

## Research Paper

# The Study on Plaster Materials: Special Reference to Rajagala Cave Dwellings

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## ABSTRACT

Rajagala is one of the cave-based monasteries, where inhabited by more than a hundred monks from the 2nd century to the 11th century AD, those who practiced meditation in the caves, had done certain construction work to make suitable living place. Some ancient construction works are still visible. This study was conducted to understand the diversity of the construction materials used, and to determine whether there was any guidance from Vinaya Pitaka, it also, emphasized the plaster materials that had been used to construct different caves, particularly eight caves, and plaster sample materials were analyzed by using analytical methods such as microscopic observation, chemical, particle size, cross-section, and Fourier transform Infrared Spectroscopic analysis (FTIR). Furthermore, had done cross-reference with literary sources such as Pali Vinaya Pitaka. According to the results, the plasters were frequently made with clay and sand while floor plaster consisted of lime and sand with different ratios. In addition, organic materials such as paddy husk and charcoal particles were identified. The use of both sorted and unsorted sands was observed. In some cave plasters, a charcoal layer had been applied to make a blackish appearance, there were some remaining pigments mainly red and yellow ochre applied on a lime layer, which had been decorated with some paintings. The study identified that the use of the materials they applied for the construction work was to some degree aligned with the code of discipline, particularly in the Senasanakkandaka in Chullawagga in Buddhist doctrine.

**Keywords:** *Rajagala, Monastery, Cave dwelling, Plaster materials, Architecture*

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## 1. Introduction

According to Buddhist culture, the monk had to stay in temporary places such as underneath a tree, forest groves, open terraces, mountains, caves, cemeteries, and temporary huts in ancient times (Cullavaggapāli, 1983). Later on, concerning the requirement of the monk, the royal patronage and wealthy devotees offered permanent monastics residence (Āvāsa), which provided adequate basic needs with stability manner (Cullavaggapāli, 1983; Dutt, 1962; Brown, 1959). Subsequently, the monks had to

arrange and maintain the buildings according to the code of discipline (Vinaya), with that guidance they had done some suitable changes to the cave building by adding some materials and colors (Cullavaggapāli, 1983; Visuddhimagga, 2000; Bandaranayake and Jayasinghe, 1986).

According to the chronicles, Venerable Mahinda had come to the country with Theravada Buddhism, after the 3<sup>rd</sup> Buddhist council in the reign of King Asoka, introduced the

monastery culture with abstemious life at the first capital city of the country (Mahavamsa 15:1-19). Later, it spread to other parts, including the eastern region where the ancient Rohana Kingdom had been established, among them Rajagala was the monastery had built by King Lajjitissa (119–109 BC), in the 2<sup>nd</sup> century BC for hundreds of monks, providing cave dwellings, counting to more than a hundred in numbers (Mahavamsa 33:14-15; Deepavamsa 20:11; Paranavitana 1970). Furthermore, it was the place where the first, and foremost inscription evidence has found that Venerable Mahinda reached to the country with his adherents. Consequently, this monastery had been representing the values of the ancient monastic culture, and might have been directly influenced by India (Mahavamsa 13:15-20; Paranavitana, 1970).

In the earliest times, monks had lived in caves (private abodes); the cave was known as *lena* or *Guhā* (Sarkar 1993). Etymologically, *Lena* is equivalent to *Skt. Layana*, which is derived from the root *li* to hide (1899: 903.2). The monks had used those caves during the rainy season (rain-retreat or *vassa*) as a custom which had influenced by Jaina and Brahmanical behavior of *Pajjusana* (Dutt, 1962; Mahavamsa 16:12-17), after the introduced monastic life to the Sri Lankan, had to do some extra perpetration work to the place where they had resided; inside cave add some features to the wall, terrace, and roof using some materials; stone, bricks, clay, sand, and limestone applied some simple techniques consisted of indigenous tradition to finish an appearance of the cave premises well (Gunawardhaena, 2009). According to Rahula (2018), some residential caves were plastered and whitewashed, sometimes those were painted. Visuddhimagga (2010) shows the story of the renunciation of the last seven Buddhas, beautifully painted in the Kurandaka Mahalena near Mahagama, the residence of Chittagutta Thera, several bhikkhus who had entered the cave wandered about the painting. In the early times, cave dwellings were arranged not only by making walls, but also decorating the wall with paintings to get an aesthetic sense and quiet temperament. However according to Bandaranayake, Sinhalese cave monasteries were in the real sense of the term than excavated Vihara in India (Bandaranayake, 1974).

