed away. An important account of this Stupa included in the report by Bell during 1911-1912. He had also forwarded a summary report on the measurements of major Stupas of Anuradhapura and Polonnaruwa. According to that report Rankoth Vehera become the fourth largest Stupa with its diameter of 186 feet. The other larger stupas are Jethawana (then Abhayagiri) 370 feet Abhayagiri (then Jethavana) 355 feet and Ruwanweliseya 294 feet (ASCAR. 1911-1912:1012-1015/86-89).

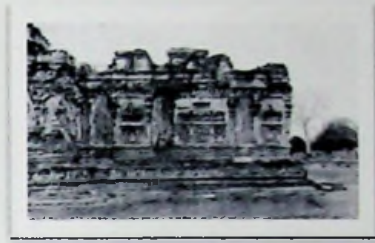
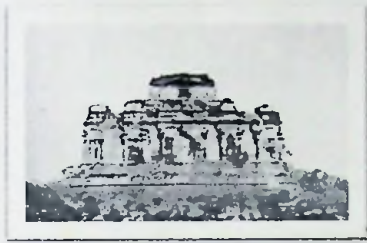
“It is compulsory to make conservation after excavation” this theory was not known to Bell, it seems. The person was to pay attention on this factor at first was Ireton. But his death in 1914 resulted closure of the Department of Archaeology and crippling of work.

Hocart understood the situation well and brought forward the theory of “excavation should be done only if it were possible to do conservation work after it” and gave many examples in his report. Further he took pain to introduce conservation theories, it appears. Secondly he accepted another theory of maintenance of buildings after conservation was carried out. He also lamented that there would be no use if the conservation particulars were not known to the people (ASCAR. 1920-1921:08).

Conservation work was carried out at places of Thuparama Vihara, Nissanka Latha Mandapa, Seven storied palace, Pothgul Vehera, Shiva Devala No- 02, Kirivehera, Jetavana Vihara and Galvihara during 1910-1911(H.A.D.1999:68).

Conservation work of Thuparama Vihara was launched in 1904 (ASCAR. 1911-1912:987/57). Carvings on west and south walls done with lime plastering needed to be filled and the decayed places of brick walls filled during 1910-1911. Fake (short) battlements with intermittent holes in them were also repaired and conserved at this time. It was not possible to find experienced masons. Bell described the dilapidated nature of this building and reported those lime plaster carvings in small cabins of south wall were preserved better than the carvings on north wall which were badly destroyed. “ Actually,Jetavanaramaya and Demala mahaseya had shown the other side of it ” he further said.

South east wall of inside Vihara wall was also repaired. A large part of entrance hall along with the door frame and the lined had been crashed down (ASCAR. 1910-1911:514/38).



Thuparama image house at the beginning of 19th Century

Picture - 09

It was not intended to re-construct the roof on it although it had been destroyed. It was necessary to make strong the walls which were crumbling down. Steps were taken to protect pilgrims from crashing of walls etc. (ASCAR. 1910-1911:514/38). Final repair work was done by September 1911. Foundation of the wall etc was repaired along with loosened parts of north, south and west walls. Walls on the both sides of the frontal door were re-constructed and the door frame was assembled upright. Further the brick facade fallen near to north entrance and upper parts of walls along with entrance walls of north and south have been raised. Chamber house floor was concreted. Grilled iron frames were fixed to keep away bats etc. Fitting seats were made to place four standing Buddha statues.

Restoration work commenced on two large statues. The great set back was the non-availability of required expenses. With all these, it was able to do restoration work to certain extent (ASCAR. 1911-1912:983/57). It was reported that Hocart applied some water resisting paint on the bricks of Vihara chamber (ASCAR. 1926-1927:01/05). This proved unsatisfactory and Windsor took necessary steps to stop seeping water during 1926-1929. Also, walls on both sides of the door were re-constructed and upper parts of the inner walls of the entrance hall were repaired (ASCAR. 1928-1929:05).



Thivanka image house in the first half of the 19th century

Picture – 10

Hocart had erected a thatched roof with coconut leaves intended to protect paintings in Thivanka Image House (Demala Maha Seya). Although it was an ugly work there was no better thing to do; he said. Hocart found an important thing of existed old painting beneath the new painting (ASCAR. 1920-1921:07). There was a large crack on the east corner on the outside of north wall. There was a problem of leveling according to old measurement.

The crack that was on west wall was restored on the advice of architect, Ewardson. Turpentine and bees wax was applied on some paintings after washing with spirits as per the instructions by Indian Archaeology authority. Should the paintings thus protected withstand the rain, the same protection could be applied on other painting as well, it was expected (ASCAR. 1922-1923:03).

Conservation work of this was ended in the following year. Major work effected was to prepare paintings on top of the walls so as to resist rain water (ASCAR.1928-1929:05). The entire building was strengthened by filling of crevices.

Treasure hunters had dug a tunnel up to the foundation. Bell admired the excellent quality of ancient brick work and plastering technology which resisted any collapse of the building. Staircase to the upper floor at southern end was restored. Palace architecture developed in Cambodia had been introduced to Sri Lanka by this unique building. Bell stated that only the surface restoration was needed to prevent crashing down of the palace (ASCAR.1910-1911:515/39).

Masons were deployed for restoration work of the walls, which had been destroyed by explosions. Backside wall had been dangerously destroyed by that time (ASCAR. 1910-1911:515/39).

During the financial year 1910/1911 this Stupa was restored by filling up of crevices on the dome of the Stupa and strengthened with plaster after scaffoldings around Stupa (ASCAR. 1910-1911:516/40).

Conservation work effected here in 1912 included filling of cavities, repairing of "Pesa" rings etc enabling to stop water seeping into Dagoba. Treasure hunters had dug a tunnel to reach the relic chamber long time ago, which was found at the clearing of a large cave near to north entrance. It was very difficult to clean and close down this tunnel used by swarms of bats. It was difficult to breath there. Coolies were deployed, in turn to clean the tunnel. Bell has prepared this plan and has forwarded an important account on its relic chamber. He further has explored the way of digging the tunnel. His account on the relic chamber would be highly important for academics of architectural features of Stupa. By 1920-1921 a part of "Kotha" was about to be collapsed but was made strong with bricks and cement (ASCAR. 1920-1921:07). In following year crevices developed in the Stupa were filled up (ASCAR. 1921-1922:06).

Square chamber of Rankoth Vehera was about to be collapsed and was restored by Sudbury (ASCAR. 1924-1925:01-05). Hocart repaired the "Kotha" with filling of plaster (ASCAR 1926-1927:01).

Preparation of suitable plaster similar to the clay used at first in the conservation of Baddha Sima palace architecture became the problem again. A satisfactory mixture was introduced after many testing and used in the conservation efforts. (ASCAR 1926-1927:16).

Although the restoring needed to be effected to the Kirivehera work suspended in 1912 and begun conservation work on the pavilion in front of Stupa (ASCAR 1910-1911:514-515/38-39-1016/90).

Hocart effected plaster work on the broken places of walls of Royal Palace in Polonnaruwa and places of the fort that required special attention as well. He has reported on the earlier conservation at the Royal palace and the" poor work was due to be unsupervised nature of work, unsupervised use of lime and use of wet bricks (ASCAR, 1922-1923:13). Further he had done conservation work on the north door of Fort during 1925-1926 (ASCAR. 1925-1926:15).

At the beginning of 1930 Polonnaruwa had been connected with many other towns by railways or by highways or both.

On this medieval city of Polonnaruwa, there had not been constructed buildings over the ruins, as have built in Anuradapura. But there were many forests to be removed from areas of ruins. During the 3rd decade the thick forest that covered the larger part of the inner city, except few large trees was removed, so the city was seen as a botanical garden (H.A.D.1999:107).

Excavation was begun in 1932 in a large area consisting building complex belonged to Royal palace of King Parakkramabhahu - II. Mr. Longherst strengthened Thivanka Image house by removing soil and stones near its entrance. He also restored in a big way the square chamber of Kirivehera which was extensively decayed, and a part of which was fallen on the ground. Also made strong an Image house of reclining Buddha statue, on the dagoba premises of Rankoth vehera, along with the excavation on "Wahalkada". Mr. Longherst took steps to re-plastering the walls of buildings of Thuparama, Lankathilaka and Thivanka Image House. Certain images remained half and restored provides witness of restoration, although he was telling not trying to restore them.

Extensive damage was happened due to the great flood in 1957. Certain crash downs place at Royal palace of Polonnaruwa and Rankoth vehera. A part from east side of square chamber of Abhayagiri Dagoba in Anuradhapura fell down. Parts from east and south east of Jethavana dagoba also fell down. Some areas were inundated (ASCAR. 1957).

Many land areas under archaeology prohibition covered with forests. Damages affected by squatting and by cattle were not small. Conservation efforts too were crippled. As such re-clearings of land reserves and erection of barbed wire fences for protection took place in 1960 (H.A.D.1999:133).

Main problem of the reserves of Anuradhapura, Polonnaruwa, Sigiriya, Mihintale, Yapahuva etc was to protect those lands from the cattle. Besides it was mentioned that many of archeological lands were under the jungle even in 1951 (H.A.D.1999:139). It was necessary to develop archaeological premises artistically. Ancient pond in Polonnaruwa was conserved during 1952 (H.A.D. 1999:140).

Although the numbers of archaeological reserves and monuments increased, required financial strength was not sufficient to maintain those places. More than half of the money received by the Department spent on the maintenance work of these lands, lest the danger of squatters always grabbing them forcibly. Especially this danger was high in the places like much populated Polonnaruwa (ASCAR. 1953).

At the same time the lands with archaeological sites were prepared attractively, and clearing of jungles continued. Especially this programme had begun in Anuradhapura, Sigiriya and Polonnaruwa (ASCAR. 1955).

The department effected several consolidation sites in Polonnaruwa. Alahana Pirivena, Rankoth Vehera and Tivanka Image House were among them. Pesa rings of Rankoth Vehera were consolidated. Rankothvehera Wahalkada consolidation in 1952 paved the way to a good study of Wahalkada construction (H.A.D.1999:149). Further consolidation works on many other important places which are mentioned in historical books had been effected (H.A.D.1999:149).

Alahana Pirivena, Rankoth Vehera and Tivanka Image House had been consolidated (H.A.D. 1999:149). More important consolidation during 1953 was done at Rankoth Vehera. Dome work up to ten feet from upper "Pesa" could be constructed during 1953. Alahana Pirivena repair work was continued since last year. It has been necessitated to do consolidation work in a very large area during a long period. It was a scattered building complex (H.A.D.1999:150). Necessary work of consolidation was effected to protect art work in

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Tivanka Image House and the chemical treatment for the statue in Pothgul Vrhera were done during 1953 (H.A.D.1999:153).

Mr. L. Maransi who came to Sri Lanka on second time in 1957 used the chemical treatment to refurbish the darkened art drawings and the statues in the Tivanka Image House in Polonnaruwa (H.A.D.1999:210). Serious damages were inflicted upon the monuments in Polonnaruwa by the cyclone occurred in 1978.

Conservations in Polonnaruwa under central cultural fund.

Most important factor that influenced the development in Polonnaruwa was the programmed of Cultural Triangle commenced in 1980. Alahana Pirivena project launched under this scheme, made the way to preserve it as a world heritage project. Accordingly work commenced on grand scale on excavation, conservation and on maintenance there. Many conservation projects which have been suspended due to financial strain of the archaeological department have commenced under this triangle.

Many of the giant brick monuments as well as small scale brick monuments and brick works have been conserved in keeping with the national and international ethics, charters, rules and regulations. The cultural triangle also had the ability to spend all money at ease. This charter begins with the clarification of its aims and expectations thus;

..... "To develop cultural monuments in Sri Lanka and in foreign lands for the development of cultural, religious and social aspects and for the preservation and restoration and to meet the expenses incurred in the improvement of religious and cultural affairs....." (Act No. 57 of 1980 on Central Cultural Fund)

This institution operated in the beginning with strong, large, administrative frame, financial, technical, as well as intellectual and man power strength, thereafter embarked on all the conservations of brick monuments with their maintenance. Even at present the archaeological excavations, conservations and preservations operated in the old city at Polonnaruwa are executed under the Alahana Pirivena project of the Central Cultural Fund.

It appears that this institution performing to the highest standards in allegiance to with national and international charters, ethics; using expert knowledge and technology in keeping with the state of intervention. Yet for all that, this institution is not without any faults.

1.2. Brick Work in the ancient city of Polonnaruwa

Brick Erections in Polonnaruwa.

There are good numbers of monuments built by ancient kings in the ancient city of Polonnaruwa. Many of these building works were Buddhist architectural erections or constructions meant for various royal needs. Some others were Hindu religious places of worship. Principal building materials used to construct the majority of these erections are brick and lime plaster. (This classification is arrived at on the basis of the material of which 60% comprises the total materials used for the entire erection.)

On the basis of this determiner the majority of ancient erections of Polonaruwa fall within the kind of which the building material is brick. Pothgul vehera of Polonnaruwa, Palace of king Nissankalmala, Sitha Maligaya (Ddupath Mandapa), Palace of King Perakum the Great, Thuparamaya, Vatadage, Sathmahal Prasada, Pabalu Vehera, Manic Vehera, Rankoth Vehera, Baddha Sima Prasada, Lankathilaka Pilimageya, Kirivehera, Demala Maha Saya, Thivanka Pilimageya, City wall as well as many other architectural brick erections be they big or small in size chief material used was brick. In view of this fact the majority of monuments built in the kingdom of polonnaruwa were erected using brick as the principal building material.

On the whole these brick erections can be classified in to 3 kinds.

1. Major brick erections
2. Intermediate brick erections
3. Common brick erections(other erections)

Major Brick Erections

Major brick constructions include the city wall, Demala Maha Seya, Rankoth Vehera, Pabalu Vehera, Manic Vehera and Kirivehera etc.

Intermediate Brick Erections

Intermediate brick erections are Thuparama Pilimageya, Thivanka Pilimageya, Lankathilaka Pilimageya, and Palace of king Parakum the Great, Thuparamaya, Vatadageya, Sathmahal Prasadaya, Badda Sima Prasadaya and palace of King Nissankamalla, Pothgul Viharaya etc.

Common Brick Erections (Other Erections)

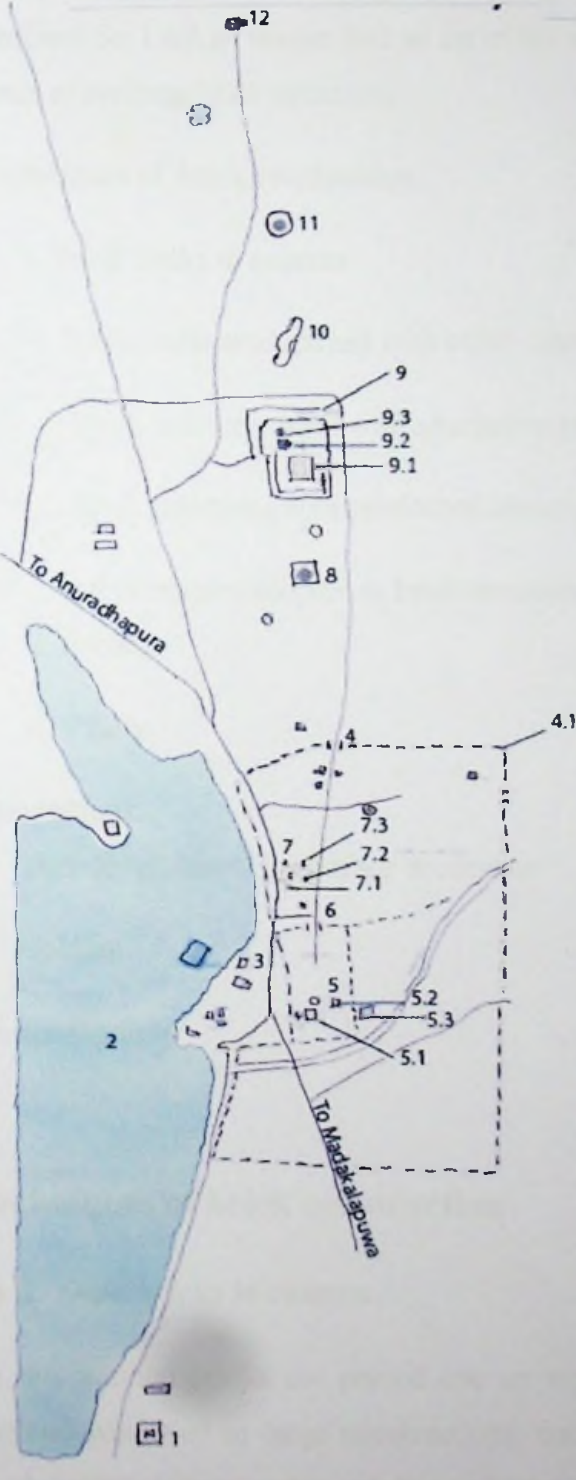
Common brick erections include big and small brick walls and other constructions such as ponds.

BRICK MONUMENTS - POLONNARUWA

N



- 1.Pothgul Vehera
- 2.Parakrama Samudraya
- 3.Council Chamber of King nissankamalla
- 4.Outer City Gate
- 4.1. Outer City Wall
- 5.Inner City
- 5.1. Palasce of King Parakramabahu
- 5.2.Council Chamber of King Parakramabahu
- 5.3.Kumara Pokuna
- 6.Inner City Gate
- 7.Tooth Ralic Complex
- 7.1.Thuparamaya
- 7.2.Vatadageya
- 7.3.Sathmahal Prasadha
- 8.Rankoth Vehera
- 9.Alahana Pirivena
- 9.1.Baddasima Prasadha
- 9.2.Lankathilaka Viharaya
- 9.3.Kiri Vehera
- 10.Galviharaya
- 11.Damilathupaya
- 12.Thiwanka Pilimage



Map 01- Brick monuments in Polonnaruwa

1.2.1. Brick technology of Polonnaruwa monuments

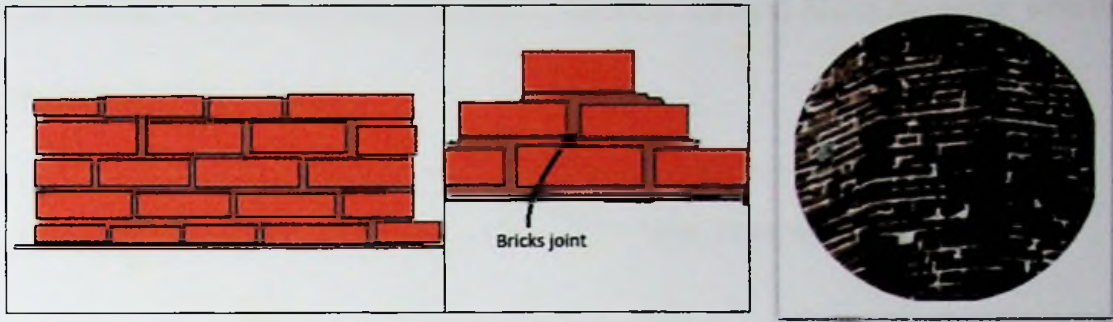
With experience gained in building construction using bricks through long periods of history. The ancient Sri Lankan mason had an art of his own in the subject. There were a number of methods of erecting brick structures.

- a) Techniques of brick construction
 - i. Solid bricks in courses
 - ii. Brick walls sandwiched with other materials
 - iii. Brick structures infill with alternative materials
 - iv. Brick structures with reinforced centers
- b) Structural principles adopted in brick structures of Polonnaruwa
 - i. Arches
 - ii. Vaults
- c) Decorations
 - i. Pseudo elements in surface decoration
 - ii. Molding
 - iii. Iconography

a) Techniques of brick construction

a) i. Solid bricks in courses

In this method bricks are placed one on top of the other changing mortar gaps. This method was used in large constructions, such as large walls, Stupas, domes, pillars at Lankathilaka Vihara and in smaller walls too.



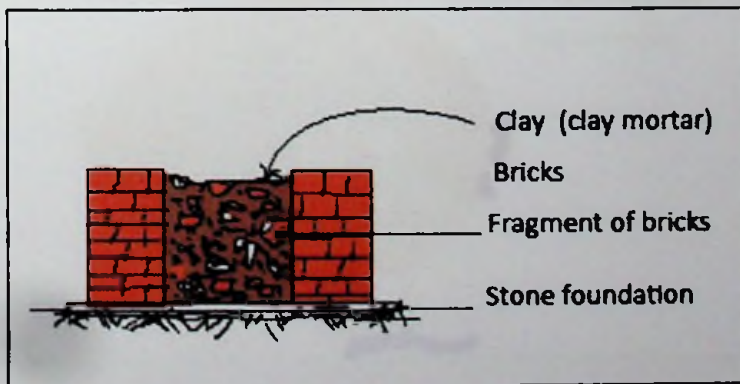
Solid bricks in courses

Picture-11

a) ii. Brick walls sandwiched with other materials

In this method the sides are made of brick using changing mortar gaps and the centre is filled with a mixture of clay plaster and pieces of bricks. Sometimes lime plaster and pieces of bricks were used. Building with bricks around natural creations like a hillock or a rock was also seen. This second type has not been so popular.

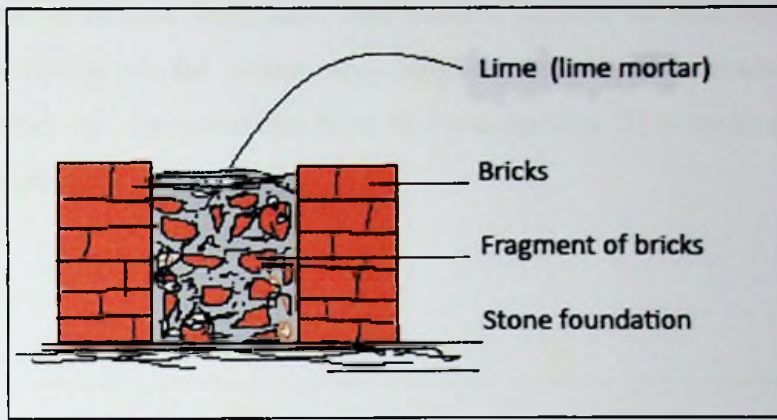
(a). The method of building using bricks on either side and filling the centre with clay plaster and pieces of bricks.



Brick walls sandwiched with other materials

Picture-12

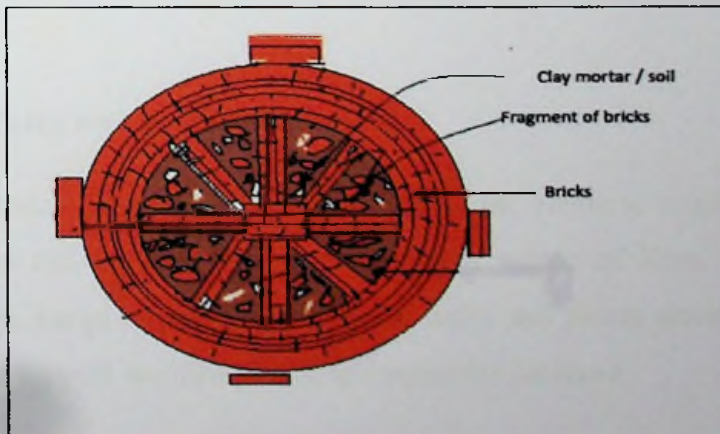
- (b). The method of building using bricks, only on either side and filling the centre with lime mortar and pieces of brick



Brick walls filling the centre with lime mortar

Picture-13

- (c). The outer part of structures like Stupas and domes are built of bricks and the centre is filled with clay and pieces of bricks.

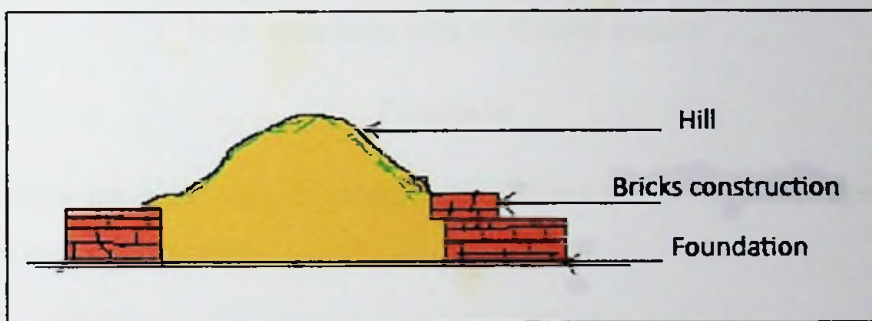


Brick walls filling filled with clay and pieces of bricks.

Picture-14

a). iii. Brick structures infill with alternative materials

There is evidence to believe that, there had been a method of building using a natural structure as the filling of the center and building with bricks around it, during the Polonnaruwa period. eg:. Demalamaha Seya in Polonnaruwa. This method of construction has not been very popular.

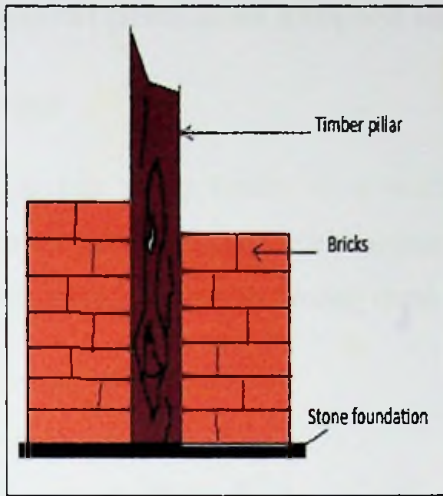


Brick structures infill with alternative materials

Picture-15

a). iv. Brick structures with reinforced centers

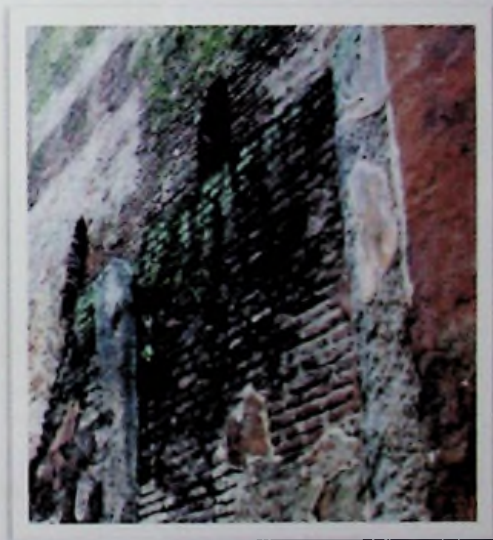
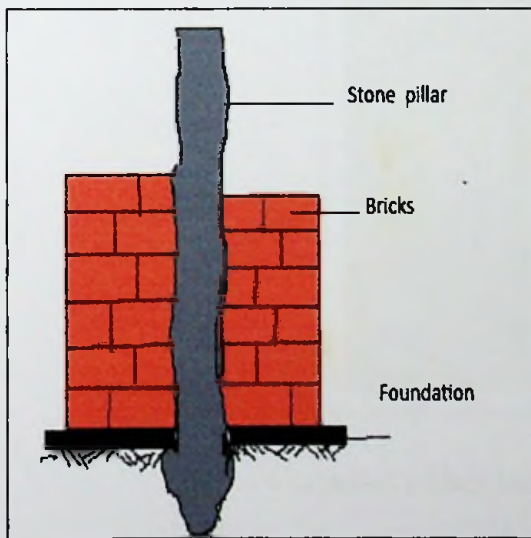
In these, wooden or stone pillars were used at the centre to reinforce the structure. This method can be seen in the ruins of the palace of King Parakramabahu in Polonnaruwa. Large cavities seen in brick walls and pieces stone bases left, which were used to support wooden pillars, are examples for these.



Brick structures with reinforced centers

Picture-16

When building the inner walls of Lankathilaka Vihara (made of bricks) stone pillars have been used as reinforcements.



Brick structures with reinforced centers

Picture - 17

b) Structural principles adopted in brick structures of Polonnaruwa

b). i. Arches

Building arches using bricks is a feature in architecture, frequently seen during the Polonnaruwa period. Many such arches of various shapes can be seen in the brick monuments of Polonnaruwa. Among them are,

- Brick corbelled arches
- Brick circular arches
- Brick corbelled and circular arches

Corbelled arches

This is abundant among the brick construction in Polonnaruwa. These can be seen in the Thuparama Image House, Lankathilaka Image House, and the Baddha Seema Prasada.



Corbelled arches in Baddha Seema Prasada.

Picture- 18

Circular arches

These are built in a semi circular pattern. The Sathmahal Prasada (Seven storied Mansion). The roof for the side entrance, from the northern wall of the Lankathilaka Image House and the roofs for the windows of the Thivanka Image House have circular arches.



Corbelled arches in Sathmahal Prasada

Picture- 19

Corbelled and circular arches

The top part of the arches was circular and the bottom parts were corbelled. This has been used mostly in the large arches in Polonnaruwa. Arches of this type can be seen in the brick arches in the intervening space of the Thuparama Image House and in the brick arches in the intervening space of the Thivanka Image House conserved according to the ancient ones that existed there. These arches are found in the windows of the Thivanka Image House and in the Lankathilaka Image House too.



Corbelled and circular arches in Thuparama image house

Picture- 20

b). ii. Vaults (Curved roofs made using bricks)

Three types of vaults can be seen at Polonnaruwa

- a) Brick corbelled vaults
- b) Brick circular vaults
- c) Brick corbelled and circular vaults

a) Brick corbelled vaults

This construction consists of two parallel wall the top of which is covered with the bricks being projected inward with every course until they bridge the opening. The best example of this is the stairway at the Thuparama at Polonnaruwa.



Brick corbelled vaults Thuparama image house

Picture – 21

b) Brick circular vaults

The circular vaults are rare but they do exist as vertical walls over which the brick is arched into a semicircular vault. The example of this in the relic chamber of the kirivehera at Polonnaruva.

Chamber of the kirivehera



Brick circular vaults in Chamber of the kirivehera

Picture - 22

a) Brick corbelled and circular vaults

This is a combination of the corbelled and circular vaults where the two walls of a passage are at first corbelled over and finally the brick work. There are many fine examples of these especially in the circumambulation passageways of the image houses. e.g Thuparama, Lankatilaka and the Tivanka image houses.



Thivanka image-house



Lankathilaka image-house



Thuparama image-house

Brick corbelled and circular vaults

Picture – 23

c) Decorations

i. Pseudo elements in surface decoration

The most outstanding achievements of Sinhalese architects during the Polonnaruwa period are the image – house of brick construction. These edifices have moulded bases, and the exteriors of their walls are ornamented with pilasters supporting horizontal cornices. Between the pilasters are facades of miniature edifices, in which are stucco figures of deities. Friezes of lions, *ganas* and *hamsas* adorn the plinth and cornices.



Pseudo elements in surface decoration

Picture – 24

ii. Moulding

Moulding were special architectural features in Polonnaruwa period. The mouldings at the base follow the lines of Anuradhapura buildings, the cyma and the torus being as ubiquitous at Polonnaru as at Anuradhapura. In one particular, however, the architects of the Polonnaru period have differed from the principles followed by their predecessors. In the shrines of Anuradhapura, the top of the cornice of the base molding is on a level with the floor of the shrine, while at polonnaru, the exterior aspect of the base moulding bears no relation to the level of the floor in the interior of the shrine.



Moulding

Picture - 25

iii. Iconography

The art of the sculptor has been utilized at Polonnaruwa for architectural embellishment in a manner that had hardly been resorted to in the Anuradhapura period, namely in decorating pillars, the surface margins of cornices, the vertical faces between moldings at bases of buildings and wall surfaces. The most striking ornamentations of wall and bases are noticed in the vestibule of the image houses built in the reign of Parakramabahu – I. Carving here can be see stucco figures in outer wall surface , friezes and base of lions, *ganas* and *hamsas*. This is rendered in stucco or lime plaster.



Lions and *ganas* figures

Picture - 26

d) Mortar us in ancient Polonnaruwa

Mortar.

When building with bricks in ancient times, the main mortar used had been clay mortar and lime mortar. At the early stages clay mortar had been used, but to prevent the absorption of water and the washing away of mortar gaps they had been plastered with lime. The plaster used to bond the bricks together in the early era was very thin. It was in the form of butter clay (M.V 29: 10-11). In addition to clay mortar, lime mortar also had been used in bonding bricks together since the Anuradhapura period. This mortar was made with lime, rough sand and quartz mixed with water (Ancient Ceylon No 07 Vol 2: 162). There is information about the contents of the lime plaster, used during the Anuradhapura period is revealed from the laboratory analysis done with the plaster. From this we can have a clear idea about the contents of the lime plaster used during the Anuradhapura period. It can be believed that the contents of the plaster used during the Polonnaruwa period is also the same. The special feature that can be noticed, in the use of plaster during the early period of the Anuradhapura era and the Polonnaruwa era is that the mortar gaps between the bricks was very small. The layers of plaster during the Anuradhapura period too were not very thick. Though lime plaster had been used during the Polonnaruwa period too, the mortar gaps were smaller than at present. Fine example for this is found at the Lankathilaka Image House in Polonnaruwa. When constructing the huge pillars, that can be seen in front the layers of lime plaster used

are very thin 8-10mm. (The records of field survey done on 14.01.2010). Mostly fine sand and lime grout had been mixed and used. They are plastered with a thick coating of lime plaster to beautify them, as well as to prevent the bricks from absorbing water. In the Stupas this layer of plaster is very thick. The thickness of the plaster that remains in the Kirivehera in Polonnaruwa is 9-10 inches in thickness.



Plaster of Kirivehera

Picture- 27

The plaster found in this structure which was built during the (12th century) reign of King Parakkramabahu has the nature of a mixture of concrete and lime plaster had been used during the Polonnaruwa period than in other periods. As this plaster dries quicker and is a stronger medium than clay plaster to bond bricks it had been used in the brick buildings built during a short time. It had been used to plaster both inner and outer walls. In the same way it had been used in making moldings, Arches, Vaults, Plaster which can be seen in plenty in the buildings of the Polonnaruwa period.

Preparation of Lime Mortar

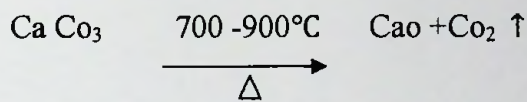
There had been two ways of obtaining lime for mortar since ancient times.

- Geological limes

- Biological limes

There are two ways of obtaining geological lime. That is from limestone and dolomite. These are raw materials obtained from the earth. Biological lime is obtained from what we get from the sea like shells, corals etc. The difference between these two kinds is that in geological lime the amount of Magnesium Carbonate ($MgCO_3$) is very little.

When limestone ($CaCO_3$) is heated at a temperature of $700^\circ C$ - $900^\circ C$ Calcium Carbonate in it releases Carbon dioxide and turns into Calcium oxide. When water is sprayed on them they form into the lime we need.



The lime prepared thus was mixed with sand, and lime mortar was made. Even at present this method is used. When mixing sand with lime, the sand should be washed well to remove the salts in it. Because the salts can cause harm to the plaster. Carbonic compounds in sand also should be removed. If not the lime plaster will take a long time to dry. When we study about the ancient lime mortar in Polonparuwa, we can understand that the ancient architects have been very careful about these things.

This plaster formed by mixing sand and lime, when hardening gets mixed with Carbon dioxide ($CaCO_2$) in the air and turns into Calcium Carbonate ($CaCO_3$) and as a side effect of this releases water (H_2O). This carbonate is strong.



Here the surface which gets exposed to the atmosphere turns into Calcium Carbonate ($CaCO_3$) and gets strengthened, where as the interior strengthens slowly.

Lime plaster had been used, as the medium of bonding bricks in the bricks structures of the Polonnaruwa period. Not only that but in bonding the bricks in the huge brick structures and in plastering them, creating beautiful moldings in them and in works of sculpture at

Polonnaruwa, the medium used was lime plaster. Either plaster of a thin nature or of a rough thick nature, like concrete had been used to suit the place and the task. This is clearly seen at Polonnaruwa.

It is during the Polonnaruwa period, that lime plaster had been used mostly in architecture in the history of Sri Lanka.



Chapter – 02

Study of brick monuments in polonnaruwa: case study

2.1 . Palace of Parakramabahu

a) Architecture of the building

If reckoned from the last year of the reign of Parakramabahu of Polonnaruwa, the palace was built at least some 824 years ago. As a residences place. At the beginning it was a massive erection which consisted of seven floors (M.V:78). Subsequent destruction reduced the palace to two floors, i.e. the ground floor and another floor

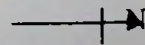
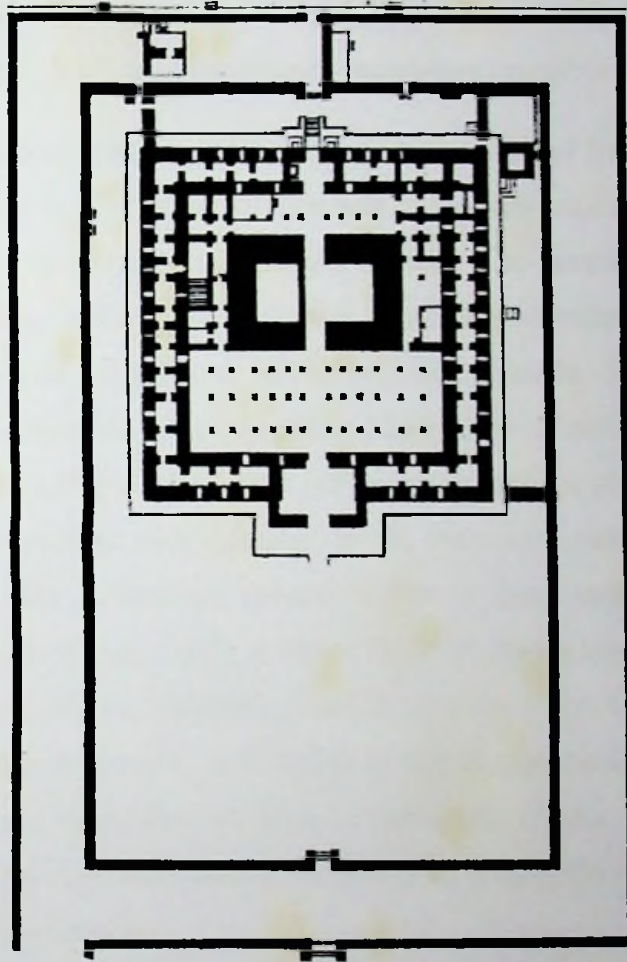


Palace of king Parakramabahu

Picture 28

The castle of king Parakramabahu stands in the south of the inner city. According to chronicles the castle had been a colossal building consisted of seven stories and some hundred chambers. According to the chronicle lists a number of subsidiary edifices, such as picture galleries, theatres, pavilions, etc., which were necessary for the life of refined luxury led by royalty in those days, and were calculated to

engender in the minds of the people ideas with regard to the exalted and semi-divine status which kingship had then acquired.



Plan in building king Parakramabahu

plan-01

b) Structural principle adopted in building

Ruins of three stories can be seen even at present. In the area where the castle stands some hundreds of accessory buildings without stores can be found. As archaeological remnants indicate, this immensely beautiful, gigantic brick construction known as *vejayantha prasada* (mansion), had been erected by using a great number of burnt brick of various sizes, lime plaster and timber, consisted of hundreds of columns, and hundreds of *Latha manadapa* creeper bowers.

Accord into ground plan a rectangular area is enclosed by galleries with an entrance on the eastern side. In the western half of the area enclosed by the galleries is a large edifice with a spacious courtyard in front. The central edifice is 150 ft. square, and the area enclosed by galleries is of proportionate dimensions. The planning of the central edifice, too, shows common features. The main flights of steps facing east leads to an imposing pillared hall which at polonnaruwa is 102 ft. by 42 ft. The pillars being of wood have left no traces, but the stone bases on which they were planted indicate their position. In the Polonnaru palace are ascribes of small cells, over fifty in number, ranged in two or three rows surrounding the apartments other than the main hall. A broad flight of granite steps led to the upper stories of this palace which, according to the description in the Chulavamsa, is said to have been of seven storey's, and had a thousand chambers. The walls of the Polonnaru palace are extraordinarily thick in the central block, because Walls in the middle of the hall are very thick as they have to uphold the weight of the walls which upper storey's contain.

It is deviant from remnants that these walls had very soft coat of lime plaster and they (walls) were painted. The ground floor had been strongly built using timber columns. Columns had been strengthened by means of fixing brick around them. Some of these columns had been colored molding. A few accessory building can be seen besides the main building. These buildings also had been erected using burnt brick and lime plaster.

c) Present state of Parakramabahu Palace

The roof of this building completely destroyed. As waterfalls upon the monument its upper parts are ceaselessly wet and as a result bricks are washed. As wetness persists in this zone humidity percentage is high and as a result moss grows on brick giving it a blackish colour.

Upper part of the wall may collapse

The walls of this building are very thick. Large holes made through these walls can be seen. Once timber beams had been interested into them. Due to wind erosion these holes themselves and the surroundings have immensely been destroyed. Owing to broken erosion and its resultant effect on these large holes made through the wall, the upper part of the wall may collapse. Continuing exposure to rain and excessive absorbency of brick will possibly make this process quicker.



Wind erosion Upper part of the wall in Palace of king Parakramabahu

Picture 29

Deterioration of plaster due to its inferior nature

Observation of the interior and outer wall of the king Parakramabahu palace revealed many places where bricks have been exposed. They thus exposed due to weathering of the plaster. Such eroded places are shown below. Many of these places can be found on interior on interior walls of the first floor.



