Chepauk Palace: A Comparative Study of Green Construction Methodologies of the Tamil Nadu Palaces and Modern Practices

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Abstract. A comparative study of green construction methodologies between Tamil Nadu palaces and modern practices involves examining the sustainable building techniques employed in traditional palaces in Tamil Nadu, India, and contrasting them with contemporary green construction methods. Traditional palaces often use locally sourced and sustainable materials like wood, stone, lime, and clay. These materials were readily available, reducing transportation-related environmental impacts. Design features such as thick walls, courtyards, and natural ventilation helped regulate indoor temperatures without excessive reliance on external energy sources. Traditional water harvesting systems like step wells and tanks were common in palaces to collect and store rainwater. Modern green building construction materials include recycled steel, bamboo, engineered wood, and sustainable concrete alternatives. Green constructions integrate energy-saving technologies such as solar panels, HVAC systems optimized for efficiency, and intelligent building designs to reduce energy usage. Sustainable water management involves rainwater harvesting, greywater recycling, and efficient plumbing systems to minimize water wastage. Green building design considers the site's natural features, maximizing natural light, and incorporating landscaping for energy efficiency and aesthetic appeal. Green construction focuses on reducing, reusing, and recycling materials. Comparing green construction methodologies between Tamil Nadu palaces and modern practices involves assessing material choices, energy efficiency, water management, design principles and cost implications. Based on the above-mentioned factors this study provides valuable insights into adapting traditional sustainable practices to contemporary construction. I have incorporated the recently renovated Chepauk Palace in Chennai as the case study for the comparison of traditional and modern green construction practices.

Keywords: Chepauk Palace, Green construction, Environmental impact, Building materials and Energy efficiency.

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1 Introduction

The blend of Islamic architectural features and indigenous Indian materials evolved into what is called the Indo-Saracenic architecture. It was further developed by British architects in India during the late 19th and early 20th centuries. It is often described as a liberal fusion, combining Islamic design motifs with Indian elements and materials. This style encompasses various architectural features like multifoil arches, domes, spires, tracery, minarets, and colourful stained-glass windows. The case study of this research, the Chepauk Palace is the most significant architectural complex in Chennai city that features the above-mentioned evolution of Indo-Saracenic building techniques and design. Traditional palaces often use locally sourced and sustainable materials like wood, stone, lime, and clay. These materials were readily available, reducing transportation-related environmental impacts. Design features such as thick walls, courtyards, and natural ventilation helped regulate indoor temperatures without excessive reliance on external energy sources. Traditional water harvesting systems like step wells and tanks were common in palaces to collect and store rainwater. Contemporary sustainable construction materials encompass recycled steel, bamboo, engineered wood, and eco-friendly concrete alternatives. These materials are utilized in green buildings, which integrate energy-saving technologies such as solar panels, energy-efficient HVAC systems, and intelligent architectural designs to reduce energy usage. Sustainable water management involves rainwater harvesting, greywater recycling, and efficient plumbing systems to minimize water wastage. Green building design considers the site's natural features, maximizing natural light, and incorporating landscaping for energy efficiency and aesthetic appeal.

2 Review of Literature

- According to Sheeba & Dhas, after the advent of medieval architecture the term “Indo-Sarsenic” faded away from scholarly discussions, it continues to serve as a descriptor for British-built structures from the late 19th century in India. Despite this evolution in terminology, an exemplary Indo-Saracenic structure persists amidst modern high-rises, preserving its commercial heritage in Chennai city (1).
- The thermal characteristics of a building's envelope play a crucial role in decreasing overall energy consumption within the building. The barrier between the interior and exterior environments like walls, roofs, and foundations, acts as this envelope. It regulates heat transfer and significantly influences the energy required to maintain indoor comfort levels compared to outdoor conditions. The building envelope is a crucial cooling system for effective controlling of transfer and reduction of heat (2).
- The Madras terrace ceiling, a traditional architectural method prevalent in South India, particularly in homes with flat roofs, entails the use of wood, small bricks (aachikal or kandikal), and lime plaster. Robust teak wood beams are positioned on the walls to support wooden rafters spaced approximately 45 cm apart along the