The architectural formation of the rock shelter monasteries was recognized as a simple feature of the construction, the natural caves, and materials, and was not highlighted to follow the pre-planning formal mechanism, while designed for the monastic shelters (Gunawardhana, 2009). Nevertheless, considered some extent rough plan when they had designed the interior and exterior conditions of the caves, also adding some bricks or stone wall for structure, and plaster.

The discovery of the cave plasters had been reported by some scholars who had studied focusing on paintings; Sana Ulla, 1943; Coomaraswamy, 1962; Wijesekara, 1964; Bandaranayake and Jayasinghe, 1986; Silva, 1990; Charles,

1995; Vajira, 1995; Agrawal and Wickremasinghe, 2002; Manathunge, 2004; Somathilaka, 2004; Priyananda, 2009.

Coomaraswamy(1962) described several examples of paintings in the 18<sup>th</sup> century in Sri Lanka, such as Ridi Viharaya, Danagirigala, Degaldoruwa, and Dodanthale, depicts the making of colors and the background for the painting, and there is no discussion of ancient wall plasters in caves or temples in his book. Having discussed the 'Cave-Shrines of the Anuradhapura period', Bandaranayake and Jayasinghe (1986) focused on the closet study of the relationship in style, figure and coloration of the paintings. Charles' (1995) discussion is similar to the previous authors, but Wijesekara (1964), Manathunge (2004) Somathilaka (2004), further discussed the plaster compositions related to the painting, particularly, Sigiriya, Pidurangala, Hidagala, Dibmulāgala, Mihintale, Mahiyanganaya, and Polonnaruwa. Their research finding had more focused to the painting, as well as they had discussed some used materials such as clay, sand, lime, pieces of straw with cross-section details which had used for the painting, and disclosed with their unique features.

Also, Silva (1990) involved his studies to discuss the painting of Sri Lanka, such as previously mentioned locations, among them, he had more focused on Sigiriya and Pidurangala had taken valuable information on the composition of the painting layers through his explorations with scientific analysis.

Furthermore, Vajira (1995) mainly focused his object on the plasters of paintings on the cave surface in Sithulpawwa, Vessagiriya, Hindagala, Pulligoda, and Sigiriya, and he had pointed out that artisans who represented Anuradhapura to Kandy period, had thought to make the plaster in a good quality manner to maintain wellbeing for centuries, therefore, they had interested to make plaster, used traditional materials such as clay, paddy husk, fibers of the plants, lime, sand. However, research had not focused on the wall which was constructed in the cave abodes. Priyananda (2009) also had considered the reading of previous works were done by scholars who focused on ancient paintings, and how plasters were made in the Anuradhapura to Kandy periods.

Agrawal and Wickremasinghe (2002), had studied and step forward to discuss the painting plasters scientifically based on 20 locations, representing Anuradhapura, Polonnaruwa, and Kandy periods, and had given detailed information regarding the plaster, pigments, and technique each location, yet, they had not included of the studies of cave walls and their plasters, and also, neither of them was able to study Rajagala nor at least cave plasters representing the eastern province.

According to the previous discussion, most of the researchers had focused on the main locations where ancient paintings were available, and they attempted to study the paintings and the plaster composition of each site

