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Architectural and Comparative Material Study of Brick and Mortar of Ahom terracotta Monuments, Assam, India.

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Abstract

The Ghanasyam house of Sivasagar district and Namath Kali Mandir(Temple) of Nilachal hills, Guwahati, Assam, are among the most unique and detailed ornamented brick architecture monuments built during the reign of the Ahom dynasty in India. Although Namath kali mandir has retained only a few portions of its original architecture due to natural causes and vegetation, the remains still display detailed ornamentation. According to historians and scholars, both monuments follow similar architectural styles irrespective of geographical differences. This paper compares and analyses the architectural structure of both monuments. It studies the elemental compositions of bricks and mortar of each monument and compares the composition and structural pattern using Energy Dispersive X-Ray Analysis (EDX), Fourier transform infrared (FT-IR), and Powder X-ray diffraction (PXRD). The results provide similarities in elemental compositions and structural patterns of the Bricks and Mortars of both monuments.

Keywords: Ahom, Architecture, archaeology, construction, History.

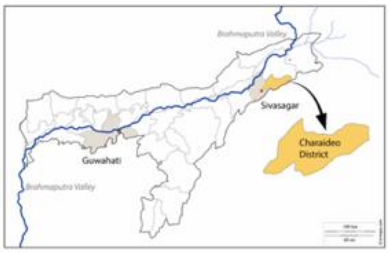
1. INTRODUCTION

The Ahom dynasty ruled over Assam from the 13th to the early 19th century. According to historians, the Ahoms are traditionally from the Great *Tai*[1] group of peoples . With the leadership of *Shan*[2] prince, *Siu-ka-pha*, the Ahoms entered Assam from Yunan in lower China through Patkai Hills to the Brahmaputra Valley. *Sui-ka-pha* became the first king of the Ahom dynasty in Assam. He established his first capital in Charaideo, which is currently a district near the Sivasagar area of Assam, India[Figure.1].

[1] *Tai* people are a subgroup of *Tai* language speakers who are widely distributed in Southeast Asia and the Yunnan Province of Southwest China [1] .

[2] The people speaking Tai language are also known as *Shans.*

Figure 1: Assam Map[12] displaying Charaideo district near Sivasagar and the Guwahati area.



By the end of 17th century, the Ahom dynasty has expanded its kingdom all over the Brahmaputra valley of Assam. During their reign, they built many temples, also known as *Dol* locally, and buildings using wood, stones, and bricks.

Most of the archaeological remains are preserved under the Archaeology Survey of India (ASI), Guwahati circle, and Directorate of Archaeology, Government of Assam, India. This paper investigates and compares the brick architecture types of one of the most ornamented monuments of Ahom architecture- Ghanasyam House of Sivasagar area with Namath Kali Temple of Nilachal Hills, Guwahati. According to historians and scholars, both the monuments resemble similar architectural style. Though, both the monuments are geographically in different locations of Assam (Figureure. 2) and the exact construction time period of Namath Kali temple is still unknown. Most of Namath kali temple in Figureure.3 (left) architecture has disappeared due to natural conditions but the Ghanasyam house in Figureure.3 (right) still retains its architectural features along with its ornamentation. This paper also studies and compares the brick and mortar composition of both the monuments.

Figure 2: Screenshot of Google Map displaying the geographical distance of Namath kali temple of Nilachal Hills and Ghanasyam House of Sivasagar by road.

2. MATERIALS AND METHODS

a. Material collection and processing

The primary data was collected using semi- structured interviews with the Archaeological conservation officer of Sivasagar area, ASI, to understand the early composition and modern day compositions of brick and mortar used in conservation. Multiple site visits of Ghansyam house and Namath kali temple were done to collect the photographic data, brick dimensions, and sample collection. The photographic data is then analyzed using computer software- AutoCAD 2018, to study structure of both the monuments. The secondary data are collected using the internet, books, journals, and libraries. For the analysis of brick and mortar, samples of each were collected from both the monuments. They were scrubbed to free from any contaminants and kept in a hot air oven at 100°C for 24 hours for the removal of moisture. This made the materials dry and easy to grind. The dried materials were pulverized in a grinder into powder form for

further analysis.

b. Characterization of Materials

Elemental Analysis: The sample of bricks and mortar of Ghanasyam house and Namath Kali Mandir were characterized for elemental composition by Energy Dispersive X- Ray Analysis (EDX) (Make: Zeiss, Model: Sigma). The materials were dried again before analysis in a hot air oven at 100°C for 8 hours and were kept in a desiccator to cool to room temperature. The samples were first dispersed in ethanol, dried, and then dropped the mixture onto a clean substrate. Later they are mounted on the stub using double-sided conductive carbon tapes for analysis.