shorter side of the room. These rafters are then filled with kandikal bricks placed diagonally and held in place with lime paste, forming a brick layer over the rafter framework. This process involves laying three layers of bricks diagonally in alternating directions to create a solid, 12-inch-thick slab, which is subsequently coated with lime mortar. To enhance weather resistance, myrobalan fruit soaked in water is applied to the surface. The roof is manually compacted to ensure stability before being covered with pressed tiles for a final, refined appearance [3]emphasizes that traditional construction methods often yield to newer systems due to factors such as limitations in lateral strength and stiffness. However, sustainable and energy-efficient construction methods can be revitalized using modern technologies with minimal interference. In this context, Krishna Chandran and colleagues conducted research investigating the lateral load response of the Madras Terrace floor—a traditional timber-supported composite brick-floor system in southern India, dating back a century. Their research revealed the resilience and resistance of this traditional system, indicating its potential for resurgence [4] A static analysis model of the “Humayun Palace” a cultural heritage building of Tamil Nadu that was built in 1700’s was developed after conducting a structural assessment by Muthukumaraswamy, by referring original design documents obtained from historical records. This thorough examination encompassed all aspects of the three-story structure, ranging from the ceiling slab system and the roof tiles. The aim of the analysis was to achieve a thorough comprehension of the initial design concept of different structural components and evaluate their current static and seismic safety conditions. The results of the study generally indicate satisfactory safety conditions and performance objectives, although there are a few noteworthy exceptions. The satisfactory performance of the structure overall could be credited to the builders of that time, who might have integrated abundant safety margins into their designs, allowing the structure to endure conditions surpassing its intended lifespan [5]

- Buildings consume energy at different stages throughout their lifecycle, and building materials constitute a substantial portion of this energy consumption. Therefore, evaluating the energy consumed by construction materials over their lifecycle is essential for assessing the overall energy efficiency of a building [6]
- Each year, India witnesses the construction of nearly two million residential buildings, in addition to offices, commercial, and industrial structures, reflecting a growing demand and supply trend. It is imperative to prioritize the conservation of conventional energy through the advancement of energy-efficient building practices. Considerations for environmental quality and the preservation of fossil fuels are increasingly vital, especially in the context of mitigating greenhouse gas emissions and lowering material costs. The primary stages with notable energy intensity include the acquisition of raw materials, their preparation and manufacturing, as well as transportation [7].
- As urbanization and modernization accelerate, cities are experiencing rapid expansion, with buildings emerging as the predominant feature. On a global scale, construction consumes around 25% of the world's wood harvest, 40% of stone, sand, and gravel, and approximately 16% of water annually. Additionally,

construction activities contribute to 50% of global greenhouse gas emissions and play a role in the production of substances that contribute to acid rain. The production processes involved in manufacturing building materials are a notable contributor to greenhouse gas emissions, notably carbon dioxide, which is emitted into the atmosphere (8).

- The state of Tamil Nadu is taking steps towards revitalizing deteriorating public heritage sites by establishing a specialized division for their conservation. Known as the Building Centre and Conservation Division (BCCD), this entity operates within the Public Works Department (PWD) and is tasked with conducting surveys to identify heritage buildings owned by various government departments. The division will assess the feasibility of preserving these structures. As per a PWD official cited by TOI, a key goal of this new division is to safeguard deteriorating historical structures [9].

3 Scope of the study

The Chepauk Palace, the origin of the Indo-Saracenic School of architecture, is challenging to observe in its full beauty today. Mostly concealed, it can only be partially seen through fragmented views amidst the surrounding buildings. The neglected state of Chepauk Palace, along with numerous other historical sites in the city suffering from neglect, demonstrates a clear lack of concern for Chennai's rich history, its priceless monuments, and the traditional techniques used in their construction. Hence there is a requirement to study and analyse these palatial monuments and their construction practices that have been followed over centuries. Comparing green construction methodologies between Tamil Nadu palaces and modern practices involves assessing material choices, energy efficiency, water management, design principles and cost implications.