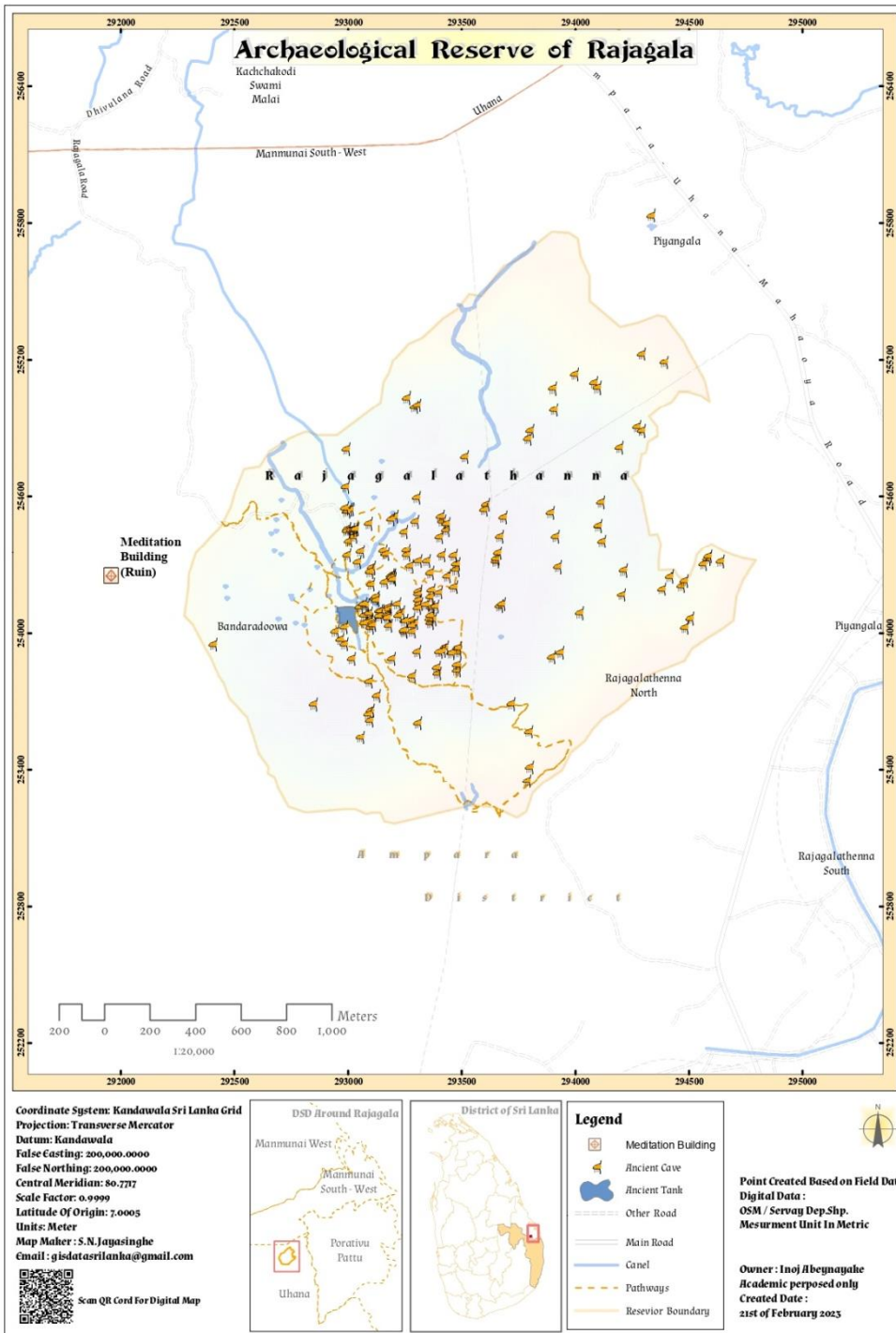


Fig. 1. Location of the Rajagala Archaeological reserve area

in a scientific manner, and also there was no discussion compared to the facts of Tripitaka (code of discipline) in their research, this study focuses to present the diversity of the materials had used for the cave walls through the scientific analysis in Rajagala and to determine there was any guidance from the Vinaya Pitaka.