Fourier transform infrared (FT-IR) Spectroscopy: Fourier transform infrared (FT-IR) spectra of the materials were recorded on a PerkinElmer Spectrum Two FT-IR spectrometer (λ_{max} in cm^{-1}) on KBr pellets in the range of 4000-400 cm^{-1}.

Powder X- ray diffraction (PXRD): Powder X-ray diffraction (PXRD) is another powerful tool for brick and mortar characterisation. The application of X-ray diffraction in the above materials is likely through the Bragg equation; $n\lambda=2d\sin\theta$. Using this equation the angles for the coherent scattering of X-rays (by diffraction) and the distance between adjacent planes is determined. By convention, n is equal to unity and λ is the wavelength of the material used as the X-ray source. PXRD measurements of the materials were carried out using a Bruker D2 Phaser X-ray diffractometer which was employed at 30 kV, 10 mA, using Cu-Kα radiation at λ = 1.5406 Å.

3. Result and Discussions

a. The architectures

Ghanasyam house or *Dol* (Temple) in Figureure. 3 is constructed during the reign of Ahom king Rudra Singha (CE 1696-1714). Its monument is on the southern end of the west bank of the Joysagar tank in the Sivasagar district of Assam. The monument's dimension covers 7m 23cm X 6m 35 cm [2]. According to [2], [3], [4], the architecture of the monument has a resemblance with the contemporary temples of West Bengal and Bangladesh. The architecture style is considered to be an adaptation of the vernacular architecture of huts in Assam and West Bengal. The *Chala* roof of Ghanasyam house falls in the *Chouchala* roof type [2]. The monument has three openings in the entrance supported with three multifoil arches on each. The entrance wall is decorated with multiple terracotta plaques of sculptures, floral motifs, patterns, and animals.

Just above the three multifoil arches, visual narratives of *Ramayana*[3] [2] with terracotta plaques is observed. The narrative includes deities, animals like monkeys and multiple symbolic motifs of *Shiva linga*[4] inside a temple. Above it, are nine lotus motifs aligned in a curved path. The top and side portion of the wall includes pattern terracotta plaques and sculptures of the Hindu god, goddesses, deities along with humans and animals. The placement of sculptures is extended towards the upper portion of the wall and continued on all the sides of the monument. The interior wall of the monument includes a mihrab

[3] The *Ramayana* is an ancient Indian epic, composed sometime in the 5th century BCE, about the exile and then return of *Rama*, prince of *Ayodhya*. [5]

[4] *Shiva linga*, in Hinduism, a votary object that symbolizes the god Shiva and is revered as an emblem of generative power. The *lingam* appears in Shaivite temples and in private shrines throughout India.[6]

design, which may denote religion and cultural fusion in architectural design- *Indo-Islamic* architecture. The monument radiates the artisan's exceptional craftmanship in terracotta brick making and plaque molding.

Figure 3: Ghanasyam House (Left), Namath Kali Temple (Right)

Namath Kali Temple (Figureure. 3) is located near the northwest side of the famous Kamakhya Mandir in Nilachal hills, Guwahati Assam. According to the Directorate of Archaeology, Guwahati, Assam, the Ahom king Siva Singha (1714 - 1744 CE) became a disciple of *Krishnaram Bhattacharyya*, who was given the management of the temple of Kamakhya. Krishnaram and his successors, generally known as *Parbatiya Gosain*, were assigned large land estates to maintain this temple. Considering the literatures, it is evident that the temple was constructed and maintained by descendants of *Parbatiya Gosain*, known as *Na-Gosain*, although the exact time period of the construction is still unknown.

Though due to the climatic conditions, and vegetations few portions of the monument retain its early structures [Figure. 3(Right)]; the left section of the façade has retained its details in ornamentation. The monument is constructed over a raised rectangular platform and some ornamentation are visible in the doorway pillars of the temple. Multiple decorated terracotta plaques are aligned all over it. The upper section of the wall consists of floral pattern plaques with floral motifs placed within parallelogram and rectangular borders. Some of the surviving terracotta sculptures of humans in acrobatic postures, gargoyles, and monkeys at corners of walls are extended like fins and are aligned vertically. The existing remains of the temple do reflect the essence of the Ghanasyam house of Sivasagar with roof style, terracotta plaques and the use of similar construction materials like terracotta bricks and lime mortars. Considering the overall structure, it is fair to assume that Namath kali Mandir had the *Chouchala* roof type as Ghanasyam house. The decoration molds of both the monuments have their own identity in the compositions of sculptures, motifs, and patterns.