4 Research Methodology

- In 1768 the Nawab of Wallajah built Chepauk Palace on the banks of the river Cooum spread over an area of 117 acres, designed by architect Paul Benfield. The Chepauk Palace (Fig.1.), The building, recognized for its use of red brick and lime mortar, consists of two sections. The southern section, known as Kalas Mahal, is a two-story structure featuring two minareted entrances. The northern section is called Humayun Mahal.

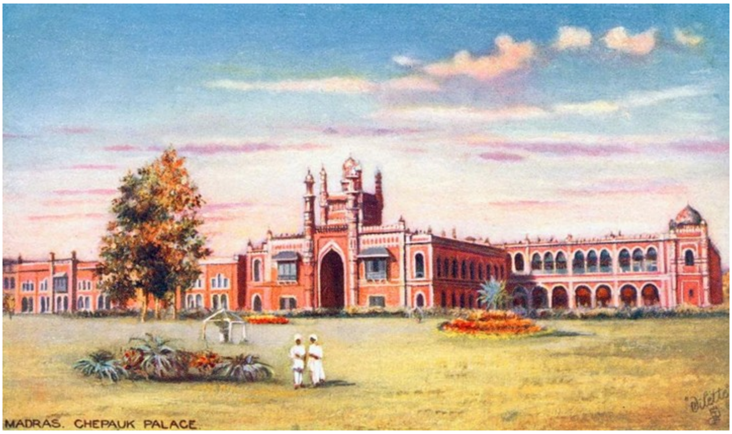

Fig.1. – Chepauk Palace - 1768

1. The structure boasts expansive arched entrances at its base, balconies positioned along each side, delicate buttresses at the corners, and a small dome. Initially, Humayun Mahal was a one-story structure with the Diwan-e-Khana Durbar Hall located at its center under a dome. In 1870, Robert Chisholm renovated Humayun Mahal by eliminating the dome, adding a second floor, and implementing a Madras terraced roof. Furthermore, he integrated a facade resembling that of the Khalsa Mahal, visible from Wallajah Road. In lieu of the missing dome, a new eastern entrance resembling the design of the Khalsa Mahal was constructed, providing views of the beach. Instead of being incorporated into the structure of Humayun Mahal, this new entrance was erected as a separate square block in front of the Mahal, known as the Records Office. To connect it with the Kalas Mahal, a 75-foot-tall tower was erected. Surrounding the Chepauk complex was a perimeter wall featuring wide triple-arched gateways along Wallajah Road, adorned with several rows of large brick columns (10).
2.
3. The Khalas Mahal was the residence of the Nawabs from 1768 to 1855 which has been recently restored to its original state. Nawab Mohammed, the Prince of Arcot, whose ancestors resided in the complex until they relocated to Amir Mahal in 1855, noted that the decline of the building began when it was secluded from public view following its acquisition by the government in an auction 150 years ago, coinciding with the abolition of the principality of Carnatic. Subsequently, the palace was repurposed as the office of the revenue board and the Public Works Department (PWD) Secretariat, and new government buildings were constructed around it between the 1950s and 1980s, cutting off access to the beach and Wallajah Road. Kalas Mahal later housed departments of social welfare, industries, and commerce, and is now being prepared to accommodate the National Green Tribunal, Southern Bench. Over time, significant portions of the palace were lost, with the Senate House replacing the former artillery park and the Nawab's bathing pavilion being converted into the Governor's residence and later the University Library. The M.A. Chidambaram Stadium was originally part of the palace complex, with remnants of the arch gate pillars adorned with terracotta reliefs still visible at the stadium entrance. Additionally, two more remnants of the arched entrance pillars can be found further down Triplicane High Road.