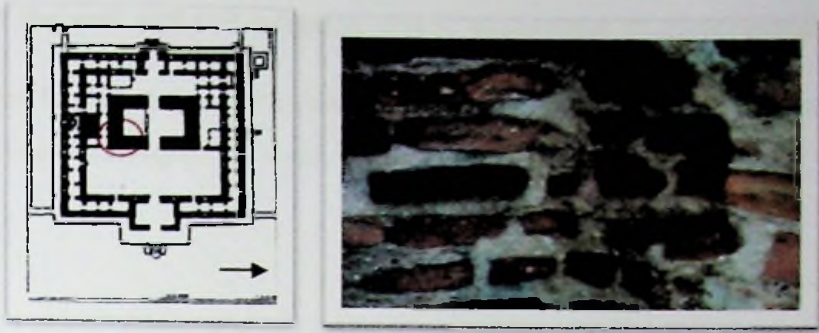
Deterioration of plaster Palace of king Parakramabahu

Picture 30

Plaster has been eroded here because it was soft. Hard bricks have survived. But if erosion goes on the building will be damaged. It will also destroy its aesthetic values of building.

Soft bricks in hard mortar

This kind of damage is also in the Parakramabahu palace. It is especially seen on interior of very high walls, i.e. on interior and both exterior surface. In many places the brick have been dissolved but the lime mortar in its entirety survives. But this feature is not wide spread. It is seen only here and there. The following photos show such instances where un burnt (soft) bricks have been dissolved leaving the mortar in its entirety causing damage to the aesthetic value of the monuments. This kind of remains can be found in thick brick walls belonging to the first floor of the interior ground floor. Of the Parakramabahu's palace.



Soft bricks in hard mortar Palace of king Parakramabahu

Picture-31

Dissolving of weak bricks. (Use of un burnt brick)

Polonnaruwa palace is a colossal structure built using a countless number of bricks. Fragile and ill-baked bricks in this construction have been dissolved and deformed holes have been formed on walls with the passage of time. These holes are a threat to the strength and aesthetic value of the walls. Furthermore, in these places as humus gathers plants also will probably grow.



Dissolved brick Palace of king Parakramabahu

Picture 32

Wetting of the wall and salt infection due to absorption of underground water.

It can be seen in the interior of Parakramabahu palace that bricks near the ground level as well as the lime plaster layers are weak owing to salt infection



Salt infection Palace of king Parakramabahu

Pictur 33

Botanical deterioration

There are a multitude of botanical damages seen in the wall and plaster in Parakramabahu palace at present. In the past there had been huge trees and plants here. Although today no such trees or plants are grown here on bricks opening and lime plaster various organisms such as small plants, grass, moss etc. are found today. As the botanical deteriorating factors which threaten the monument are countless in number and the whole monument is affected by them (or they are widespread) and also as their form, nature and activities are the same, for reasons of easiness and accuracy.

Two methodologies, random survey and systematic survey were followed in fieldwork.

Random survey in botanical deterioration

This method included irregular walks we did on the monuments, surrounding brickwork on wall and plaster of the Parakramabahu palace. While walking we reported the deteriorating plants that were found on the monument. This study enables us to identify a variety of

deteriorating factors such as plants, species of grass. Bacteria, Algae, Lichen and moss. There were also plants belonging to trees with branches and foliage such as Bo (*Ficus religiosa*), Nuga (*ficus virens*), Aehetu (*Ficus tinctoria*), Kolon (*Adina cordifolia*)



Bo

Kolon

Nuga

Trees grown on wall Palace of king Parakramabahu

Picture 34

The whole monument has been covered with these plants. In the random plants such as Thuththiri (*Chrysopogon Aciculatus*), Wal sarana (*Trianthema portulacastum*), Wal pathpadagam (*Oldenlandia corymbosa*) and two other unidentified plants were found on the brick wall of the Parakramabahu palace. They are also widespread.



Thuththiri and

Wal sarana

Mimana

Plants grown on wall Palace of king Parakramabahu

Picture 35

Bacteria and Fungi infection

On this monument bacteria and fungi infection hardly can be identified. Only in a few places on brick wall some fungi and bacteria we could identify.

Fungi



Fungi Palace of king Parakramabahu

Picture 36

Moss

This is the most widespread and harmful micro organism found on brick wall and plaster Parakramabahu palace. Black and green moss is widely grown on upper parts of brick walls on which rain directly falls.



Green colour moss



Black colour moss

Moss in Palace of king Parakramabahu

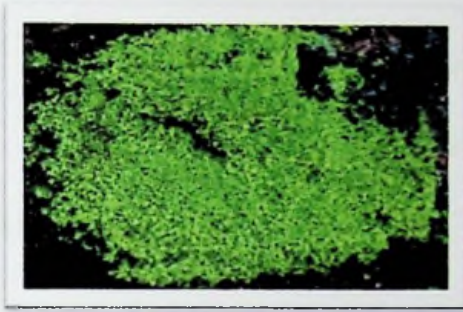
Picture 37

Further, a wide growth of moss can be found on both sides of trails on walls along which rainwater flows down during the wet weather. This plant harmful to the monument is also

found in the corners of the monuments. This damage is worst on decoration, molding, bead, archives. Even on the every walls and plaster of the building this damage can be seen.

Algae

In Parakramabahu palace on brick wall and plaster with the increase in humidity the growth of algae also seems species to be also seems to be on the increase. Especially green and brown varieties seem to be widespread.



Green algae



Brown algae

Algae in Palace of king Parakramabahu

Picture 38

Green algae is the one most widespread. Brick wall in the Parakramabahu palace on the surface of brick wall this variety is very common. On top of all the fall and wide walls in the middle of the palace this algae along with moss is found.

Lichen

It is very clear that much of the brick wall surface of Parakramabahu palace is covered with lichen. On brick constructions and lime plaster whitish light green, ash and black varieties are found in abundance. Many of them are shall like and leaf like in form.



Black Lichen



Light green, Lichen

Lichen in Palace of king Parakramabahu

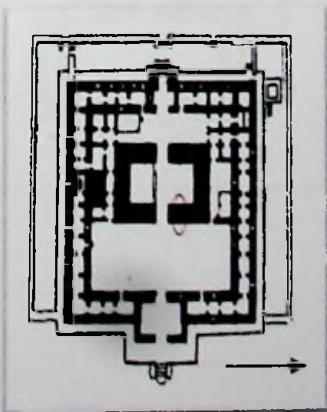
Picture 39

Cracks

Micro cracks

A large number of micro bursts caused as a result of heat movement process on bricks used to erect the Parakramabahu palace can be seen. As shown in the plan below such damages can be noticed on interior walls of the palace. These are small cracks and thus can be called as micro bursts. This process can, of course continue and it leads to gradual decay of the surface of bricks and ultimately destroys the brick. It has caused age old destruction. This kind of deterioration is common among the exposed bricks lacking lime plaster.

Example:-



Small cracks on bricks

Picture 40

Numerous thermal small cracks can be identified even on lime plaster spread on bricks. Although they are tiny cracks they can cause a considerable and both long-lasting damage to brick monuments.



Small cracks on plaster

Picture 41

Major cracks

Major cracks can be seen a few on wall and plaster on the palace of Parakramabahu palace. Further, those cracks have not developed to a great extent so as to affect the structure directly. But there are some major cracks of considerable size in Parakramabahu palace.



Major cracks

Picture 42

The above photo shows cracks found in the holes of the high brick wall where timber beams were once fixed. Cracks occurring at points where brick walls join one another are not to be found, while cracks between the bricks and plaster are found in the palace of

Parakramabahu. Cracks leading to some sort of disconnection between brick and plaster weaken the strength of walls.

The moss grown on bricks due to excessive sunlight it receives in dry weather peel off also a part of the surface of the brick or lime plaster. This effect can be seen very well on the wall and plaster on Parakramabahu palace. This process of peeling off wears away the brick and in case of a brick surface depicting painting or containing lime plaster accompanying paintings the deterioration will be much more severe. This kind of damage is very often found in lime plaster and masonry erections.



Moss and cracked growth on bricks and lime plaster

Picture 43

Damages done by man (They defile antiques)

Names of persons and various scribbles have been written on this more than 800 years old yet well preserved lime plaster surface in the small rooms of the back portion of the Parakramabahu palace.



Scribble on lime plaster

Picture 44



Some visitors walk on conserved brick s wall and damage them

Picture 45

Continued activities of the nature are a threat to both existence and beauty of the monument. Lime plaster well preserved and belonging to the back base has been cracks and in some places algae has been grow. Many places were covered by moss. The following instances deserve special mention. (i) Negligence of and erosion that occur (a) on the holes in to which timber beams had once been inserted and (b) surrounding of (a) referred to above (ii) absence of removal of moss, plants, trees etc. grown on uppermost parts of the monument, and (iii) negligence of blackened appearance caused to upper parts of the monument by moss. It is a pity that no attention on the part of the conservation has been paid to prevent very severe damages caused to lime plaster layers of the rear parts of the palace which are covered with lichen, algae and moss. This state of affairs is a threat to beauty and both existence of the monuments

There is no can be seen door and window those were complexly deterioration

Water logged places in the surroundings

In seasons when heavy rain falls comparatively more water accumulates around the west base of the monuments. Such accumulation of water is a great threat to the existence of the monuments.



Evidence for the submergence of the base

Picture 46

Again with the increase of the rain following soakage clay particles of the brick are disintegrated and this process can be seen on the right foundation brick wall. Ceaseless wearing away or finding away is a great harm not only to its beauty.

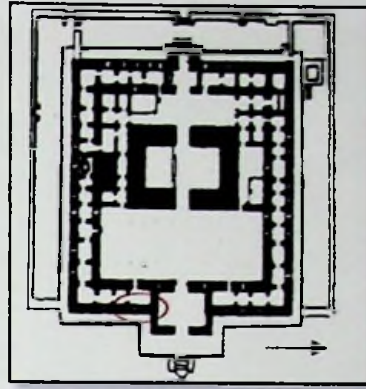


Wearing a way of brick

Picture 47

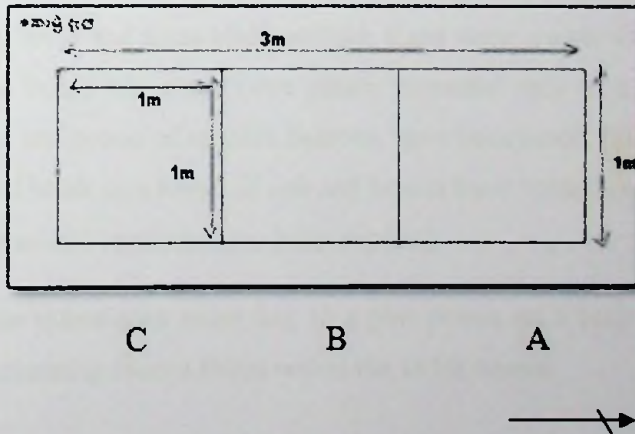
Botanical deterioration

There are a vast of botanical damages seen in the foundation in Parakramabahu palace at present The foundation in its entirety is excessively covered with plants and micro plants. Therefore, it is not at all feasible to study the foundation in its entirety. So the study had to be confined to one particular place of the foundation on which findings had to be drawn with regard to the whole foundation. To achieve this purpose systematic survey method was utilized.



Area in systematic survey

We selected on area $1 \times 1 \text{ m}$ high by the base left to the entrance in accordance with the east of the foundation Parakramabahu palace and we divided this area into three squares. Then we studied the plants found in these three squares.



Plan- I

The whole monument is covered with large and small plants. Therefore with a view to making a thorough study we studied plants to within $1 \times 1 \text{ m}$ squares and other deteriorating factors. What the photo shows is three squares $1 \times 1 \text{ m}$ high.

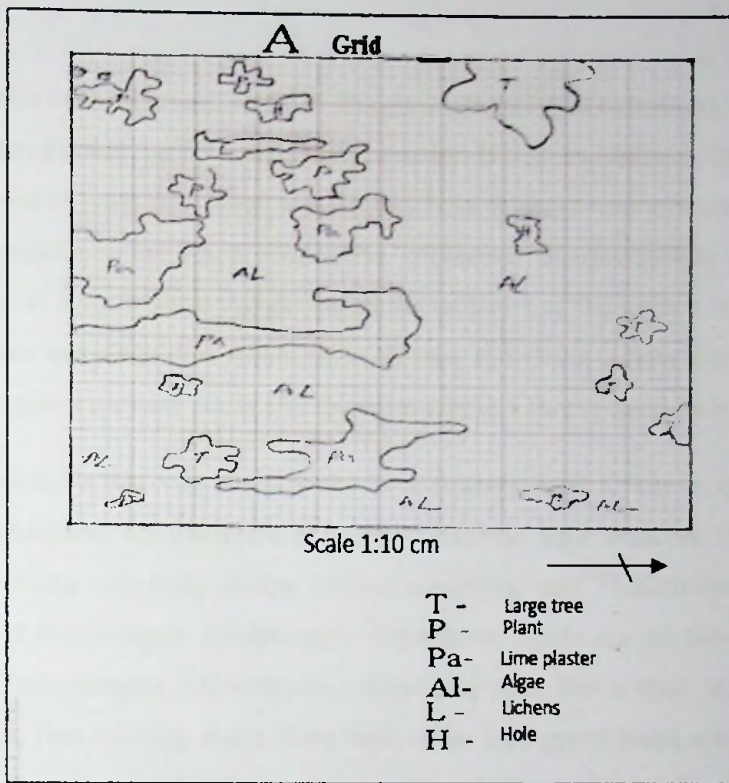


Botanical damages in foundation

Picture 48

In the square A we studied, there were two *Bo* sapling one small and other big three *Nuga* unidentified grass which villages call *Val Pathpadagam*, *Thuthithiri* and grass. In addition blue white algae and moss and much black and ash lichen were found. Major portion of 1x1m square was covered with moss and blue white algae. On number of brick surfaces where there was no moss and algae black and ash algae were grown. On one brick surface light green thallose lichen was seen. Lime plaster remained only in a small area. Due to dissolving of bricks and action of animals burrows have been made. On those burrows due to action of ants and black ants heaps of soil and humus have been formed. In many places lime plaster weathered and openings have been exposed.

We obtained all this information according to a plan drawn on a scale and we calculated percentages of deteriorating factors found within the 1x1m square.



Botanical damages in foundation – squares-A

plan 02

Algae-68%

Remnants of lime plaster-13%

Area covered with large trees on brick-4%

Area covered with plants on brick-3.5%

Area covered with lichen on brick -1.2%

Holes -1.5%

Other-8.8%

Plan 2

The results of this calculation are likely to change in places such as corners where humidity is usually greater. Further, on the whole the above conditions are likely to change in case of new constructions or parts conserved. But by this kind of survey we can come to a general conclusion in regards to the whole monument. Moreover, this monument is a one which needs high cost as maintenance. According to the officials of the central cultural fund the whole monument was cleared of weeds three months ago. So it is important to record that weed and other plants we have studies have grown within a short period such as 3 months.

Accordingly, we did a thorough study of the three squares A, B, C 1x1 m contained which the weeds we identified. On the whole of more widespread huge trees are Val Nuga (*Ficus tinctoria*), Bo (*Ficus religiosa*), Kolon (*Adina cordifolia*) and Thuthitrisrs (*Chrysopogon aciculatus*), Val Pathpadagam (*Oldenlandia corymbosa*) plants are the mostly grown ones on bricks. Val Pathpadagam (*Oldenlandia corymbosa*) plant has a small white flower and long lean leaves. This is a bush about 20cm high. It has light green small seeds. This plant is one most widespread on the brick monuments. The life span of this plant is one year. Its growth is very quick. It bears flowers, produces seeds and dies within a short span. Although the mother plant dies it leaves behind a great deal of seeds. As this plant is of widespread dominance it is not at all easy to destroy.

Besides another grave danger which the monument confronts is deformation and deterioration caused by algae, moss etc. which cover molding, lattice designs. They make molding, lattices and sculpture corrosion, wet and in turn the surface becomes covered with humus. In turn the surroundings are made favorable for the growth of more advance plants such as trees, further, these organisms (such as algae and moss etc.) they are deform the monument very much. The state is worst where ancient brick monuments made of lime plaster are concerned.

One can see how these moss and algae deteriorate the lime plaster bands. At the back of the Parakramabahu palace which belongs to a period dating back to some 800 years. (Polonnaruwa period).



Moss and algae on lime plaster

Picture 49

A larger portion of the north wall of the monument is deteriorated by moss owing to the thicket surrounding the place. The tendency to increase various small stains on the old lime plaster greater in this zone. Actually these stations develop humidity in the old lime plaster, and also favor the increase of the spreading of moss and some kind of algae.

As there is a formal maintenance program already carried out by the central cultural fund, plants in this zone are not given time and opportunity to grow in size with considerable foliage. The work of CCF is responsible for minimizing the damage that would have otherwise been caused to the monument. In former times roots of trees used to travel through across brick walls and thus the latter were damaged. But at present no such damage can be seen.

Damage caused to Parakramabahu palace by animals.

Parakramabahu palace is a building with no roof and thus exposed to weather etc. There for, no damage is done by birds etc. because they cannot perch on the monument. There are some tracks made by termites towards the left on the front base of the monument. A part from the above on the back wall towards the west of the palace there were some stones taken out by iguanas. Sometimes Monkey and Ape who frequent this zone can be seen walking along the brick walls. When they walk along the upper walls of the palace they remove brick fragments and drop them down.

2.2. Thivanka image house

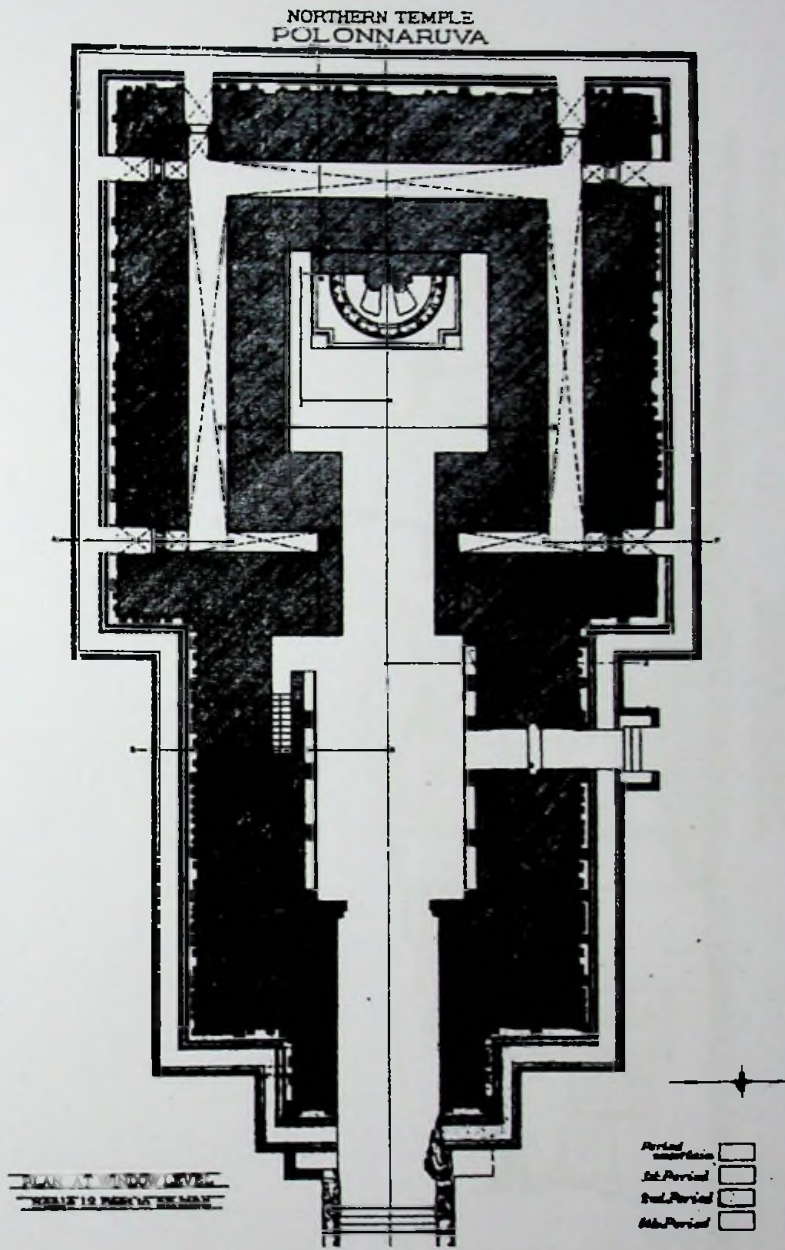
a) Architecture of the building



Thivanka Image House

Picture 50

In the north from the city, Thivanka image house stands on a mound comparatively higher than other mounds. This was built as religious building. This construction also consists of the three parts called *Mandapaya*, *Antharalaya*, *Grbagruhaya*. There is a huge standing statue made of brick and stucco. The statue is three curves in shape (*thibanga*).

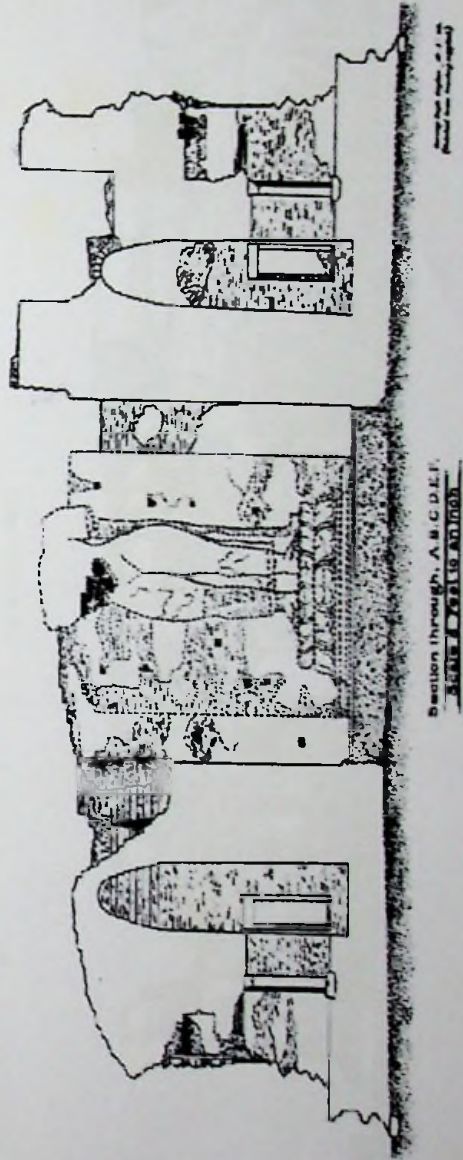


(Source: Hocart, A.M. 1926, *Memoirs of the archaeological survey of ceylon*. Government printer, Colombo)

Ground plan at window level in Thivanka mage house

plan 03

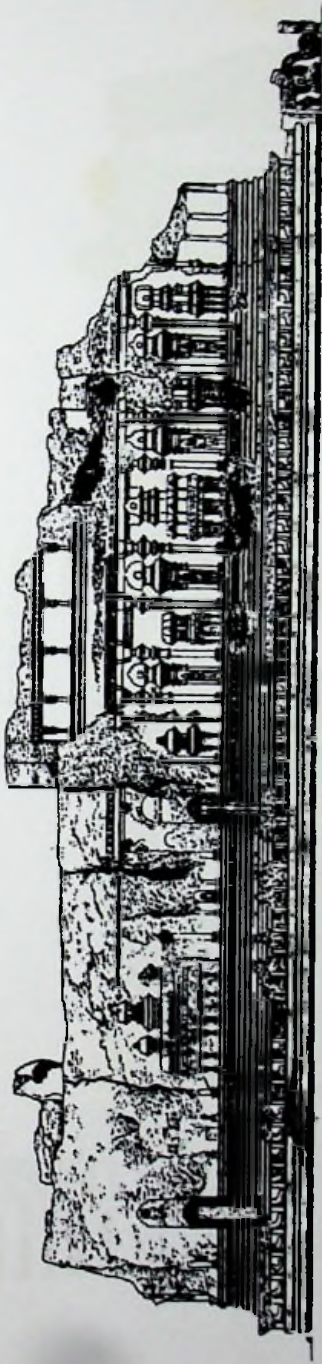
THIVANKA TEMPLE
ECOLONNARUVA



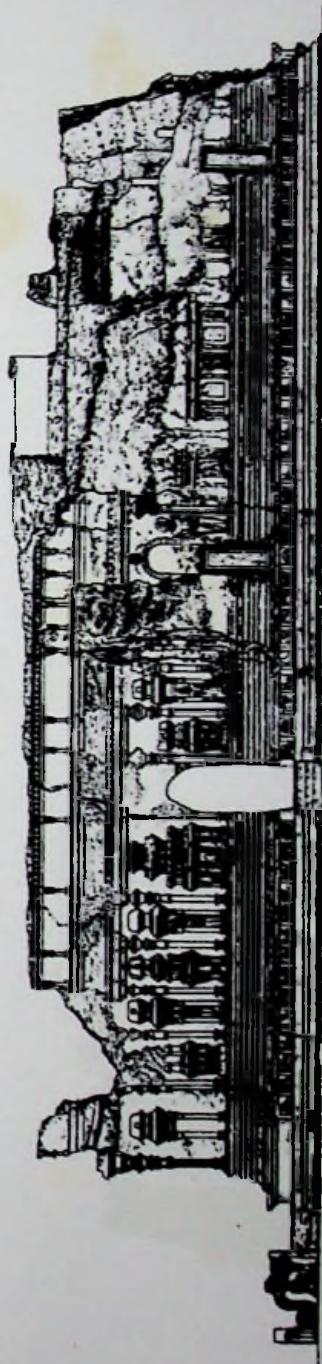
(Source: Hocart.A.M. 1926, *Memoirs of the archaeological survey of ceylon*, Government printer, Colombo)

Section in Thivanka image house

plan 04



Side Elevation South.



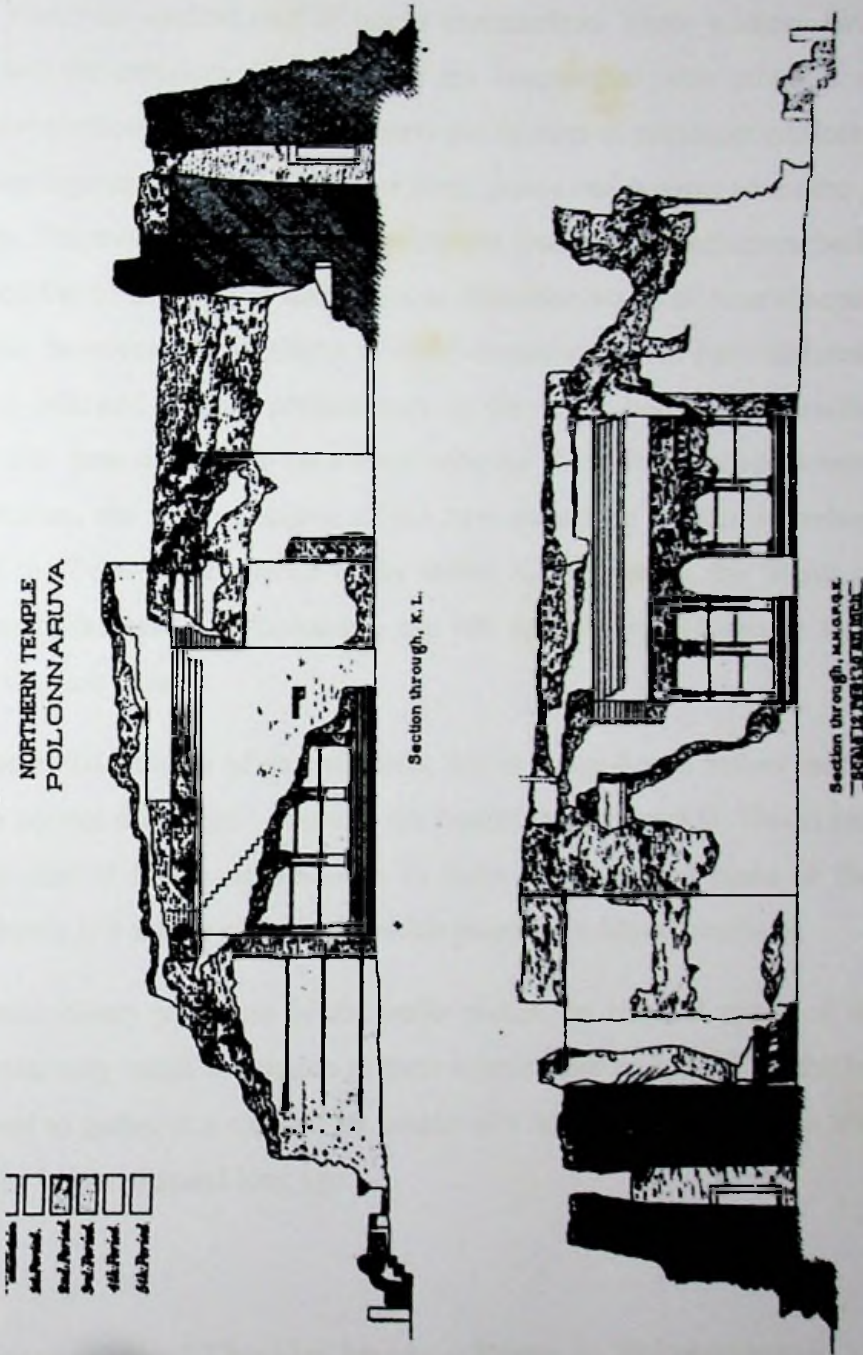
Side Elevation North.

SCALE 1/16" = 1 FOOT

(Source: Hocart.A.M. 1926, *Memoirs of the archaeological survey of ceylon*, Government printer, Colombo)

Side elevation in Thivanka image house

plan 05



(Source: Hocart.A.M. 1926, Memoirs of the archaeological survey of ceylon, Government printer, Colombo)

Inner side elevation in Thivanka image house

plan 06

b) Structural principle adopted in building

This is also with vaulted roof of bricks construction. These edifices have molded bases, and the exteriors of their walls are ornamented with pilasters supporting horizontal cornices. Between the pilasters are facades of miniature edifices, in which are stucco figures of deities. Friezes of lions, *ganas* and *hamsas* adorn the plinth and cornices. The moldings at the base follow the lines of Anuradhapura buildings, the cyma and the torus being as ubiquitous at Polonnaruwa as at Anuradhapura. In one particular, however, the architects of the Polonnaruwa period have differed from the principle followed by their predecessors. In the image-house of Anuradhapura, the top of the base molding is on a level with the floor of the image-house, while at Polonnaruwa, the exterior aspect of the base moulding bears no relation to the level of the floor in the interior of the shrine. Consequently, the flights of steps in these image-houses at Polonnaruwa are not so lofty in relation to the building, though they are broader.

In the essential features of ground plans, this is image-house follow model that had become normal for image – house in the Anuradahapura period. This is basically the same as that of Hindu image-house in India. The ground plans of the Tivanka image-house is a square cella, from which projected a bayed vestibule.

The extraordinary thickness of the walls makes the internal space of this image-house relatively small in relation to their exterior dimensions. This thickness walls are joined to gather at a top and by means of a corbelled arch. At this image-house the vaults have collapsed long ago.

c) Present state of Tivanka image – house in Polonnaruwa.

This erection can be named as one of the most significant constructions among those built following *Gedige* tradition of architecture with a roof exclusively made of brick. However, owing to shortcomings of the plan the vaulted roof subsequently has collapsed. This kind of plan is not suitable to a country like Sri Lanka which

receives heavy rain. This monument has been directly exposed to deteriorating factors such as the sun and rain for hundreds of until 1980 decade. However, for the purpose of conservation a temporary roof covering the monument was erected by the central cultural fund in the beginning of 1980 decade. Subsequently the roof has been improved by the department of archaeology.

But conservation work carried out on upper part of the monument and the roof proved successful. The monument was exposed to more dangerous state amend the removal of *Purage* was delayed.

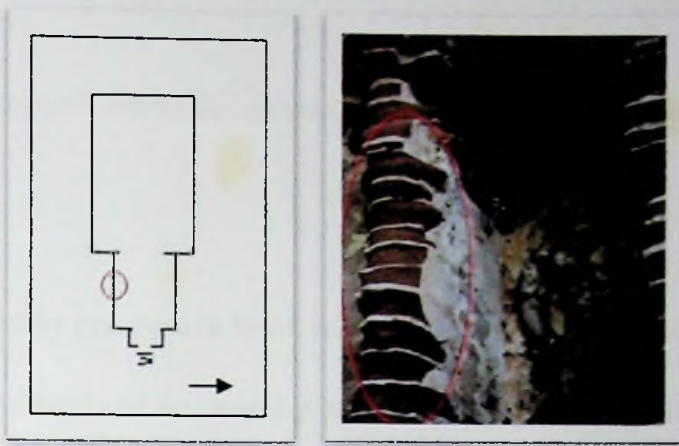
In place of the old bracken arch roof a new brick arch was erected in *Antharalaya* portion in 1980 decade. This new roof was built. It is for this roof that monument has been protected from direct fall of rain for main than one and half decades. Therefore damage caused to Thivanka Image House by rain since 1980 decade was minimized. But slight damages such as wetting of bases of walls by drizzle during heavy rain occur. Further due to this roof the interior of the monument is protected from rain.

Deterioration of soft mortars and plaster in wall

The plaster used at the time of the original construction of this erection was so poor in quality that it has been washed as it could not resist the erosion factors. When the plaster was washed bricks become exposed and among them openings appeared. If this process goes on further contact among bricks will come to an end as a consequence the whole wall can be deteriorated. Moreover, such process will damage aesthetic values of the monument too.

Deterioration of soft brick in wall

While plaster remains the soft bricks disappear this kind of plaster which is stronger than the brick tend to preserve it in the presence of erosion factors while the latter is eroded.



Deterioration of soft brick and preserve stronger plaster

Picture 51

In these circumstances what plaster does is to make the monument deformed. This kind of infection features can be found even in the Thivanka Image House of Polonnaruwa. These weathered features are very common on the most deteriorated south wall of the Thivanka Image - house.

Dissolving bricks in bricks wall

In the construction of Thivanka Image House some bricks of inferior quality below standard had been used and such bricks unlike others rapidly deteriorate and as a consequence they made holes among the bricks wall. It is a threat to the strength of the wall. It damages aesthetic values in monuments.



Dissolving bricks in bricks wall

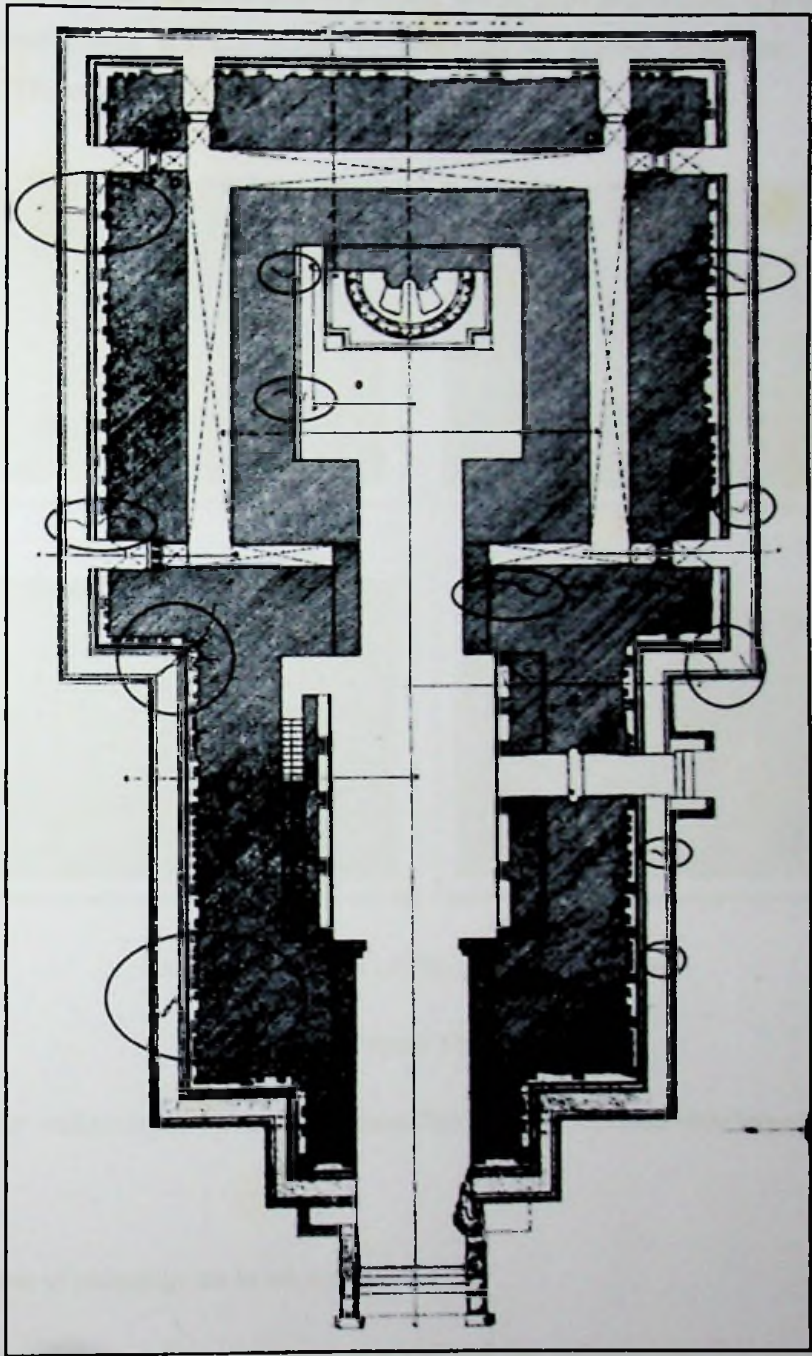
Picture 52

The above photograph shows the present state of un burnt bricks which have been deteriorate.

Damages caused by pressure in brick walls in Thivanka image-house.

Although both vertical and horizontal pressure has to some extent affected the huge walls of the monuments damage of bursts due to vertical pressure is comparatively more. The brick arch and the roof of this erection which had been destroyed were conserved by Alahana Pirivena Polonnaruwa project of the central cultural fund in 1980 decade. In consequence vertical bursts on walls become quicker as they could not uphold the exceedingly heavy weight which the countless number of new bricks spread on the old walls. On the other hand burst which already had existed were further increased by thrust the soaked bricks produced during the wet weather. But as a result of the temporary roof that has been built rain does not fall directly on the monument. They do not get wet too.

A large number of splits, micro, medium and macro, of the kind already refer to above can be found on both interior and exterior walls of the Thivanka Image House. Some of these splits date back to some centuries. There are marks on them which indicate that they have been conserved.



Cracks on the walls of the Thivanka image house

plan 07

These bursts cannot be recent ones but they have been there for ages. Although no rapid increase can be noticed yet some sort of increase seems to be in progress. It is believed that some of these cracks are the results of processes of thermo expansion and thermo contraction. These bursts can be seen on interior walls.



Cracks on the walls of Thivanka image house.

Picture 53

Even on other walls minute bursts can be seen. But we have reported only large scale bursts.

Deterioration of paintings on brick wall.

Then the paintings are deteriorating composed and the colours lost. For instance on the southern wall of the Thivanka Image House many plaster layers and both painting layers have been peeled off. As a result only small portion of colour paintings survive.

Loss of colours and peeling off of surface of the painting can be noticed. More ever, it is only in places which receive no sunlight or well sheltered from the direct sunlight that some painting survives. Even here only colours such as red and yellow remain while other

colours have been vanished. Even what remained is not the real colour but somewhat deteriorated.



Peeling off so painting and Places where colours are well preserved

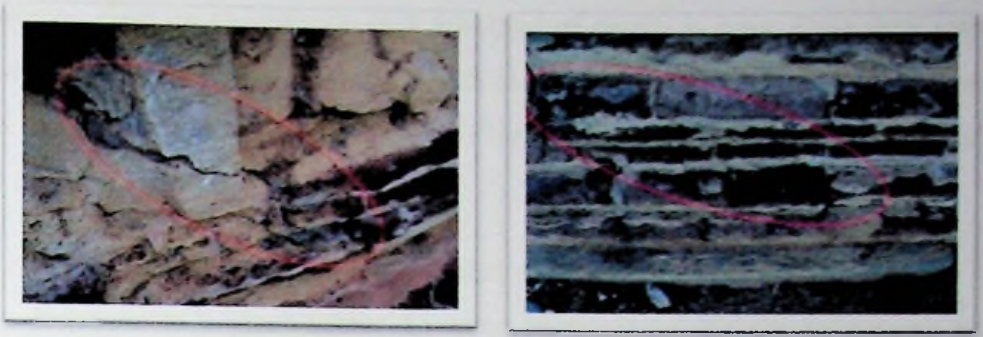
Picture 54

Cracks in bricks wall

There are two kinds of cracks identify in walls of Thivanka image- house this are micro racks and major cracks.

Major cracks.

Excessive and continuous heat makes bricks hot, expand and contract and in consequence their structure becomes fragile and then burst giving way to subsidence of the base of the brick wall. This subsidence finally becomes worse when it produces a number of large cracks owing to the heavy mass it is uploading. If the processes are continued, i.e. cracks widen, a part or the whole building will break and deteriorate. A large number of such major cracks can be seen on the front side of the southern wall as well as in the interior. Those cracks referred to above cannot be recent effects but can easily be identified as a long-standing process. However, if they are in progress is a matter to be studied continuously.



Major cracks on the wall.

Picture 55

Micro cracks

Lime plaster which the brick of the monuments consists of cracks when exposed to excessive heat and then all of a sudden changes the heat drastically. Then the plaster separates from the wall and fall down. Due to continue process of expansion and contraction of heat that went on for the centuries plaster on the exterior wall as well as interior walls have produces a large number of major and minute cracks on walls. The kind of damage is more widespread on exterior walls where it resembles a cobweb. These cracks are the most widespread on the southern wall do the Thivanka Image house.