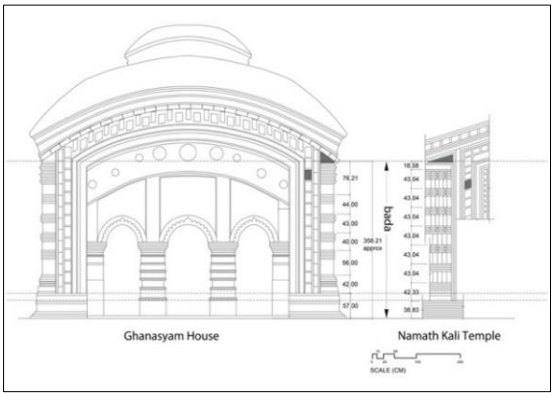
b. Comparison of bada[5] *of Ghanasyam House and Namath kali using computer software- Autocad*

The comparison was analyzed considering the primary data like photographs, brick dimensions, and measurement mentioned in the literature. Using the AutoCAD software (2018 version), the monuments' linear extraction is modeled; both the models are then placed side by side to study the variations and similarities. The results [Figure. 4] display similarity in height (approx.) from *jagati* (platform) to the top portion of *bada*, but the difference in the brick arrangements and plaque molds are noticed. The brick layouts in the *bada* are in horizontal and vertical arrangements. The horizontal bricks are arranged in a group of five layers of thin decorative bricks in both the monuments. These horizontal bricks groups divides the *bada* into multiple sections. The alternate sections are arrange with vertical bricks which are

[5] The *bada* is the vertical wall portion of a temple, typically considered in Orissa temple architecture (fig 4).

mostly wider and thicker than the horizontal bricks. Some of them are floral decorative plaques in Ghanasyam House, whereas only the brick remains are visible in Namath kali Mandir. Although there is a similarity in the decoration style, both monuments retain their unique arrangements of the terracotta plaques. Figure. 4 also displays the variation of plaque molds (highlighted with dark color). Near the *bada* Ghanasyam's decorative terracotta plaques are rectangular, whereas the Namath kali plaques are in a parallelogram. It's noteworthy that, in both the monuments upper section of *bada* forms a scalene triangle with a 90° angle (highlighted with dark color).

Figure 4: Comparison of *bada* of both the monuments.



c. The Early construction materials of the monuments

The early construction materials for houses and buildings of Ahom dynasty was in woods and bamboo. As with due course the materials decay, hence they shifted their construction materials to stone and bricks. Gupta [7] states, according to Eric T.D lambert the bricks of Ahom era is similar to those used in Siam in the *Ayuthia* period. The bricks were square, rectangular, triangular, round, perforated and fluted. The *Chung Rung Phukanor Buranji* mentions, Ahom during the late medieval era used burnt bricks and lime mortars for construction of houses, temples, buildings and *maidams*[6]. They used lime mortar to cement the bricks. The *buranji* states mixture of many organic and inorganic raw materials for the mortar mixture. Some of the raw materials in the mortar composition includes molasses, duck eggs, *borali* fish (helicopter catfish or wallago catfish), snail shells, limestones, oil, quick lime, brick powder [8]. Its noteworthy that particles of snail shells are still visible in the mortars of the monuments [Figure. 5].

Figure 5: Zoomed in photo displaying particles of snail shells: Ghanasyam Mortar (left), Namath Kali Mortar (Right)

[6] A *maidam* is a tumulus of the royalty and aristocracy of the medieval Ahom Kingdom in Assam, India.

d. The Early construction materials of the monuments

The elemental compositions present in the bricks and mortar of Ghanasyam house and Namath Kali Mandir were determined with the help of Energy Dispersive X-ray Spectroscopy (EDX). The results of the EDX are summarized in Table 1. Figureure 6-9 shows the electron micrographs and EDX spectrum of bricks and mortar of Ghanasyam house and Namath Kali Mandir. The Ghanasyam and Namath Kali Mandir brick sample analysis revealed the presence of silicon, aluminum, and iron in high percentages and calcium, potassium, magnesium, niobium, platinum, copper, and sodium in low percentages (Table 1). Out of all elements present in the brick samples, the percentage of calcium and iron is higher in Namath Kali brick, whereas the percentage of silica and aluminum is found more in Ghanasyam brick.