### 1.1 Study area

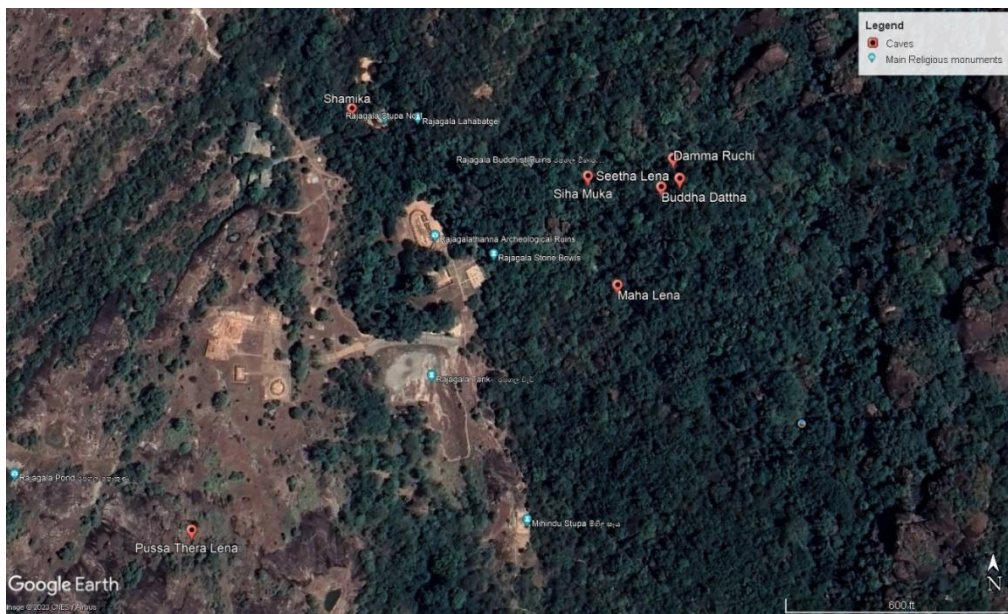
The Rajagala archaeological reserve is in the eastern part of the Ampara district, spans 943 acres, an elevation of 346 m above sea level. It has remarkable diversity due to its geographical complexity and geomorphologic variability dominating a striking tectonic province called Vijayan

complex (Cooray, 1984). The area lies between  $8^{\circ} 29' 24.21''$  and  $81^{\circ} 36' 59.33''$  (Fig. 1). The mountain spreads from south to north and consists of different sizes of land areas, and deep slopes can be seen on the eastern side of the mountain, and lower slopes on the western side consist different kinds of geological features. In the historic sequence, the pre-historic man had inhabited the caves dating back to  $7493 \pm 34$  BP (2016), evidence of the proto-historic site, such as urn burials, can also be seen at this site, but it has yet to be identified with scientific research. In the historic period, the natural caves had been used by Buddhist monks as their residences, and found more than hundred cave dwelling with drip-ledge and some inscriptions attached to those, dated to the 3<sup>rd</sup> century BC to 1<sup>st</sup> century



Sample No.	Cave Name	GPS Location	Sample Location	Type of sample
RC 1	Sāmikā	7.49119 N, 81.61573 E	Inside back wall	Wall Plaster
RC 2	Maha Lena	7.48969 N, 81.61795 E	Inside back wall	Wall Plaster
RC 3	Maha Lena	7.48969 N, 81.61795 E	Inside terrace	Floor Plaster
RC 4	Pussa Thera	7.48772 N, 81.61449 E	Inside front wall	Wall Plaster
RC 5	Buddha Dattha	7.49046 N, 81.61828 E	Inside right wall	Wall Plaster
RC 6	Buddha Dattha	7.49046 N, 81.61828 E	Inside terrace	Floor Plaster
RC 7	Dhamma Ruci	7.49068 N, 81.61837 E	Inside right wall	Wall Plaster
RC 8	Sihamukha	7.49057 N, 81.61771 E	Inside wall	Wall Plaster
RC 9	Korawakgala	7.49224 N, 81.61702 E	Inside left wall	Wall Plaster
RC 10	Seetha lena	7.49052 N, 81.61842 E	Front wall	Wall Plaster

**Table 1. The description of the samples taken from caves (RC-Rajagala cave), Name, GPS location, sample Location, type of the sample, and sample size**



**Fig. 2. The locations of the sampled**

AD. The specific characteristics of the Buddhist cave architecture belong to the Anuradhapura era, and remain some unblemished features after the subscription of the monastery (Hettiarachchi, 2018).