4. The Public Works Department (PWD) has historically undertaken maintenance of buildings with heritage significance, but the creation of a dedicated division for conservation marks a significant first. This division has collaborated with multiple state departments, including those responsible for Hindu religious charitable and endowment, tourism, and archaeology, to create a comprehensive list of heritage structures under their jurisdiction. Following enumeration, conservation efforts have been initiated for these structures, with the division coordinating and supporting the respective departments in their conservation endeavors. As part of this initiative, the restoration of the Chepauk complex marked the inaugural conservation project for the division.

5. Under the leadership of an engineer-in-chief, the newly established division serves as a centralized system for the maintenance of all heritage buildings across the state. It is equipped with a comprehensive database of all heritage structures and will oversee all conservation and restoration efforts. Given the unique requirements of renovating heritage structures to preserve their aesthetic value, the division will coordinate all such efforts, distinct from those employed for modern buildings. To ensure expert guidance, a six-member committee comprising professionals such as the dean of the school of architecture and planning, the chief planner of the CMDA, the superintending archaeologist of the Archaeological Survey of India (ASI), and architects from the PWD collaborate to provide advisory support to the division. While the division's headquarters is located in Chennai, three sub-divisions are operational in Coimbatore, Madurai, and Trichy (11).
   The restoration started by removing the debris of the dilapidated portions due to fire and removal of unwanted trees growing out of the old structures followed by scraping the plaster on the wall in the interior and exterior of the building (Fig.2.). The renovation of the building followed the same traditional method employed over 250 years ago, mirroring the methodology previously utilized in conservation efforts in Karaikudi and Thanjavur. Several groups were actively engaged in the extensive restoration project of the Chepauk Palace: one team of skilled workers was tasked with mixing limestone and sand, while another group meticulously separated egg whites from yolks. Additionally, a smaller team of five workers was responsible for grinding Whitestone, producing crystal sugar-like particles.

1.

Fig.2. – Complete removal of plaster from walls

Four crucial aspects of the restoration process warrant attention: the procurement of construction materials, experienced labor in traditional methods, timing, and implementation.

4.1. Raw material

- The selection of raw materials was unconventional (Table 1), straying from the typical cement, sand, and bricks. Instead, traditional raw materials, known for providing the building with enduring strength for centuries, were meticulously researched and subjected to numerous trial and error experiments to restore Humayun Mahal to its former splendor. Obtaining raw materials of superior quality was paramount. A specific timeframe and procedure were designated for the application of the mixture, and only skilled laborers were capable of adhering to these guidelines.

RAW MATERIAL	**SOURCE**
Sand	Cauvery River
Whitestone	Rajapalayam and Rajasthan
Limestone	Virudhu Nagar
Curd	Chengalpet and Tiruttani
Granite stone	Hilly regions of Rajapalyam
Square tiles	Tirunelveli

Table 1 – Raw material and their source.

4.2. Construction practices.

Madras Terrace roofing - The construction of Humayun Mahal introduced the Madras Terrace roofing technique, utilizing wood, Madras 'achikal' brick, and lime plaster. This roofing method, also prevalent in numerous buildings in the United Kingdom, was also utilized in the renovation process. The term "Madras brick" continues to be widely recognized even in contemporary times. Inside the rooms, wooden rafters are positioned along the shorter side, with their dimensions matching the depth of the beams, typically exceeding 150mm. These wooden rafters extend horizontally for the sloped roof, forming a base for the brick and lime mortar slab. The structure of the Chepauk Palace follows a unique Madras terrace slab system. Unlike the conventional method where rafters are placed at specific intervals to support tiles, here a primary beam of larger size is installed, relatively smaller size secondary beams were placed perpendicular to it.

Wall thickness - In contrast to the typical thickness of 110 to 115 mm slabs found in modern commercial structures, this particular building predominantly utilized slabs with a thickness approximately three times greater, around 300mm. Similarly, while walls in standard construction are typically 230 mm thick, the walls in this structure vary in thickness, ranging from 400 to 1000 mm.