Figure 6: Electron micrograph (left) and EDX spectrum (right) of Ghanasyam House brick

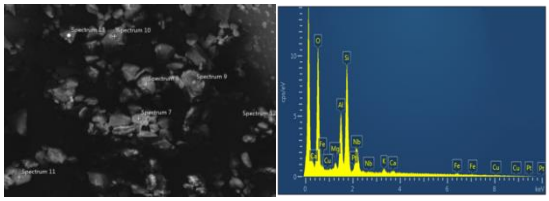


Figure 7: Electron micrograph (left) and EDX spectrum (right) of Namath Kali brick

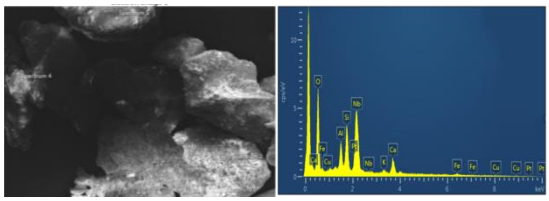


Figure 8: Electron micrograph (left) and EDX spectrum (right) of Ghanasyam House mortar.

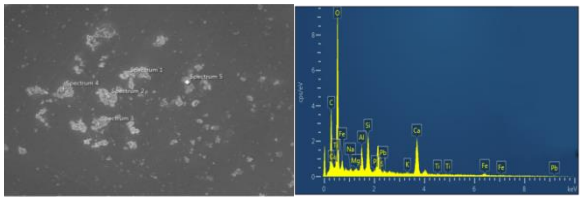
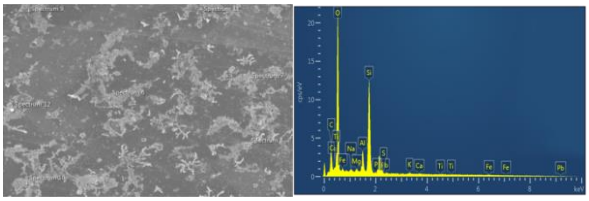


Figure 9: Electron micrograph (left) and EDX spectrum (right) of Namath Kali mortar



In Ghanasyam and Namath Kali mortar samples, silicon and calcium are present in high percentages, and aluminum, iron, sodium, and potassium in low percentages. The other elements magnesium, titanium, phosphorous, lead, and sulphur are also present but in trace amounts. From the results, it is seen that bricks contained a higher percentage of iron than mortars. Theoretically, it can be explained that bricks contained more clay, which leads to a high percentage of iron oxide. Though reportedly, the construction of Ghanasyam house and Namath Kali Mandir were of a different time period, the results of the elemental study pointed out in Table 1 display that the raw materials were taken from the same sources.

Table1:

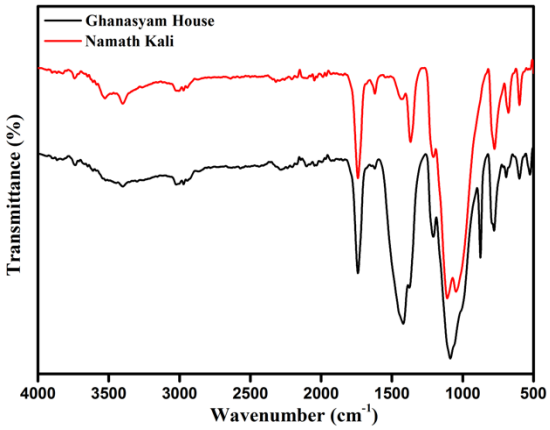
Component	Ghanasyam Brick (wt%)	Namath Kali Brick (wt%)	Ghanasyam Mortar (wt%)	Namath Kali Mortar (wt%)
O	41.5	45.5	37.7	44.3
C	5.7	0	27.6	24.3
Si	21.3	16.9	10.3	11.9
Al	14.2	11	5.4	2.9
Na	1.4	-	0.9	0.4
Fe	9.2	10.6	6.3	2.5
K	1.4	1.5	1.5	0.4
Ca	2.5	5.7	9.2	11.9
Mg	1.2	0.7	0.2	0.3
Nb	1.2	5	-	-
Pt	0.4	2.7	-	-
Cu	0.1	0.7	-	-
Ti	-	-	0.2	0.03
P	-	-	0.1	0.2
Pb	-	-	0.2	0.6
S	-	-	0.1	0.2