## 2. Materials and Methods

### 2.1. Sample collection

Eight cave sites were randomly selected based on the evidence of plaster materials, which have been available since ancient times (Fig. 2). All samples were collected with the approval of the Director General of the Department of Archeology in Colombo., in small samples had been taken by using scientific tools manually without causing a disturbance on the walls or floors. Among them, eight plaster samples have been taken from the cave walls and two samples from the floor (Fig. 3).

### 2.2. Data Analysis

The samples were tested out through different analytical distinctive and non destructive techniques methods;

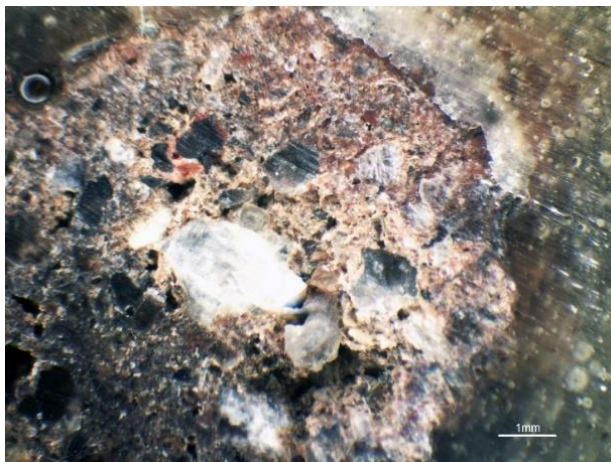
Microscopic observations had done first, Next the samples were divided into four sub samples for analyzing.

- Particle size analysis
- Microscopic observations
- FTIR analysis
- Cross section analysis
- Wet acid dissolved analysis

To study the particle size of each sample, a series of sieves were used to separate the particles according to their sizes, and the diameter of the sieves ranged from 4mm to 0.0625mm, each fraction of sieved sediment was weighed by analytical scale. The physical nature and particle shape of the plaster were detected by the microscopic observations under the stereo microscope (LaboMed CZM4) in different magnifications. To identify the pigments of each plaster sample, had used FTIR (Fourier-transform infrared spectroscopy) analysis, and small sub-samples were grounded to fine powder and mixed with KBr followed by



**Fig. 3. Location of Sampling a. Dammaruchi Cave wall plaster b. Mahalena floor plaster c. Mahalena floor plaster with two layers d. Buddha Dattha Cave wall plaster e. Korawakgala cave wall plaster f. collecting samples for analysis**



**Fig. 4. The higher iron content of clay indication cross section CR 1**



**Fig. 5. The river sand after wet acid dissolved CR 6**

pressing to make small pellets which were analyzed with the FTIR-Drift detector (Bruker Alpha). The cross-sections of the samples have made by impregnating low viscous resin into the cutting face, and then resin-embedded samples had lapped and polished to achieve the required smoothness, afterward, the cross-section was studied under a stereo microscope (LaboMed CZM4), to determine the calcium carbonate content of the sample, wet acid dissolving method used. All the analysis have been done by Laboratory

for cultural material analysis post graduate institute of Archaeology (LCMA), PGIAR.

### 3. Results

#### 3.1. Composition of the Wall plasters

Having analyzed, the wall plaster samples number of RC 1, RC 5, RC 7, RC 8, RC 10 composed of clay and sand as paddy husks, as a basic earthy material for the construction, clay had been used, and it was in red color indicates clay may have taken a higher content of iron ( $Fe_2O_3$ ) (Fig. 4). The sand is a granular substance made up of tiny mineral fragments that had intentionally added to this plaster, and this sand originated from two different sources: the riverine and the clay deposit-sand associated with the clay particles, the distinction of sands from these two origins can recognize by their morphologies (Fig. 5). The sand particles combine with clay have sharp angular edges, and the added sand fraction, particles of rounded shape which indicates they had taken from river origin. the clay and sand proportion were 1:1.

Sample number 2, was found mainly contained with clay and sand. Also, microscopic analysis revealed that this plaster contained paddy husk, the cross-section study discovered that this cave plaster consists of two separate layers over the plaster surface, it belongs to two separate section, the first, the cave was made a blackish appearance applying a carbon emulsion mixture on the clay plaster, used a kind of fiber brush. Then, cave turned to a whitish appearance by applying a lime layer over the blackish surface of the cave plaster, subsequently, paintings had drawn over this whitish lime layer as red ochre and yellow ochre (Fig.6).