Micro cracks on the southern wall

Picture 56

Moreover, even on the interior wall this kind of cracks is seen. Here they seem to occur more near the main entrance which receive excessive sunlight. Then there are rows of animal figures in relief made of lime plaster near the base on the southern wall of Thivanka Image House.

But at present lime plaster has been peeled off and some of the animal figures have been destroyed to a great extent. In some parts animal figures have been totally deteriorated.



Gana (Dwarf) figures totally damages by thermal cracks.

Picture 57

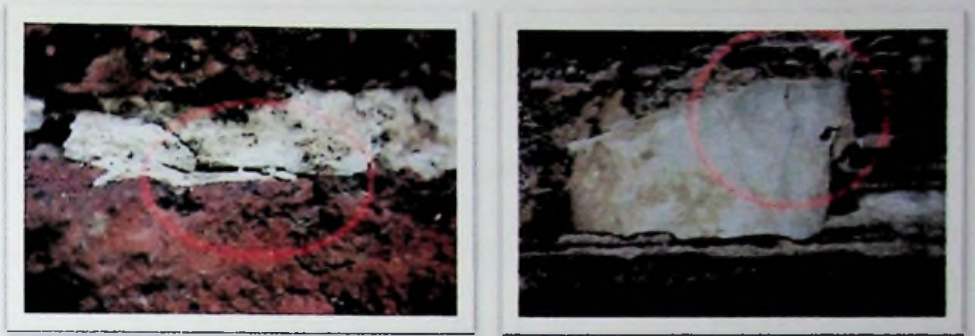
Even the plaster spread on lattice in relief among the rows of dwarf figures like that of animal figures has been burst. A part from this even the exterior plaster has been burst due to heat expansion.

One can see an isolated lump of burst plaster of the kind referred to above on the upper part of the southern wall of Thivanka image house. Even in the interior where paintings are found plaster has been burst.

Cracks separating brick from plaster

As a result of heat expansion the plaster layer cracks and the bricks are separated. There are such instances. Speed of expansion of brick due to heat is different form of that of lime plaster. So when the expansion of contraction differs between the brick and the lime plaster they crack and separate. Or else the brick expand or contract by cracking the plaster. As a result of contraction the lime plaster

and the brick may separate from each other and remain in the form of without folds empty. This feature is common in case of southern walls and the walls with interior paintings of Thivanka Image- house.



Crack on the plaster

Picture 58

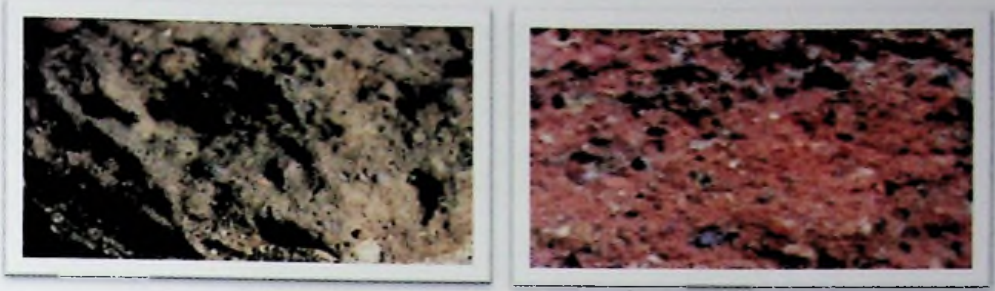
Even in the interior of Thivanka-Image house lime plaster accompanying painting is cracked and peeled off.

Cracking of brick wall

A brick wall becomes the object of multitude of fine (minute) cracks and this instance belongs to the walls of Thivanka Image house. Here the surface of bricks peels off. As bricks daily undergo

Excessive heat and thermal changes surface of bricks crack.

Moreover, the surface of the brick experience minute cracks, peeling off and minute holes. Process of this kind goes on for hundreds of years. And finally the bricks are destroyed in its entirety. Rain and dew make the process seedier by eroding the brick surface.



Eroded brick surface.

Picture 59

When bricks are daily exposed to excessive heat and undergo thermal change they form both minute and large cracks. These cracks develop with time and tide and finally the brick is destroyed. Like this destruction of bricks leads to the destruction of the monument. But as the process is very sluggish generally no attention is paid to it. Compares with the life span of the monument although this process of deterioration is obviously long and the process is very slow it favors the growth and development of a deteriorating factor.

Deterioration of brick surface in the process of deterioration of moss algae etc.

Micro organism such as moss algae etc. which grow very well in humid weather tend to dry up and peel off in dry season when exposed to excessive heat. When these micro organisms thus peel off they also remove a part of the (outer) crust of the brick along with them. A single such peeling off costs the brick damage some 3mm deep. The process of growing in main rain seasons and that of peeling off accompanied by a removal of crust is a common occurrence. When this process becomes unbroken it may be harmful to the existence of the monuments. Now when moss dries up it impairs the lime plaster rather than the brick. Ideal illustrations could be found among the exterior walls of Thivanka Image Houses in this regard.

Stains of black moss can be found even on the lime plaster of the interior of Thivanka Image House. The surface referred to above had painting on it at the beginning and was subsequently destroyed and is being destroyed further by moss.



Peeling off of moss along with lime plaster.

Picture 60

Deterioration of wall and plaster in Thiwanka absorption of underground water

A zone about 30-60 cm in extent commencing from the base of the surface covered by painting has been deteriorated by salt deposits formed in consequence of absorption of underground water by means of capillary process. Lime plaster in this zone has been swelled, cracked and destroyed. Subsequently some parts of the zone have been preserved by lime plaster.

But this deterioration has been minimized since the erection of the roof to shelter the whole monument. Only the signs which indicate that the salt has come up on some walls of the interior of the monument can be seen today. Now the process of deterioration has been caused.



Deterioration of wall absorption of underground water

Picture 61

Damage caused by wind erosion

The southern wall of the monument which is facing wind is the side mostly eroded by wind in this respect.

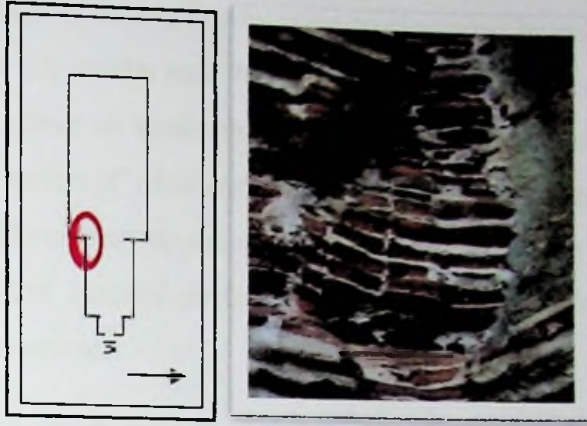
The southern wall of the Thivanka Image House more than the other walls has become an object of wind erosion as it (a) stands on a higher location compared to other monuments, (b) absence of taller trees adjacent the southern wall and (c) surrounding of the monument is absent from trees. In a study of monuments open to wind in erosion in n Polonnaruwa, Thivanka Image house comes first. We say this because it is in this monument that whole of the wall inclusive of its plaster, brick etc. have been totally eroded by wind.



Wind eroded south wall - Thivanka image house

Picture 62

Wind has eroded all vimana, pillar, dwarf figures, lion figures, sculpture of the south wall as well as and molding done by lime plaster of the base. All angular linear shape of the monument has been turned somewhat spherical. The following picture shows how wind has eroded the brick and the plaster.



Corner of the wall eroded by wind

Picture 63

The corner of the wall where *Antharalaya* of the south wall joins sanctuary (*Grbhagruhaya*) and its surrounding upper limit of the monument have extremely been eroded by wind. The wind when it approaches this corner to above behaves like a whirl and strikes against the wall. This is the manner in which monuments become objects of excessive erosion. *Vimana* found on the whole wall have been eroded and their lime plaster layers having been waste away bricks also have been eroded in various ways. In consequence the south wall has been given a deformed appearance.

Vimana and plaster found on the north wall of the monument are well preserved on the leeward. The chief reason for this preservation of the lime plaster is that it lies on the lee ward.



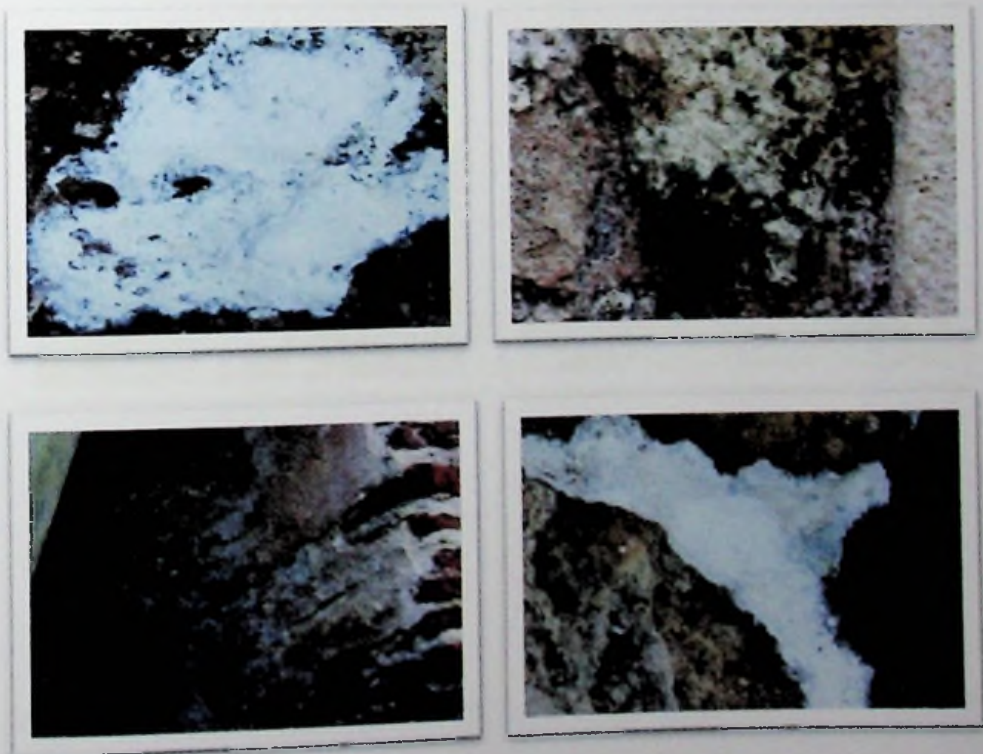
North wall – Thivanka Image house - Picture 64

Reasons for such serious destruction by wind erosion must have been (i) exposure to the windward and (ii) unlike rock brick and lime plaster are rather weak and so cannot resist the effect of wind. In addition, dusts etc. are deposited inside the monument by the action of wind and consequently it has a damaging affect on the interior painting. Moreover, various seeds, pollen etc. carried by wind and deposited on both interior and exterior surfaces of the monument favors the growth of numerous weeds, trees etc.

Bacteria and fungi attack on wall and plaster in Thivanka image house.

fungi

As Thivanka Image-house is equipped with a shatter roof at present its brick walls aren't wet. They are dry. Therefore infection of bacteria and fungi is little here. It is in surrounding where no ventilation and humidity is present that bacteria and fungi grow.



Fungi infection - Thivanka Image house

Picture 65

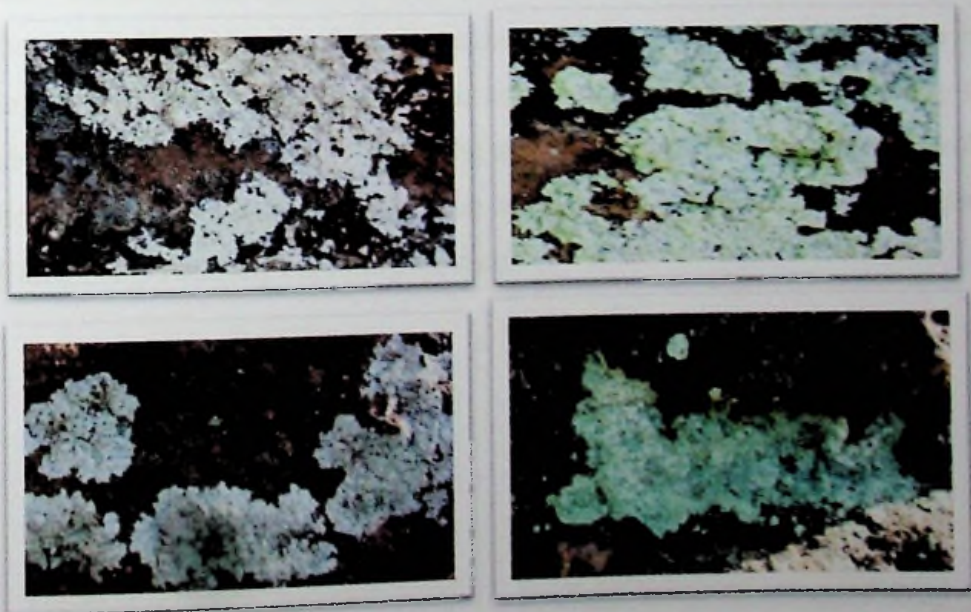
No fungi and bacteria is grown on exterior walls of Thivanka Image house. Observation we did on 14 May 2010 revealed a spread of milky algae on the southern wall of Thivanka Image house.

Algae

Green and brown algae can be seen on brick monuments in Polonnaruwa. It is a relief that algae infection is not much present in Thivanka Image house.

Lichen

Lichen is formed by combination of fungi and algae. There are a number of kinds of Lichen grown on brick walls, especially on exposed bricks and brick with lime plaster. These are some thallose Lichen on exposed bricks, while on protected lime plaster there are some kinds of white and ash lichen. On exposed bricks light blue and light green Crustaceous shape light blue lichen in shape of leaf, leaf like milky lichen can be formed.



Fungi infection in Thivanka image-house

Picture 66

Ash and white lichen which grow on the lime plaster severely damaging it is, found widespread on the exterior of the north wall and above the base where *Garbha gruhaya* and *Antharalaya* and join. These two kinds of lichen not only deteriorate lime plaster but also a threat to the aesthetic value of the monument. Lichen damages a number of parts of the interior of the monument



Lichen which grow on the lime plaster

Picture 67

.Moss

Another important biological deteriorative factor is moss which is found on brick erections and lime plaster of the monument. Damage caused by moss has been minimized to a great sentence since the set up of the shelter roof following 1980 decade. The absence of moss is due to the absence of humid environment. Therefore, spread of moss is not wide. Damage done by moss can be seen only in a few places. They also occur naturally adjoining the face.



Moss attack in Thivanka Image house - Picture 68

Accumulation of humus on brick openings

A good number of brick openings were filled with dead leaves. This accumulation of leaves is a threat to beauty. Further, accumulation of humus on the monument paves the way for surroundings favorable for the growth of large trees. It is a threat to the existence of the monuments.

Damage caused by animals

In consequence, a great deal of damage is caused to this monument by animals such as insects, birds, apes, and monkey.

Major damage is being caused to Thivanka Image house by the potter-wasp and the termite. On the outer walls of Thivaka Image house where *viman* are depicted the paintings are well preserves but the potter-wasp has built a great deal o nests here.

Among various sculptures, carvings, cornice and moldings a great number of potter-wasp nests can be found. Moreover, on the surface of the most voluble paintings inside the Image house several potter-wasp nests are found. Then again potter-wasp nests are a common occurrence on the of the brick arch roof belonging to the *Antharalaya* built by the central cultural found recently. Throughout the *Grbagruhaya* and also on the Buddha's statue potter wasp nest can be found.



Damage caused by potter-wasps

Picture 69

These potter-wasp nests built on the paintings and the lime plaster are a threat their beauty and existence both.

The next destructive insect found in Thivanka Image House is the termite. In the south western corner of the rear wall of the monument there is a large anthill. Traces of termites can be found on window arches and on the base where the lime plaster has been split.



Damage caused by termites

Picture 70

In addition, we found on the brick walls two kinds of cocoons belonging to unidentified two insects. They were built near the lime plaster and openings.

Moreover, holes dug by black-ants and blind burrow *Bimkundan* can be found on the plaster of the base. They dig holes through the opening filled with plaster. This action of theirs favors the formation of soil on the monuments.

Damage caused by birds living in Thivanka Image house

In dark corners of the upper parts of wall in Thivanka Image House animals such as pigeons, bats and swift swallows live in their nests. Although we were not in a position to see them because they were living very high yet we could identify the places where the animals were by means of the places where their faeces were found and also through the call. The presence of bird faeces on the shoulders of the Buddha statue is very common. You can observe that the birds chiefly live in nests built in the dark zone between the shoulders of the Buddha's statue and the wall. It can be seen that regions such as the right shoulders, the thigh of the right foot and the instep of the foot are defiled by faeces of birds. The dark environment that

prevails in the *Grbagruhaya* has created a suitable niche for these animals.



Damage caused to the statue by birds.

Picture 71

In addition, one can see that on the base faeces of birds who live on *vimana* on exterior walls of the monument. Thus deteriorative factors such as (a) the very dwelling of birds on the monument (b) defiling of the monument by their faeces (c) reaction of acidic substance which faeces contain to lime plaster (d) growth of various seeds brought by animals and of seeds which contain faeces are present.

Damage caused by quadrupeds

Among the quadrupeds harmful to Thivanka Image House are the monkey and the Ape. When these animals that come in large packs sit on the brick walls, and walk along them the old bricks detach from the wall and fall down. At some such occasions the bricks thus falling may collide with other old bricks or sculpture and damage a considerable portion of the monument. Further the spread of faeces of the Monkey and the Ape can be seen on the whole exterior wall and it is on the one hand threat to beauty and on the other seeds which faeces contain favors the growth of various weeds on the monument.



Excretion on monument

Picture 72

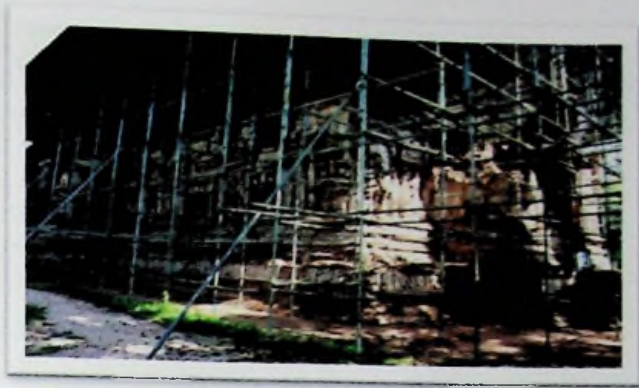
Damage caused by action of man

The most serious harm caused to Thivanka Image House by action of man in incorrect and irrelevant conservation carried out by him.

In place of the old bracken arch roof a new brick arch was erected in *Antharalaya* portion in 1980 decade. This new roof was built.

By placing a countless number of new bricks on the old wall. Now the old wall could not carry the weight of the mass (of new bricks). In wet weather when the brick absorb water the weight becomes more. However, due to the weight of these new bricks the vertical cracks the wall already had widened. This is harmful to the existence of the monument. Furthermore, according to scholars this new roof built to protect the *Grbagruhaya* gives a wrong impression on the contemporary roof of brick buildings.

However, as these new erections leak in wet weather it has become difficult to remove the temporary roof built in order to conserve the monument. This roof made of G1 pipes places at 2x2 m distance and tin sheets is a threat to beauty of the monument.



Shelter roofs of Thivanka Image house

Picture 73

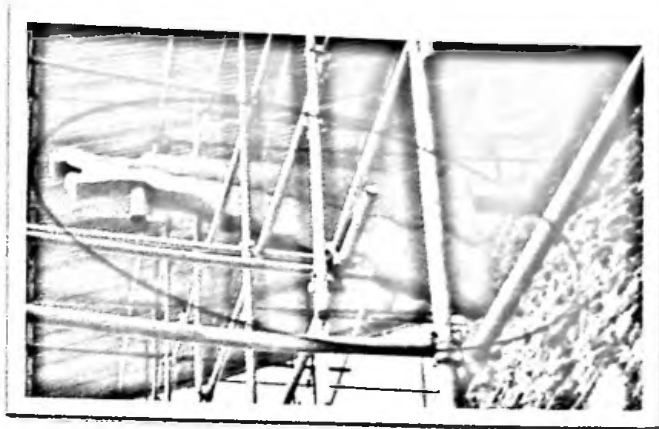
Further, certain parts of *Viman* on southern wall which had been eroded by wind were subsequently conserved using cement distorting the original erection and without understanding artistic value of the original erection or colour of raw material used. This is also a threat to beauty.



Unsuitable conservation

Picture 74

Guttering made of sheets and meant for removal of water collected on the roof does not go with the ancient look and beauty of the monument. One who looks at the monument at once will be convinced of the unsuitability of raw material and that of the new erection.



Unsuitable guttering

Picture 75

Although more attention has been paid to conserve interior paintings of Thivanka Image House potter – wasp nests can be seen on them. Things such as cobwebs, cocoons built for laying eggs can be seen on painting.

There is evidence for absorption of underground water by capillary suction As high as 50 or 80 cm of the interior of the image house. No attention has been paid to repair the damaged portions where lime plaster flaked off and dropped following the accumulation of salt in consequence of the process refers to above.

Deterioration caused to the interior of Thivanka image house

A serious problem has arisen from leaking above the paintings walls and absorption and travel of water from the ground upwards.

Water travelling upwards through walls by means of capillary rise

Every interior wall belonging to *Mandapaya*, *Antharalaya* and *Garbagruhaya* has faced this problem. Almost all the lower parts of the interior walls have been destroyed by the process of capillary suction.

The following shortcomings have been identified under this deteriorative process:-

- Change of plaster, colours and layers (Deltached)
- Accumulation of salt covering colours (Salb efflorescence)

- Crystallization of salt in the interior of colours and plaster (salt sub florescence)
- Cracks of colours and plaster (Cracks & Fissures)
- Flocking off of colour as small peels (Micro losses)

The above defects can be described as result of long range capillary rise rain

Invasion of micro-organisms

The action of micro organism is also responsible for deterioration of colour layers and plaster layers. On paintings in all three sections *Mandapaya*, *antharalaya* and *Garbagruhaya* not only the action of micro organisms but also some features of groth can be seen. Due to current excellent maintenance growth of fungi has been curbed. Their spore filaments have not developed upwards. During the growth of filaments of fungae, enzymes which are flowed out weather the surface. This action may deteriorate painting surfaces and flake them off.

Weakness of plaster layers interior of Thivanka image house

Deterioration of colour and plaster layers.

With the passage of time, in the process of drying up and fixation layers have undergone some kind of separation. Depending on the humidity of the plaster lime plaster layers in a different manner and fixation, drying up and formation of layers on bricks seaport have been taken place.

Although plaster layers seem to be very close to one another bonding between the brick layer and the plaster layer is infirm. Hence, owing to external forces such as earth quakes etc. both interior and exterior plaster layers have somewhat inclined. In turn this inclination has given rise to the formation of empty spaces among plaster layers in some parts of the lower portion of the walls. Such empty spaces are very common on exterior wall, in particular on the southern wall of the exterior. So plaster is exposed to the risk of the void.

Widening of crack on walls

Birth of cracks on Thivanka Image House probably dates back to some centuries. But evidently these cracks have developed as a result of some recent occurrences.

Several reasons for the development of these cracks can be suggested on the basis of their manner of development and of locality where their occurrence is comparatively more. The direction of the development of cracks is vertical along the wall downwards.

Factors such as (i) defects in building construction planning (ii) the raw material of great antiquity (iii) Gravity causes of building material (iv) the sun, (v) rain (vi) exposure and long -range tremors of earth have affected the base of the building and in turn they have caused cracks and also have contributed to their increase in size.

This image – house the door and window have completely collapsed long ago.

Nature of the base

On the whole long-standing bursts, filling etc. can be seen on the base. Among them (bursts) there is a considerable dip associated with the base near the western corner of the monument. A burst associated with the dip also can be seen in the vicinity.

On the gneiss base there are mounds and submerges places here and there. Again bricks in the base have been severely eroded and weekend. The contact between the brick and the plaster has come to an end. Lime plaster is either dissolved or weekend as a result of sifting of powders particles. Where contact between the brick and the plaster is absent big and small opening have been formed. In such opening (or holes) accumulation of dirt, refuse etc. can be found due to the action of insects.

Botanical damages

Experience we had through our fieldwork pertaining to the biological damages to Thivanka Image House we carried out on 15 May 2010 proved optimistic where the monument was concerned. A major scale maintenance programmed on the monument has been launched. There seemed a kind of decrease in the population of micro organisms such as moss and algae etc. which grow there and make the surroundings humid. Prior to this conservation programmed the base was covered by these plants.

In addition to weeding of the area, Dept of archeology carried out another work, i.e. erection of the shatter roof in 1980 decade for the monument. Due to those two tasks mentioned above now the monument does not have a humid atmosphere. Now even if the monument receives seeds in numerous ways the atmosphere is not favorable for their germination growth and development because the place is free of humidity. In other words the growth of weeds was checked. We identified the following weeds. However, in the field work we did on 15 may 2010.

Elephant foot (*Elephantopus*)

Kepum keeriya (*Euphorbia hirta*)

Iramusu (*Hemidesmus indicus*)

Thubs (*Leucas Zeylnica*)

Podisingnaomaran (*Chromolaena Odorata*)

Val sarana (*Trianthema Portulacastrum*)

Val pathpadagam(*Oldenlanda conymbosa*)



Plants grown on bricks walls of the Thivanka Image house, their characteristics and the damage caused to the image house by them.

Plant	Morphological features	Distribution	Locality the plant on the monument and the damages caused	Root system
Elephant foot (<i>Elephantopus</i>)	Height 15-20cm	Through seed		
kepum keeriya (<i>Euphorbia hirta</i>)	Maximum height 10-30cm. If stem broken sappour down. Stem has a inflorescence	Through seeds. Produces great number of seeds.	Tends to grow on the openings of the monument. Weaken the surface plaster. Threat to beauty.	A plant with a tap root. Height 10cm. Top root 5cm. Diameter of lateral roots is 4 cm.
Podisingno maran (<i>Chromolaena adorata</i>)	A perennial bushy plant about 90-120cm in height. Inflorescence is white.	Seeds grown in an inflorescence are by action of wind.	* Grows on openings and on plaster. Widens cracks and bursts in the monument. *Grave threat to beauty *Weathering of raw material of the monument, making soil, excessive addition of organic rubbish. *Makes a suitable environment on	Root system with the tap root differs according to age and size. A plant about 10cm high has a tap root about 4.5cm. Diameter of spread of lateral roots is about 5cm.

			the monument for the growth of huge trees.	
			*Tap root going through openings towards the interior bursts the brick monuments. *Lateral roots deteriorate bricks and lime plaster or clay plaster in the surrounding openings.	
Thuba(<i>Leucas Zeylanica</i>)	Grows 30-50cm high. Abundant in leaves. Flower is tiny. Abundant in flowers. Flower is white and plant is annual.	Seed grown in tiny white flowers are by the action of wind.	*Grows in openings of the plaster. *Grows where brick is fragile and in consequence where humus accumulates. *Organic substances on the monument. *A threat to beauty.	Has a tap root. A plant grown up to about 10cm has a tap root about 3.5cm. Spread of lateral roots is about 3.5cm
Iramusu (<i>Hemidesmus indicus</i>)	A creeper with long leaves. Dark green leaf has a white line in the middle. A perennial	Distributed through seeds by action of wind, animals and rain water.	*Grows very often in plaster openings and in cracks of bricks monuments. *Can endure	Tap root is like a bulb. Very difficult to uproot the plant. Young plant 10cm has a tap

	plant		and climate.	root 3.5cm long
Val sarana (<i>Trintema portulacatrum</i>)	An annual tree. Branches extend from the stem. Maximum height is about 40cm. Leaf is round and flower is rose and white	Distributed through seeds by the action of wind, animals and water.	*Grow very often in opening of brick monuments, on lime plaster and clay plaster. Prefer to grow on lime plaster. Weaken plaster on openings. *Accumulate organic substance on monument. *Weathers lime plaster. *Threatens beauty.	Tap root is like a bulb. Plant grown up to about 10cm has a tap root 4cm. Lateral roots do not spread more than 2.5cm. (diameter)
Val pathpadagam (<i>Olden landacorymbos a</i>)	Annual plant. Stem is not straight. Branches extends from the lowest part of the stem and development thallose Leaves are very thin and long. Abundant in white, small flowers.	Distributed through seeds. By the action of wind animals and water seeds are conveyed to any place. A widespread plant produces a large number of seeds.	*Very often tends to grow in openings of brick monuments. *Grows on walls, bricks and on any other place. *Grows in large numbers on monuments. *Grows even on bursts, lettuce and murals. *Weathers and bursts plaster	Top root looks like a small bulb. It does not grow long. Lateral root system does not grow long. A tree generally having about 10cm long branches carefully uprooted without damaging its root system has a tap root about

			layers by the action of root system. *As the plant is common on monuments it is a threat to its beauty.	2.5cm long. Spread of lateral root system is about 3cm.
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Many of these plants are either annual or perennial. According to our observations much damage is done by these plants to lime or clay plaster which is the material of the monuments. These plants choose the openings of plaster as the place of their growth. Due to the thrust of roots openings widen and crack and plasters become powder. As a result opening gets filled with a lot of soil and humus and thus surroundings suitable for the growth of huge trees is formed. Then the root systems of these trees will damage the monomers.

We made a study of the plants grown on the walls of Thivanka Image House so as to ascertain the process of damage caused to monuments by root systems of those weeds.

To begin with lest we should cause any harm to tap roots and lateral roots of the plants we very carefully uprooted weeds either 10cm or which approximate to that height that were grown on the walls of Thivanka Image House. Then we measured the length of

The tap roots of these plants to ascertain whether how long they would be when the plants grow up to a height of 10cm. Then we also studied and found out the diameter of the circle formed by the lateral roots when they spread around the plant. By this method we could roughly gain an idea as to what extent the tap root damages the plaster and the lateral roots damage the area covered by their circumference. The results of the observation are as follows.

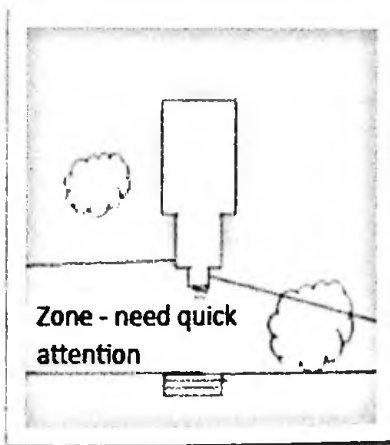
Plant	Length of tap root in cm	Spared of lateral roots in cm
Thuba (<i>Lecucas Zeylanica</i>)	3.5	3.5
Elephant foot (<i>Elephantopus</i>)	3	4
Kepumkeeriya (<i>Euphorpia hirta</i>)	4.5	4
Val sarana (<i>Triantema portulacastrum</i>)	3	2
Val pathpadagam (<i>Oldenlanda corymboss</i>)	2.5	3.5
Podisignamaran (<i>Chromolaena odorata</i>)	4	5

The plants we observed were about two months old. The stem of these plants were about 10cm. The plants affected the plaster or opening of the monument either by development of its foliage or by the spread of its root system. The damage these plants cause to the monuments is not really apparent at once but it is a slow and regular process of course which culminates in massive destruction. Root system is continually in action while the tap root travels deep in to the monument.

Lateral roots exert horizontal pressure to lime plaster and the surrounding opening. This action might turn surface plaster etc. into powder like particles and break the contact between the plaster and the brick wall. Besides through weathering leaves, flowers and stems etc. of plants increase the amount of organic matter on the monument. This action in turn favors the increase of humus.

Landscape of the surroundings

This monument standing at a summit of a hillock has a remarkable scenic beauty. The area lying to the south and to west of the monument is in particular very rich in natural scenery. But the area lying to the east and to the north of the monument still needs attention. The region (east and north) which is subject to the action of rain the place is washed and stones are exposed. Even the main entrance to the monument is found somewhere here. So it is somewhat harmful to the reputation of the monument that the main road and the main entrance should lie in a region which is severely eroded.

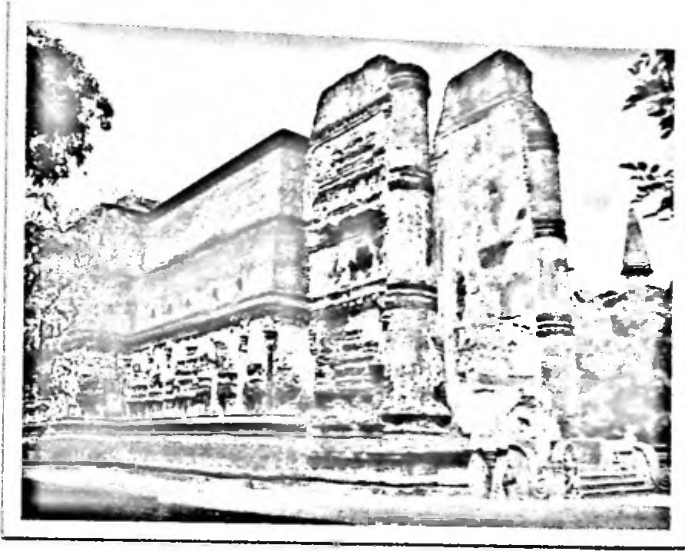


Landscape of Thivanka Image house

Picture 76

If a means of excavation can find out whether any wall had been there in the past and if it is restored the topography of the front portion can be altered and rearranged the site. If conservation programmed of the kind referred to above be carried out erosion of the eastern zone could be prevented. And topography of the place could be improved.

2.3 Lankathilaka image house



Lankathilaka Image house

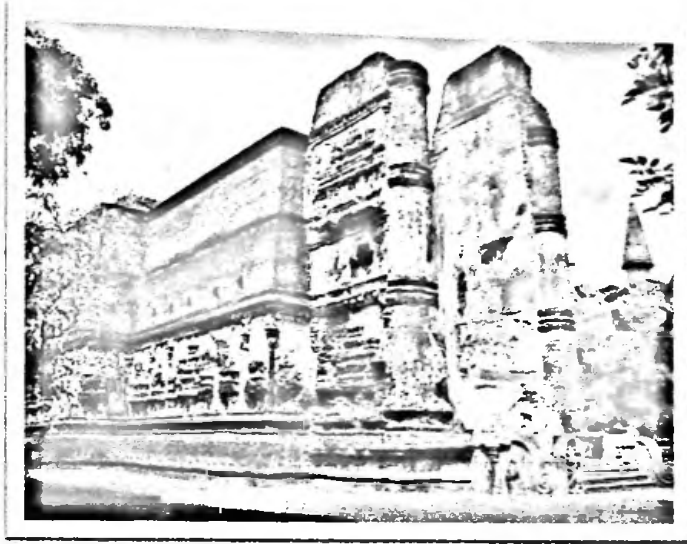
Picture 77

Architecture of the building

On the north from Buddha sima parasadaya, a large image house built of brick is found. A colossal statue of the Buddha made of brick can be found in the *Garbha gruha* inner house of these image house which has all the three features, i.e. *Mandapaya*, *Anatharalaya*, *Garbha gruha* inner house peculiar to image houses. This statue is about 40 feet in height.

Chronicles say that Lankatilaka image house built by king Parkramabahu-i, consisted of five storey's and was extremely attractive (M.V 78:57). It is evident from the surviving fragments of colored and flower carved plaster that this image house was decorated with various flower and drawings in the beginning. Figures of gods and Brahma made of lime plaster are carved on the outer walls of the building. It is also adorned with architectural features of celestial
ars

2.3 Lankathilaka image house



Lankathilaka Image house

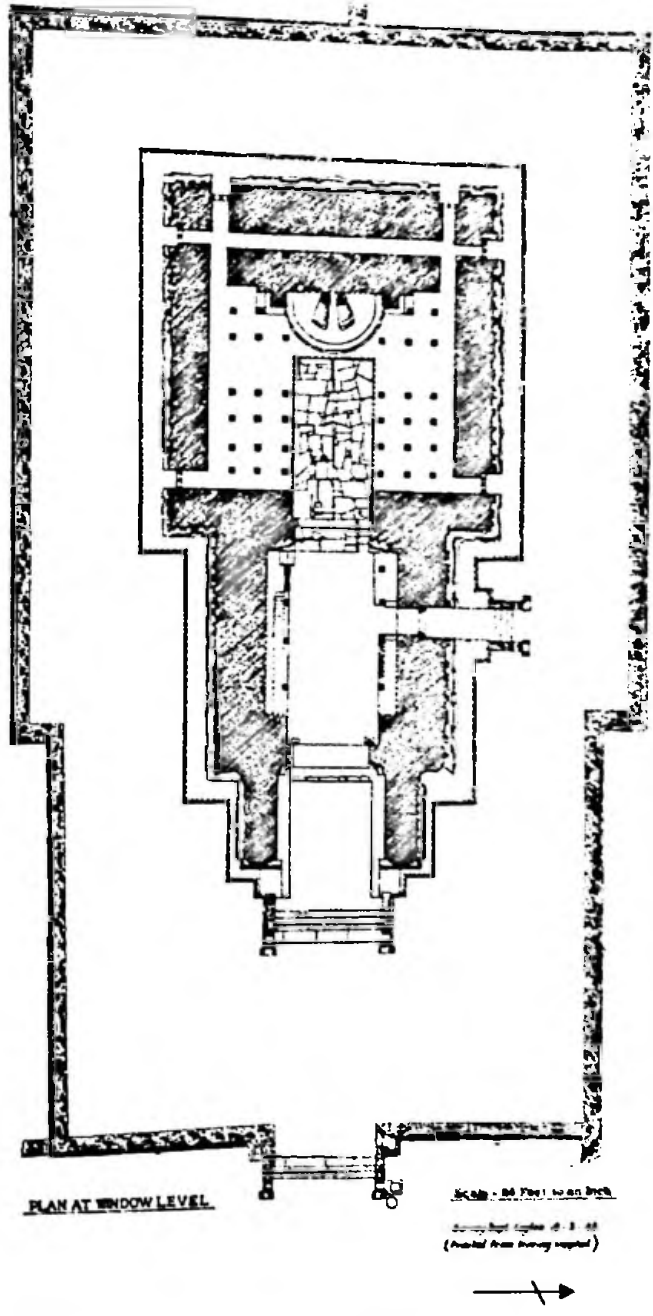
Picture 77

a) Architecture of the building

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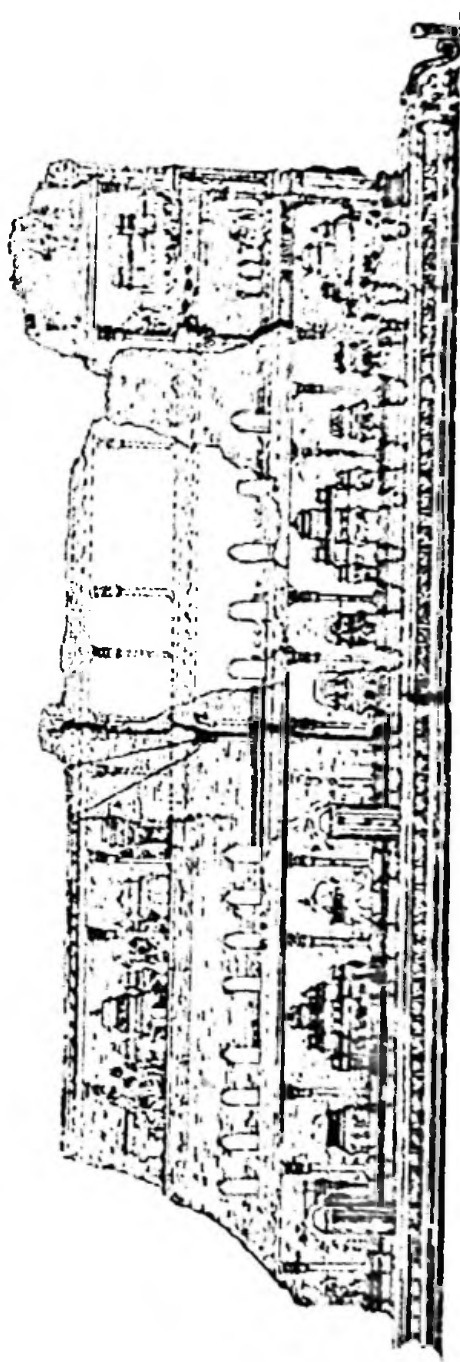
WANGA SUTTA
POLONNARUVA



(Source: Hocart.A.M. 1926, Memoirs of the archaeological survey of ceylon, Government printer, Colombo)

Ground plan in building- Lankathilaka image-house

Plan 08



(Source: Hocart.A.M. 1926, Memoirs of the archaeological survey of ceylon, Government printer, Colombo)

South side elevation in building- Lankathilaka image-house

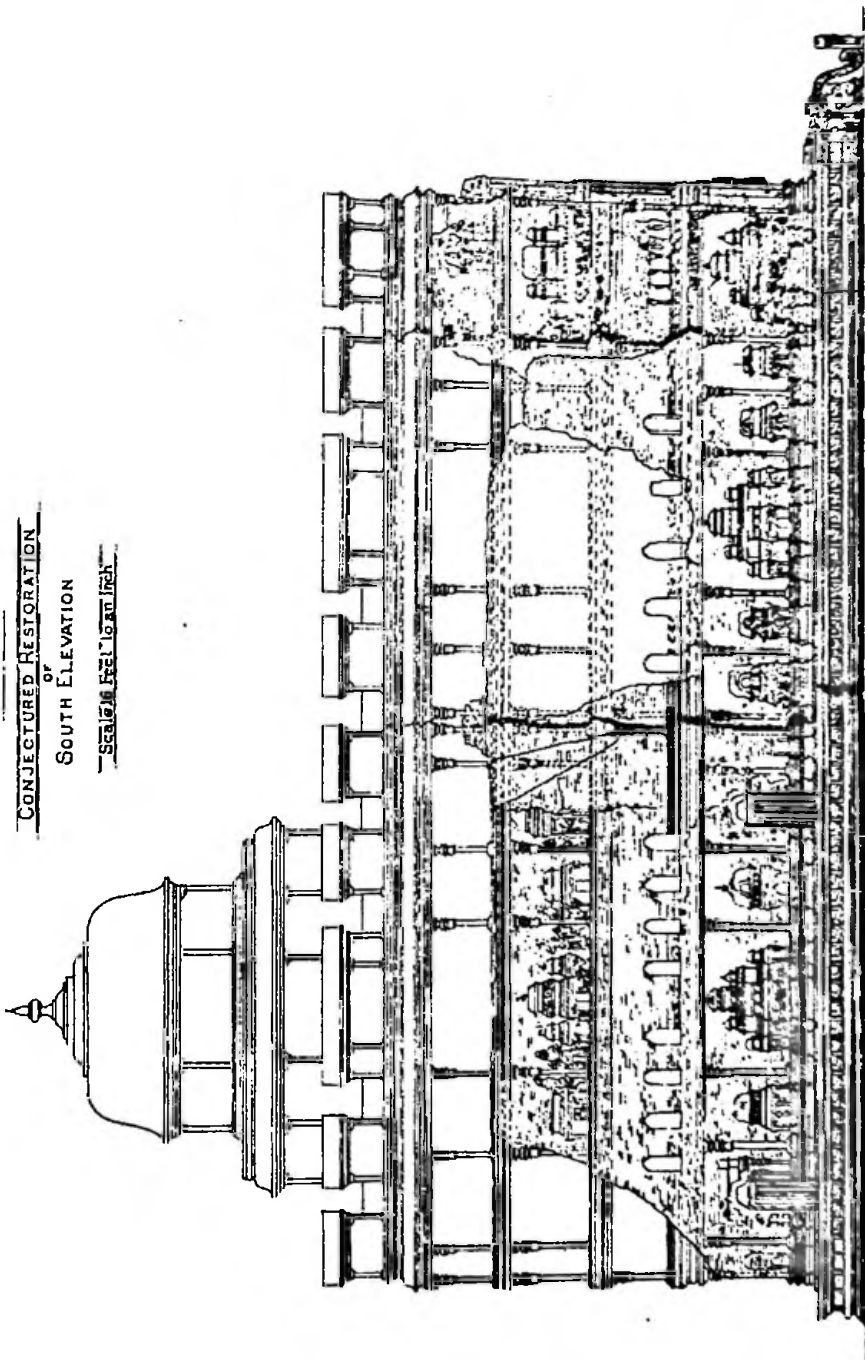
Plan 09

LANKATILAKA
POLONNARUVA

CONJECTURED RESTORATION
OF

SOUTH ELEVATION

SCALE 1/16 FEET TO AN INCH



(Source: Hocart.A.M. 1926, *Memoirs of the archaeological survey of ceylon*, Government printer, Colombo)

Conjecture south side elevation in building- Lankathilaka image-house

Plan 10

b) Structural principle adopted in building

Burnt brick and lime plaster have been used to erect this building and the form of brick has some remarkable features. These are made of brick moldings and of various sizes. Original walls about 55f. in height still survive here. But parts of the middle of the vaulted roof which may have been exclusively made of brick are broken. The two huge brick columns standing in front of the monument show the excellence of the contemporary technology of brick making.