The percentage of calcium in the mortar is comparatively higher than the bricks of Ghanasyam house and Namath Kali Mandir. The finding is very encouraging as the *buranji* states mixture of many organic raw materials for the mortar mixture as mentioned above in Section 3.3. Construction with these mixtures of products, in the form of interlocking crystals, increases the strength of the mortars which in turn, vindicates their use as construction materials of many ancient buildings across the globe [9].

e. FTIR analysis of bricks and mortar

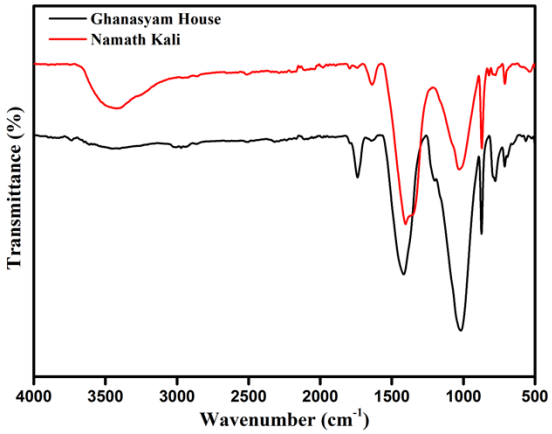
FTIR was done for study of surface functional groups on brick and mortar samples. A comparative FTIR spectrum of bricks and mortar of Ghanasyam house and Namath Kali Mandir were shown in Figureure 10 and 11. The bands at 1080 and 1040 cm^{-1} of bricks samples of Ghanasyam House and Namath Kali Mandir represents the Si-O-Si stretching vibrations of Kaolinite [10, 14]. In the FTIR spectra of Bricks of Ghanasyam House and Namath Kali the bands at 599 and 593 cm^{-1} attributed to the presence of Fe-O of hematite. The bands at 785 and 760 cm^{-1} of Ghanasyam House and Namath Kali bricks are related to the stretching vibrations mode of Al-O bonds. The IR bands around 683 and 671 cm^{-1} of Ghanasyam and Namath Kali brick and 694 and 693 cm^{-1} of Ghanasyam and Namath Kali mortar respectively are due to the presence of Si–O bond of quartz [15]. It indicates that all the brick and mortar samples have quartz in their compositions.

Figure 10: FTIR spectra of Bricks of Ghanasyam House and Namath Kali



The interpretation of the OH stretching region (3700-3400 cm^{-1}) has received special attention as this peaks are absent in case of bricks of Ghanasyam House and Namath Kali Mandir which suggests that the clay materials in the bricks must had been fired during their processing at about 650°C. Further the structural pattern of the spectra of both the places is found to be similar indicating the manufacturing process of the bricks and mortars were almost same.

Figure 11: FTIR spectra of Mortar of Ghanasyam House and Namath Kali



f. Powder X-ray diffraction of bricks and mortar

PXRD analysis was done to study the structural changes of bricks and mortar of Ghanasyam house and Namath Kali Mandir and their respective comparison are shown in Figureure 12 and 13. The minerals identified by PXRD of bricks and mortar are shown in Table 2 and 3. PXRD pattern of bricks of Ghanasyam House and Namath Kali Mandir shows that they were mainly composed of quartz (SiO_2), hematite (Fe_2O_3) and kaolinite ($Al_2O_3(SiO_2)_2(H_2O)_2$). Apart from the common minerals, albite ($NaAlSi_3O_8$) in Ghanasyam brick and orthoclase ($KAlSi_3O_8$) in Namath Kali brick are also detected. May be small amount of these feldspars are present as most of these minerals are common in clay composition of this geographical region, which also showed in elemental composition of EDX.

Figure 12: PXRD pattern of Bricks of Ghanasyam House and Namath Kali Mandir.