CR 4 and CR 9 consisted of clay and sand with a ratio of 50:50, which contained paddy husk, the clay has high iron content, and it is resilient to water and moisture, an iron oxide emulsion paste had applied on the surface of plaster CR 4, which had made of rich iron red-colored clay. The plaster of sample RC 9 has whitish lime (calcium carbonate)



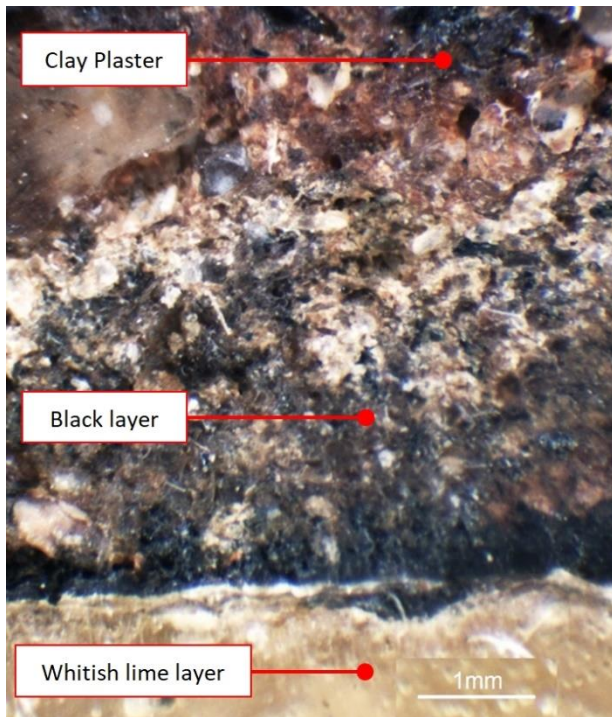


Fig. 6. Layers of plaster RC 2

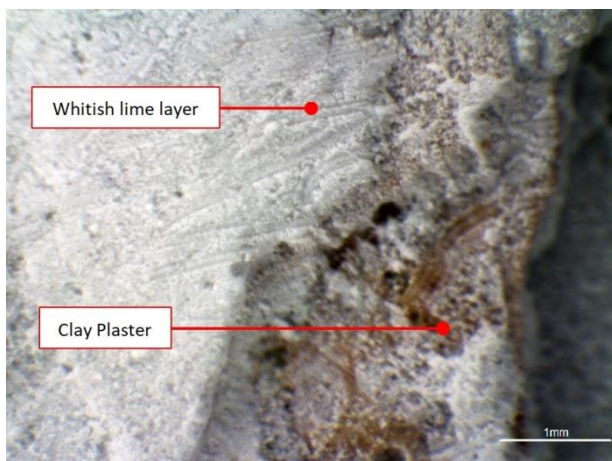


Fig. 7. Clay plaster with whitish layer in the sample RC 9



Fig. 8. Unsorted, different sizes of sand particles presenting RC 3

layer applied over its surface (fig.7); a red pigment could identify on this lime paint receiving layer.

### 3.2. Composition of the Floor plasters

Having analyzed, the floor plaster RC 3 and RC 6, RC 3 was identified as the lime sand plaster with the ratio of 20: 80 % by weight of the materials, sand fraction not sorted (fig. 8), different sizes of sand particles can identify with the range between 4mm to 0.025mm, sand, and lime proportion 4:1.

## 4. Discussion

Technical and rational theory frequently seeks some historical aspect of construction work with the material culture, according to Conwey and Roenisch (2005), architecture is not only based on the material environment, for buildings express our aspirations, our hopes for the future and our beliefs. Concerning the discussion of cave architecture concepts, the Rajagala monastery, in their opinion, may have revealed that cave plaster was the most important feature in the construction of the dwellings, which shows the affiliation of the Buddhist monastic construction discipline that had been followed by the monks in Rajagala.