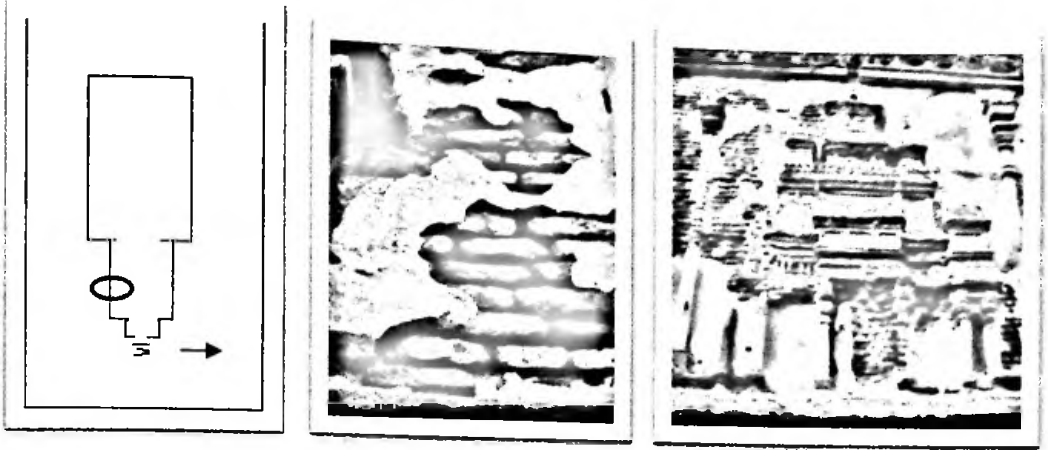
c) Present state of Lankathilaka Image houe

This construction which was built following *Gedige* tradition and with a vaulted roof made of brick was the tallest of its kind set up in Sri Lanka. At present dome shaped roof made of brick is extinct. It has been broken and destroyed. There serious two powerful damages due to the incessant heavy rain. The first is the heavy showers falling on the surface of monuments and washing away of it and cracking much water seepage in to brick walls and to brick works through the cavities in bricks, also the erosion caused by flowing water on the surrounding area of monument, sometimes the foundation washed away leaving the wall to crash down. Besides, excessive seepage of water may cause sliding or crashing down higher parts of walls. Unburned bricks were loosening and weaken the monument, due to erosion of clay mortar, time mortar, lime plaster etc.

Multitudes of deterioration factors have been identify on the wall and plasters in the Lankathilaka image house.

Survival of brick while deterioration of soft mortars and plaster

A number of instance can be noted, where the mortar and plaster incapable to various kinds of erosion has quickly disappeared while remaining only the bricks. When the process goes on the like then comes a stage where the medium of building bricks together, i.e. the mortar and plaster will totally be vanished. Then the bricks will begin to fall down. So this kind of action Will probably affect the other parts of the movement as well. A good number of such places where plaster has severely been eroded leaving only the bricks can be found on the eastern wall of Lankathilaka Image house.



survival of bricks and disappearance of infirm plaster and mortars

Picture 78

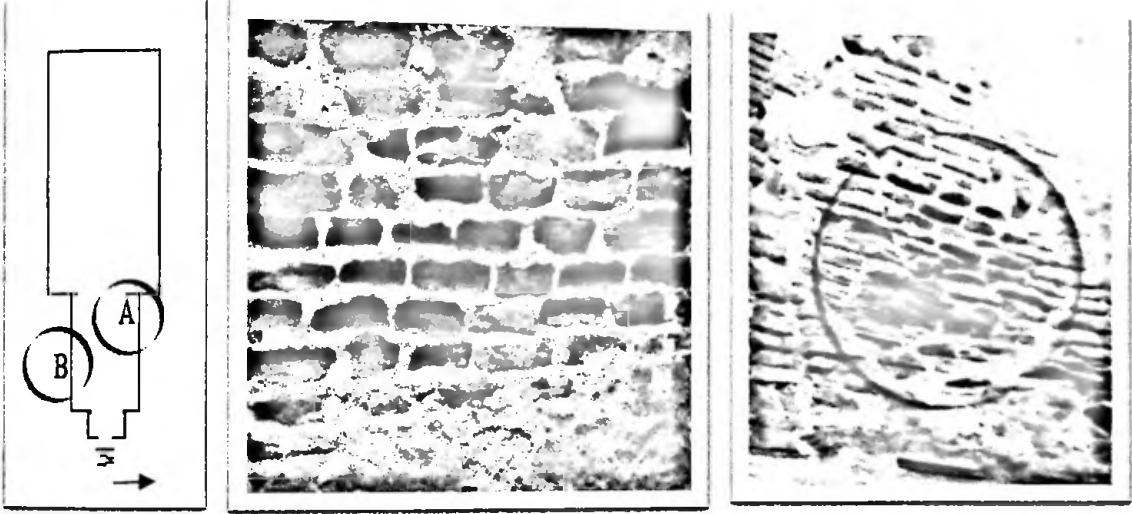
Above pictures show how the major portion of the movement is stripped of plaster leaving only the bricks. Even in the interior of the movement a number of such places where plaster has dissolved while leaving the bricks can be found.



Deterioration of tender bricks and survival of the tough mortars

Picture 79

Lankathilaka Image house provides us with numerable instances where bricks less strength in face of erosive factor have been dissolved, while parts of the plaster which had more resistant power have been survived in the form of ribs. If this process takes place a continuously and if the bricks accordingly dissolve completely it will cause grave damage to the monument. Further, it is a threat to both artistic value and existence of the movement. This deteriorative factor in numerous on the southern wall whereas it in found number of places on interior walls of the monument.



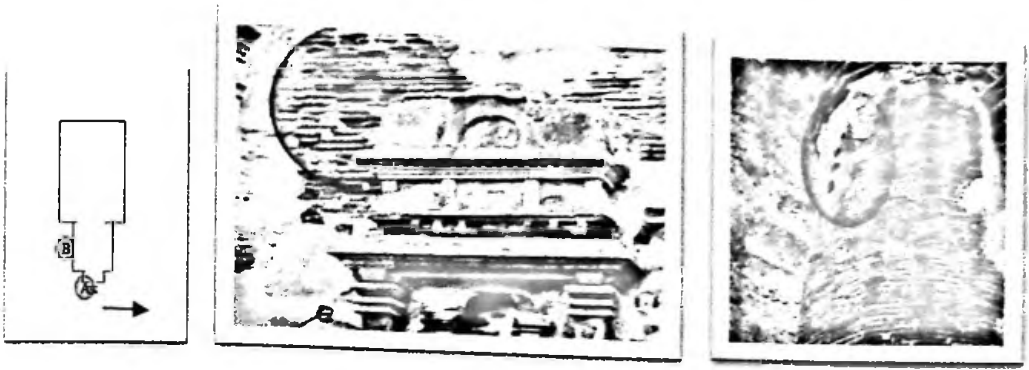
A) Interior of movement B) Southern wall of monument- picture 81

Survival of mortars while deterioration of soft brick and plaster

Picture 80

Dissolving of tender bricks

Which had been wade in erecting Lankathilaka Image House readily eroded in face of erosive factors on bricks walls here and there. Such brick dissolved giving way to openings. This has a harmful effect on both strength and beauty of the monument. Such opening which replaced the dissolved bricks are found



Dissolved bricks Lankathilaka

Picture 81

Damage caused by pressure

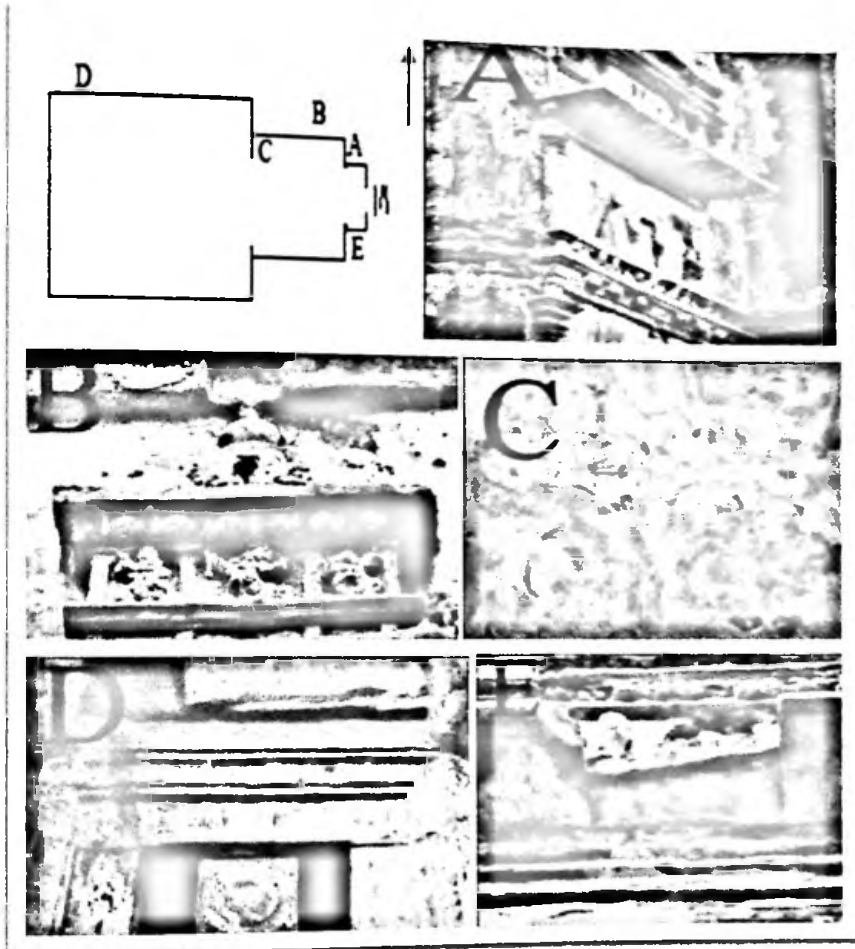
At present no large scale cracks or bulges caused by horizontal and vertical pressure. But there had been such major damages when the monument was discovered during the European rule. They have been conserved. Although at present several small cracks and openings are found they cause grave damage to the remaining structures of the building.

Deterioration in painting and colours

As the sun light falls direct on the monument colour washing as well as painting of both exterior and interior have been destroyed. Fragments of ancient colouring as well paintings are extent to a very little extent in places which are protected from sunlight very well.

These fragments of colouring and painting provides us with evidence for the feat them this whole building was white washed with lime, colour washed furnished with paintings. Yet, due to fact such as breach of the roof and exposure of the monument to sunlight for a number of centuries the colouring has been destroyed.

Fragments of colouring survive A, B, C, D, E

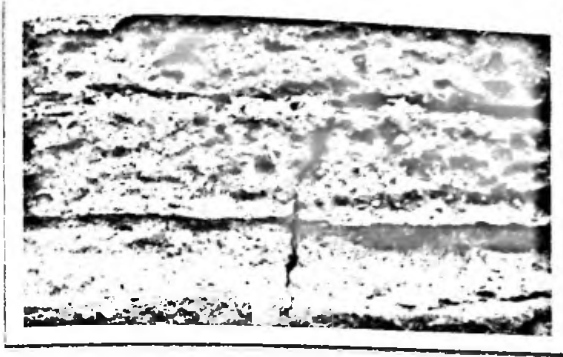


protected in panting and colours Lankathilaka

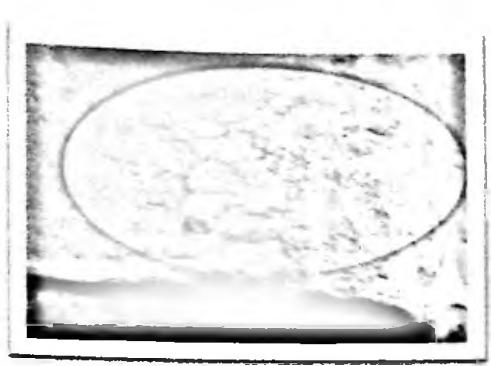
Picture 82

cracks

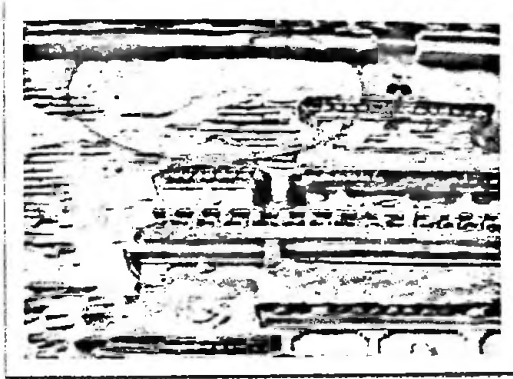
Not only bricks but also its medium of building, i.e. lime plaster may in face of excessive sunlight get heated, expand and in case of sudden contraction may crack, become powder and fall. Again the plaster which has been used to spread on the wall in face of thermal movement has cracked and it is somewhat like a cobweb.



Micro cracks in bricks



Micro cracks in plaster



Micro cracks in bricks and plaster

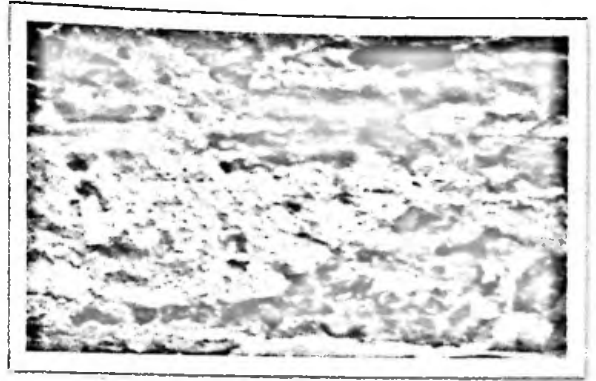
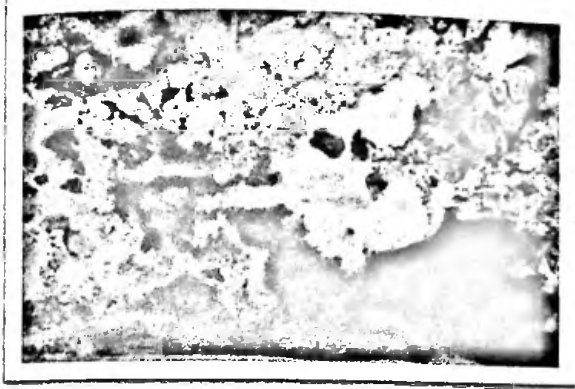
Picture 83

Compared with other walls, the occurrence of cracks in plaster of the kind is more probable on the southern wall and northern wall and Lankathilaka Image House which receive heat during a greater part of the day.

Rain erosion of wall

Damage caused by rain fall is extremely severe to this building with no roof. Harm caused included (i) erosion of brick and lime plaster as a result of direct rain fall (ii) unfastening of bricks on the upper parts of the walls in this very tall building due to excessive absorption of water (iii) creation of humid environment on the brick wall due to (iv) above. In consequence, moss, algae, lichen and small plants and fern as well as various trees grow on these walls. Again, due to (i) rain as underground water surrounding the monument goes up the amount of rain

absorbed. By the movement through capillary suction increases and (ii) various salts dissolved in the underground water deposit as crystals on brick walls and crack both brick and lime plaster and drop particles in the form of powder.



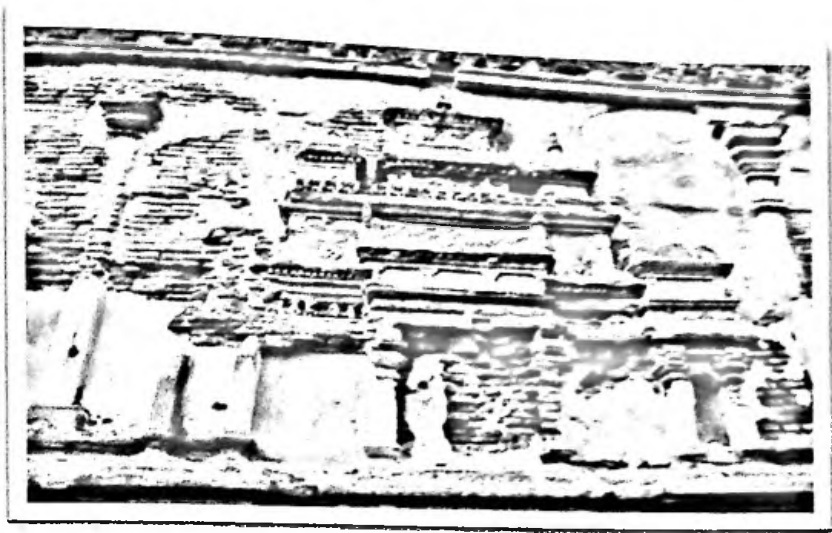
Salt infection in wall

Picture 84

Rain erosion

This monument is very tall. And also it has no roof. Therefore, the rain directly falls on brick walls. When rainwater flows down along the surface of walls it might wash lime plaster spread or bricks.

Although several services of protective bricks have been fixed on the brick wall of the monument they do not suffice to prevent this damage. Further, an accession of rain accompanied by a strong wind, hard rain fallen upon the middle parts of the wall and fallen in the form of spray severely damage both brick wall and its lime plaster. A considerable damage of this kind is in evidence on the southern wall of the monument which is on the windward of the north eastern Monsoon which brings rain to this zone.



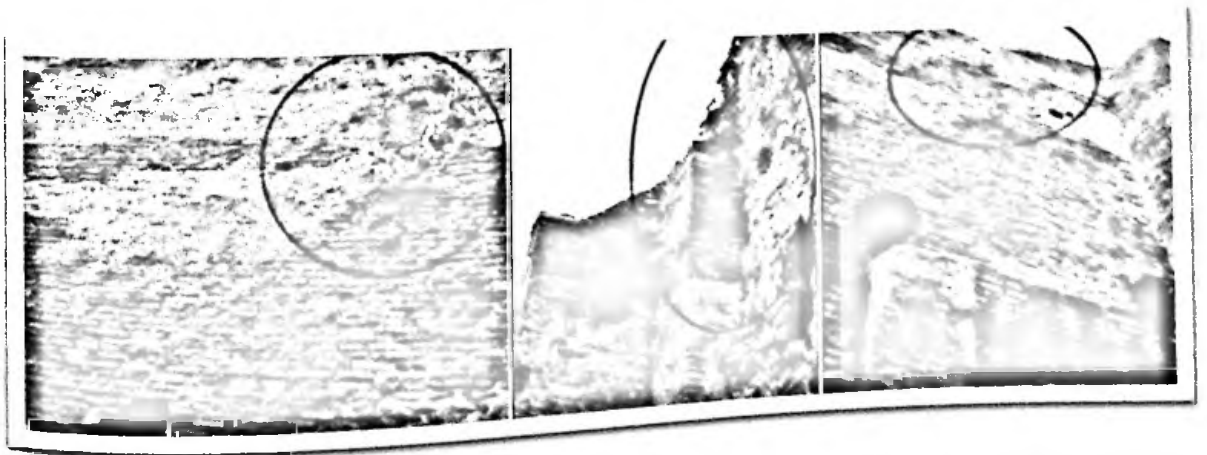
places where lime plaster has eroded

Picture 85

Even in the interior of the monument lime plaster has been eroded in the same manner.

Dampness prevailing on upper parts of interior walls

As there is no roof. Water fallen upon the brick during wet weather is absorbed and in consequence upper parts of the interior walls of the monument remain humid. So moss and algae grow very well here. Not only plants but also huge trees such as Bo, Banyan and Kolon can be found grow on these walls. On the land one land growth of these trees are threats to beauty of the monument and on the other it is harmful to its existence in the long running.



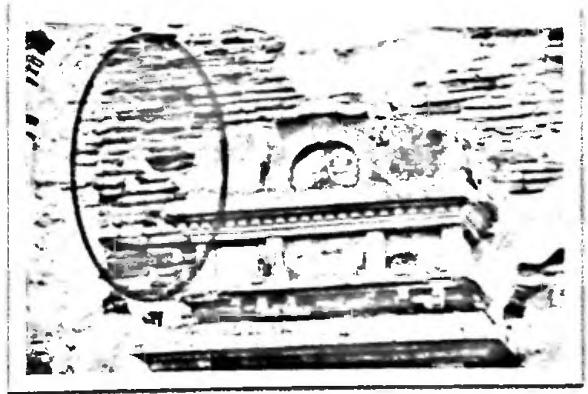
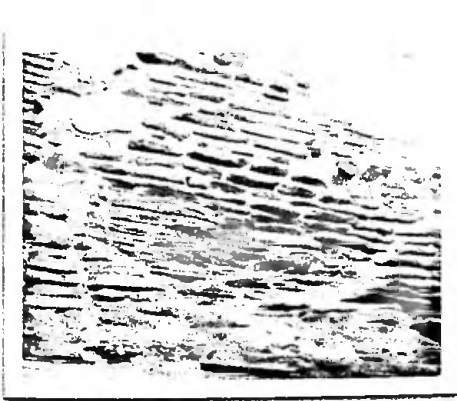
Plants and trees upon the inner brick wall

Picture 86

Furthermore, even the base of the building in face of excessive rain becomes damp due to factors such as erosion, spray and absorption of underground water. When humidity reaches its highest point various weeds such as moss, algae etc. can be found on the base. This state is a threat to both to the existence and the beauty of the monument.

Damage caused by wind outer and inner wall and plaster

The southern wall of Lankathilaka Image house has been greatly damaged more by wind erosion. There bricks which had already been made infirm by the action of rain and salt are now victims of wind which erode them giving them various features.



Parts of the southern wall eroded by wind

Picture 87

Again even in the inside of the monument old infirm bricks as well as the planter have been eroded by wind. The wind which enters the monument through its entrance swings round within the walls of the Image House as a whirl and leaves the building through the windows on both sides, entrance the roof as well. Wind has eroded the bricks of the interior which directly face the windward. If this erosion is continued bricks of the interior will dissolve and as a result strength of the walls might decrease. In consequence there is a risk of collapse of the walls. It might also harm the beauty of the monument. In this manner, old bricks of both sides, interior and exterior of Thivanka Image house are being destroyed by wind erosion.

Botanical Damage in wall and plaster

In the study of botanical damage pertaining to Lankathilake Image house the exterior wall of the monument. Compared with a great many weeds and trees were found on upon parts of the interior walls. These walls are very tall.

It adds to the difficult of daily weeding. Again an environment favorable for the growth on these fragmentary walls of weed, trees, and moss has been created owing to

- (i) Prevalence of exceedingly humid surroundings on a top of these bricks walls which have absorbed rainwater.
- (ii) Prevalence of humidity on bricks walls and
- (iii) Absence of sufficient sunlight in the corner of the interior. Similarly, on lower part of both interior and exterior base of the monument is excessive covered with moss and algae.

We conformed to the method of random sampling in order to study the botanical damage caused to the monument. Giving proving to the interior we studied samples taken from the comets where relevant damage was greatest.

As the upper parts of the interior of the monument has turned a suitable environment for the growth of trees one can find development of a number of different plants here.

Trees and plants



Ficus religiosa



Ficus virens



Adina cordifolia

Trees in Lankathilaka image house

Picture 88

119



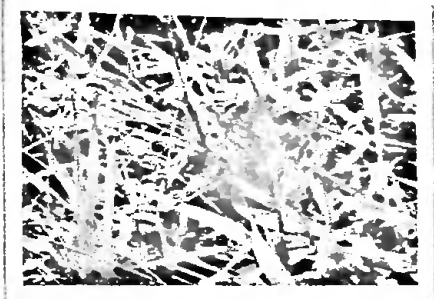
Out of these plants the interior of the monument is abundant in Bo (*Ficus religiosa*) tree.

Plants

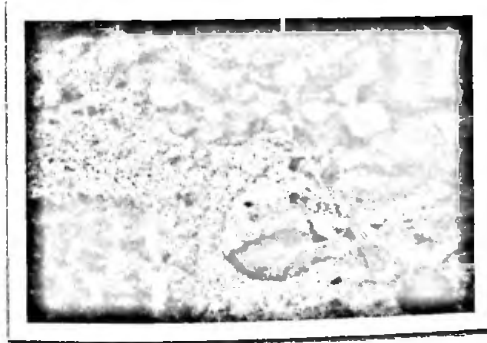
Plants grown on brick erections of Lankathilaka Vihara as we found in the sampling study



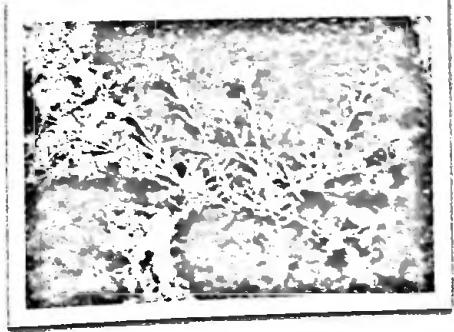
Bryophyllum



Dactyloctenium aegyptium



Trianthema portulacastrum



Oldenlanda corcymbosa

Plants in Lankathilaka image house

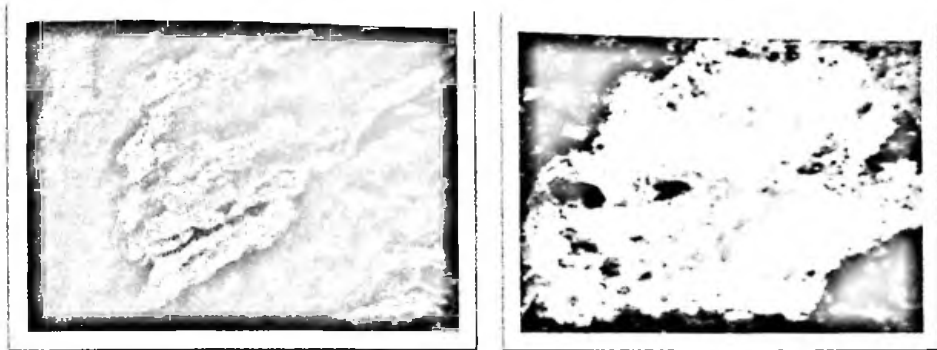
Picture 89

The plants referred to above have been densely distributed. Many of these plants are distributed in upper corners off interior walls of the monument.

Bacterial and Fungal infection

A number of places infections were found inside Thivanka Image House. Towards the interior of the monument there in a tunnel erected so as to circumbulate in window arches and about the statue. On the upper parts of this tunnel we could identify white fungus infection.

Fungi infection brick walls



Fungi in Lankathilaka image house

Picture 90

We can identify this infection thickly spread in much covered dark corners which receive no sufficient sunlight and no ventilation

Moss

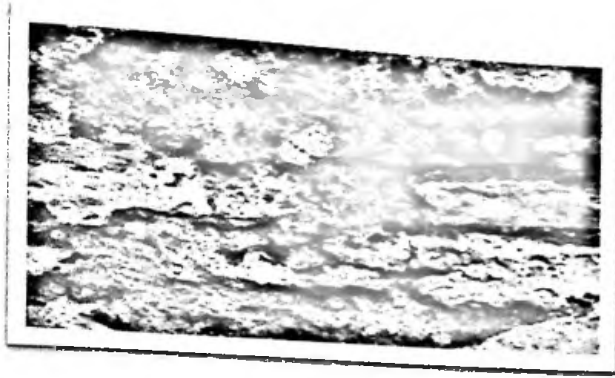
Dense distribution of moss can be found on the whole monument. Upper parts of the interior wall of the monument are abundant in moss.



Moss grown on upper parts of the brick walls in Lankathilaka image house

Picture 91

On regions near the floor of the interior a thick growth in moss can be seen.



Moss in interior side in Lankathilaka image house

Picture 92

Outside the monument on the molding near the base excessive growth of moss can be found.



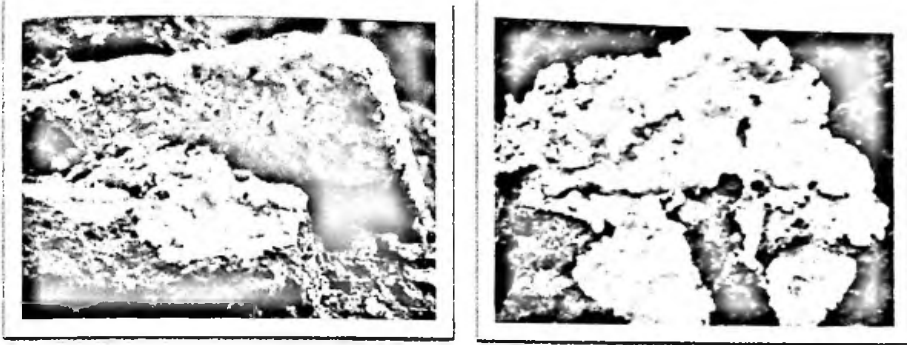
Growth of moss on molding in Lankathilaka image house

Picture 93

Majority of this moss is green and black in densely distributed biological deteriorative factor on the monument in it's entirely. Deteriorative factors depending on humidity are quickened and a suitable environment for the growth of other trees in created by this moss which forms a humid surroundings on the bricks and is a great threat to the aesthetic value beauty of the monument.

Lichen

On bricks of the monument, resembling flower patterns, white, blue and light green lichen is found here and there on the one hand as isolated individual units and on the other hand as a range covering a vast area. The spread in comparatively, less on the exterior of the monument where as it is found as a range on interior walls which are shaded and humid.



Lichen spread as isolated individual units



Lichen spread as a range

Lichen in Lankathilaka image house

Picture 94

Lichen weathers not only lime plaster but also surface of bricks. In addition, it is a threat to the beauty of the monument. Most of this lichen takes the form of scabs, leaf and heap.

Damage caused by animals

Damage is caused every animal to this monument which stands with in Alahana Peruvian is a more isolated environment.

Damage caused by birds

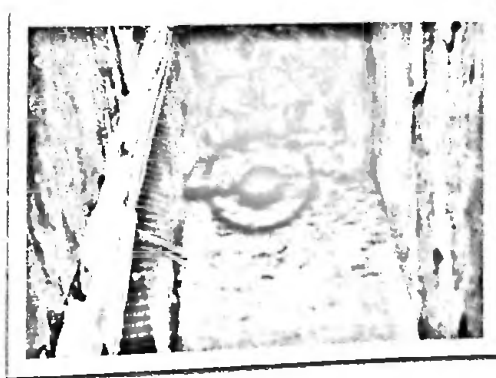
The most damage is caused to this monument by birds. Although the damage is slight when goes on for a long time it becomes destructive. Harm caused by birds include making nests, discharge of faces, dropping leftovers on to the monument and the damage caused by birds is serious. According to our observation it is an evidence that the under mentioned birds live between the Buddha statue and the wall inside the monument and also in the tunnel built so as to circumbulate around the statue.

Bat (*Pteropus giganteus*)

Pigen (*Columba livia*)

Swallow (*Petrochelidon pyrrhonota*)

Further these were also a few nests built by wasps inside the tunnel.



Nests built by wasps in Lankathilaka image house

Picture 95

Moreover, on upper parts of the southern wall in the monument birds such as Swallow, woodpecker, kingfisher live in nests. Again on the exterior walls in, Vimana and within the molding some birds have built nests.

Insects

Again potter-wasps have built their nests more close parts both in interior and exterior Vimana features.

Quadrupeds

Quadrupeds causing much damage to the monument are chiefly Monkey and Ape They walk along the wall on monument in packs and this action of theirs may make bricks. Unfasten and fall down.

Damage caused by Man

As this monument is cut off from the inhabited are an impudent tourist's cause damage to it by scribbling or writing names etc. on the lime plaster and brick.

Again if upper part of the brick wall the monument is allowed to be washed continuously by rain in the long run it will cause serious damage. The gravest harm done by conservators and the authorities included in attention of weeding upper walls and leaving not being taken prompt action to minimize the damage of wind erosion.

Door and window were completely collapsed long ago. When the past number of centuries are taken into account relative to other parts of the monument not much of damage has been caused to the base. No large cracks of considerable size or subsidence can be seen here except that lime plaster spread externally has undergone severe damage. The lime plaster in covered by moss, lichen and small plants.



Base of Lankathilaka image house

Picture 96

Outside the monument on the molding near the base excessive growth of moss can be found. Majority of this moss is green and black in densely distributed biological deteriorative factor on the monument in it's entirely.

Deteriorative factors depending on humidity are quickened and a suitable environment for the growth of other trees in created by this moss which forms a humid surroundings on the bricks and is a great threat to the beauty of the monument. In Lankathilaka image house there is an excessive spread of two kinds of algae, i.e. green and brown (i) on the molding associated with the base of the exterior and (ii) on, animals' figures almost covering them and (iii) on bricks and the lime plaster. Brown algae seem to be widespread here.

2.4 Thuparama image house

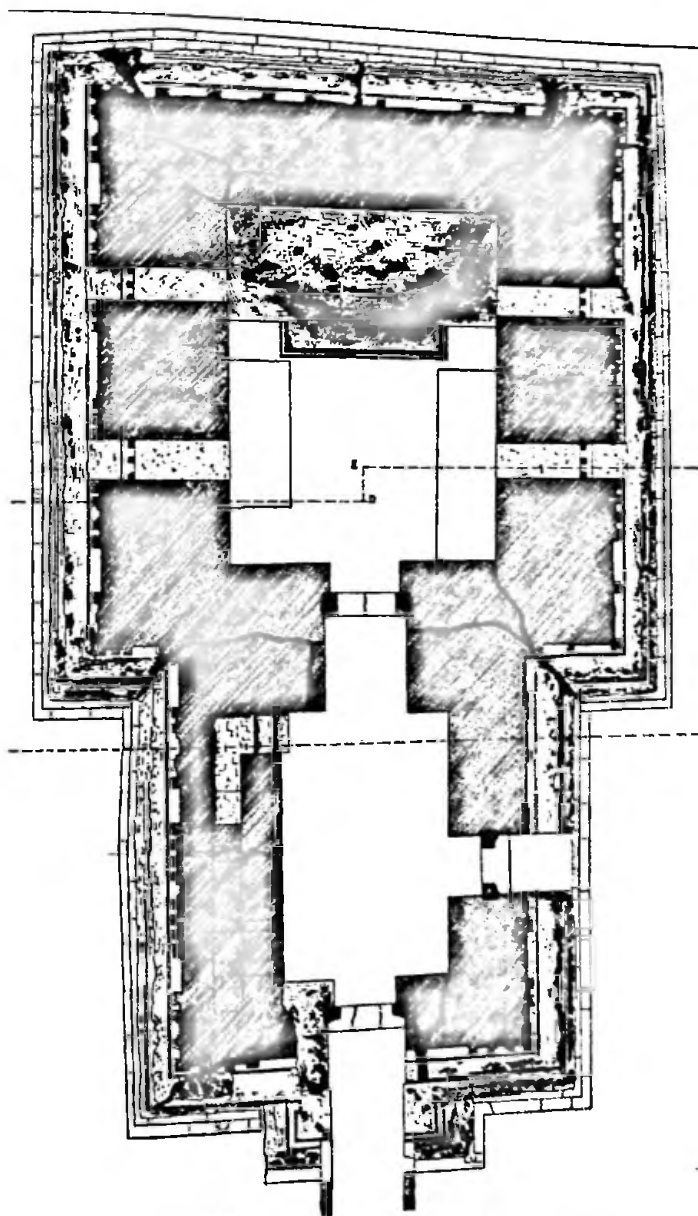
a) Architecture of the building

In the north from the site of the palace, out of the inner city, on the left of the road leading to north and where Shiva Devala No-1 stands, a large platform with a bund made of stone is found. This is known as Dalada Maluwa. On these stairs which can be treated as the centre of the old city a multitude of priceless erections very rich in architectural tradition of Polonnaruwa period is found. Thuparama pilimageya also was the Gedige tradition protected largest image house built in the south west of these stairs.



Thuparama image house - Picture 97

This architectural erection built as an image house of Buddha has features peculiar to the Si Lankan architecture.