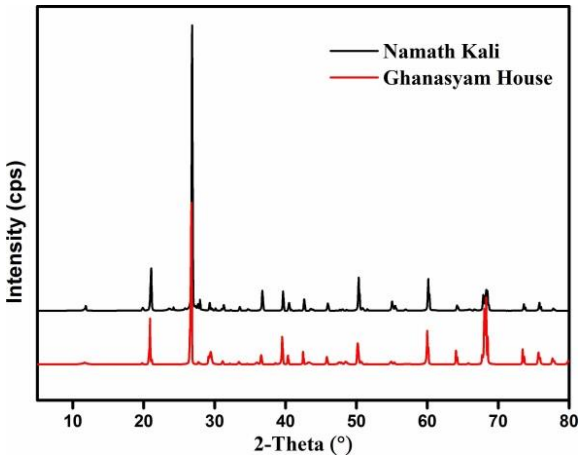


Table 2: Mineral identification of (a) Ghanasyam House brick and (b) Namath Kali Mandir brick

(a) Ghanasyam Brick			(b) Namath kali Brick		
2θ	**d[Å]**	**Mineral identification**	**2θ**	**d[Å]**	**Mineral identification**
20.8860	4.2497	Quartz	21.0292	4.2211	Orthoclase
26.6139	3.3466	Quartz	26.8237	3.3209	Quartz
36.5629	2.4556	Albite	45.9768	1.9723	Kaolinite
39.6498	2.2712	Quartz	50.3305	1.8114	Quartz
45.9769	1.9723	Kaolinite	55.1124	1.6650	Hematite

The results suggested that the bricks were manufactured by using materials of high clay content. Quartz is a major mineral which makes the brick self-tempered and hematite is considered as a concentrated coloring material which presence makes the bricks reddish [14]. Whereas the PXRD patterns of mortars of Ghanasyam House and Namath Kali showed that they were mainly composed of quartz and calcite with a mixture of albite and hematite. It was assumed that the calcite was derived from carbonated lime, while quartz, hematite and albite were from brick powders [11]. The results indicated that the source of raw materials or the method of preparation of bricks and mortars might result in similar products manufactured in two different places.

Figure 13: PXRD pattern of Mortar of Ghanasyam House and Namath Kali Mandir.

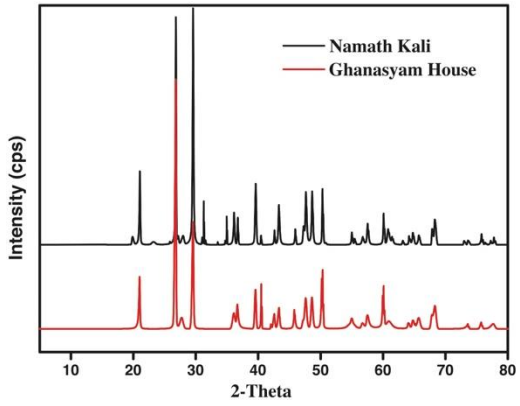


Table 3: Mineral identification of (c) Ghanasyam House mortar and (d) Namath Kali Mandir mortar

(c) Ghanasyam Mortar			(d) Namath Kali Mortar		
2θ	**d[Å]**	**Mineral identification**	**2θ**	**d[Å]**	**Mineral identification**
21.0446	4.2180	Quartz	21.0446	4.2180	Quartz
29.5734	3.0181	Calcite	26.8132	3.3222	Quartz
36.6104	2.4525	Albite	29.5733	3.0181	Calcite
36.7346	2.4445	Quartz	36.6104	2.4525	Albite
40.5499	2.2229	Quartz	39.6066	2.2736	Quartz
48.6670	1.8694	Quartz	47.6590	1.9066	Quartz
55.0303	1.6673	Hematite	55.0310	1.6673	Hematite

4. Conclusion

The Ghanasyam House of Sivasagar, and Namath kali of Nilachal hills, Guwahati are the most unique and ornamented monuments of the Ahom dynasty, Assam. Irrespective of the geographical differences, both the monuments display the same *chouchala* architectural style. The comparative study of both *bada* provides an in-depth insight into the similarity in *bada* height (approx.), variations in arrangement styles of the bricks, and the shapes of terracotta plaques used in ornamentation. The results display a strong aesthetic similarity. The architectural style purely defines the exceptional skills of the artisans and their knowledge in terracotta moldings. As both the monuments are constructed using Bricks and Mortar, it is observed that the architectural features are fading away due to the climatic condition and vegetation with due time. The material test and comparison results also provide similarity in brick and mortars' elemental compositions. The PXRD and FT-IR graphs also show similar structural patterns. With the above analysis and findings, it can be assumed that the monuments' construction could be during the same time period.

5. Acknowledgments

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