In the construction of the Avāsa (a single inner room, a single hut, or a whole monastery for the community is called a Avāsa or dwelling), they considered, avoiding cold, wind, heat, and beasts of prey from there, as well as creeping reptiles and insects, and avoiding water in the rainy season (Cullavaggapal, 2001). Further, to meditate and obtain insight in retreat at ease, the permanent abodes were recommended. As a result of the construction of buildings and caves, monks considered not only the physical characteristics, but also the spiritual practices to be important to success in acetic life. The building wall may have been made using bricks, stones, and wood, and to avoid the cold and hot conditions inside, the plaster was used outside on the wooden template to maintain the dwelling area well (Cullavaggapli, 2001). References to the Rajagala cave walls, RC 5 and 6 were mostly modified by using stone flakes and clay bricks with clay mortars; there is no evidence of wood being used for wall construction; wood might have been used for the frame of windows and doors, but those are unable to be recognized at present; the researchers can detect the caves' walls having used plaster to finish the surface, according to the available evidence.

Since ancient times, clay and sand compositions may have been used for construction works due to different reasons; both materials can be found easily in nature and mixed well with water. Considering the wall plasters RC 1, RC 2, RC 4, RC 5, RC 7, RC 8, RC 9, and RC 10 are composed of sand and clay, additionally, a small amount of paddy husk is added as an organic material to help the mortar bind well and plaster would not crack or lose its surface due to the vapor system; furthermore, when sand is mixed with clay, the clay particles

fill all the open spaces between the sand particles, and often the clay acts as a 'glue' to bond all the particles together, resulting in a mortar becoming thick. In terms of Vinaya, the plaster, including clay, ash, and cow dung, could have been used as a screen to protect building walls from rainwater (Samanthapāsādika, 2009). According to that, clay and organic materials were used to make a shield to maintain the wall for a long time. The clay with rich iron oxide ( $\text{Fe}_2\text{O}_3$ ) was used for making plaster, and collected from the specific clay deposit in the area. Because every clay sample showed the same compound of properties, the iron oxide clay was used to finish the wall plaster, because of its resistance to water and other climatic conditions, the clay could have been collected from an area near the Diwlana tank in the west.

The Manjusri Cithrakarmasatra (Chapter XII), an ancient Silpa Shathra text, has described the methods of clay preparation for the plasters used for the paintings. According to the clay, it could have collected from near the lake, well, tank, oblong pond, or holy site, and one should perfume the clay after it had been strained into a pot. Having heated, a slab of stone surface add the collection of substances in the given quantities (Marasinghe, 1991). There are three kinds of metals: gold, silver, and copper; three kinds of sweets: sugar, honey, and ghee; three kinds of pungents: pepper, long pepper, and ginger; as well as some other materials with recommended quantities used to make mortar. Nevertheless, there are no records of such methods being used in Rajagala constructions.

Considering the composition of the plaster, the painting walls in ancient times, for example, Sigiriya main cave (5<sup>th</sup> century), Pidurangala (5<sup>th</sup> century), and Pulligoda (8<sup>th</sup> century), showed signs of having used clay and sand, with some organic materials like paddy husk, straw, and coconut fibers, which certainly provided strength to the plaster and helped it avoid cracking (Agrawal and Wickramasinghe 2002). Also, Vinaya confirmed that paddy husks, soft clay, tree glue, mustard powder, oil of beeswax, and flour paste needed to be adhesive to the rough walls before being colored. However, Vinaya mentioned that those elements should be mixed in the right manner and pasted on the wall by hand; to make it smooth, apply the cloth to thin it out (Cullavaggapāli, 2001).

Sample RC 2, revealed the data of the black (lamp black) emulsion layer applied to the clay, which served as the early context to finish the surface of the wall; later, lime plaster was applied on top. Regarding the code of discipline, white, black, and red chalk colors were allowed to be used for the building at the monastery (Cullavaggapāli, 2001). Red and yellow were recognized as the lines of some pictures that had been drawn on the surface lime layer; both colors were made using red ( $\text{Fe}_2\text{O}_3$ ) and yellow ( $\text{Fe}_2\text{O}_3\text{XH}_2\text{O}$ ) ochre.