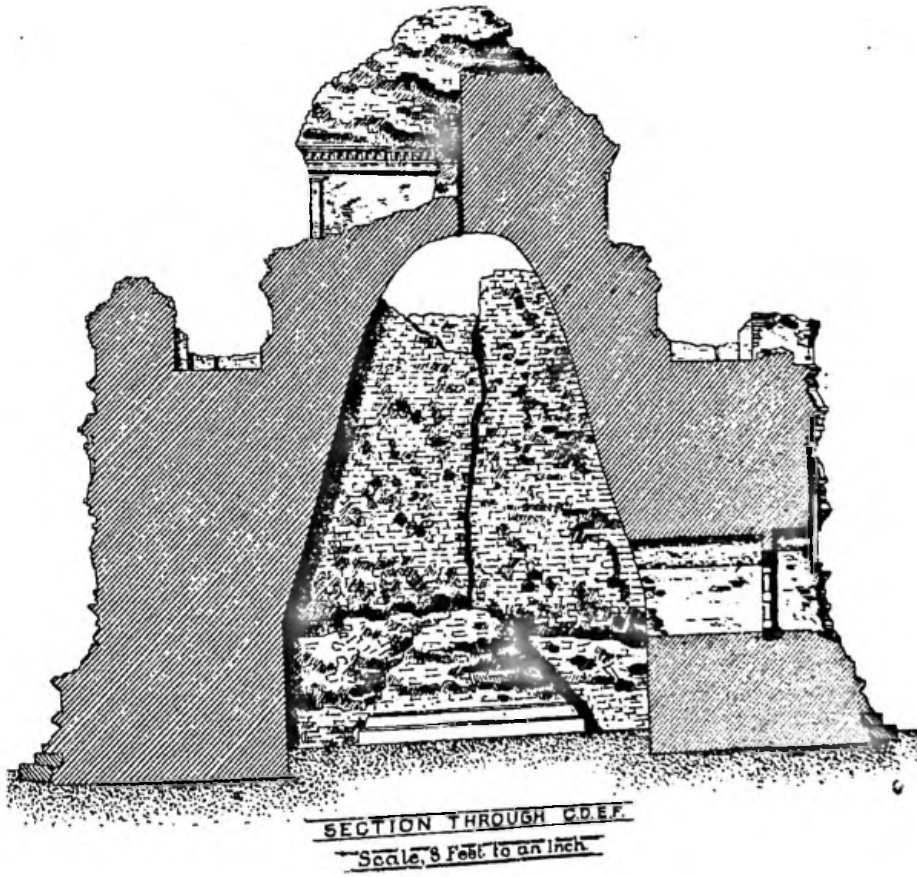


(Source: Hocart.A.M. 1926, *Memoirs of the archaeological survey of ceylon*, Government printer, Colombo)

Ground Plan in Thuparama image house

Plan-11

POLONNARUVA
THUPARAMA



(Source: Hocart, A.M. 1926, Memoirs of the archaeological survey of ceylon, Government printer, Colombo)

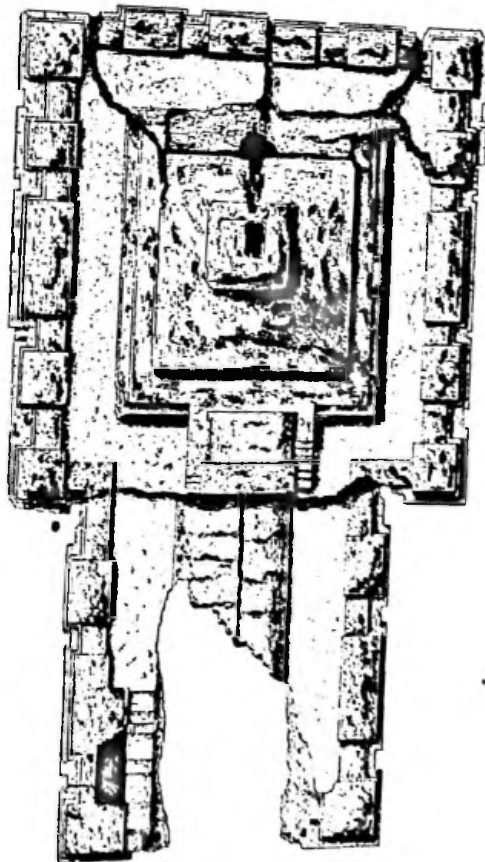
Section in Thuparama image house

Plan-12

a) **Structural principle adopted in building**

The roof itself is made of brick, has a shape of an arch, (vaulted roof) and follows the *Gedige* tradition. This is one and the only brick construction building with such a roof of which so many remnants survive. The vaulted roof made of brick belonging to the *mandapaya* (bower) and *anthralaya* (interior hall) of this building which consists of *garbhagruhaya* (inner house), *antharalaya* (interior hall), *mandapaya*, has been brackles. The vaulted roof made of brick (brick arch) belonging to *Garbhagruha* which is well protected can be seen even today.

POLONNARUVA.
TUPARAMA.



PLAN OF ROOF
TUPARAMA

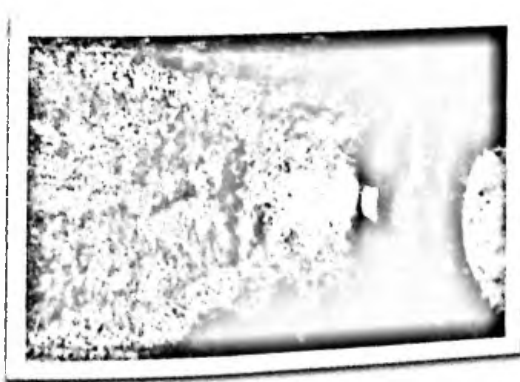
Survived vaulted roof in Tuparama image - house

Plan-13

Further, seat of an image of Buddha made of brick and remnants of the lower parts of the image are found inside the *garbaha gruha*. This provides us with clear examples of for the features of architectural style of the Polonnaruwa period. Rain water falling on the roof made of brick and covered with a thick lime plaster come down along the slope and then falls on the ground through a pipe which resembles a dragon. In spite of the fact that the lime plaster with which the brick is covered is some centuries old it has been well preserved. At the beginning this building must have been well plastered with lime, painted and decorated with drawings. In consequence of environmental and both human actions that went on for centuries they have been deteriorated.

d) Present state of Tuparama image house

Out of the erection built following the *Gedige* tradition in Sri Lanka, Thuparama Image house of Polonnaruwa is the only one extent with vaulted roof made of brick. This erection can be designated as one of the most significant of its kind made of brick following the *gedige* tradition. This building which consists of three parts, *Garbagruhaya*, *Aantharalaya*, and *Mandapaya* has a roof which is an arch resting upon an excessively wide brick wall. But owing to subsequent deteriorative factors its roof made of brick and belongs in to the front *Mandapaya* and *Aantharalaya* has been collapsed.



Protective vaulted roof



Broken vaulted roof

Vaulted roof of Thuparama image house

Picture 98

Failure to implement the plan of the building properly, raw material used, relevant of plan irrelevance of plan to climate and the effect of gravitation etc. wood have been the cause behind the destruction of the monument. Erection of *gedige* tradition made of brick does not seem to last along in a country like Sri Lanka which is torrid and rainy. It is a weakness of the plan.

Further, building materials are also a determinant of the existence of an erection. Inattention to suitability or unsuitability of building materials leads to the birth of a number of deteriorative factors. They are as follows :-

- (i) As the plaster which the binding medium is lacking of the stranded and is infirm it is the first thing which the monuments lose.
- (ii) Due to the use of bricks lacking of strength, quality and standard only ribs of the plaster remain while the brick dissolves.
- (iii) Factor (II) referred to above gives an ugly look to the monument and is harmful to its durability.
- (iv) Further, un burnt bricks used to erect the roof in monument might subsequently dissolve and make openings on the walls.

The above deteriorative factors are common even to roof in Thuparama Image House.

Damage cause by rain fall

Until recent (past) years this monument was exposed to direct sun and rain. But recently a temporary protective roof has been put up in order to cover the dome roof of the *Garbagruhaya*. This renovation seems to have been carried out with a view to preventing the collapse of dome roof in case of heavy rain. This is the only surviving example of arch belonging to this tradition. Therefore, it must be protected somehow. Before erection of this *Purage* roof the monument had directly exposed to rain and there was a leak in the middle of the dome too. The interior of the dome convinces of one how bricks in its middle have dissolved and of bricks have been eroded by wind. If this process had continued dome would have been in the danger of becoming vanished.



Mode of dissolving of bricks in the middle of the dome

Picture 99

Lime plaster on the surface has been dissolved owing to the direct fall of rain. In addition, due to constant absorption of water moss, weeds etc. have grown on the exterior of the dome while salt precipitation trickled have been hanging like creepers in the interior of the dome. Bricks have been made infirm and plaster has been left as ribs owing to salt, weak bricks and by the action of wind etc. inside the brick dome.

Though a shelter roof in order to remedy this risk has already been erected covering the dome, some parts of the wall have become blackened due to dampness which is a result of rain dome received before the erection of the shelter roof. Even at present those traces of rain remain blackened by the presence of moss which could be easily identified.

Again, at the beginning of conservation, cement was used to keep the dome and upper parts of walls of the *Garbagruhaya* from harm. Now by the action of rain which the dome and upper parts of walls receive, water and portions of salt have leaked in to the *Garbagruhaya* This is a threat not only to beauty but also to the existence of the monument. A shelter roof has subsequently been made remedying the undesirable state to some extent.

Botanical Damages

In the interior *Mandapaya* of Thuparama where a part of the roof has been collapsed and where excessive dampness prevails, plants belonging to the family of ferns are grown.



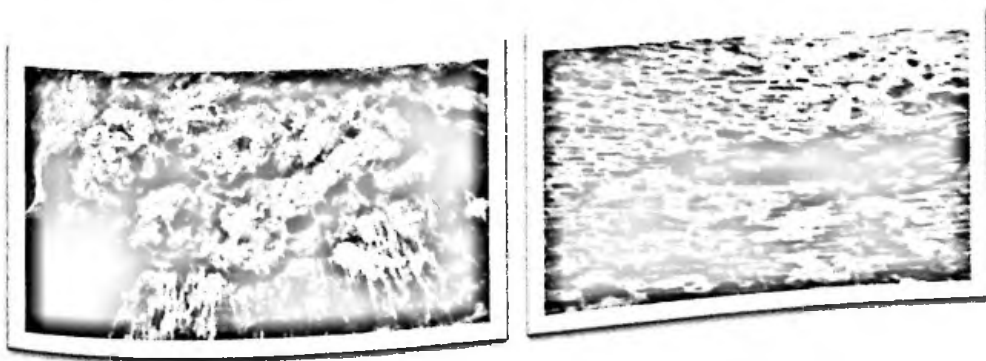
Ferns -Picture 100

In the interior as well as in the exterior of the monument algae, lichen, fungus and moss are spread. In the interior within the part of *Mandapaya* where excessive dampness prevails moss, fungus, algae, lichen all micro organisms are more or less found grown on walls.

Damage caused by animals

Swallows

A large number of nests built by swallows can be seen at the entrance to the *Garbagruhaya* in the *Antharalaya*. Walls have been stained by faces of swallows. Again swallows have built nests at the center of, the dome roof of the *Garbagruhaya*. Activities of these animals cause grave damage to both existence and beauty of the monument.



Nests of swallows - Picture 101

In most places of wall and plaster in Thuparama image house are very weak in due to infection natural environmental and manmade case of decay.

Deterioration of plaster due to its weaknesses

Due to defects and lack of standards of plaster subsequently it dissolves and disappears leaving only the brick. Then openings are made and bricks come to the surface. If this process is continued not only the plaster will disappear in its entirety but also the wall will collapse due to breach of binding among bricks. It might damage the monument to a great extent. Several places that had undergone this infection can be identified in both interior and exterior walls of Thuparama Image house.

Deterioration of fragile bricks while leaving the hard plaster intact

According to this process less strong, bricks are deteriorated while more strong plaster is left intact. This plaster which is survived looks so ugly that it is harmful to the beauty of the fine bricks erection. If this process goes on like this the monument will be destroyed. This kind of harm caused by dissolving of brick can be found on rear and side well as.



Soft brick in hard mortar

Picture 102

Dissolving of un backed bricks

Bricks not properly burnt are liable to disappear more swiftly than other bricks. When they dissolve they leave unpleasant openings on walls of the monuments. This

ugly appearance readily destroys the aesthetic value of the monument while dissolving of wall bricks may be harmful to its existence.

Damage caused by pressure

Although on large walls of the monument a few cracks caused by vertical and horizontal pressure were seen at the begging subsequent conservation restored them. But signs of a considerably large crack just above the first window of the *Garbagruha* adjoining the southern wall of the monument can be seen.



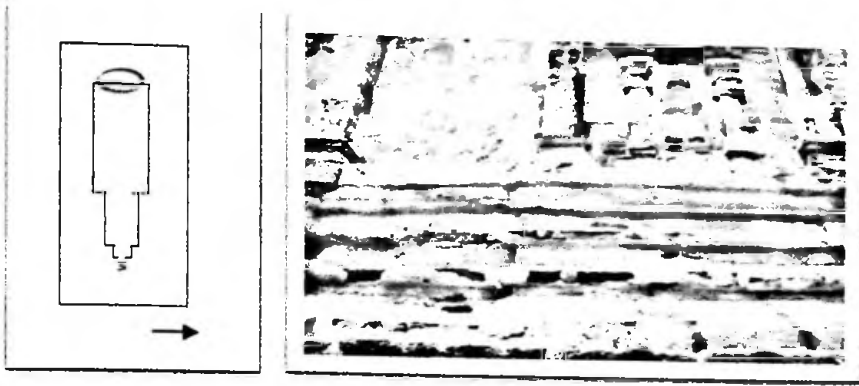
Cracks in Thuparama Image house

Picture 103

Damage caused by wind

When swiftly blowing wind strikes against the monument it causes harm. Wind vibrates bursts and splits building with high roofs. Then wind also erodes surface of monuments by striking, giants them grains of sand and dust. Particles brought with it. The rate and form of deterioration are determined by the speed of the stroke of wind and the span of its striking against the surface which it contacts. As Thuparama Image house is small in size and not much tall the first stage of deterioration cannot be seen here. Brick and lime plaster layers have been weakened in the face of various environmental factors for the last hundreds of years and we can see how wind has made its load carried with it strike against bricks lime plaster layers of Thuparama Image house and eroded them.

Then again Vimana, Boredom lime plaster and bricks at the rear of the monument have been eroded by wind.



Back side of Thuparama eroded by wind

Picture 104

Influence exerted on interior walls of Thuparama by wind

Wind has eroded bricks and plaster of the front wall by striking against the face direct. Again by travelling further inside bricks of side walls of the *Mandapaya* and that of corners have been eroded. These bricks which lie near the ground are very fragile as they have soaked water. They have been eroded by wind. Place eroded seem to have been subsequently conserved.

Botanical Damages

Thuparama Image House is also a monument which has undergone severe botanical deteriorative factors at the beginning. However, owing to recent conservation it is protected from botanical deteriorative factors to a great extent. But still harm is caused to brick and plaster layers of this building by micro pants such as fungae, algae, lichen, moss and other plants. On the basis of random sampling we studied out collected specimen from places abundant in them. It is in interior of the Image House that bacteria and fungae are most common. low Light and excessive humidity have provided them necessary environment for the growth of bacteria and fungi. In particular, *Mandapya* of the Image House *Antharalaya* are the parts where fungi and bacteria are found to a great extent. A white fungus can be seen on upper walls of *Antharalaya*.



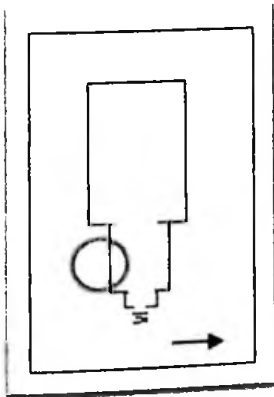
Bacteria and Fungi attack in Thuparama image house

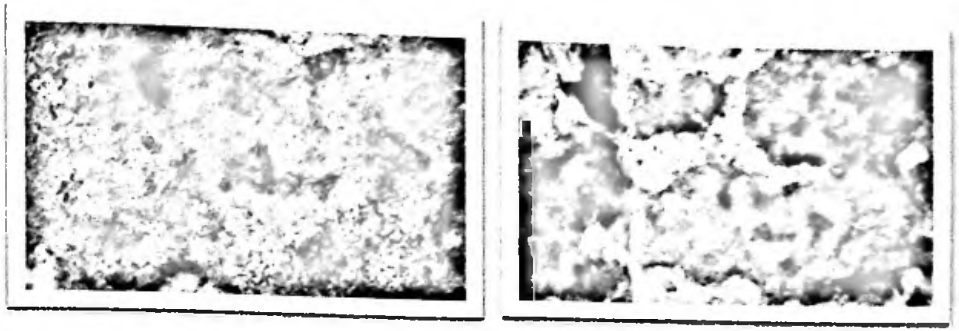
Picture 105

A white fungus can be seen under the broken arch which lie at the starting point of *Antharalaya* the monument. Another fungus can be found in past of the arch at the rear of the main wall.

Algae infection

Algae infection is found both in the interior and exterior of the Thuparama Image House. The growth is noteworthy specially interior of front and side walls of Mandapaya of which of roof has broken. They grow very well here because the environment is humid and but they damage bricks and plaster of the monument and a threat to its beauty.





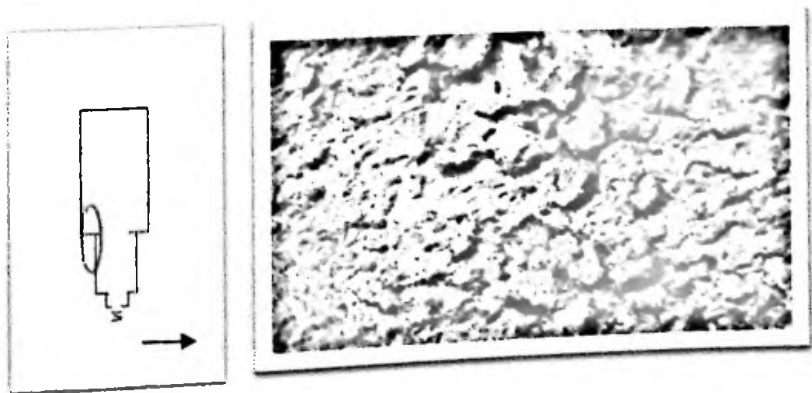
Algae infection in Thuparama image house

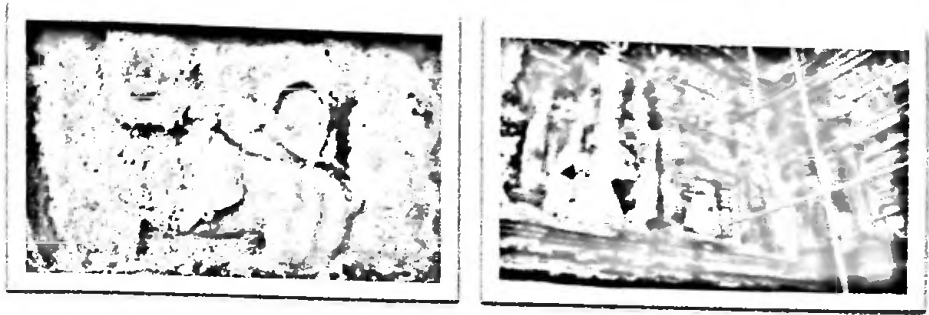
Picture 106

Green algae as well as brown algae can be found here. They grow on plaster and harm the beauty. Compared with Lankathilaka, Thiwanka Image house, Kiriwehera, Prakramabahu palace etc. Thuparama Image house has the least algae infection in it. Algae infection is found at the base of north wall in the exterior of the monument.

Lichen infection

Compared with other monument white and light yellow lichen infection is lesser here. But on the base of the southern, northern and western walls where *Antharalaya* and *mandapaya* join. Light blue lichen with moss are grown covering an extensive area. Light green lichen is grown under the gutter of the northern wall. Light green lichen is grown under the gutter of thee northern wall. Light green lichen is in the process of being grown on the upper part of the southern wall.



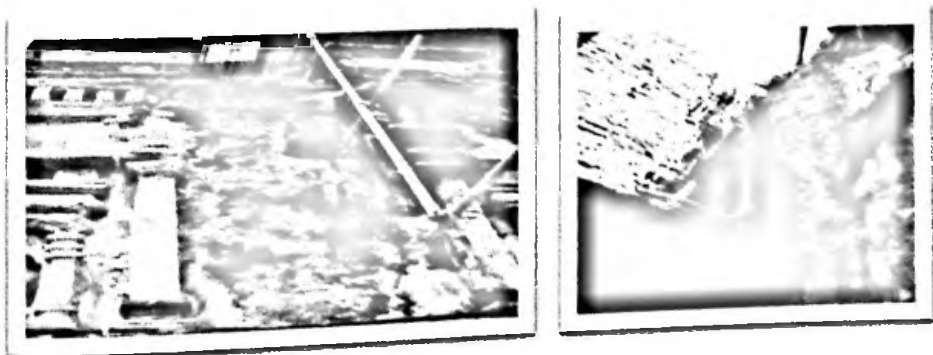


Lichen infection in Thuparama Image house - Picture 107

In the interior of *Mandapaya* on the southern wall mixed with moss finer growth of light green lichen is found. Again in the *Mandapaya* light green lichen is grown.

Moss

Moss is a micro organism, widely distributed on exterior and both interior of Thuparama Image House. Black moss covers lime plastered walls and Vimana erections of the Thuparama Image House to a great extent. When dry season comes this moss flakes off removing along with it part of surface of lime plaster. And the blackness of this moss is harmful to the aesthetic value of the monument. This deteriorative factor is not much wide in the part where the shelter is erected and in the Thuparama Image House. Accordingly the root cause of this ugly looking moss is the constant exposure of the monument to rain. Again this black moss is widespread on walls of Thuparam Image House. Reason for this thick growth of moss on these walls is that rain water which the roof receives flows down along the surface of these walls. In the dry season as we have already referred to above the black moss flakes off removing a part of the surface.



Flakes off moss - Picture 108

In Thuparama Image House the interior ground where a part of the arch roof collapsed become wet and damp during the rainy season. Interior walls remain damp continuously and as the interior does not receive sunlight well they do not dry fast. Therefore excessive humid conditions prevail on walls and in corners of walls. This exceeding humidity favors the growth and existence of moss on the bricks and in corners. In the *Mandapaya* this monument on lower and upper parts of walls which are constantly exposed to rain moss has grown.

At the foot of the wall salt deteriorative factors are exceedingly active and on such walls moss is widespread. In the *Mandapaya* On the path near the lower base of the southern wall. Moss is grown covering a vast area. This growth makes bricks on the wall excessively wet, and in turn they become less strong and fragile.

Damage caused by animals

Activities of animals frequenting Thuparama Image House include the presence of swallows and potter-wasps and presence of large number of their nests.

Potter-wasp

Potter-wasps have built exceeding large number of nests inside *Garbagruhaya* at its rear, in interior of western, southern and northern walls, on side walls and on the firm seat in which the Buddha is seated.



Invading erections of Potter-wasp the infirm seat



Attact of Potter-wasp in Thuparama image house

Picture - 109

Termite

Mode of life of termites in the interior of the *Garbagruhaya* can be seen on its, northern wall. A large anthill built by termites on the base in the north-western corner in the exterior of the monument can be seen. If this process develops and goes on further it might lead to grave consequences.



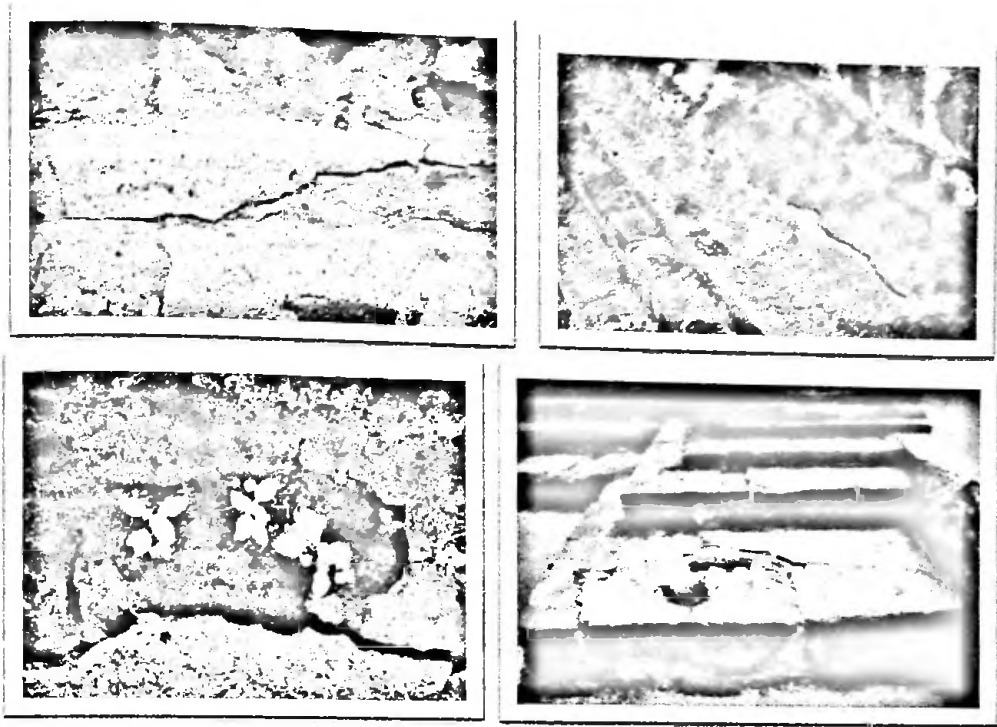
Termites on the base - Picture 110

Quadrupeds

In addition Ape and monkey who frequent this zone cause damage by walking on the monument and by discharge of faces.

A number of defects caused by various deteriorative factors during a long time can be seen on the base. Lime plaster spread on the base has been dissolved, cracked

length wise and separated from the wall. A number of such cracks separating. Plaster from the wall can be seen on the base of the entire monument.



Base if split, cracks and subsidence in Thuparama image house

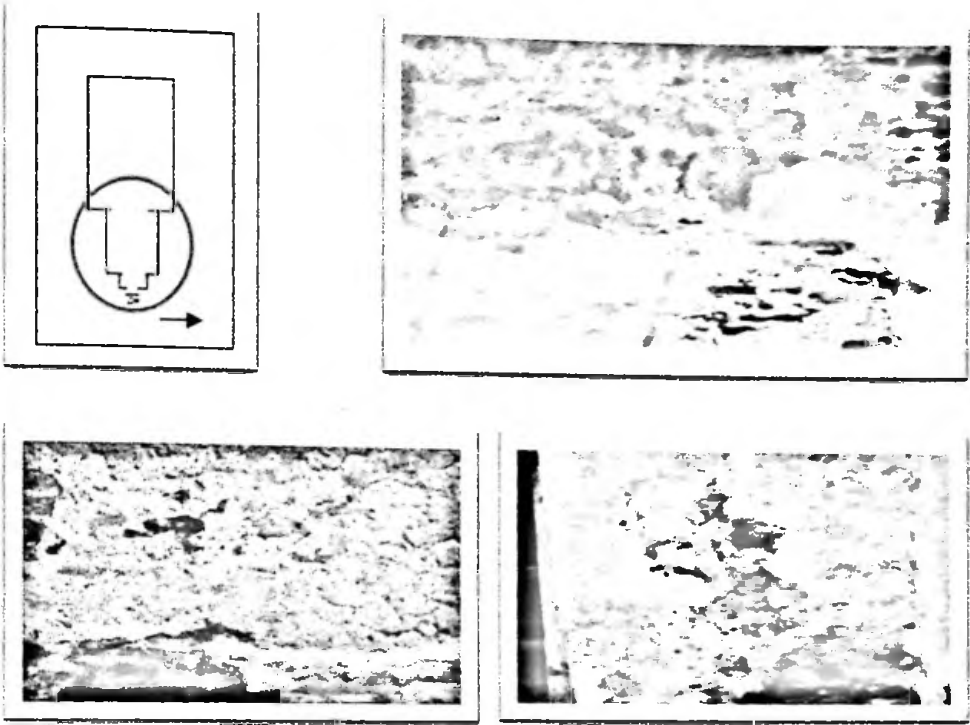
Picture 111

Moreover, some places have sunk, some cracked and some separated. It is not liner in from but infirm with subsidence and bends. Taken as a whole plaster in some places of the base has been dissolved. Some places have subsided. Some places have been cracked to a great extent.

Damage due to rise of underground water

With the excessive rain amount of water which the earth ground receives rises and in consequence underwater level goes up. With the rise of the underground water the amount of water absorbed by the monument through capillary process increases and also goes un further, By this process salt laying underground mixes with water and then goes up. Following vaporization salt deposits on brick walls approximately their surface. This action leads to dropping of both brick surface and lime plastered surface in the form of

powder. This salt infection process can be seen on both interior and exterior base of the monument.



Damage of salt - Picture 112

As the bricks adjoining the base absorb more water clay particle containing in them may expand and untie. Then bricks decay and ultimately monument decays.

Furthermore, as the region of the monument affected by ground water is damp the risk of the growth of micro organisms such as moss, algae, etc. is more. Further, dampness is a threat even to the beauty of the monument. Again the salt containing ground water may easily break lime plaster spread on the brick and untie it.

Plants and trees

In our sample collection on both interior and exterior of Thuparama Image house we found sapling of large trees such as Bo, Nuga plant.



Bo (*Ficus religiosa*)

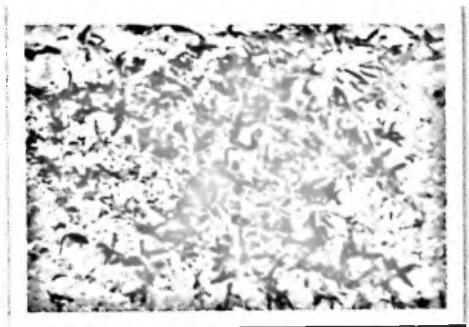
Nuga (*Ficus virens*)

Trees in Thuparama image house - Picture 113

Various plants of trees grown on bead behind the monument have been seen

.Kind of plants

Various weeds such as grass, *val pathpadagam*, *kepumkiriya*, *valsarana*, grown on molding behind the monument have been seen.



Plants in Thuparama image house - Picture 114

It is evident that brick monuments in Polonnaruwa are being damaged by multiple causes, which include natural, environments, factors and human facts. If the causes are identified without ambiguity it is possible to formulate a guideline and a philosophy for preservation of them.

Chapter-03

Identification of the courses of decay brick monument in Polonnaruwa.

In this chapter a deep study is made in to the brick built monuments where deteriorative factors presently are in action and the causes that helped them at the beginning.

3.1. Roof

In the study of all four monuments, namely Royal palace of king Parakramabahu, image houses of Thuparama, Lankathilaka and Thivanka have been taken to task. Roofs of these monumenyts other than Thuparama image house had been completely destroyed with the passage of time. The time of their deterioration cannot be established exactly. All the time of the discovery of these monuments during the latter past 19th century by Europeans those roofs had been collapsed and destroyed. The royal palace of king Prakramabahu in Polonnaruwa was constructed with seven floors consisting about hundred rooms. Archaeologists believe that the wooden roof had been erected over it and covered with tiles. During the rule of Magha, the ruthless invader, this remarkable palace along with other buildings were destroyed by fire. These are some things that found in the premises providing clauses about an excessive heat by the palace at a certain incident. Due to the exposes to various environmental and natural deteriorations without any protective roof, this building has been subjected to large scale erosion through centuries. Especially heavy rainfalls frequently experienced in the present times, pave way too many deteriorative agents to inflict tremendous damages to this once magnificent building.

Although the roof of Parakramabahu palace was destroyed by human action during early times, monuments like Lankathilaka and Thivanka had to face different group of factors that resulted destruction of their roofs. They were the image houses with vaults roofs, a sort of brick and motar masonry work in arched shape built upon two thick high rising

side walls. These types of vaulted roofs are not to be seen presently either at Lankathilaka or Thivanka image houses. Only a part of typical vaulted roof remains to this day. Remains to this day threatened with imminent collapse. Frontal part of it already collapsed.

3.1.1. Natural cause of decay in roof

Ancient monuments are also subjected to natural causes of decay. Gravity of the monument in relation to the earth and also the weakness of the structure cause serious damages to the existence of brick monuments. Completely destroyed roofs of Lankathilaka and Thivanka image houses and the remaining part of the roof of Thuparama image house provide several instances providing this fact.

These roofs had been constructed in accordance with certain architectural design and specifications. It must have been very important to design with accessory the structure and also the selection of qualitative raw material. Any weakness in these factors could have made some lapses with regard to the strength of the structure.

Construction of arched roofs using bricks is not suitable to a country like Sri Lanka where heavy rainfalls occur regularly. This mode of architecture was long lasting in south India where stone slates were used instead. But Sri Lankan builders opted for earthen bricks which could not withstand regular heavy showers as in Polonnaruwa. As such, the major factors that affected the destruction of vaulted roofs, was the incessant rain and heavy showers.

The raw material used for the structure is important. The strength or the weakness of the structure depends on the quality of the raw material used. The monument will collapse when it cannot bear the weight due to defective raw materials. The buildings in Polonnaruwa with roofs made of bricks have confronted this danger. (*Gedige Tradition*). E.g. Lankathilaka Pilimageya, Thivanka Pilimageya and the front section of Thuparama Pilimageya.

Deterioration of material

Weakness of bricks

As a result of using unburnt bricks of poor quality when the monument is being built holes and small cracks will appear in the structure before long. This affects adversely on the beauty, existence and strength of the monument. This condition is very often visible in old brick buildings. This also can be identified as a fundamental weakness in brick constructions. When the framework of the structure is visible due to wearing away of the outer coating, it will display an ugly sight.

Vaulted roof covering the chamber dome of Thuparama still survives to this day. Presently, there appears some ribs of mortar remain as a result of bricks within the inside had been eroded due to the seepage of rain water. This process, if continued may lead to the collapse of this remarkable vaulted roof.

Weakness of mortar

Similarly when poor quality plaster used with strong bricks, we can see that the bricks remain unchanged against climatic conditions while the coating gets corroded very quickly.

When the plaster is worn off, the binding force of the raw materials will be diminished and the joints of the structure will be weakened. As a result the whole roof of building will collapse. Presently this kind of infection can be found in roof of Thuparama.

A layer of mortar had been spread over the top brick layer of the brick built roof, in order to prevent the rainwater seeping inside the roof. However with the passage of time this protective lime mortar had been eroded and crack due to action of various deteriorative agents. It can be observed how water finds its way in the interior side of roof during the fall of rain. Image houses of Thivanka, Lankathilaka are without their roofs today all due to penetration of water to the interior and weakening lime mortar that resulting the collapse of overhead roofs. This factor could be understood by the evidence found at the Thuparama image house.

3.1.2. Environment case of decay in roof

Climatic cause, biological and botanical cause and natural disaster like environmental factors directly intervene in the deterioration of roof entirely built with bricks. Several deteriorative agents, by their activities on insides and outsides of these monuments inflict these damages. External erosion caused by sun light, rain fall and wind exhibits high level deterioration. Major internal factor is the humidity. Collapsing of all brick made roofs of ancient monuments in Polonnaruwa caused mainly by environment factors.

Climatic cause of decay

a) Deterioration cause by sun light and heat

Sunlight causes the destruction of every monument including brick monuments. Mainly, sunlight acts in two ways to destroy the monuments.

1. The ultra violet rays in the sunlight can fade the colours and the paintings in the monument, greatly damaging the artistic beauty of the monument.
2. The rays up to 500 nano meters can warm the building materials. This heat can cause a great destruction to buildings.

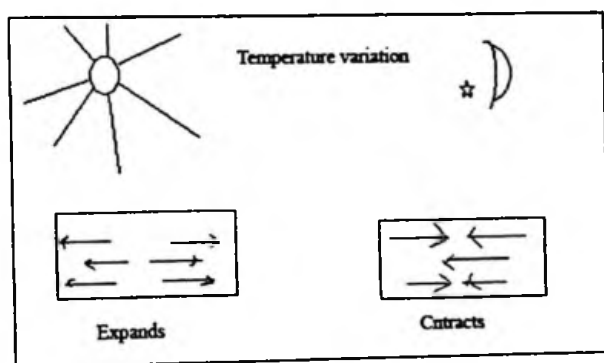
Due to long waves and short waves emitted by sunlight during the day, the atmosphere gets warm. Convectional activity during night makes the atmosphere cold. When the heat increases the monument gets more heated externally and internally causing changes. The sun's rays act in three ways to make the building material heated.

1. Direct fall of sun's rays (as external rays)
2. Indirect fall of sun's rays(Through windows and ventilation holes)
3. Indirect heat (When the air in the environment is heated, the air inside also gets heated making unexposed parts also heated.)

All these building materials expand when heated by sun's rays and when it gets cold, they contract. Brick and lime plaster which made of vaulted roof all so faced this

situation. This process takes place about 8-10 hours per day and when the sunlight falls again the process of heating starts. This happens nonstop in a cycle and causes great damage. Raw materials which face this process for a long time, sometimes for centuries get damaged. This heating and cooling process causes its destruction of building material. Building material becomes prey to the process of heat circle happening daily and periodically. Because of this, the heat cycle supplies an important sources about the stress caused by the heat on building material

This affects the raw material to be expanded and contracted continuously. There by the strength of this raw material is lessened by making big and small cracks, splitting and loosening the joints of the structure. Besides, due to the process of expansion and contraction damage is caused to the attachment between bricks and lime coatings with different heat expanding qualities. It causes the whole structure to be weak. In this manner, the brick monuments in open spaces face a lot of stress in interior and surface areas of the raw material as consequences.



Expansion and contraction damage caused

Picture - 115

Consequences

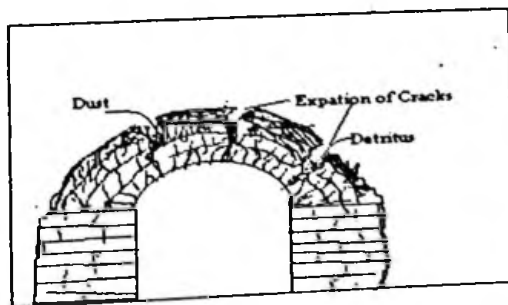
- Breaking away of large parts
- Peeling off the surface
- Minute cracks on the surface and interior parts
- Losing the attachment between the plaster and the bricks

- Loosening and splitting the attachment between the brick structure and the plaster.

In this way, changes that place take place during day and night because a lot of harm as Sri Lanka has a tropical climate, the deference in temperature during day and night in great. Hence the harm caused to the vaulted roof and building material is also greater than that of the other regions.

Due to continuous thermal expansion the edges of the fittings in buildings go apart. During contraction they will not fit as at first. The particles that get into the edges when opened do not allow them to fit well. Therefore during continuous thermal expansion process the cracks are formed again and again (Torraca.1982:28)

This kind of cracks grown can be seen vaulted roof in the Tuparama image house. When the thermal expansion which occurs on building material comes together, there will be stress on the raw materials and when scattered, it will cause harm to the monument. This resign also affect deterioration of brick roof in Thivanka, Lankathilaka and Thuparama Imaje houses. Stress is caused to the structure of the roof by the thermal expansion making it weak. This weakness results in collapsing the whole roof. Protected original lime plaster of vaulted roof in Thupareama imaje house was crack and destroyed the reason of this The stress caused by thermal expansion on the structure of the building, will cause the outer covering raw material like plaster to be destroyed. The plaster and the structure expand in two ways during thermal expansion. The edges do not expand in relation to the plaster. When the outer covering expands leaving out the edges, monuments will be deformed with cracks and parts jutting out. Those are the effective factors deterioration of brick roof.



Growth of cracks during heat expansion - Picture -116

In this way due to stress caused by thermal expansion, the plasters of the vaulted roof get deformed. Due to the impact of heat and stress on the outer coverings of buildings, it is estimated that 6mm will jut out in 10 °C temperature. All the building material expand when heated and contract when cooled. This process of expansion and contraction is reason thermal movement cause. This process strongly affects the destruction of vaulted brick roof in historic buildings. But the colours and the ability to reflect change the contribution of getting sun's rays. Thus it is clear that the raw material used in building constructions contain different levels to thermal expansion qualities. To be brief the value of thermal expansion coefficients of the raw material is the expansion of the raw material resulting by sun's rays. The raw material which has high rate of thermal expansion shows high sensitivity to the heat and they will get deformed or destroyed when faced with heat. Efficiency of thermal expansion is low in brick raw material in relation to other raw materials. (Thermal expansion coefficients of the brick 5×10^{-6}) Therefore in relation to other raw materials it has the power to stand against heat. But lime plaster Thermal expansion coefficients is 8:- 10×10^{-6} then the brick.

When brick structures get expanded and contracted continuously by heat, they face destruction. Large cracks, splitting parts, peeling off the surface, small cracks on the surface, weakening the grip within soil particles, loosening the bricks, weakening the grasp between the bricks and the plaster can be mentioned as destructive forces that deform the structures.

In the same way, range of changes in weather and Heat considerably affect the process of thermal expansion the climate in the temperate zones close to the equator changes daily, six monthly and annually and the historic brick buildings are susceptible to these changes. Deteriorate in vaulted roof structure in Thvanka and Lankathilak are the factors that affect deeply.

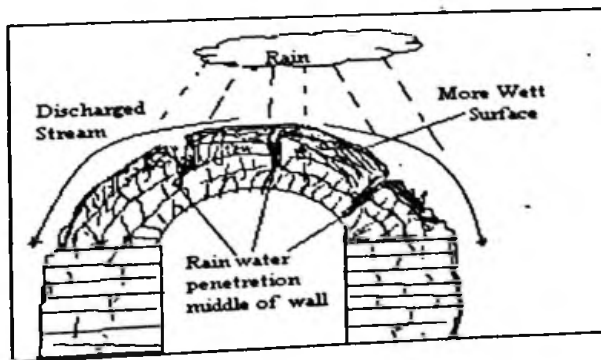
When studying the degree of changes in the temperature, the minimum and maximum heat in the atmosphere and the time duration are taken in to consideration. Even in Sri Lanka within 24 hours, the temperature changes from 21^{oC} to 37^{oC}. (Data collected by us in Polonnaruwa on 14th and 15th January 2010) the changes that occur due to the impact of temperature on building materials are determined by several causes.

b) Deterioration cased by rain

Erosion caused on the surface of brick made roof

Polonnaruwa city is situated in the dry zone of Sri Lanka. About $\frac{3}{4}$ of the land in Sri Lanka is in the dry zone which receives a rainfall of 12,700 – 19,000 min (50-75 inches) annually, mainly from the north east monsoon wind. Almost whole of the rain is fallen on to the dry zone during the months of October, November, January and February. Rainfall during the rest of months is less than 500mm. The rainfall received a Polonnaruwa is 890- 1900mm, annually. When compared to the annual rainfall received at other dry zone area of the world Polonnaruwa in our country receives considerably higher rainfall with higher fluctuations. Therefore it is questionable, whether this zone really belongs to dry areas, when compared to the other dry areas of the world.

During rainy seasons, rain water directly falls on the brick built vaulted roof and thick layer of lime mortar is washed away. This layer already weakened by other deteriorative factors is easily worn out by this eroding process. As the roofs of Lankathilakaya, Thivanka and Parakramabahu palace are already collapsed ,the wall upper parts of these monuments and the interiors are feing washed away and water is being permeation of water in the into with each rainfall. In rainy season there serious two powerful damages due to the incessant heavy rain. The first is the heavy showers falling on the surface of monuments and washing away of it and cracking much water seepage in to brick walls and to brick works. Besides, excessive seepage of water may cause sliding or crashing down higher parts of brick roof. Unburned bricks may loosen and weaken the monument, due to erosion of clay mortar, time mortar, lime plaster etc.