Accordingly, we can suggest that artists of the early period used limited earth colors for their paintings. For instance, at Mihintalē, there are only red ochre, yellow ochre, and lamp black, while the main cave at Sigiriya used red ochre, yellow ochre, Terre vert, and lamp black. Later on, artists used an extensive color pallet, in which there were inorganic as well as organic coloring materials (Agrawal and Wickramasinghe 2002).

The Rajagala cave floor plaster was made of sand and lime, but the Vinaya included some more details of the elements used for the floor during an ancient period: clay with paddy husk, earthworms' soil, glue from the tree, an astringent decoction as binding materials, and they richly used back color on the floor (Cullavaggapli, 2001), though those had mentioned in Vinaya, yet, cannot identify evidence on the floor elements applied in Rajagala caves. Probably, at the beginning those types of materials might have used on the floor, with the time and experience mostly had used lime with sand. According to the finding, they had used unsorted sand with quartz particles on the floor to make it tightly packed; thus, some friction couldn't be avoided; furthermore, using lime ( $\text{Ca}(\text{OH})_2$ ) mortar became stronger when carbon dioxide ( $\text{CO}_2$ ) absorbed from the environment; therefore, the cave floor used calcium carbonate ( $\text{CaCO}_3$ ) to protect it for a long time without much destruction.

Some religious buildings embody something of the spirit of the religion (Conway and Roenisch, 2005). The architectural design of the dwellings always tried to maintain the minds of monks properly according to doctrine as well as the code of discipline by having a focused psychological aspect. It had created nature, and the inside environment of the place was more conducive to the concentration of the mind for the monks. This background helped to characterize the meditation (Rahula 2018). According to the Visuddhimagga (2010), there are only six types of people: one of greedy temperament, one of hating temperament, one of deluded temperament, one of faithful temperament, one of intelligent temperament, and one of speculative temperament. And also, further, described the suitable resting place for each one, both inside and outside of the dwelling, to maintain concentration and avoid temperament. For instance, to control the hateful mind, well-proportioned walls, posts, and steps could have been arranged with well-prepared mural work and latticework, brightened with various kinds of painting, an even, smooth, soft floor, adorned with festoons of flowers, and a canopy of many-colored cloth like a Brahmá-god's divine palace" (Visuddhimagga, 2010). According to that, Rajagla monks maintained the caves after, arranging them in suitable architecture and colors (white, red, and black) to befit an ascetic.



Following the preceding information, suitable characteristics such as wall plaster, floor, and paintings may have completed according to the code of discipline. The Buddhist monks who followed the doctrine of obtaining the divine existence of life needed to arrange their residence place in a way that respected nature; the construction began with minimal intervention and primarily used natural materials. The monks who need to get concentration (samādhi) should reside in a suitable place, such as Rajagala caves were to be appropriated places for monks to practice their achievement.

## 5. Conclusion

In accordance with the Buddhist culture and its discipline, the monks who had entered the Sangha society had to follow the code of discipline, they had to select most suitable residence at first, had to concern the unique advantage of the places for ascetic life. The Lord Buddha also impressed on his followers to select the recluse residence to become the spiritual master in the religious path, most of the extreme meditative monks followed meditation life in the forest settlements using natural caves as an ascetic life, with reference to the Rajagala was the monastery where had been developing for a long time to focus on meditation activities for the monks.

To develop the residence place in the cave premises in Rajagala, the monk included some features such as wall and floor with proper manner, particular the wall plasters made of clay and sand by adding organic masteries to combine elements and preserve well, whereas floor plaster was made of sand and lime to maintain the strength of the floor. The complexity and multiplicity of roles played by architecture, make the study to a certain degree challenging with the use of the materials and code of discipline, in accordance with the investigation, both factors influenced to maintain the residence places for the monks.

Considering the context of each cave, the wall and floor had changed with experience of the works and follow the traditional cultural methods and beliefs, according to Conway and Roenisch (2005), Spaces for a particular function will depend on the period, the culture, and the geographical context, as well as social, and political manners, status, finances and the desire to be expressive, as well as with time all of these may have changed.

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