Erosion caused on the surface - Picture - 117

Presently at Tuparama image house where the only remaining brick built vaulted roof could be seen, has a crack towards the center of the roof through which rain water seep inside and the bricks there in had been atrophy out.

As the roof of *Antharalaya* and *Mandapaya* of Thuparama has been collapsed interior walls as well as other parts become wet during the rainy season. This gives rise to increase of humidity in the interior of the monument. Further on side walls of the monument moss, algae as well as small plants have grown.

Image houses like Thivanka and Lankathillaka built in ancient times and which had been built exclusively with bricks including vaulted roofs. Fall of rainwater's continued on these monuments through centuries have gradually eroded the protective roofs by permeating water through cracks, washing away of brick surfaces, soaking bricks with abundant water etc. All these deteriorative factors jointly contribute to weaken the finding strength of bricks combined with other agent of erosion have finally caused the collapse of these roofs.

c) Deterioration caused by wind in roof

Deterioration cause by seasonal wind

Wind makes certain action in destroying historical buildings which don't have resistance power. As such there should be a resistance power in the structure and wind wards of those buildings to withstand wind pressure. Historical buildings built with bricks possess the strength to resist powerful winds. But this resistance power would not be sufficient to withstand very powerful gusty wind. At these instances, wind may cause damage to the structure of the brick monuments. Forces generated by wind can do much damage high towers of the buildings. Not a single building of Polonnaruwa retains only roofs. Particularly brick buildings in Polonnaruwa period don't have any roof. Lankathilaka and Thivanka Image Houses had their arched roofs built with bricks. Presently they are collapsed down to the ground. Especially, it is evident, that the brick built roof on Lankathilakaya, which was a very tall building, must have been destroyed by strong winds.

The vibration generated by powerful gusts of wind also cause serious damages to monuments. All the roofs of brick buildings must have been collapsed down due to wind action. Thparama image house short than other image house in Polonnaruwa therefore it can covered by speedy winds attack. Therefore large part of vaulted roof protected. But owing to subsequent deteriorative factors its vaulted roof made of brick and belongs in to the front *Mandapaya* and *Aantharalaya* has been collapsed.

When swiftly blowing wind strikes against the roof is causes harm. Wind vibrates bursts and splits building with high roofs. Then wind also erodes surface of monuments by striking, giants them grains of sand and dust. Particles brought with it. The rate and form of deterioration are determined by the speed of the stroke of wind and the span of its striking against the surface which it contacts. As Thuparama Image House is small in size and not much tall the first stage of deterioration cannot be seen here. Brick and lime plaster layers have been weakened in the face of various environmental factors for the last hundreds of years and we can see how wind has made its load carried with it strike against bricks made roof and plaster layers of Thuparama image house and eroded them.

d) Damage cause due to joint impact of wind and humidity in roof.

There are instances of damages caused to brick built buildings by joint action of wind and humidity. With the fall of rain water regularly on to the vaulted roofs bricks get sacked excessively, thereby loosening their binding strength. At this juncture mass of particles propelled by wind power dash on to the brick surface thus quickening erosion process. This erosion could be witnessed at the still surviving vaulted roof on Thuparama image house. This same process might have been the cause for the likewise collapsing of vaulted roof of Lankathilaka and Thivanka image houses.

Botanical and Biological cause of decay in roof

a) Botanical cause of decay

Activities of animal and herbal factors are also important, in this study of bricks built ancient buildings in Polonnaruwa.

In early times builders used earthen bricks in their building works including roofs. Soon a

growth of herbs appeared particularly on the bricks built roofs where checks, pores and cavities developed by the roots of various growing herbs moreover the spreading roots make pressure inside of the brick layers. All these activities have directly contributed to the collapse of those vaulted roofs. After the centuries of covering by vegetation these monuments were rediscovered by Europeans during the latter part of the 19th century. Thick growth jungles had almost caused entire buildings to seemed.

These growing of wild herbs had taken a major part in contributing for the deterioration of roofs walls and other parts of Lankathilaka and Thivanka image houses.

Presently, vaulted roof could be seen only at Thuparama image house where the growth of large plants no more to be seen. However, it appears that growth of smaller plants various. Wild herbs algae, lichen, moss, bacteria, fungi are take part in destroying the surface layers.

Algae and moss have grown profusely over the dome. Small herbs are also growing on it. Due to thick spread of moss over the dome, there prevails more humidity wherever moss dries away the surface mortar layers is wearing away, damaging about 03 millimeters depth at a time. Each year this cycle of growth and decay of moss begins with the rainy seasons, ends with the dry seasons. This process is injurious if continued for a long time, to the existence of the monuments.

Antharalaya and *Mandapaya* the pavilion parts of the Thuparama image house had suffered with the collapse of the roof and as a result, rainfall is directly experienced there during the rainy season. As a result humidity goes up and allows moss, algae, lichen and various wild herbs to grow on interior of the monuments as well as on the wall parts that bore the roof and other parts in the vicinity.

Lichens have the ability to survive in any difficult environs and also to prepare situation conditions for, any herbal community to grow upon. Lichen settled on bricks and lime mortar excretes some liquid, enabling chemical dissolution of lime mortar. Remnants thus dissolved are deposited in cavities of brick work or on the cracks found on brick. As time goes on, a thin layer of some soil is formed on these cavities and cracks, on which moss and fungus grow up easily. Moss dries up allowing more carbonic materials to gather in, these thickening soil layers. Furthermore moss create humidity environment within the monument encoring for their growth of various plants and shrubs

spreading their roots and branches freely.

With the growth of herbs on lime plaster and bricks process of deterioration is quickened. Spreading of herbal root luster's within the cracks and cavities forever enlarge such points these allow more water travelling inside especially, this process do more harm during the drying up of herbs and roots. The collapses of vaulted roofs built with bricks have been affected by these processes.

(b) Biological causes of decay in roofs

From the Thuparama image house where the roof is somewhat preserved, we are able to identify several of animal made activities potter wasp (*Delta flavopictu*) have built numerous dwelling abodes there, tarnishing beauty of the place. These dwellings destroy the original lime mortar. Paintings are not to be seen inside of the chamber wherein potter wasp would have disfigures them all.

However Swallow (*Petrochelidon pyrrhonota*) have built their nests inside of the vaulted roof and continued process of this deed shall damage the aesthetical value of the monuments. Their excreta may also degenerate the interior lime plasters of the image house.

3.1.3 Manmade causes of decay in roof

When considering the damages inflicted to this monument by man we can comprehend several instance like, desertion by man, lack of attention and also the harm done at the conservation efforts. He has used cement in conserving vaulted roofs thereby salt is deposited inside of it and also building downs are appeared. This situation poses a threat to the aesthetic value of the monuments.

Due to the back of good maintenance work many herbs algae fungous cause extensive damages. It is necessary to prevent rain water flowing down, along the walls from the roof, by introducing a suitable drainage system. Smaller cracks near the foundation and the wearing out of lime plaster there, need vital repairs furthermore attention that not

been paid yet to remove nests built by potter wasp (*Delta flavopictu*) and Swallow (*Petrochelidon pyrrhonota*) at the interior which is thus disfigured now. Hence these causes of decay belonged to the responsibility of man.

Further, harm caused to this monument through conservation itself can be seen here. The following serious damages caused through improper maintenance were identified.

1. If nests of swallows are not promptly removed their population will increase and in turn the amount of faeces fallen on the monument will increase and thus the walls will be defiled.
2. Various acidic substances contained in faeces of birds will lead to chemical reactions on the lime plastered wall and thus will Wee ken the plaster.
3. Further, excessive presence of faeces and nests is harmful to the aesthetic value of the monument.

Again no action has been taken so as to minimize or to curb altogether the spread of potter-wasps who invade the *Garbagruhaya* swiftly.

Again fungus, algae lichen and small and big plants grown on both interior and exterior of the monument are a threat to its aesthetic value as well as existence. More attention must be paid so as to remove them. In particular a more formal action must be taken so as to remove the black moss which predominates the outer sides.

The interior of the monument where the arch roof has collapsed is getting wet and as a result salt infection and damage caused by humidity occur. Therefore, formal action must be taken to prevent the interior from the wetting due to absence of the roof.

Therefore, inattention on the part of the man to conservation and maintenance itself is the grave harm, caused by men. Therefore, it must be eliminated.

3.2. walls and plaster

Palace of king Parakramabahu and the image houses of Thuparama, Thiwanka and Lankathilaka are 800 years old construction built with bricks notwithstanding that many parts of these monuments had been destroyed there still remain brick made walls and

lime mortars in considerable portions. However it is evident that, ecological, environmental and manmade causes during several preceding centuries as well as in present times have caused series damages against the future existence.

3.2.1. Natural cause of decay in walls and plaster

All the building of Parakramabahu palace, Thivanaka, Lankathilaka, Thuparama etc. had thick brick walls constructed with lime mortars. Surfaces of the walls covered with lime plasters and colour painted. Below the moldings of walls, lime plaster made statute of lions swans were there and presently they are mostly destroyed.

Another aspect is that numerous cracks, bulging, subsidence and collapsing appearing on brick walls and lime motor may have caused by the heavy weights of raw materials and weight of roofs themselves. Even the very foundations couldn't withstand the unusual heavy weights of sinking and cracking walls.

Upper wall pants of Parakramabahu palace had collapsed due to long time detritions process and the gravity of the construction materials used. Presently remains of only two floors are to be seen where large scale and small crakes and also crashing downs of lime plasters visible.

Weakness of Materials used in Walls and Plaster

Un-burn Bricks

It could be seen from the studies made on buildings as to the decay of worn out bricks allowing formation of gaps evident in the walls of monuments built with bricks. This phenomenon poses a threat to the beauty and to the very existence of the building concerned.

The reason for wearing out of bricks used in ancient brick built monuments is the weakness of raw materials used at the time of construction. Using of unbent bricks in masonry work might have invited in the deteriorative agents in making holes and gaps in these monument walls.

The royal palace of king Parakramabahu is a colossal building constructed with a

tremendous amount of bricks. But the use of weak bricks and not well bunt were vulnerable to the elements with the passage of time these worn out bricks gave way to formation of holes and gaps, thereby tarnishing the beauty of the edifice and also weaken the strength of these remarkable creations.

About this place of degeneration other deteriorative agents settle in easily. Especially uman's soil is formed allowing a favorable getting to grow up various grass, herbs and plants etc. Bricks of some sub standard guiltily had been used at the construction of Thivanka image house had worn out speedily due to erosion resulting formation of holes and goals in the walls of the monument. This development is more widely spread about the western and southern walls of these monuments.

of this monument too had worn out speeding in the face of deteriorative agents. This is a threat to the beauty and strength of the monument. Bricks had been worn out extensively n southern wall and in the inner walls near to the foundation and also in two large frontal columns. Use of sub standard bricks had been subjected to soaking of water and flowing of wind expediting the process of decay.

These deterioration features can be seen also at the Thuparama image house there the inside bricks of hither to surviving vaulted roof are being decayed. Outside bricks of westward wall had been delayed due to deteriorative agents. Winds flowing with high humidity from western side Parakrama Samudra had quickened the wearing out of weak bricks in western wall is another factor.

Weakness of mortar

Majority of buildings were constructed with the use of bricks. As such lime motor is very important factor, being the foremost finding materials employed in setting of bricks. At the time of preparation of mortar correct ratio of mixture need to be attained. Any weakness of mortar paves the way to delay brick work completely or partly and supporting brick walls remain to be seen continuous exposure of brick walls for a long period, as a result of the decay of lime mortar various eroding factors have made their mark in brick walls. Palace of king Parakramabahu and the Lankathilaka image house are without their roofs presently and as a result 90% of the mortar applied on brick surfaces

had vanished. Also lime mortars of Thuparama and Thivanka image houses were largely destroyed. As a whole these lime mortars used in the construction work were of very high standard. However due to the change of quality at several places, there appears some instances where mortar had decayed in a short time. In fact rainfall and wind too had directly contributed to quicken this process.

3.2.2. Environment cause of decay in walls and plaster

Majority of buildings of the ancient city of Polonnaruwa have been constructed with the use of brick and mortar. These materials are very sensitive to the environmental factors. Climatic factors like sun light and heat, rainfall and wind as well as floods and cyclones; Botanical and biological factors like herbs and animal made deteriorations man made follies like deterioration abandonment and faulty conservations etc. all these deteriorative causes have subjected these brick built monument during the post 800 years.

Climatic cause of decay

a) Sun light and heat as a cause of decay in bricks wall and plaster

Sun shine has affected to decay all the types of monuments as well as brick works and mortar. The extent of damages caused to bricks and mortar by sun light cannot be identified. Nevertheless damages caused gradually for a long duration need not to be ignored, for the reason that monuments are considered as national heritages for several future generations. Lankathilaka, Thuparama and Thivanka image houses and the Royal palace of king Parakramabahu situated in Polonnaruwa have been built with bricks and mortar of which decay had been caused by long time exposure to sunlight.

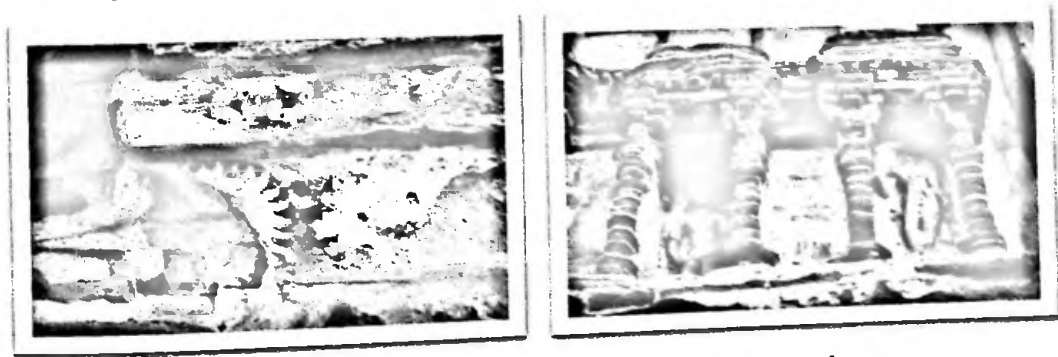
Sunlight causes the destruction of every monument including brick monuments. Mainly, sunlight acts in two ways to destroy the monuments

1. The ultra violet rays in the sunlight can fade the colours and the paintings in the walls and lime plaster, greatly damaging the artistic beauty of the monument.
2. The rays up to 500 nano meters can warm the building materials. This heat

can cause a great destruction to buildings.

Sunlight is a form of electromagnetic energy with two types of radiation, as visible radiations and invisible radiations. The naked eye can detect wave length ranging from 400 to 700 nano meters. Waves that are shorter than 400 nano meters are named ultra violet waves. Waves that are longer than 700 nano meters are named infra red waves. Rays of both kinds are invisible to the eye. Whether the source of light is natural or artificial, the rays emitted by it contain rays both visible to the eye and insensitive to the eye. Theories on electromagnetism explain that the energy incorporated in light is due to the equality in proportion of the wave lengths and that more power is generated by short waves. (Agrawal 1988: 12-13). Hence, wave lengths between 300 to 500 nano meters directly causes the disintegration of pigment applied on monuments made of bricks, art works etc., these light waves may also cause the destruction of the carbonic matter within them.

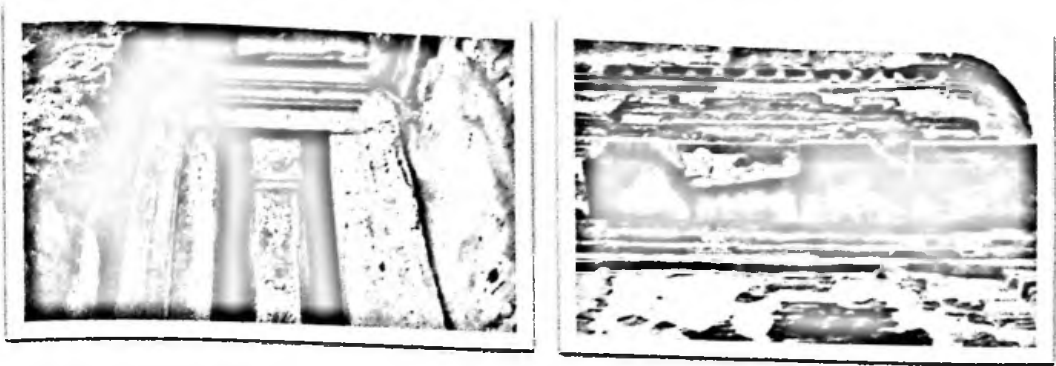
Inner and outer walls of these monuments had their lime plasters colour painted and beautified with paintings. All these had been faded away owing to the long time exposure to sun light. Outside of the southern wall of Thivanka image house still keeps a place where colourings survive, owing to non respectoin of direct sunshine there still remain places with colourings where the sun light does not fall directly, as in the places covered by moldings in between the carvings of outside and arched shaped window sections.



Paintings - southern outer walls in Thivanka image house

Picture- 118

In outside walls of Lankathilaka image house there remain colored places above the arched windows etc. where sun light does not reach directly.



paintings - outer walls in Lankathilaka image house - Picture- 119

Furthermore sun light had faded away coloring of paintings at the interior of Thianka image house. As the monument is facing towards east, sun light projects brightly in to the interior from morning to mid day. Collapse of roof had aggravated the damage resulting fading away of paintings beyond recognition drawn on interior wall near both sides of main doorway. Also, the colorings at places where sun light falls in to interior through windows and other doorways had been faded away. Example is *antharalaya* of southern wall of Thivanka image house possessed paintings drawn on walls, but had faded away by the sun light. Scorching sun light falls to the outside of southern wall during most of the day time fading away its colorings and paintings.

Wave lengths greater than 500 nano meters may cause the heating of the surfaces of these monuments. Through this, the processes of thermal expansion and thermal movement may take place. Other than that, it may supply the heat necessary for certain chemical reactions. As a result of all this, the heating process causes great damage to the surface of the monuments that originate from sunlight.

Likewise sun's radiation is the principal cause which determines climatic and weather factors. Sri Lanka is a country situated near the equator in the tropical zone. Here much sunlight is obtained throughout the year. Due to the presence of a long day time and much heat the monuments in the area are much affected by sun's rays. Accordingly in the Asian region the daily temperature is over 80 F. Sri Lanka is situated close to the equator in the 35⁰C zone. As a result the sun's rays fall directly and incessantly on the monuments in this region, while the day time is very hot, the environment gets very cold during the night. When the monuments have to face these contrasting forces they get

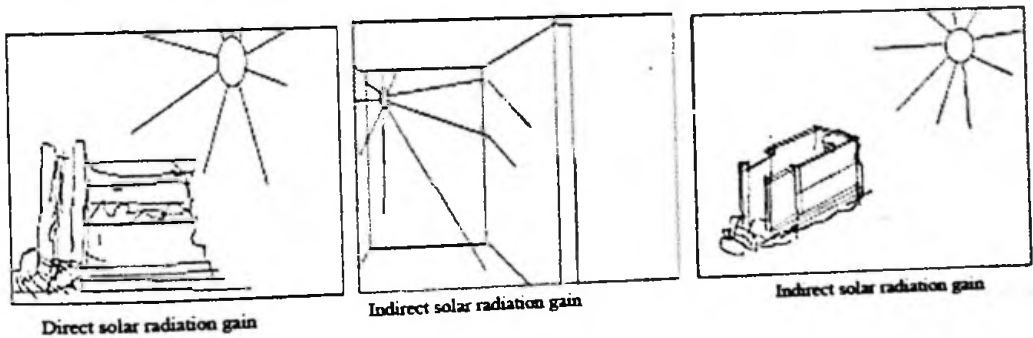
damaged easily. Sunlight causes greater damage to monuments in this region, than in other regions of the world. Different raw materials respond differently to the temperature. When sun's rays fall on the surface of the raw material, the energy is absorbed in different quantities. Some reflect light waves.

When there are no obstacles, sun's rays fall on the earth directly. It causes the sun rays fall directly on the walls of the monuments. These are measured by meteorologists using radio meters. Light colours ultra violet rays which can destroy monuments. Specially, carbonic raw materials are at a high risk of being destroyed.

Thermal movements' causes

Due to long waves and short waves emitted by sunlight during the day, the atmosphere gets warm. Convectional activity during night makes the atmosphere cold. When the heat increases the monument gets more heated externally and internally causing changes. The sun's rays act in three ways to make the building material heated.

1. Direct fall of sun's rays (as external rays)
2. Indirect fall of sun's rays(Through windows and ventilation holes)
3. Indirect heat (When the air in the environment is heated, the air inside also gets heated making unexposed parts also heated.)



The sun's rays act - Picture - 120

All these building materials expand when heated by sun's rays and when it gets cold, they contract. The raw material which reaches its maximum heat at noon gets cold late at night. This process takes place about 8-10 hours per day and when the sunlight falls

again the process of heating starts. This happens nonstop in a cycle and causes great damage. Raw materials which face this process for a long time, sometimes for centuries get damaged. This heating and cooling process causes its deterioration of building material.

Building material becomes prey to the process of heat circle happening daily and periodically. Because of this, the heat cycle supplies an important sources about the stress caused by the heat on building material. This kind of infection can be seeing even in Parakramabahu palace, Tivanka, Lankathilaka, and Thuparama image house.

This affects the raw material to be expanded and contracted continuously. There by the strength of this raw material is lessened by making big and small cracks, splitting and loosening the joints of the structure. Besides, due to the process of expansion and contraction damage is caused to the attachment between bricks and lime coatings with different heat expanding qualities. It causes the whole structure to be weak. In this manner, the brick monuments in open spaces face a lot of stress in interior and surface areas of the raw material as consequences.

Consequences

- Breaking away of large parts
- Peeling off the surface
- Minute cracks on the surface and interior parts
- Losing the attachment between the plaster and the bricks
- Loosening and splitting the attachment between the brick structure and the plaster.

In this way, changes that place take place during day and night because a lot of harm as Sri Lanka has a tropical climate, the deference in temperature during day and night in great. Hence the harm caused to the building material is also greater than that of the other regions. Heat expansion stands as a strong factor in the destruction of building constructions. Heat expansion causes stress on building materials. As a result the structures split and become ugly.

Due to continuous thermal expansion the edges of the fittings in buildings go apart. During contraction they will not fit as at first. The particles that get into the edges when opened do not allow them to fit well. Therefore during continuous thermal expansion process the cracks are formed again and again. This reason is common monument that we studied in Polonnaruwa.

b) Rainfall as a cause of decay in walls and plaster

Polonnaruwa city is situated in the dry zone of Sri Lanka. About $\frac{3}{4}$ of the land in Sri Lanka is in the dry zone which receives a rainfall of 12,700 – 19,000 min (50-75 inches) annually, mainly from the north east monsoon wind. Almost whole of the rain is fallen on to the dry zone during the months of October, November, January and February. Rainfall during the rest of months is less than 500mm. As a result, there prevails about four month long drought, in the dry zone from May to August under normal conditions.

Table—Annual Rainfall Chart in Polonaruwa

Year 2009 (LAT: 7.87LON:81.05ELEV:43.0M)	
Time	Rainfall mm
January	-9.9
February	1.1
March	16.1
April	246.1
May	21.0
June	0
July	35.4
August	49.8
September	20.1
October	105.1
November	301.2
December	543.6

(Source: Dept of Meteorology Polonnaruwa (2010.02.04))

Annual Rainfall Chart in Polonaruwa – 02

As per the chart most of the rainfall received in the Polonnaruwa city during November to December in the north east monsoon period. Next highest rainfall has been received from March to April during the first inter monsoon period. Accordingly it is accepted that a heavy rainfall occurs upon the brick monuments in Polonnaruwa.

The rainfall received a Polonnaruwa is 890- 1900mm, annually. When compared to the annual rainfall received at other dry zone area of the world Polonnaruwa in our country receives considerably higher rainfall with higher fluctuations. Therefore it is questionable, whether this zone really belongs to dry areas, when compared to the other dry areas of the world. Dry zone rainfall is highly fluctuated and so is the high rainfall fluctuation on the monuments premises at Polonnaruwa. During the wet phase the rain causes high humidity, water seepage, weakening of bricks, rising up of underground water level followed by depositing of salt etc affect the decay of brick monuments in this zone.

Effects of seasonal aspects of the rainfall to decay wall and plaster

Major rainfall period to Polonnaruwa area begins from the October, up to the first half of January following year. Short spells of *Yala* rain occur during the last week of March or the first week of April. Due to heavy falling of this rain within short period serious damages are caused to the monuments. Bricks affected by powerful solar heat during daytime are suddenly lashed with heavy showers causing heat movements inside bricks. As a result, the monuments might crumble down due to cracking of these bricks. These cracks widen day by day allowing water to seep in to them, thereby causing internal disintegration. Constant flowing of water on the surface and seeping in to the clay particles of bricks loosening the bindings in between them may cause decay on external surface. During the months after first week of April decrease of rainfall or having any rainfall, could be seen while excessive solar heat projected on the monuments

Longtime rainfall fluctuation affected to Polonnaruwa city and decay in wall and plaster selected brick monument.

While studying on the long time rainfall fluctuations in Polonnaruwa city, we have investigated rainfall data of Polonnaruwa [Pertaining to 55 year. Period since 1953 up to

2008. There it was made clear, that a higher rainfall was being received here, along with high fluctuation rate than the other parts of the dry zone.¹

Table--Normal and mean rainfall statistic 1953-1977

Place	Average	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mahailupperuma (polonnaruwa)	Average	67	34	73	180	97	7	9	38	69	235	222	230	1.39
		83	46	79	193	100	18	21	41	59	253	242	252	1.39

(Source: Dept of Meteorology; prepared with the sources 1953 -1978)

Normal and mean rainfall statistic 1953-1977 years -03

Table--Normal and mean rainfall statistic 1977 -2008

Place	Average	January	February	March	April	May	June	July	August	September	October	November	December
Mahailupperuma (polonnaruwa)	Average	63	50	52	167	70	6	18	20	62	228	202	199
		98	42	65	169	86	11	30	44	61	253	236	263

(Source: Dept of Meteorology; prepared with the 1978 – 2009 data along with necessary amendments)

Normal and mean rainfall statistic 1977 -2008 years - 04

According to the data above, it appears a duplication feature in the rainfall system of Polonnaruwa during Maha (October – February) and Yala seasons. (May – September) However it is difficult to decide the exact beginning and end of such two seasons.

1. We have faced big difficulty in obtaining climatologically data pertaining to the early times of Polonnaruwa city. There was not a climatologically station in Polonnaruwa to collect these data. Recently in 2008 such a centre was established in it, facilitating the collection of required data. However we have chosen climatologically centre at Maha Ilukpallama which is situated close by Polonnaruwa and also having very similar climate, in order ascertain such data that might have affected Polonnaruwa, too before 2008. Accordingly we have prepared a chart depicting 55 years reception of normal mean rainfall in Polonnaruwa, on the basis of all the statistics and data, which could be obtained as possible.

Climatologically department defines, that the north east monsoon rainy season (*maha*) which makes highest rainfall to Polonnaruwa stretching from October to February in the following year. (Report of the Colombo observatory – 1965; published in 1970). South west monsoon wind (*Yala*) being the lowest rainfall (254 - 508mm) to this same area during May to September. In between these two highest points of raining seasons there occurs cyclone as well as afternoon thunder showers.

There appear two significant features in the rainfall experienced, in these areas during first weeks of April. First is the thunder showers experienced in the evening, limited to several days only. The second is the lashing of heavy rain in to a pocket area. Brick monuments which were subjected to excessive heat during daytime in the dry zone affected with the instant fluctuation of heat, due to the lashing of heavy rain on them in a short time. As a result of these heat movements cracking of bricks breaking them in to pieces loss of binding between layers of plaster and bricks, washing away of bricks and plaster, collapsing of weaker walls and plaster, weakling of bindings in clay particles, expansion and contraction of mortar layers causing the separation from bricks, blasting by animals collection of water inside the brick monument and destroying them. This process contained for centuries resulting serious damage and threat to the very existence of these monuments. As such, the damages occurring by instant heavy rains are very serious and with the continuation of this process prepare the background for other deterioration factors.

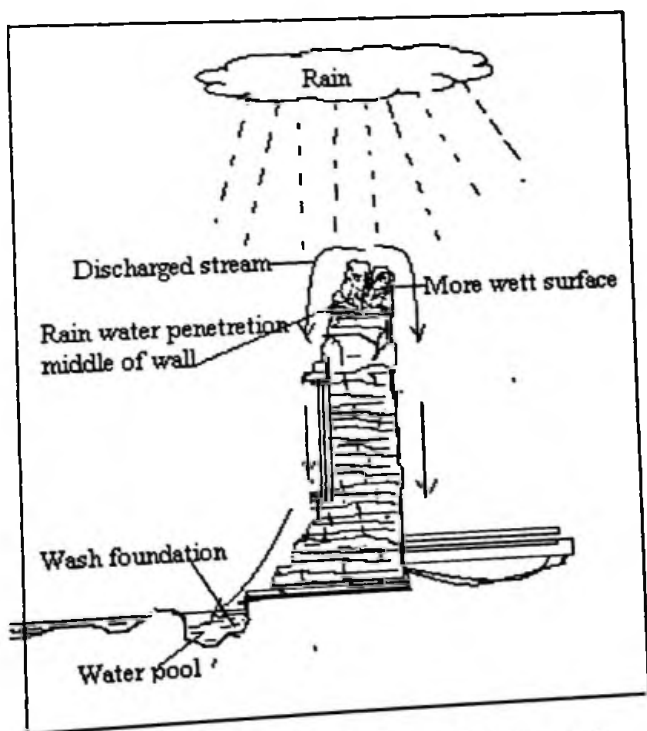
When there makes an analysis on the rainfall to this area, during august and September these slender rains do not inflict any considerable damage unit the brick monuments and also moderate rains may fall in August September in November. Yet we have to pay attention on the excessive heat prevailing in these days and the stresses endured and also by the sudden fluctuations endured by these brick monuments

Damages cause due to north east monsoon rain on wall and plaster

North east monsoon wind season is the main period of supplying water to the dry zone of Sri Lanka. Ancient city of Polonnaruwa too gets its heavy rain fall during this season.

During this season some heavy rains inflict unbearable damages to the brick monuments each year. Perhaps pre monsoonal rains accompanied with cyclones were not received in September, the downpour of month east - monsoon rain might commence, any time during October to the end of December, or up to the beginning of January in the following year. Most of the north east monsoonal rains fall on during November, December in many of the years. This is the time, when the brick monuments in Polonnaruwa are seriously getting damaged. During this period the rain affects maximum deterioration on the brick monuments Polonnaruwa area with its monuments become a sort of marshy land during this season.

through the cavities in bricks, also the erosion caused by flowing water on the surrounding area of monument, sometimes the foundation washed away leaving the wall to crash down. Besides, excessive seepage of water may cause sliding or crashing down higher parts of walls. Unburned bricks may loosen and weaken the monument, due to erosion of lime mortar, lime plaster etc.



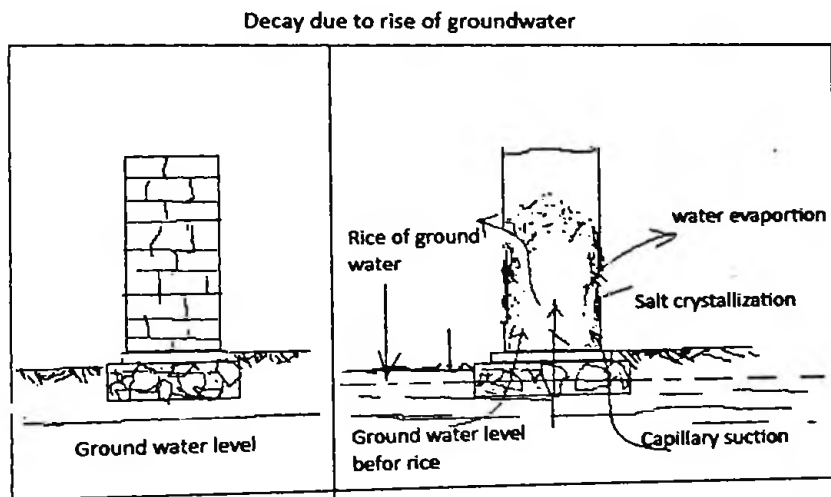
Erosion caused on the surface of monuments

Picture-121

The second damage is the upcoming of ground water level which increases water seepage pace upwards thereby depositing safety elements into the pores inside bricks, causing salty them to disintegrate in to small parts

Binding in between clay particles may disappear. Salt crystallization may also weaken both sides of bricks, In addition layers of plaster and colored parts may be affected. Raised ground water level may weaken the foundation of the brick monuments together with the solidity of the around finally bog down the monument. Also clogging water in the surrounding area, gathering of water in to this area, moisture, becoming a marshy land etc. make negative appearance of landscape.

Whenever the water level of the monument premises goes up, any lime plaster and frescos etc. on both sides of interior and of the monument. Flakes like pants come out and environ with moisture originated bacteria, fungus algae lichens etc. will be formed. Bricks of the foundation due to water seepage and due to weight of the monument may vanish.



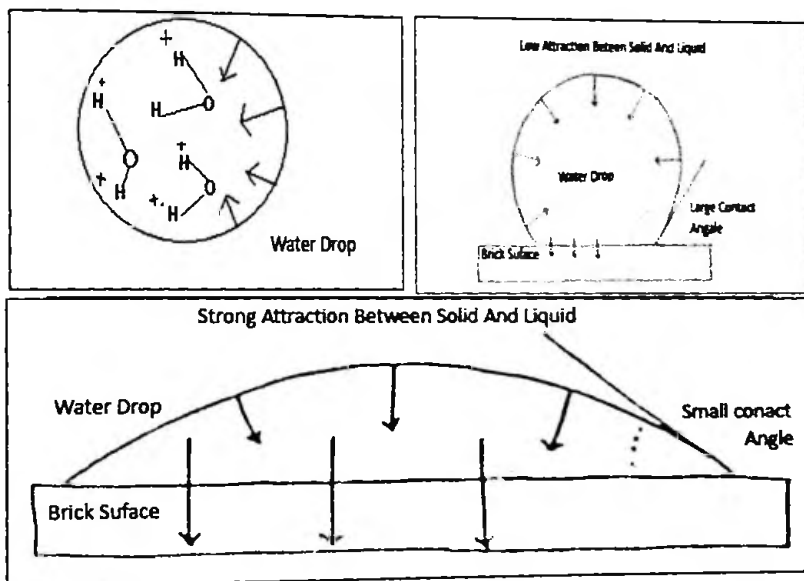
Decay due to rise of ground water

Picture-122

All deterioration factors referred to above can be seen wall and plasters on Parakramabahu palace, Thivanka, Lankathilaka and Thuparama image house which studied in Polonnaruwa as a result of heavy rain fall gets city of Polonnaruwa. Exposure to incessant rain wall and plaster water penetration directly or indirectly in to

them. Mostly, the water fallen on brick monuments in the forms of rain mist etc. do so by drops. All the molecules on the surface are attracted inwards by hydrogen bonds, formed with other water molecules inside the drop. The speed of the drop is determined by the force of attraction of water molecules to the solid surface. The speed of permeation to the inside is determined by, the angle of water drops fallen on the surface, after falling on porous surface

The shape of the drop of water fallen on the brick surface takes a large contact angle (that is a high drop) shows that the force of attraction, water to solid is weak. Conversely, a small contact angle (a low drop) indicates that the attraction force is strong. In rainy occasion in the shape of the drop of water is small and its contact angle on the bricks and lime plaster it is case to be develop penetrate water and infection reefered to above



(Source: Torraca, G 1982. Porous Building Materials, 8-9pp).

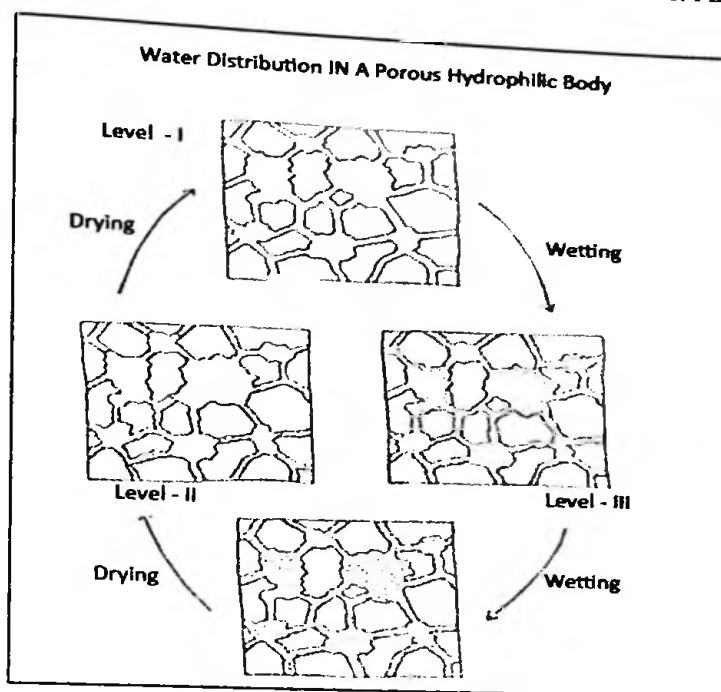
Contact angle of water drop

Picture-123

Permeation of water in to the bricks in whatsoever caused the bricks, as well as many building materials to expand. They are subjected to contraction when the water was evaporated the continued process cause the decay in bricks, due to the stress on internal bonds. Also the loosening and cracking bonds between the bricks and plaster cause

structure the of whole building to be destroyed.

Bricks being the porous building material soak water in to the pores inside. An analysis;



(Source: Torraca.G 1982.Porous Building Materials , 12p).

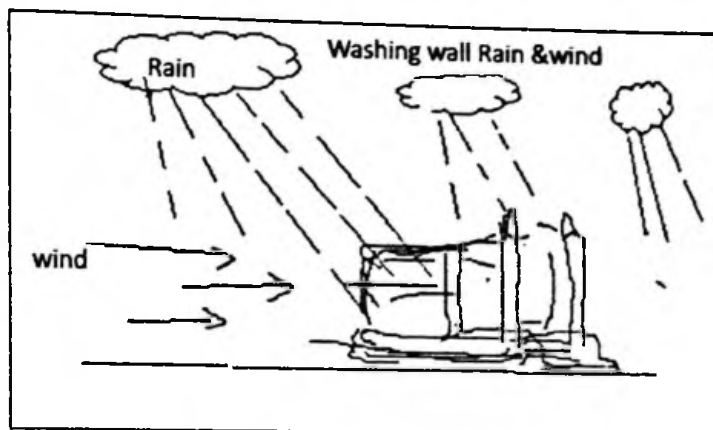
Water distribution in porous hydrophilic body

Picture - 124

First stage denotes porous raw material in dry condition. Both the big and small porous remain dried. Second stage begins with the humidity settling on the environment. Smaller porous will be filled first, while big porous remain dry. In third stage, small capillary lines are filled up fully; a thin film of water is appeared on surface. Thereafter the capillaries, as well as large porous, filled with water making further dampness in the environment. In this process of soaking water makes bricks expand. However these bricks may be subjected to contraction in a dry environment. A bond between clay particles inside the bricks may be loosened. Rainfall is the foremost fact in decaying of brick monuments in Sri Lanka.

Rainfall is the prime factor in increasing the atmospheric humidity. Normally tropical regions receive annual rainfall of 10,000 mm (400 inches) while U.S.A. in temperate

climatic region receives, 116 mm (4.96 inches) of annual rainfall. Annual rainfall of Sri Lanka is 1861 mm. Rapidity of rainfall on the monuments is very important and serious damages may happen to the monuments by a heavy rainfall within a short period. Sometimes the speed of draining water from the rainfall directly affect to the existence of the monument. A large amount of water received by rain if failed to flow smoothly, cause flood.



Washing wall rain and wind

Picture - 125

Wind times, precipitates rain water in the form of minute droplets on to the side walls, and to the foundations of monuments. This result washing away, separation of plaster lime, mortar, bricks etc. Rainwater fell on the bricks because activities like permeation overflowing, pouring down, lashing water on the surfaces etc. Thos were reason of the south wall deterioration in Lankathilaka image house.

As there remain no roofs on the most of bricks built monuments precipitation of rain directly takes place on brick walls, as well as in to the very buildings. This results various deteriorative factors activating in these buildings.

Thin brick walls are quickly saturated with rain water and deteriorative actions begins forthwith. Possibility of water suction in bricks is relatively more than in stones and as a result of water suction bricks are finally subjected to cracking. Due to insertion of rain water to the insides of brick walls they are decayed resulting large gaps therein. Unless

necessary repairs are affected these gaps may make way to loss of many buildings. Raw materials like bricks are easily decayed due to suction of water.

Damages brick wall and plaster due to heavy rainfall

Heavy rainfall too helps decay monuments. Very heavy rain falling on the monument, in a short time cause serious heat movement, cracking and washing away, crumbling down by water seepage etc. like various deterioration factors active. Monuments in Polonnaruwa must have faced against these activities for centuries of time.

Heavy downpour of rain is common to all the areas of tropical region it has been reported (farmer 1957). Such rains had been fallen even in early times. People lived in those days had invented such usage as *Dobathalana Vehi*, *Jalagedi* etc. to describe unusually heavy rains, So far, we have studied the influence of rain on Polonaruwa area as an archaeological site with important brick monuments. So it appears that the seasonal feature of rainfall and its anomalous nature, scanty no rain, duration or heaviness of it apparently threatened the very existence of the brick monuments in Polonaruwa.

Damages brick wall and plaster due to penetration of ground water.

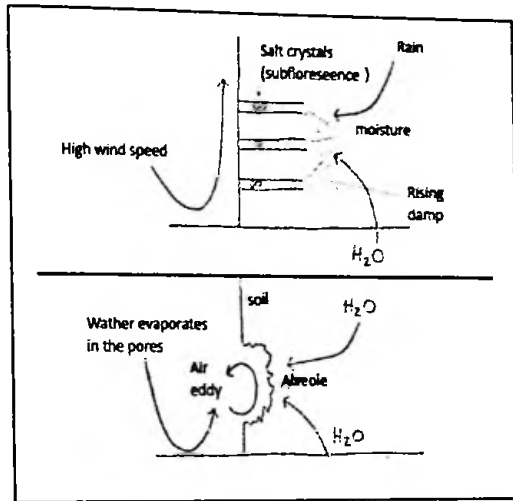
Bricks are raw materials with porous capable of seeping ground water by capillary rise process. Hence the ability of brick monuments to seep water from underground steadily through capillary rise process. Speed of this process is decided by the quantity of seepage height size of porous or the condition of it, or on factors active on the external surface. Dry condition around the premises and high evaporation expedite raising water upwards accompanying various salt elements in to the raw materials. At the end of evaporation end the salty elements are crystallized on both sides

Some of these surfaces which have been weakened by salt infection have also been worn away by particles brought by wind. Exceedingly broad brick walls evaporate underground water by means of capillary process. Then in turn this underground water which the brick contain is taken away by extremely strong sunlight and wind present in this zone during the day, while salt particles which are deposited in minute opening called pores in the brick make such a thrust it causes the further weakening and break. Then dust particles which wind bring wear away these bricks already weakened. They are

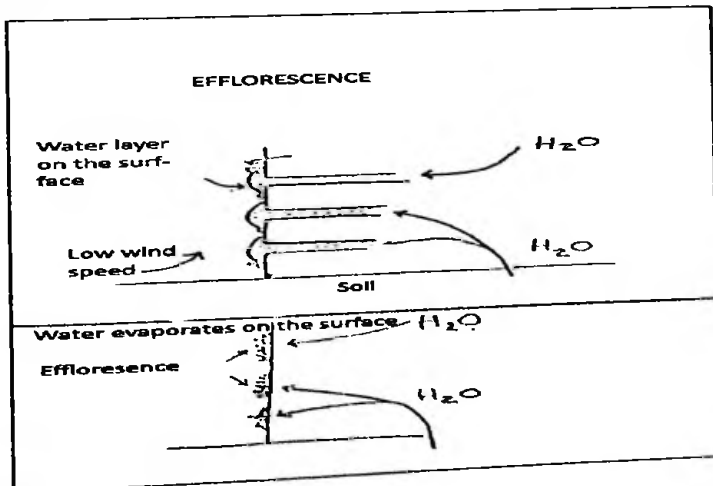
subjected to that bricks wall near the ground level as well as the lime plaster layers are weak owing to salt infection, interior of Parakramabahu palace, Thiwanka, Lankathilaka and Thuparama image houses.

Depositing ground water salt inside the bricks through capillary rise process and thereby causing the destruction of brick walls, as shown below.

A) Erosion caused by salt



B) Efflorescence



(Source: Torraca, G 1982. *Porous Building Materials*, 35p).

Erosion caused by salt - Picture - 126

According to internal pressure is generated by the crystallization of salt water inside porous which decay the bricks. When the water is evaporated, then the wind erosion will activate on the surfaces already weakened.

Water seeped in to bricks from ground water, rain etc. makes a thin film of water on the surface plastered with lime mortar or on the exposed bricks and after the evaporation small particles of salt could be seen. This process destroy colour painted surface, also lime plaster and the brick surface. Likewise the top surface is deposited with this coarse salty film this process makes way to tarnish the beauty of these surfaces. It can be seen in the interior of Thivanka, Lankathilaka and Thuparamya that bricks near the ground level as well as the lime plaster layers are weak owing to salt infection occasionally'

Salt dilution and their behavior during evaporation on brick wall and plaster.

Salt activities cause serious damages on the surfaces with frescos and plaster. This was one of major reason of the deterioration of painting in Thivanka image house. Types of sulphate which are mostly found dissolved in the water are sodium (Na) potassium (K) magnesium (Mg) and calcium (Ca). If this salt crystallization occurs anywhere on building materials, (surfaces, walls or insides) it results serious breakings fractures and confusions on these material. Calcium sulphates possess the ability to create a whitened film covering porous raw materials used in the construction. Calcium sulphate (CaSO_4) also has the ability to deposit salt crystals on the plastering and to aggravate further, these harms jointly with the polluted air existing in the atmosphere.

Salts that could be dissolved like sodium (Na) potassium (K) calcium (Ca) and nitrate work on their way in to porous then crystallizes, dust formed etc. contribute to disfigurement and disintegration.

Certain stones clay and cement with silica (Si) can be seen with whitened thick layers. Silicon dioxide contain considerable amount of calcium carbonate, cause aforesaid thick layers.

Parakramabahu palace, Thivank, Lankathiolak, and Thuparama image house all these salt formations are found in the those brick monuments. Factors like rainfall drizzling, water seepage, ground water, frost etc. increase the humidity around the monuments in Polonnaruwa.

c) Wind as a cause of decay in walls and plaster

How to deterioration of brick walls and plasters due to wind erosion in Polonnaruwa

Wind is created as a result of different atmospheric pressure. One of the most important factor of the climate is factor of the climate is the wind with its direction, velocity, gustiness and frequency of calms. Velocity of wind differs according to the heights. The reason is humidity.

Wind makes certain action in destroying historical buildings which don't have resistance power. As such there should be a resistance power in the structure and wind wards of those buildings to withstand wind pressure. Historical buildings built with bricks possess the strength to resist powerful winds. But this resistance power would not be sufficient to withstand very powerful gusty wind. At these instances, wind may cause damage to the structure of the brick monuments. Forces generated by wind can do much damage high towers of the buildings.

Height of the building and the light structure attracts more damages. Brick built buildings like Lankathilaka and Thivanka in Polonnaruwa too shows the damages caused by wind erosion

Speed of gusty wind, period of prevailing. The load, it carries and the conditions (weak or strong) of structure are the factors that affect deeply on the erosion of the walls and plasters

Normal flow of wind when accompanied with windstorms cause damages to monuments. Large scale destructions are caused suddenly by violent windstorms calls for much attention. But the normal wind in a slow process, also inflict harms thus avoiding much attention. Some time normal winds accompanied by turbulent wind damage monuments.

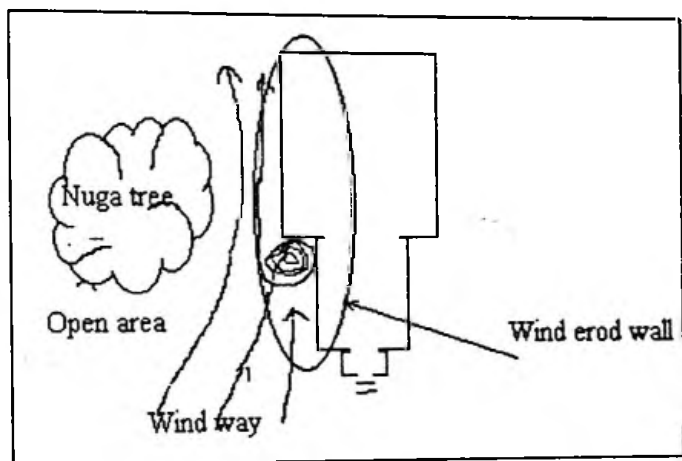
Centuries of by normal winds may make serious damages to monuments.

Not a single building of Anuradapura and Polonnaruwa retain only roofs. Particularly brick buildings in Polonnaruwa period don't have any roof. Lankathilaka and Thivanka Image Houses had their vaulted roofs built with bricks. Presently they are collapsed

down to the ground. Especially, it is evident, that the brick built roof on Lankathilakaya, which was a very tall building, must have been destroyed by strong winds.

The vibration generated by powerful gusts of wind also cause serious damages to monuments. All the roofs of brick buildings must have been collapsed down due to wind action.

In the Thivanka Image House of Polonnaruwa we can find the extent of erosion occurred on southward wall by the wind and the load it carried. Wind has eroded all the moldings, drawings of animals and lime plastered brick works. Cyclones have eroded bricks and plasters in large scale on the outside of southern wall.

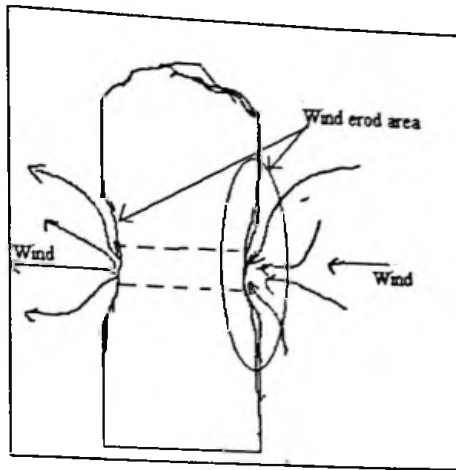


Wind erosion cause on southward wall in Thivanka image house

Picture - 127

South wall of Lankathilaka Image House in Polonnaruwa too had been subjected to powerful wind erosion, Royal palace of king Parakramabahu had also suffered by the wind erosion. Its Royal interior walls have faced against the wind and the load it carried. Bricks decayed due to the salt crystallization by the ground water near the foundation are quickly eroded by wind action.

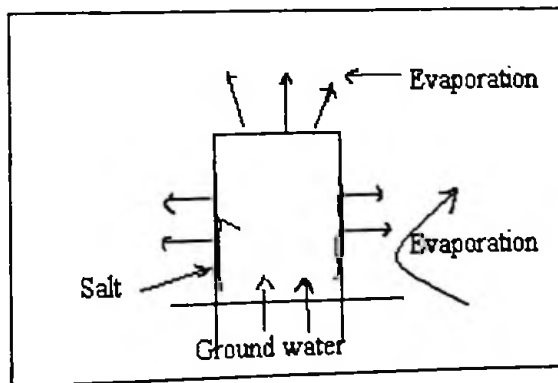
The large holes which were made to fix heavy wooden beam of upper floors of the palace have been enlarged by wind erosion. As the middle parts of walls appear feeble, while the upper parts are seen as giant mass.



Wind erosion cause on brick wall in Royal palace of king Parakramabahu

Picture -128

Evaporation process quickened by wind also expedites the deterioration of building constructed with porous raw material. Water gained from rain, as well as from the ground is evaporated by wind, depositing salt contained in ground water on the walls and windward frontal parts in addition to the pores, holes and cavities in the building materials. Depositing salt on all fronts causes to weaken those fronts and to disintegrate and to make cavilities on them. Salt hasten to weaken the raw material and create deeper and large holes inside the bricks.

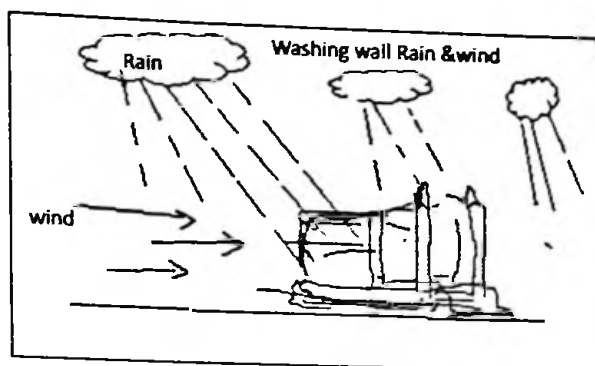


Salt weaken the raw material

Picture - 129

Wind also takes part in action like penetration and washing away. The eroding action, of wind combined with sand or dust can ultimately destroy massive buildings. Heavy rains

cause water to enter in to the monuments and to hasten washing away of monument walls due to downpour of shower.



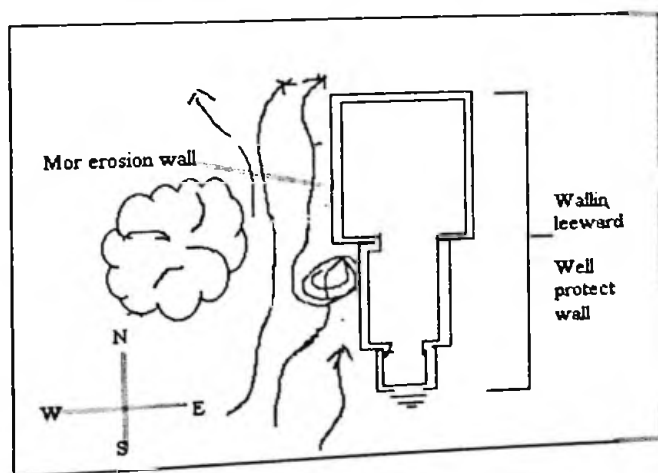
Washing wall rain and wind

Picture - 130

Deterioration of south walls and plasters in Lankathilaka image house, these reason is main Factor.

Wind at ground leaved strong enough to dislodge and propel stationary particles to distant places specially. They may be forming dust storms. By these monuments of sand grain are eroded. (Especially seer faced and front is subjected to friction producing awkward seines. Lights winds help all invisible movement slowly).

On the lee side of the building there occurs a low pressure zone and damages are in lessee's extent. Example north wall and a part of wall of Thivanka Image House are situated leeward and the damage by wind erosion in lesser here.



Walls in leeward Thivanka image house

Sand and dust particles of the exposed area around the buildings brought down by wind and heavily eroded by friction. Sand and pebbles contained in the wind cause damages to historical buildings. Wind blown dusts are slowly deposited on the carvings walls, moldings and ceilings and statues disfiguring them. Humidity of these places goes up with the seep of water.

Resulting chemical reactions and making a suitable ground for the activities of fungus and bacterial. Here the external and internal appearance of monuments become ugly with the depositing of dust on them. Colored sections and plastering of monuments are blackened with dust thereby harming the aesthetic value of the building.

In Sri Lanka, the brick monuments in Plonnaruwa are not affected much by the dust although the pressure stirred up by wind inflict much harm on them.

d) Damages due to joint activities of wind and humidity

There are instances of deterioration factors activated on brick walls and plaster jointly by wind and humidity. Porous raw materials suck water through capillary process and bring up various salt elements on its upward flow. With the quick evaporation by wind action these salts are deposited inside brick porous. This process is continued, until the internal pressure, due to salt deposits, breaks away the bricks. Wind action on the surface of the monument expedites the disintegration of the brick. Examples are the lower parts of the ground floor of the interior of Parakramabahu palace in Polonnaruwa, parts between chamber and south wall dome of exterior Thivanka Image House.

Deteriorating of brick walls and plaster due to biological and Botanical reasons

Flora and fauna take part in the deterioration of brick built monuments. Animals and the trees are major living factors in the environment. These communities or one of them living or acting in area with brick walls or plasters poses a serious threat to the existence of such monuments.

Biological deteriorate factors acting directly as well as indirectly are insects, birds, mammalians, reptiles and invertebrate. Botanical factors are certain bacteria, fungus algae, lichens, herbs and various bushes. These do grow on the walls and plasters cause serious damages to them.

Animal contribution on deterioration of brick walls and plaster monuments

In comparison to the other deteriorative factors, we cannot undervalue the parts contributed by the animals. Activities of animals cause various factors directly and indirectly that would destroy brick monuments.

Animals belong to all the families normally; insects, birds, reptiles, mammalian, invertebrate etc. do their parts in the destructing of brick walls and plasters. Insects like termite (*Losoptera*), potter wasp (*Delta flavopictum flavopictum*), fire flies (*Photuris sp.*), spiders (*Arachnid*), etc., birds like pigeons (*Columba livia*), crows (*Corvus*), bats (*Pteropus giganteus*), woodpeckers (*Megalaima flavifrons*), king fisher's (*Halcyon smyrmensis*), mynahs (*Gracula religiosa*), swallows (*Petrochelidon pyrrhonota*) etc, Beasts like rats (*Rattus rattus*), ape (*Macaca sinica*), monkeys (*Kasi senex*), etc. Mammalians.

Ant is the chief insects in the destruction of monuments. Ants cause decay in bonds of the clay plasters in the structures. Ant, being the quick re producing insect, cause much damage by building its ant hills, with clay and soil near to the brick masonry, sometimes digging cavities in between the layers of bricks.

Clay plaster used in the brick masonry is thus decayed allowing making cavities in it, finally weakening the structure. Rainwater seep through the ant dug holes and reaches the interior that would destroy both exterior and interior parts of the construction. Ants busily build their many ant-hills covering a large area in no time, tarnishing the aesthetic importance of the monument and its premises. If there existed carvings and paintings the loss would be greater. Ants also cause damages indirectly. Some animals chased after by lizards etc, creep and hide in ant- hills wherein lizards in turn, dig further inside, there to catch their prey. This is the indirect way, brick built monuments suffer damages.

Potter Wasp

This insect does not do anything to harm the structure of the building but inflicts harm to the aesthetic value of it. Its main characteristic is to put up small abodes in any place, not excepting frescos, paintings, carvings or decorations on the surfaces. These insects build their numerous nests on the walls and plasters in abandoned monuments. For example, the inside wall of the dome of Thuparama Image House and black ants etc. dig holes in to the clay plaster used to make brick masonry work. Although it seems as a small matter, it provides suitable ground to form humus and soil, allowing various herbs to grow. Spiders weave their webs in large scale on the monuments and spoil wall surfaces with frescos on them with their excreta.

Birds are also among the creatures, which inflict more damages on the brick walls and plaster monuments. These damages can be analyzed in several ways.

- The damage caused due to building of nests and by digging of holes
- Damage done by excreta
- Various seeds and herbs in excreta begin to grow up.
- Acidity action in excreta, harming lime mortar and frescos.
- Tarnishing of aesthetic beauty by the appearance of excreta

Birds staying on monuments and buildings or on thereabouts, for long times accumulate dirt. This dirt with nitrogen combination makes salt and decay the place. Primary bond making raw materials of lime (CaCO_3) is also degenerated due to this salt. Various seeds and herbs borne by bird's excreta are grown on bricks works sending down their roots resulting disintegration. Bo (*Ficus religiosa*), Nuga (*ficus*), Wira (*Microcos paniculate*), Kirilla (*Microcos Paniculate*) etc. like trees with large trunks are grown on bricks monuments, despite the non-availability of space, solely due to the indirect action of birds. The acidity contained in the birds muck might generate chemical reaction in lime plasters, lime mortars and colorings.

Carnivorous birds like king fisher's, mynahs, wood peckers etc. dig caves on brick walls etc. Thereafter these birds and other birds build their nests and lodgings, lay eggs and make habitat to live in. These birds bring in food for their offspring, whose muck joined

with food leftovers make the environment and the monument full of degeneration.

Abandoned brick monuments are covered with trees and creepers wherein live rats, mongoose and porcupines in their holes, gaps and caves causing immense decay into these monuments. Rats and bandicoots inflict heavy losses by digging holes, inside the monuments severing the bonds of material and weaken the building. Also monkeys and simians (ape) in their groups jump and playing about these walls, lead to dismantled bricks of monuments. When these animals walking on higher buildings, some bricks get loosened and fall down caching on another part and damaging it too. Continuous happening of this phenournon cause tremendous harm to the brick monuments.

Microbes and herbs destroying brick walls and plasters

Many of the bacteria or microbes obtain the necessary strength for survival through oxygenate process or through electron ate by non-carbonic chemical reaction. As a result of these actions strong and weak acids are produced as by products. These acids make chemical reaction on the surfaces wherein lives microbes & fungus. More sensitive building surfaces.

We know, established microbes activate on are eroded corrosion by acids. That is sulphate producing bacteria growing on building surfaces. Sulpher produced by them can make sulphuric acid. (H_2SO_4) Moreover it can produce sulpher dioxide gas too. (SO_2) Thus the sulphuric acid (H_2SO_4) and sulpher dioxide gas too. (SO_2) Thus the sulpher dioxide gas (SO_2). Thus the sulpheric acids (HO_2SO_4) and sulpher dioxide gas (SO_2) produce bacteria not only corrosion easily the lime mortar that acted as bindings stones and bricks but also layers of plastering on which color paintings done (Torrcaca 1982:47) Accordingly damages caused by microbes and fungus could be seen in the interior of Thuparamaya in Polonnaruwa and in certain old buildings in Galle fort in Sri Lanka. Likewise microbes and joined with nitrogen cycle produces nitric acid Production of nitric acid, on building raw material does not help their existence. Instead more sensitive parts of monuments may be disfigured and corrosion

Where ever bacteria and fungus in search of energy recued for their growth, produce carbonic acid as the last production reaction, through the process of oxygenate upon the carbonic raw material. Oxalic acid is one of such acids. By this destructive corrosion cause on the surfaces of ancient brick walls and plasters weakening and them. Normally important micro biological processes cause considerable amount of chemical and physical losses. This action continued nonstop expedites the deterioration process.

Algae

Sri Lanka is also having a tropical climate. Algae activities are present in the ancient brick walls and plasters and in the raw materials used in the constructions. Specially, brick monuments have been seriously damaged in their existence and also in beauty. There are grown on brick surface and make humus causing big damages to monuments. Walls are moistened and wall cavities get cracked. Formation on humus helps weeds and larger trees to grow on monuments. Great loss caused by algae is the damage, made on lime plastered surfaces, colour painted surfaces or on bright surfaces. Algae make them designed covered, destroyed by embrittlement action. Surfaces are damaged at the removing of these algae.

Lichens

Lichens are a kind of herb widespread in various environments and also they grow on every construction, as well as on manmade raw materials bricks and lime plaster. The brick monuments in Polonnaruwa depict the might of lichens invasion on their exteriors and interiors.

Lichens can be divided in to three parts. According to their appearance

1. crustaceous lichens

2. Foliaceous lichens

3. Fruticose lichens

Lichen is a product of a combination of two lives, algae and fungus, thus having a special identity. Fungus is normally an ascomy.

Algae are green or bluish green coloured one cell body, or a thread like body, big part of this herb is composed by interwoven fungus threads. Special fungus threads called rhizoidal reach downward and help fix the herb with the layer beneath. Absorbs water like sponge. Algae obtain water and essential elements through fungus. In turn fungus depends on food produced by algae through Thermo luminescence. Therefore these lichen co – existing with algae and fungus able to survive on any difficult environment and cause immense damage to brick monuments. On the outward surfaces of historical buildings, many species of lichens are settled. But they cannot live in polluted atmosphere. Lichens of white colour and Crustaceous shape lichens are domiciled on the brick monuments. Their growth accompanied with the carbonic acids produced inside (ex: oxalic acid) may harm several milliliters, to the inside from the surface of raw material

Moreover lichens possess the ability and strength to penetrate through the brick surface and hold tight the brick and mortar. Thus lichen gradually disfigures the monuments surfaces with frescos and carvings like decorations. When algae fallen out like dried flakes, lichens also take out a considerable amount of particles in to several millimeters inside from the brick surfaces. Continued process of this activity erodes brick surfaces considerably.

Moss

Moss is grown on the brick walls and plasters in the environments with high humidity. Brick built constructions with lime plasters, bead, archives, decoration and designs, as well as brick works without shelters, moss take part in moistening of surfaces cracking, blasting and inflicting stains etc. Moss is capable of harming the surfaces of building materials to the depth of several centimeters. Surfaces with concrete or lime plaster suffer more damages. Moss obtains the means of survival, also from the bricks and erosion set in gradually. Bricks surfaces are broken due to moss, allowing more water in than necessary and not getting in required air and heat enhance the damages. At the end flakes of moss detached with a part of brick surface. This process continues again and again and

weakens the resistance power of bricks, wearing away brick surfaces with decorative motifs, designs etc.

High humidity environment made by moss, find its way to inside porous and cracking and react against weak combinations and loosen the strength of brick works and pave the way to crumble down. Lime mixed with sand are widely used in brick construction works and this plaster help hold the entire brick building strongly. However the calcium carbonate (CaCO_3) chemical Parts react with carbonic acids water, contained in moss, converted to calcium bicarbonate. This chemical easily dissolves in water, loosen the bonds in lime plaster and affect to dislodge bricks. Same thing happens to the clay mortar with more water seeping Another way of decay, of soil made creation is silicate (SiO_2) mineral, converting in to other mineral salt. Silicate has resisting power and is used in the production of bricks. Example is the silicate chemical called pelsper converts to clay with less strength and the increase of volume due to soaking of water pressurizing cracks in the bricks. This kind of deterioration is abundantly seen in the bricks walls and plasters.

Superior plants

Superior plants like weeds, bushes or trees mostly affect, in the deterioration on masonry work including brick built creations. Plants are existing in their diversity. At the same time they have common patterns and equalities. Living plants have been categorized on the basis of equalities appearing in them.

Thus herbs, weeds, bushes or trees belong to all these families can deteriorate bricks walls and plasters built monuments. These herbs and plants cause immense damages to the premises with brick monuments which are neglected, ignored or abandoned or in the absence of suitable maintenance programmed or paying of attention.

Microbes and herbs can destroy brick walls and plasters. Lichens have the ability to service in any difficult environs and also to prepare situation conditions for, any herbal community to grow upon. Lichen settled on bricks and lime mortar excretes some liquid, enabling chemical dissolution of lime mortar. Remnants thus dissolves are deposited in

cavities of brick work or on the cracks found on brick. As time goes on, a thin layers of some soil is formed on these cavities and cracks, on which moss and fungus grow up easily. Moss dries up allowing more carbonic materials to gather in, these thickening soil layers. Furthermore moss create humidity environment within the monument encoring for their growth of various plants and shrubs spreading their roots and branches freely.

With the growth of herbs on lime plaster and bricks process of deterioration is quickened. Spreading of herbal root luster's within the cracks and cavities forever enlarge such points these allow more water travelling inside especially, this process do more harm during the drying up of herbs and roots. The collapses of wall built with bricks have been affected by these processes.

3.2.3. Intervention of man on the deterioration of brick walls and plaster in monuments

Major factor that cause deterioration of monuments are the mistakes occurred in the plans and of the materials, at the time of construction, as well as the environmental reasons, in addition to the biological activities. Of all these, the human factors inflicts the gravest harm. Activities of several centuries could be subjected of human action within a very short time.

Thus man's intervention on deterioration of monuments could be noted, as the damages caused, directly by man and the damages caused indirectly, as a result of his actions. Modes of men's intervention are neglect, faulty conservation, sacrilege of monument etc. contributing to the destruction of monuments.

Neglect

This means abandoning of the monuments. When they are not used, not maintained, not conserved, then the monuments are decayed. The damage caused due to abandonment is

more than the damage caused while in use. Deteriorative factors act speedily on the monuments in neglect.

Faulty conservation

Unwise conservation Leads to cause damages to the monuments. Wrong decisions coupled with faulty planning taken by the conservationists further aggravate the problem of deterioration. Therefore utmost care needs to be taken in any conservations project.

Further, harm caused to this monument through conservation itself can be seen here. The following serious damages caused through improper maintenance were identified.

4. If nests of swallows are not promptly removed their population will increase and in turn the amount of faces fallen on the monument will increase and thus the walls will be defiled.
5. Various acidic substances contained in faeces of birds will lead to chemical reactions on the lime plastered wall and thus will Weekend the plaster.
6. Further, excessive presence of faeces and nests is harmful to the aesthetic value of the monument.

Again no action has been taken so as to minimize or to curb altogether the spread of potter-wasps who invade the Thivanka and Lankat5thilaka image houses *Garbagruhaya* swiftly.

Again fungus, algae lichen and small and big plants grown on both interior and exterior of the monument are a threat to its aesthetic value as well as existence. More attention must be paid so as to remove them. In particular a more formal action must be taken so as to remove the black moss which predominates the outer sides

The interior of the Thuparama monument where the arch roof has collapsed is getting wet and as a result salt infection and damage caused by humidity occur. Therefore, formal action must be taken to prevent the interior from the wetting due to absence of the roof.

In Lanka thilaka image house upper part of the brick wall the monument is allowed to be washed continuously by rain in the long run it will cause serious damage. The gravest harm done by conservators and the authorities included in attention of weeding upper walls and leaving not being taken prompt action to minimize the damage of wind erosion. Farther ration of as this monument is cut off from the inhabited are an impudent tourist's cause damage to it by scribbling or writing names etc. on the lime plaster and brick.

Therefore, inattention on the part of the man to conservation and maintenance itself is the grave harm, caused by men. Therefore, it must be eliminated.

Sacrilege of monuments

Some people knowingly or unknowingly scribble and touch on the monuments harming them. Frescos are affected due to high voltage flashes by cameras taking photographs of them

3.3. Foundation

Strength and durability of a monument is decided by the strong foundation and its long lasting construction materials. When the researching were carried out in to the foundation work. It become clear that strong bricks, stones and lime mortar were used to build foundation inability to withstand proposed edifice. However it could be seen that degenerations and disintegrations have made its mark as a result of long term deterioration action. Causes of natural environmental and human factors etc. have continued to this situation.

3.3.1. Natural cause of decay in foundation

Crashing cracklings sinking visible in the foundation are caused mostly due to the lapses of designing and also weaknesses of row materials used in. when constructing a

foundation for a monument sinking cracklings may occur in the foundation, if it had to sustain much heavier masonry load. Sections of foundation may sink due to the pressure from above. South east corner of southern wall of Thivanka image house shows some depression in the foundation can be seen. There appears a crack in the wall above due to this depression. Pressure made by construction materials paved way to this features. Also a slight building out could be observed at the south east corner of the foundation of Thuparama image house. Here also the excessive weight of building material above might have existed. Bricks in the foundations of Thuparama, Lankathilaka, Thivanka and palace of Parakramabahu had been washed away forming some gaps. This may be the result of using bricks of less strength. As a result there materials had been worn out speedily with the facing of various natural and environmental factors.

3.3.2. Environmental causes of Decay

Certain parts of foundation of Lankathilaka , Thuparama , Thivanka and Parakramabahu Palace shows complete degeneration of lime mortar. Lime plaster of some places had been cracked and erupted. Moreover the attachment between bricks and lime motors of the foundation had been detached. The reason for this phenomenon is the excessive heat experienced during day time, while cooling process prevailed during night time, thereby loosing the finding power of construction raw materials. Apart from this, rainfall and wind etc. Have activated detraction like erosion and washing away.

Lime mortar of frontal part of the foundation of Parakramabahu palace have cracked and collapsed completely. This edifice faces east resulting the fall of sunshine for more time uninterrupted during the day. As such, thermal expansion during daytime and thermal construction during night time continuously for a long duration has done this declension. Sometimes the sudden fluctuations of heat ha also affected in this work.

Likewise southern walls and foundations of Lankathilaka and thivanka image houses and bricks and lime mortar of the foundation and walls of Thuparama image house have cracks effected by thermal expands and contacts cased. Especially “the Dalada maligawa” had been built on a higher platform without any plants or trees. This allows direct sun shine falling on this open platform and causes small cracks on lime

mortar of the foundation of these monuments.

Deterioration caused by rain (foundation)

Foundation of image house like lankathilaka, Thuparama and Thivanka have been extensively worn out by washing away occurred during rainy seasons. Southern wall of Lankathilaka had been washed away thoroughly by rainfall. Lime plaster applied on the moldings of these image houses had been washed away extensively.

Depositing of salt weakness the brick and lime mortar resulting the declension of that mortar moss has grown extensively in the vicinity of Lankathilaka and Parakramabahu palace as a result of much rainwater increases the humidity around the foundation.

Wind had also had a hand in destroying the foundations of these edifices. The moldings along with attractive motifs of animals of the foundation of Thivanka image house had been erased by the impact of wind and wind carried load of sand and dust.

Bricks of the foundations had been degenerated as a result of underground water containing salt and the wind action bricks weakened by salt had been worn out by impact of wind carried particles dust and sand mass.

Botanical and Biological Causes of Decay in Foundation

Over the foundations of Lankathilaka and Thuparama image houses and the palace of king Parakramabahu moss and small herbs have grown extensively. As the foundation is near to the earth on environment of humidity has been easily created by rainfall and capillary action allowing easy growth of herbs like moss. This increases humidity again and at the times of during up of herbs humus soil is formed on the foundations. Then the seeds brought by wind, water, animals begin to grow and their spreading roots further cause decay in bricks and lime motor. Again humus is further developed with the dried up plants with their stream and leaves, thereby allowing larges herbs and plants to come up.

Biological Causes of Decay in foundation

These monuments are situated in rather solitary areas resulting more animal borne activities. Animals like ants; Potter wasp and Iguana cause damages about the foundation premises. At Parakramabahu palace too activities of Iguanas could be seen. However this phenomenon cannot be seen near Thuparama image house probably due to situated at more open land where people often move about.

3.3.3 Man made cases of Decay in Foundation

There shows not much influence of mans activities with regard to the decay of these foundations. However the absence of suitable eminence schedule weeding and pointing etc. could be witnessed there.

Chapter – 4

Proposal for conservation of brick monument in Polonnaruwa.

In this study, on the conservation of brick monuments at international and national levels as to the necessary procedures to be adhered to in the preservation of those monuments from natural environmental and human made deteriorative factors in concurrence with the ethics and polices, limitation and mediations acts and ordinances and the procedures are discussed.

4.1. Causes of deterioration of brick monument in Polonnaruwa.

When reviewing the factors of decay of brick made monuments, there appears many instances where several factors of decay of brick made monuments, there appears many instances where several factors jointly causing damages than by a single cause damaging a monument. Most of the times factors are interconnected. Causes of detracton can be classified in to groups namely, natural environmental and manmade causes.

Natural causes are the lapses made a in the designing of monuments resulting collapses, sinking and cracking etc. Also, the weakness of raw materials like bricks and mortar cause decay of the building of parts of it. Environmental reasons are climatic botanical, biological and natural disasters. Climatic factors are sunlight, rain wind and humidity. These factors activate thermal movement cause, rain water evaporation, underground water level elevation, wind erosion. Damages due to joint activities of rain wind humidity and salt cause brick built monuments.

Botanical deteriorative agents are algae lichen, moss, superior plants, ferns plants and trees while biological deteriorative agents are insect's, reptiles, mammalians, invertebrates take part in degeneration of brick monuments in polonnaruwa. Intervention of man is another important factor in the decay of these edifices. Lapses like neglecting protection of

monuments faulty conservation and sacrilege of monuments, with or without the knowledge of man had cause decay of monuments built with bricks.

4.2. Principles of conservation pertaining to brick monuments

It is important to follow up conservation procedure accepted at national and international levels in conserving ancient monuments. These exist as in any of the conservation programmes accepted of ethics, as well as a system of intervention. It is mandatory to honor these ethics, mediations policies and limits at all the conservation projects.

Ethics, Policies and limitation respected at the conservation of monuments built with bricks.

Ethics observed on the conservation of brick monuments

Conservation processes shall observe and honor the charters, rules and regulations respected at international levels shall have to be applied in order to affect more methodical conservation processes.

As such, any conservation of Brick Monuments shall follow up aforesaid conservation acts and ordinances, policies, rules and regulations for effectual conservation tasks. Following are some such ethics and policies commonly adhered to, whenever a conservation of monument takes place. These rules should be observed at the brick monument conservation as well.

Ethics observed at conservation process

1. First of all, the existing condition of the building should be reported.
2. Should not erase any historical mark.
3. Should not dispose or change anything of the original condition of the monument.
4. Check as to all the intervention which would not injure or damage any aesthetic, historical and physical integrity of the monument.

5. A clear description on the procedure adopted and the items used in the conservation of monument should be submitted. (Feildon,1997:6)

Apart from these ethical norms care should be taken to not to give general public any hint of additions made unto the monument conserved, whilst enabling the academics to trace such additions.

Further, the conservation is ought to protect following features whilst engaged in the conservation of monuments.

1. Whenever technically feasible, the ability to use conservation process in bringing a monument back to its original condition.
2. There shall not make any untoward influence upon future conservation programmers by affecting a new conservation process.
3. Conservation process should not carry on in a way making any hindrance to future research work and accesses.
4. Existing building materials etc. Should be used maximum in the conservation project.
5. Newly used building materials in conservation should tally with the original parts of the monument in their colour, scale and the outward appearance.
6. Conservation programmed should not be executed by a beginner in the field.

Further, a thorough study of the area where the monument is situated, its social pattern, technical know-how, political and economic factors, environmental features, historical importance in detail alternations effected to the monument, numerous activities, features of the original craftsman, aesthetical principles embedded in the monument, symmetry and inter connection of sections, structure of the monument, quality of building materials used, stages and periods of construction, conservation effected lately, special features of interior and exterior parts, peculiar nature of monument area, and any other significant factors plus any archeological excavations, surveys and the results obtained there from should also be made. It is also very important to adhere to the rules & regulations honored by the international community and to implement conservation effort accordingly. Following are the main regulations as laid out by:

- 1931. The conservation of Artistic and Historical monuments, Athens, International Museums office.
- 1964. International Charter for the Conservation and Restoration of monuments and sites. Decisions and Resolutions of the 2nd International congress of the Architects and Technicians of the Historic Monuments, Venice.
- 1987. The Burra Charter, The Australian ICOMS Charter for the conservation of places of cultural significance.
- ICOMOS charter for the conservation of Historical cities and there environs.

These are the commonly accepted charters on policies, rules and regulations allowing operating conservation work accordingly. Particularly, the Athens Charter for the Protection and Restoration of Monuments and sites has immensely influenced upon the necessary rules and regulations laid out for the conservation of brick; monuments.

In Sri Lanka following Acts and Ordinances,

- 1888 -02 - 17 - Act on the Prohibition of Hiding Ancient Treasures.
- 1940 - No - 09 - Archeological Artifact Ordinance
- 1980 - No 57 - Central Cultural Fund Act.
- 1998 - No 24 - Archeological Artifact (Amendment Act)

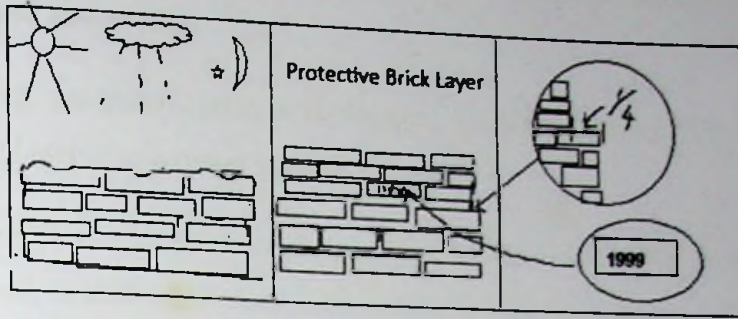
Have prepared legal background enabling conservation tasks. All conservation work on brick carried on in Sri - Lanka have adhered to the norms by Venice Charter.

Policy and limitation in conservation of bricks monuments

1. Minimum intervention steps

- (A) Minimum removal of existing old brick works, brick masonry work and minimum introduction of new brick work.
- (B) Up keeping of existing brick work in good condition.

Every part of a wall that is intact has to be protected with three lines of brick, laid down on the top of the ruined or exposed wall as a protective layer.

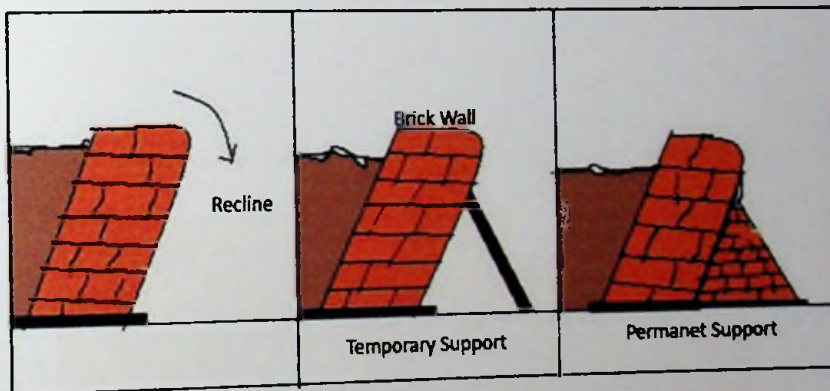


Protective brick layer

Picture- 132

Nature of the new brick wall should be in harmony with the existing old brick masonry in the size of brick, joining, thickness of plaster, texture of plaster and bricks.

Wherever a brick wall is bulgy it has to be supported by posts or erecting supporting wall.



Supporting wall.

Picture-133

If there remains any plaster or smooth surface on existing brick masonry, steps need to be taken any how to preserve them without dismantling.

Dismantling and restoration must be the last step to be taken when there are no alternatives.

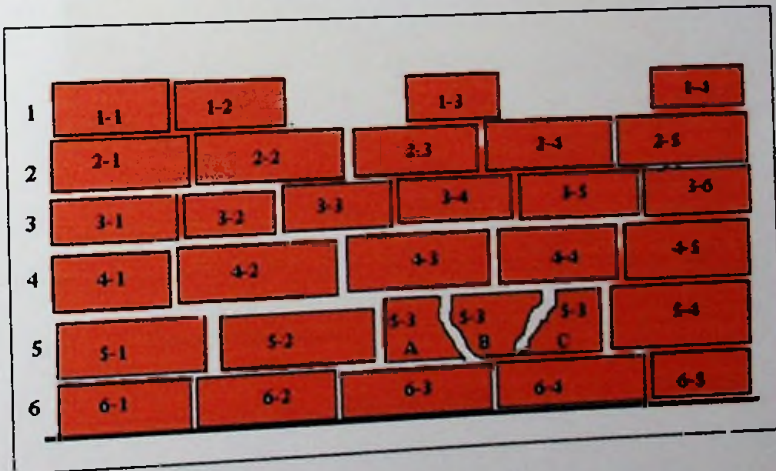
Dismantling and Restoration

In the beginning, pre-identification of all features, qualities and quantities, scales of walls or erections and preparing a report in detail is necessary.

All the sections should be planned, photographed in black and white, if necessary, maps may be prepared. In addition to plans, maps, photos are written report on everything should be kept. Numbering of parts to be dismantled to be planned and photographed.

When numbering, ahead of dismantling a brick wall,

- Numbering to begin with upper layers of the brick wall and then towards lower layers consecutively.
- Numbering should begin from left side as the accepted way.
- Direction of "North" to be marked upon the plan.
- Numbering should be carried out disregarding any missing of bricks.



Numbering brick walls

Picture - 134

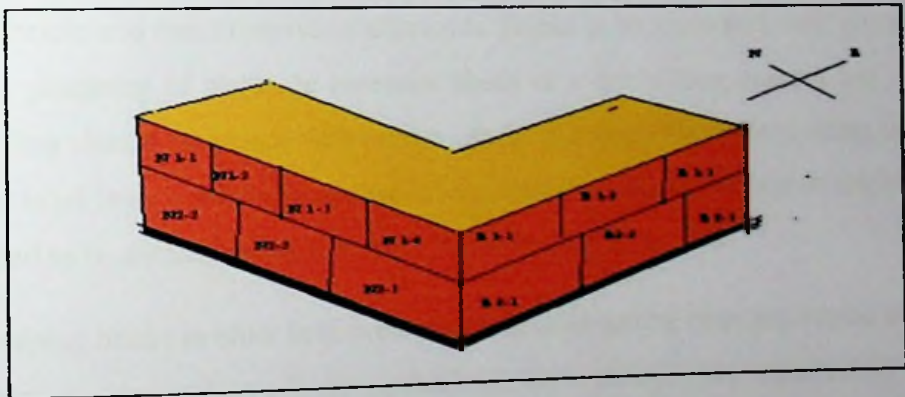


Numbering bricks on the side wall Hathareskotuwa of Abhayagiri stupa, Anuradapura.

Picture - 135

Numbering brick walls with several directions

Numbering is done according to the direction as shown below.

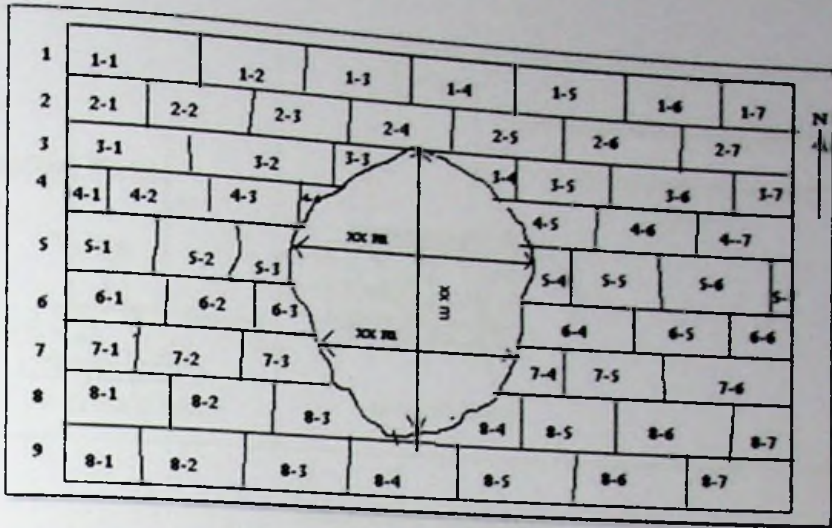


Numbering brick walls with several directions

Picture - 136

Numbering upon scaled plan

Where there is a missing part exists on a brick wall, it is easy to re-build it by being numbered on a scaled plan.



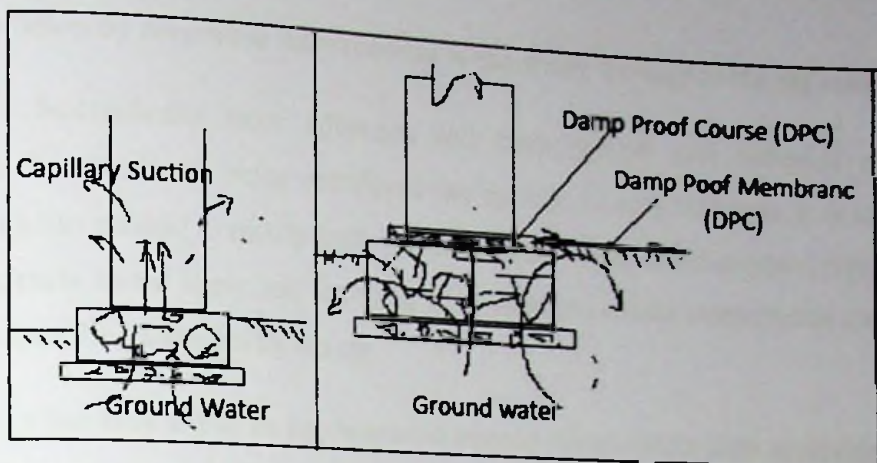
Numbering upon scaled plan

Picture – 137

Thus numbering and preparing a scaled plan of the missing part make it easier to dismantle existing bricks and exact restoration afterwards. Bricks to be numbered, then photographed and then preparing of plans are necessary ahead of a dismantling process put to action. Dismantling should take place with utmost careful planning. When dismantling begins, its top most brick layer needs to be removed to a certain distance and be kept in one line. Then the second to be dismantled brick by brick and kept close to the wall.

Thus keeping bricks in order help overcome difficulties arising from any erased marks etc. In this way, re-construction of a dismantled brick work, make it very important by being its accuracy and validity. At the same time, it is important to pay attention on the thickness of plaster.

After removing the wall, steps may be taken to find the cause that made the wall to crumble down. Such causes ought to be remedied. Weaknesses of the foundation should be strengthened. (In most cases concrete layers are introduced) Sometimes underground water seeps through the foundation and reach the wall making dampness therein. At such instances Damp Proof course or Damp Proof Membrane techniques should be used.



Damp Proof course layer

Picture- 138

All these lying of D.P.C., strengthening of foundation etc., are effected, only with the removal of walls up to the foundation. D.P.C. layer will not be put, in case of walls and buildings whose upper parts alone were removed. Thereafter brick wall may be erected using the numbering marked, thus giving its original appearance. Also make use of the original plaster mixture whenever possible. Old plaster mixture was analyzed at the laboratory and a similar plaster is used at the Abayagiri stupa conservation work.

At the restoration of missing parts or dilapidated sections

- Use of old bricks remaining at site.
- Use of new bricks, only when the old bricks are in short supply.

New bricks need to be similar with the old bricks in their size, color and finish. Yet the strength of new bricks should be somewhat of less strength. However, where it is not practical to produce new bricks, then the engineering bricks may be used instead.

- No alternatives to bricks may be used.
- Texture pattern of new bricks should necessarily be equal. Whenever possible use the original plaster mixture only.

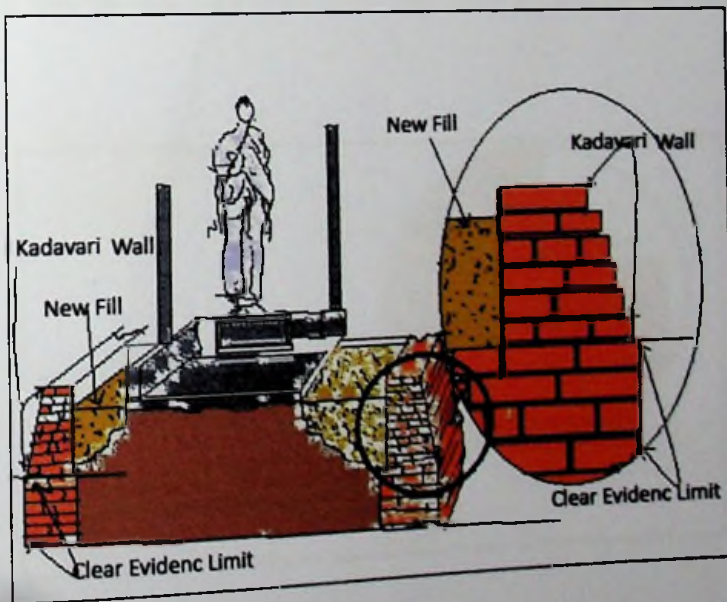
Conservation by reversible interventions without any damage to the old constructions.

Scientifically more advanced and more suitable raw materials along with efficient Procedures are being introduced day by day. At such instances, it is important to follow up this method to rectify faults occurred in the conservation projects, replacement of missing parts traced lately and founding of monuments amidst conservation concepts and opinions, drifting away era by era etc.

Conservation task not to be implemented beyond the evidence limit available.

Conservationist shall be careful as to limit his task only up to the clear evidence made available from the ruined brick monument. Conservation works are not implemented on hypothetical basis, or on unidentified evidence. Lest a misconception on the monument would be arrived at, afterwards. In order to prevent such an occurrence the conservationist sees to his limitations as with the evidence available.

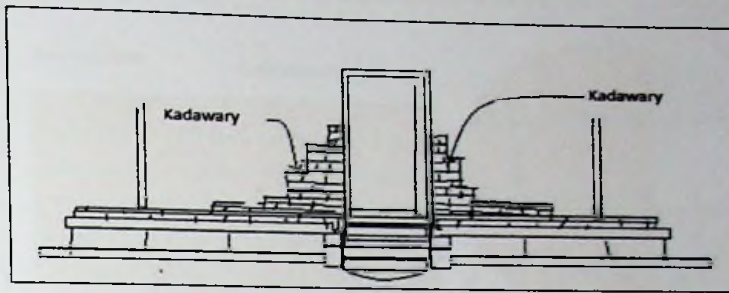
However, in order to preserve the monument beyond surface evidence (design, plastering, carving etc.) it requires applying "Kadavari" on brick surface.



Applying "Kadavari"

Picture - 139

Where it is harmful to the existence of a monument, walls are raised beyond the level decided upon evidence available, in order to perpetuate its existence.

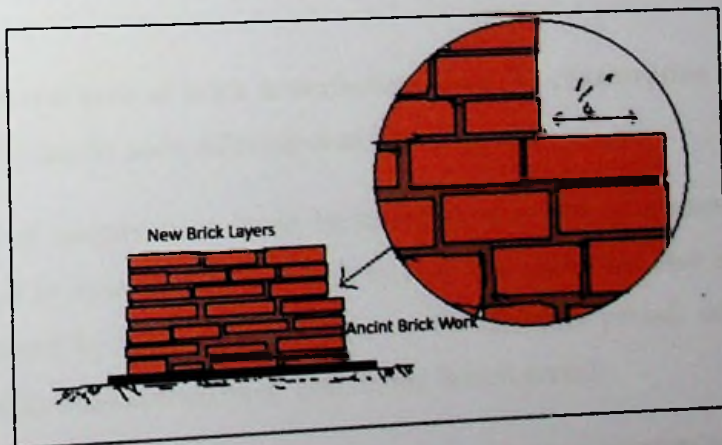


Applying "Kadavari"

Picture - 140

Any parts added to the monument should be done so as to identify by experts of the field but not to the knowledge of others.

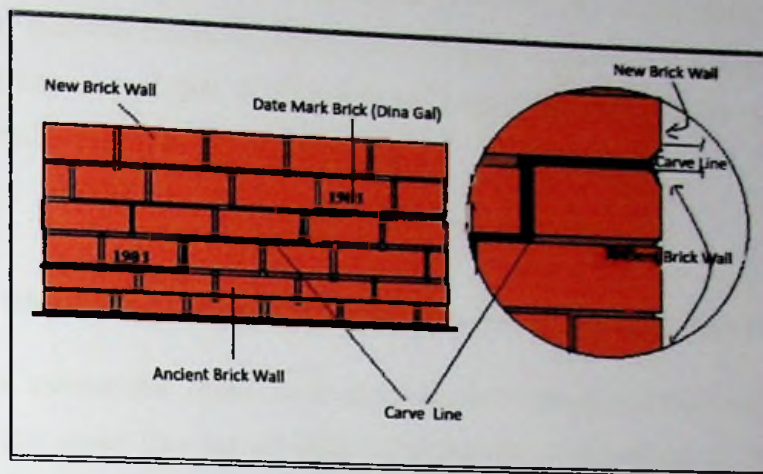
Such additions should also be effected in order to preserve the importance of the monument. About $\frac{1}{4}$ of an inch backwards, laying and finishing of newly added surface, from the existing wall surface.



Identification mark

Picture - 141

(A) To carve a line in between newly added part and the existing part and insert the put dated stones near to the joining.



Identification mark

Picture -142

(B) Some suitable mark and the year of manufacture are carved on new bricks produced for conservation work.

These bricks used by Central Cultural Fund of Sri Lanka have the year of manufacture and the Buddhist era and the CCF - Logo carved on one side of their face.

If there are several eras of brick manufacture, then the conservation should be done so as to identify clearly such differences as possible.

Several stages of constructions could be traced even in one monument. For example, Abayagiri Stupa in Anuradapura, first built by king Walagambahu: then enlarged by king Gajabahu, restored by king Parakramabahu in Polonnaruwa period; conservation with several supporting walls carried on by Bell during British period.

(Buttress for Hathares kotuwa of stupa) As such conservation programmed need to finish depicting all the stages and eras of constitution age as of competition of restoration.

All the Scientific particulars of raw material used for conservation, their texture the procedure employed etc. should be recorded.

Ex: - If they are bricks, their size capacity to suck water, resistance to tension etc. It was plaster, material containing their ratio, strength, endurance to compressor, tension etc, and recording is important. If chemicals were used, the chemicals their ratio and their mixture in detail

Standard of intervention followed in the conservation of brick monument.

Brick monuments found from excavations, explorations need to be conserved according to the values they are enriched with, namely, emotional values, cultural values, use Values, practical values. When the embedded value in each monument is identified, a suitable intervention needed so as to protect the peculiar it possesses. Choice of method is to be decided by a group of experts. Frankly some damage is inflicted at any type of conservation project. Hence the minimum steps taken in the conservation effort, and do what is essential only.

Therefore according to modern conservation programmers there appear seven modes of intervention.

1. Prevention of Deterioration.
2. Preservation
3. consolidation
4. Restoration
5. Rehabilitation
6. Reproduction
7. Reconstruction

Out of these seven intervention stages most suitable option will be chosen to launch brick monument conservation pregame in Polonnaruwa.

4.3. Proposal four conservation of brick monument in Polonnaruwa.

4.3.1. Proposal for conservation of brick monuments from natural

Causes of decay.

It is a difficult task to treat the damage developed in ancient monuments naturally by ageing process. However, these damages occurred due to natural causes could be prevented, if any satisfactory maintenance program is implemented.

Lapse in palming and designing at the commencement of construction of the monuments cause collapses and disintegrations. Further it is possible of falling down of materials used in the construction work due to the effect of gravitational pull. Therefore the structure should be laid out strongly so as to withstand the weight of such balding materials.

The weight of construction materials should be equally distributed among sections in order to prevent horizontal and vertical cracking and crashing. As such, it needs to examine the roof and the Upper constructions at first instance and if identified a location wherever the weight is imbalanced such places should be rectified as first step. As many of the roofs of brick built monuments are not to be seen today this situation could be seen at minimum. However at recently built vaulted roof of bricks in Thivanka image house there appeared vertical cracks on the walls in *Antharalaya*.

At such instances roof of the wall parts should be reconstructed so as to distribute the weight equally and to see whether those cracks develop further in not happening, such cracks need be filled out.

Also if the foundation is not strong enough to been the weight the building then the foundation will log down causing walls to crack. At such instances foundation could be enlarged enabling to withstand heavier mass. Bugged down foundation could also be strengthens by employing concrete supporters underneath. This step need to be taken very carefully provided the essential situation enforces. If the soil around the foundation is weak soft of loose then need to apply relevant chemicals to harden such soil. In Polonnaruwa,

weak foundation of this nature, requiring such treatment are not to be found in brick built monuments. They remain very strong despite the presence of small detractive activities. Moreover if there are any walls found inclining supporting walls could be erected against such inclinations, or else to dismantle and re build it.

Moreover new bricks may be used to fill up those holes of gaps made due to natural decay owing to the interior quality of early construction materials. Holes are well cleaned to accommodate sized brick leaving 1/4 inch distance from wall surface. New ricks should tally with the original in colour texture, strength etc. in conservation work sometimes the new brick is considered more suitable when it is less strong. Mortar plastering's washed down due to natural causes should be re done with lime and sand. Any cracks found in the plaster should also be filled up with lime plaster if the lime plaster is thinning out them liquated lime could e spread to strength such points.

Sometimes brick lines remain forming cavities without mortar which had been worn out due to some reason. Such cavities could be covered and filled up with pointing plasters. It is important to have this pointing plaster similar to the earlier substances.

4.3.2. Proposal for conservation of brick monuments from environmental Causes of decay.

Climate factor is a major aspect of environmental cause of decay wherein prevail sun light rain wind etc. like deteriorative agents joining with other agents have contributed to destroy monuments like the royal palace of king Parakramabahu and image houses like Thivanka, Thuparama and Lankathilaka.

As the sun shine project directly upon bricks and on lime plasters causing damages to these brick built monuments for many centuries now. This phenomenon should be prevented at least now. Polonanruwa receives a temperature beyond 30⁰C during most of the year. From May to September the city receives still higher temperature beyond 37⁰C affecting excessive heat directly on brick built monuments. Thus the damages caused are highly destructive. Hence it is required to erect roofs with a view to cover these ancient

monuments from devastating heat. This overhead roof will provide protection from the rain as well.

For all that, the task of erecting roofs over these colossal monuments like king Parakramabahu palace and Lankathilaka image house is practically very difficult. Further it requires a huge amount to build these roofs which might tarnish the aesthetic outlook of these ancient monuments. Also the lime plaster disintegrated due to extreme heat should be required well.

Erection of the protective roof will be very important to prevent washing away and permeation of water by the rainfall. When this is not practicable some protective brick lines could be added on to the wall of monuments. Cavities could be covered with pointing work.

Most of the serious damages caused to the brick built monuments in polonnaruwa had occurred on south side walls of the monuments. The apparent reason is these walls face windward of the north east monsoon. During the rainy seasons the heavy rainfall joined with gust of wind lashes on these walls and inflict much damages. A column of trees should be grown against the windward directing as a buffer line. A suitable variety of all trees that grows quickly and able to resist oncoming gusts had to be chosen for this purpose. This buffer zone should be maintained well.

Maintenance programmer should be affected so as to encounter heavy rainfall. Re-conservation of walls, foundation etc. need to be carried on following rainy season holes and gaps in monument walls ought to be repaired ahead of October – January north east monsoon which facing highest rainfall in the year. Cracks could be filled up with lime plaster. Replacement of worn out bricks with new ones have to be effected. Pointing work of cavities need to be done.

Any place accumulating water near to the foundation need to be attended by introducing suitable drainage gutters. Each year rainy season causes its erosion on the monuments surfaces. Hence the need to organize re-conservation programmed. A suitable system of maintenance, with a view to encounter regular rainfall seasons required to be scheduled.

Following the rainy season there arises the need to weeding which becomes the priority owing several succeeding week.

Blowing of wind causes extensive damages to the monuments. Especially the walls of Parakramabahu palace are subjected to the wind erosion large holes on walls used to hold timber floors are subjected to wind erosion presently. These halls are being enlarged by the impact of particles brought up by wind. Bricks are worn out in their sides forming still larger gaps in between upper and lower parts of huge walls threatening to crash down any moment. This requires immediate attention to remedy this precarious situation and to fill up with new bricks.

At the interior of this palace are can see the wind erosion wearing out of weakened bricks lying above the foundation of inner walls. Salt contained in the underground water weaken the bricks and then worn out by wind brought sand dust other particles. Some of the times incoming wind lashes out on the interior palace walls, forming whirlwinds rinsing upwards because wreaking out of brick surfaces.

Particulars the royal palace of king Parakramabahu is located in open land allowing winds to dash upon freely and directly thus causing many damages. As such it requires introducing a suitable wind "breaking" system in the vicinity of this palace.

There is a layers of sand accumulated inside of the palace several inches thick. Wind borne sand and dust wear out the brick walls and to prevent this occurrence some alternative covering materials may be laid on the floor instead.

Rain accompanied with the north east monsoon wind caused to wash away brick and lime mortar of outside of southern wall of Lankathilaka image house. As this monument are higher than other buildings wind dashes directly against the walls. They are it is important to make a wind preventing tree line which would also prevent sun light and heavy rain. It has to fill up the rain washed places with lime mortar and to apply plaster of brick surfaces and to replace new bricks. Higher brick walls get more wetness during rainfall. Some remedy, like laying of additional brick lines on the top of existing brick lines could be experimented. Yet this remedy may be ineffective even it is also not practicable to

construct protective roof over these very high buildings. Hence the need to operate a suitable maintenance programmed on this high rising monuments.

Inside wall of Lankathilaka are heavily eroded by wind. Wind direction could be diverted planting trees in frontal side. Sand accumulation in the inside should be cleared.

South wall of Thivanka image house has been heavily eroded by wind. As this monument is situated on a high ground and trees are not appearing in at south side, and whirlwind formed due to banyan tree nearby, south side wall has been subjected to wind erosion. Also the premises south to the monument is devoid of grass permitting wind to carry sand and wearing out brick walls. This requires to grow grass again and to plant trees covering wind direction. Some plantation has been made there already but steps to be taken to strengthen such buffer areas.

Recently built roof of the Thivanka image house should be removed. This roof has been built with using a large numbers of G.I pipes and sheets. This roof injuries the aesthetic beauty of the monument. It is important to erect a permanent roof instead. That will perfect outside walls and also have important paintings inside from the sun shine and rain. It is important to erect their roof a new due to the cultural importance of the monument, although it might do some harm to the beauty of the place. Parts of colour paintings still remaining at outside of south wall need to be protected by some remedial measure.

Further the landscape around this image house need to be imported. Premises in the front, north and south sides have washed away leaving stones and pebbles. Frond door way and the access road should be found by excavation, then conserved and the landscape need to be improved.

Thuparama image house too is exposed directly to the sun light thereby under goes thermal expansion and contraction cause resulting the decay of bricks and lime mortar. As the wall surfaces exposed to the rain bricks get soaked and are washed away. Water permeates from the vaulted roof. Water leaks through broken roof cause dampness encouraging growth of moss. The image house being a relatively small in scale a similar roof like *Galvihara* could

be fixed here. The only surviving vaulted roof built entirely with bricks, during the Polonaruwa kingdom is this Thuparama building. This is more the reason to fix a protective roof over their monument.

Lankathilaka and Parakramabahu palace are huge buildings and it requires immense capital to construct overhead roofs despite causing harm to the aesthetic importance of the places. Therefore it requires putting up a covering roof above the high walls using suitable raw materials.

All these image houses and palace are accounting the next major problem of damages caused by herbal and animal factors. Although there appears vast vegetation in this area, only few kinds of herbs are seen on these moments they are;

Trees with spreading branches

Bo (*Ficus religiosa*), Nuga (*Ficus virens*), Ahatu (*Ficus tinctoria*), Kohoba (*Azadirachta indica*), Diul (*Feronia Limonia*), Jam (*Muntingia calabura*), and Kolon (*Adina cordifolia*) like plants grow on brick made buildings. Bo, Nuga, Ahatu, Kolon plants grow luxuriously on brick works.

Roots of these trees go through the cavities and reach interior. These trees are able to grow on even in arid climate they should be removed or updated during the drought season from many to August. Arsenic may be applied on the cuts of remaining roots or welding plant may be employed to burn out any resisting root systems.

Bushes and Plants

Iluk (*Imperata cylindrica*), Wara (*Catotropis gigantea*), Kaladuru (*Cyperus rotundus*), Akkapana (*Bryophyllum*), Thuththiri (*Chrysopogon aciculatus*), Wal Sarana (*Trianthema portulacastrum*), Walpathpadagam (*Oldenlandia Corymbosa*), Udapiyalaya (*Desmodium*)

Ath adiya

(*Elephantopus*), Kapum keeriya (*Euphorbia hirta*), Iramusu(*Hemidesmus indicus*), Nidikumba

(*Mimosa pudica*) Sudupitawakka, (*Phyllanthus amarus*) pothuthana (*Dactyloctenium aegyptium*), podisingnomaran (*Chromolaena odorata*), Hulanthala(*Azerratum conyzoides*), etc grown on extensively on brick monuments.

These herbs mostly live as annually growing things. They provide plenty of seeds during a short period and are spreading widely. Some of these plants namely, Walpathpadagam, Walesarana, Thuththiry, Kapum keeriya have the ability to grow quickly on brick and mortar. Their seeds are very light and born by wind and water to distant places. They may grow on any types of historical buildings. These seeds, having thick husks resist insects and any wired environment. Whenever water is received they can grow on making it difficult to control their growth. Wind takes seeds to any palace anywhere. The best way to tackle this problem is to uproot the young herbs well before producing seeds. Thousand of seeds will not enter in to the environment. As such maintenance programmers need to be operated after a study of climate life cycles of various herbs. Polonanruwa gets rain from much to April and heavy rainfall during October to January 12700-19000 mm (50 to 75 inches) growth of herbs begin with the rainfall requiring to uproot herbs well before two weeks time.

Ferns herbs

Several varieties of ferns belonging to ferns family can be identified at the brick walls having more dark and high humidity places.

Roots of these herbs take a shape of carnose. Those are grown easily on the places where water clogs and often wet. These herbs produce a large amount of seeds. Which are transported in turn by wind. The remedy to this situation is to make the environment devoid of darkness and humidity and also to up root and disposal all herb community.

Fungus

Several varieties of light gray and light yellow and cream colored fungous can be identified from the brick built monuments of Polonnaruwa. These are grown on exposed brick surfaces and insides of windows and holes etc. Growth and expansion of these fungous could be controlled by allowing sun light and air sufficiently on to the brick surfaces and in to the interior. Existing fungus could be seen catch out, and if essential some chemical liquid could be applied provided it does not inflict and harm either to bricks or to mortar.

Algae

Algae have grown extensively on the walls and the foundations of all these buildings.

Varieties of algae in green and brown colour have grown on the places with high humidity. As such it required to control humidity. Also any place retaining water or draining water has to be attended. Grown up algae need to be scratched or applied chemicals. These remedial measures should not harm brick surfaces or mortar.

Lichens

There are many kinds of lichens could be identified grown on brick monuments in Polonnaruwa. They are in green, grey, light blue, cream, light dark green colors. They are in the forms of foliaceous and crustaceous. Light green lichens have a wider growth. They are able to survive in highly arid environmental. Therefore it is necessary to research these herbs or to dispose them with some chemical liquid.

Moss

Moss can be seen in the dark wet places of brick monument foundations. The upper parts of walls in the palace of Parakramabahu and its back side foundation show the rich growth of moss. At the foundation of Lankathilaka and Thuparama image houses and inside corners

are grown with moss. As the humidity encourages moss it requires creating the environment devoid of humidity. Places of water clogging permeating draining soaking etc, Should be attended with suitable remedies. When disposing moss during the dry season by searching on applying chemicals. Cavities among bricks to be point done.

Best way of disposing herbs to uproot and burn then altogether. Use of poisoned chemical may be harmful maintenance. Programmed has to be organized according to the rainy season and of growing herbs. During the drought roots of Bo, Banyan (Nuga) and colon trees need to be cut and uprooted. Where it is impartibly some chemical liquid mat be applied on such roots as to twin by a welding plants. Cavities formed with the uprooting work have to be filled up.

Animals causing damages to brick monuments.

Brick monuments of polonanruwa are subjected to decay by numerous animals like Quadrupeds, reptiles, birds, and insects.

Quadrupeds who cause damage to brick monuments in Plonnaruwa.

Monkey (*Kasi senex*) Ape (*Macaca sirica*) Cattle (*Baos taurus*) and such like animals inflict damages of the monuments. Whenever they are abandoned by people. Watchers should be employed to guard the monuments when the visitors etc. have gone out. Watchers need to have a good knowledge of damages caused by various animals.

Birds

Swallow (*Petrochelidon pyrrhonota*) Pigion (*Columba livia*) Bat (*Pteropus giganteus*) and such monument and used to spend their lives. Hence the need to dismantle such abodes' and to chase away such animals without delay. Such places need to be made unwelcome to the birds again. Suitable item made nets could be fixed in to such places discouraging birds community to build their nests.

Insects

Termite is the insect that does most devastating damages to the monuments. It has built up ant hills on and around of foundations of brick walls in the Thivanka and Thuparama image houses. These eye sore creations must be wiped out at once and an insecticide be sprayed around these places.

Potter wasps have built their abodes extensively on brick made arches etc. of Thivanka and the inside wall of Thuparama image houses, it is evident that their expansion is rapid. Hence the action to be taken to dislodge their habitat and same chemical treatment need to be done.

Reptiles

Lizards are causing some damages by digging holes and tunnels near and around the foundation of brick monuments. As many of the monument are in the solitary places it required to keep these buildings clean and well maintained with a view to control this devastation.

4.3.3. Proposal for conservation of brick monuments from man - mode

Causes of decay.

Damages caused by man

This can be checked by making awareness and imposing laws and regulations. Awareness programs may be conducted to visitor's tourists, students and also the neighbors' dwelling close by to the monuments.

Conservation projects need be carried out by a board of expert academics, who process voluble experiences there by the loses of damages to the ancient monuments could be minimized. There advisory boards are already in operation and these should be

strengthened with more enforcing capacities. Decisions should not be depended on personal grounds or on single reason.

Conservationists clever in archeological field should be engaged in these works. Suitable programs to enhance knowledge in this discipline need to be launched. The knowledge skills and attitudes needed to future protection of monuments. The importance of deploying experienced hands than near helpers is useful in minimizing the damages that might cause to ancient heritage.

Sightseeing visitors used to walk on monument walls etc. Searching on there and making the premises daily and such like untoward activities. In order to prevent these happening display of notice boards. and deploying watches and guards can be introduced. Although these steps have been taken already still prevails the habit of scratching by people as appearing on the lime plasters of the back side of the palace of king Parakramabahu.

Valuable drawings existing in the Thivanka image house should be protected from cameras and also from touching them by person's introduction a security cameras may even be useful in employing new technology for conservation efforts watches need to be trained in this field.

Punishment should be meted out to who sacrilege the heritage sites. Fines and penalties should have to be increased, and notices in this regard may be displayed on notice boards. People living in the neighborhood, students of nearby schools and traders etc. Should be educated on the inestimable value of these monuments sites whereby many damages caused by man could be prevented.

General proposal to the conservation of brick monuments in Polonnaruwa.

The same attention directed to the major monument, should also be directed to the small monuments as well. They have fallen to risky existence, owing to be left out of conservation and maintenance.

Maintenance work should effect speedily and with good management. A special conservation unit should be formed, while the existing maintenance works continue as it is.

- One conservation officer, skilled laborers and weed removers (trained to reach any difficult place and necessary protective instruments, helmets and security belts should also be provided) cleaners, point workers should be appointed to this unit.
- Materials needed to any small conservation project implements and raw materials should be available to this unit.
- They have to be responsible for the task to be fulfilled and a definite time table.
- Monuments areas to be divided to sections, and to visit each monument once or twice a week, and to give instructions on suitable actions in response to the visible agents of decay. This cycle of visits should be repeated so that the monument is looked after continuously. Whatever any tiny point detected should be attended to, without delay. E.g.:
- Weeding
- Stones loosened on wall tops by people and animals should be fixed again
- Allow rain water to drain cut ward from the monument
- Brick walls to be repaired replacing new bricks where there are decayed bricks
- Washed away Point plasters need to have new points work
- Removing garbage dumped by tourists
- Not to allow animals to make holes, nests etc.
- If required to subject to major conservation, make aware of it to the head office conserved.
- Landscaping for attraction

Small scale construction and maintenance work could be attended by such a small unit

Keeping a file on each monument is necessary future conservation plans and the ways and means of executing them on time etc should be in these files. Also any restoration work

done or chemicals applied should be in it. Building with frescos like Thivanka Image House should have these files.

Royal palace of King Parakkramabhahu needs prevent wind erosion by which heavy appears parts of central walls might collapse down. New bricks can take place of worn out bricks there. Thus rain eroded bricks and wind ended bricks could be replaced with new bricks saving the monument concerned.

Daily recording programmed of the weather changes affecting on the monument to be introduced.

It is important to collect data of daily fluctuations and recording them, even on some selected brick monuments. Especially, it is important to record the quantity received of climatically factors like hat in every six hour period (if possible hour by hour). Also the fluctuations of humidity within the monument wind speed and its pattern and directions should be recorded continuously. This will definitely help planning of future long time conservation efforts. A research unit to study botanical eroding factors activating on the monument and to pay more attention in this regard.

More attention on landscape planning should be paid.

Planting of trees that would provide a cover to the frontal sides of Thivanka and Lankathilaka monuments should be done suitably with the sacred area. More attractive landscape plan should be executed in the vicinity of Thivanka image house. It is essential to stop the soil erosion in the eastern area. Excavation in front of the Image House to find the ancient wall and the limit, which should be re-constructed and the main access road to the monument should be constructed. The area in front the monument needs earth filling and leveling the premises attractively. Landscaping should be done an stages beginning from the east and an access to the front entrance of the monument to be made.

Conclusion

Ancient city of Polonnaruwa had acquired the most important place in the history as a place, where a multitude of brick built monuments of varying giant structures, relatively concentrated in to a small area. Within a short period of about 150 years, a great number of gigantic brick work constructions had been created in Polonnaruwa. While being the great works of art, the technology of high quality bricks had well established.

On the other hand, the reason to select the brick as the main raw material should have been the possibility of making quality bricks in a short time with less expenses and the availability of raw materials abundantly. Also the political crisis continued in Polonnaruwa made the situation very unstable. As such, it was thought much easier to use new materials like bricks which were obtainable in short period.

The magnificent royal palaces, image houses, stupas , monstaries, forts and romparts ponds and parks etc. built within a spaces of about 150 years, amidst numerous internal strife finally destroyed by the ruthless ruler Magha in the 12th century A.D. People immigrated to south – western parts of the island, resulting the great civilization disappear under encroaching jungles.

Polonnaruwa city this destroyed was first conserved by the prince Vijayabahu – IV, the son of king Parakramabahu - II during his reign 1236 – 1270 AD. This is about 50 years after those monuments were built. But people left the kingdom due to non stopping foreign invasions. There after thick forest covered the kingdom with all its buildings large and small alike. Natural elements like sun shine, rain, and wind had contributed their share in destruction, trees, animals and treasure hunters dealt the last blows.

The vaulted roofs of Thivanka and Lankathilaka which were built with bricks collapsed at this time. Frescos and parts of large wall vanished. Large trees growing on the brick monuments brought about the destruction with their mass of roots. Only the very strong parts could resist the onslaught aforesaid. At the beginning of 1800 AD, British military officials who were passing these areas paid attention on these monuments. As a

result these fantastic creations were brought to the light, after 600 years of oblivion under thick forest.

At first British persons carried on some conservation which was taken over by the archaeological department in 1890 and by the Culture Triangle in 1980. Thus various conservation projects have been launched to preserve these historical monuments for future generations.

There is no decreasing to be seen even today of the eroding factors of human intervention biological factors like vegetation and animals, as well as the natural elements like the sunshine, rain, wind working upon the brick monuments in Polonnaruwa after passing many centuries.

Sri Lanka is situated close by the equator and the tropical climate prevails in it. Accordingly heavy rainfall and high temperature prevail in the country. Further, Polonnaruwa lies within the dry zone and the temperature is very high during the daytime upon the brick monuments. Generally a temperature of more than 35.5°C directly affect Polonnaruwa monuments during May, June, July, August and September. Fluctuations of the temperature between day and night are between 12°C – 14°C. As such bricks are liable to expansion during day time and contraction at night time there causing, extensive to the monuments. During day time, Instant temperature fluctuation cracks the brick surfaces and the lime plaster. Hence the high heat expansions and heat movements cause damage to brick monuments.

A heavy rainfall of about 500 ml in the year during October and November precipitated on the bricks. This results monuments loosen and collapsing and washing away of landscaping, collection of water in and around, dampness causing brick walls to attract bacteria. Algae, fungus, Lichens, etc. Brick walls and plaster are subjected to destruction with the raising up of ground water level that weaken the foundation and also seeping this water in to brick walls contribute to the same. Another finding of the research made on the brick monuments is the extent of wind erosion and washing away of southern walls of Thivankaya and Lankathilakaya. These walls have been faced towards southern direction straightly face north east monsoon which bring rain to Polonnaruwa. This resulted these

walls heavily subjected to wind erosion and lashing of rain water on the walls, directly contributing to their wash away. Lime plaster of southern wall of Lankathilaka had been fully washed away.

Although numerous trees are grown on the brick monuments, it is evident that wider growth of large trees like Bo (*Ficus religiosa*), Nuga (*Ficus virens*), Colon (*Adina cordifolia*), be seen. Among the variations of Ficus, *Ficus virens* could be mostly seen on monuments. Through weeds are grown profusely about the monuments premises, generally Walpathpadagam, (*Oldenlandia corymbosa*) Wal Sarana, (*Tranthea portulacastrum*), Kepumkiriya, (*Euphorbia hirta*), Thuthtiri (*Chrysopogon aciculatus*) are widespread on the monuments. Walpathpadagam, (*Oldenlandia corymbosa*) is mostly grown on the bricks due to the resistance against dry conditions producing many seeds and making adaptability to any climatic conditions.

Other weeds Wal Sarana, (*Tranthea portulacastrum*), Kepumkiriya, (*Euphorbia hirta*), Thuthtiri (*Chrysopogon aciculatus*) also capable of producing much seeds which are carried away easily to long distances of varying heights by wind, water and animals contribute to this. Hence the spread of weed on the brick monuments appear.

Bacteria and fungus growth are relatively insignificant on the brick monuments. However a milky colored fungus growth could be noted in more covered monuments like Thivanka and Lankathilaka image houses. Also, another two specimens of algae in green and brown colors were to be seen in more wet places of bricks walls. These algae in green and brown colors were to be seen in more wet places of bricks walls. These algae could be seen in very large quantities on the foundation bead at the Lankathilaka image house. These are easily grown on places with more moisture.

Lichens of various colors and shapes are grown largely on bricks and plaster and destroying them afterwards. These lichens are of light green, light blue, milky and bluish ash colors and of sometime singly of sometime a masse.

The brick surfaces of monuments and the lime plasters upon it are mostly damaged, by the micro herb called moss. Upon the every surface with humidity, black and green coloured moss caused damage visible in all the buildings built with bricks. Exposed to air high brick

walls and the covered corners of Lankathilaka and Royal Palace of king Parakramabahu have been affected with the growth of this moss this menace poses serious threat to destroy the brick surface and the beauty of the palace. As the dampness on the bricks developed by moss several factors have joined to erode the same bricks.

Among the animals who the most damages to brick monuments are swallows (*Petrochelidon phrrhonota*) and. These swallow build nests on the monuments and excrete on them have caused extensive damages as have happened in Thuparamaya, Lankathlakaya, Thivankata etc. these birds are in quick growth than others and they bring down grass like carbonic material in large quantities aggravating the problem potter wasp Had built its shelters in large numbers on the brick walls of image houses. The back side wall of the dome, inside of Thuparamaya could be seen though pestered with a mass of these shelters. Most injurious damage is this pestilence being spread upon the most valuable and most sensitive, numerous frescos of the Thivanka Image house. It's dome as well as on the arched roof built with new bricks, in the conservation project is almost covered with these shelters. In between the carvings and moldings of outer walls of the image house are scattered with these shelters. It is essential to take urgent remedy against this menace.

Man made damages on these monuments are the scribbling on the lime plaster surfaces which are in good preservation in good. People also dump rubbish and dirt on and around the monuments. They also walk on the walls of the monuments; touch frescos as done at Thivankaya and also taking photographs using high power electric flash lights.

At the same time the mistakes occurred during the conservation efforts are apparently seen as in the Thivanka image house. The necessity of an efficient and methodical maintenance schedule is also apparent. Conservation sits do not pay due attention on landscape either. Another lapse of their duty is the failure of launching a suitable, effective and long lasting procedure to avoid wind erosion as now happing in Thivanka, Lankathilakaya and in the Royal Palace of king Parakramabahu. Another serious damage caused to Thivanka image house is the sheet roof supported by closely stood G.I. pipes undermining its aesthetic value.

Therefore it is now time to replace that roof and supporting with a more suitable roof of same Gal vihara in Polonnaruwa.

So far on the conservation of brick built monuments various programs have been implemented, in order to effect the environmental limitation maintenance consolidations and such like step which have been mainly experimented with a view as to find and decide on future programmes.

Although these temporary conservations procedures should necessarily have to be continued further steps need to be taken in order to execute more effectively long lasting and satisfactory conservation efforts. To achieve this goal long term planning and various faceted researches need to launch and to achieve genuine ways and means.

From example uprooting of herbs that cause damages to brick built monuments is the method used at present. Will it be possible to find out easier remedy in addition to the practice in use now. Herbs of quickly growth and wider expansion could be made as short living thing but introducing certain biological or genes deviation.

Researches could be focused so as to look for any preventive steps to be used affectively to minimize deteriorative factors such as wind rain. It is possible to re-construct the broken vaulted roofs using lightened variety of newly tested bricks having some colour texture and strength.

Another very important aspect is to find out satisfactory ways and means as to exhibit these bricks built monuments to general populace. The monument and the environment are inter connected well making it necessary to develop the landscape to suit the grandeur of the monument. Further the landscaping need to have executed in keeping with the historical interest. It should also add a sense of attractiveness and aesthetics so as to make visitors proud of themselves.

These procedures may be followed with due attention in order to preserve the brick built monuments in Polonnaruwa for future generations enabling them to relate their historical pathway accurately.

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