Plaster - Lime mortar with egg white - Lime mortar with egg white is a traditional construction material that was often used in historical buildings for its adhesive and strengthening properties. The process involves mixing lime, sand, and egg white to create a durable and flexible mortar. Curd is mixed in lime plaster in a traditional technique that enhances the workability and durability of the lime mortar. The lactic acid present in curd acts as a plasticizer, improving the cohesion and preventing cracking (Fig – 03).

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Fig – 03 – Preparation of plaster at Chepauk palace

4.3.Materials required to prepare plaster

Quicklime: Calcium oxide (CaO) or hydrated lime (calcium hydroxide) can be used. Quicklime will need to be slaked before use by mixing it with water.

Sand: Well-graded sand without impurities. The type of sand can affect the final properties of the mortar.

Egg Whites: Egg whites act as a binding agent and add flexibility to the mortar.

Water: Clean water for slaking lime and mixing mortar.

4.4.Process of preparation

Slaking Lime: slake quicklime by adding it to a container and gradually adding water. Stir the mixture thoroughly to form a lime putty. Allow the lime putty to mature for several weeks, periodically adding water to maintain the right consistency.

Mixing Sand: Determine the necessary quantity of well-graded sand. The lime-to-sand ratio may fluctuate based on the intended characteristics of the mortar.

Preparing Egg White: Egg white is separate from the yolks and whipped until they form stiff peaks.

Combining Ingredients: Gradually add the whipped egg whites to the lime putty while continuously stirring. Mix in the sand gradually, ensuring an even distribution of all components. Modify the water content as necessary to attain the desired texture.

Mixing Thoroughly: Mix the ingredients thoroughly to create a homogenous lime mortar with egg white. The mortar should have a workable consistency for application.

Application: Apply the lime mortar with egg white using appropriate tools (such as a trowel) to the prepared surface. Ensure proper adhesion and alignment of masonry units.

Curing: Allow the mortar to cure slowly. Lime mortar requires a curing period for the chemical reactions to take place and for the mortar to gain strength. Protect the applied mortar from drying too quickly. Covering with damp cloths or using a curing compound can help retain moisture.

After finishing the plastering procedure, it is essential to scrape the surface using a granite stone for at least three days. After analyzing the aforementioned factors, it becomes apparent that the structure has been meticulously engineered, resulting in enhanced stability and promising outcomes.

5 Results and Discussion

5.1.Vernacular Materials and Energy considerations of construction

A range of choices exist for building construction, each varying in energy content and construction particulars. In India, several roofing systems have been developed, with RCC slab being a commonly utilized material for both flooring and roofing. Modern alternatives to traditional cement and concrete encompass masonry cement, blast furnace slag cement, fly ash cement, and fiber-reinforced composite cement. For wall partitions, lightweight and weather-resistant sisal-based composite panels with polyester resin can be employed. Sustainable construction options include organic materials like wood composites and coir-based boards and tiles. Recent research suggests that recycled plastic or post-industrial waste can function as effective insulation materials for flooring and roofing purposes. Moreover, the utilization of municipal solid waste and construction & demolition waste holds promise as building materials in the construction industry.

Green buildings integrate energy-efficient technologies such as solar panels, energy-efficient HVAC systems, and intelligent building designs to reduce energy consumption. Sustainable water management involves rainwater harvesting, greywater recycling, and efficient plumbing systems to minimize water wastage. Green building design considers the site's natural features, maximizing natural light, and incorporating landscaping for energy efficiency and aesthetic appeal. Green construction focuses on reducing, reusing, and recycling materials.

In the present context, reintroducing vernacular concepts and enhancing them with alternative technologies may be explored to reduce environmental impact while ensuring high-quality and efficient construction, leading to significant cost savings. The focus is also directed towards gaining an understanding of energy-efficient construction methods and alternative technologies, with careful consideration given to vernacular and cost-effective solutions.

6 CONCLUSION

The comparison of green construction practices between Chepauk Palace and modern green building standards reveals a fascinating interplay of historical wisdom and contemporary innovations. The palace construction exemplifies the sustainability inherent in traditional architecture. Its use of locally sourced materials, intelligent design for natural ventilation, and incorporation of indigenous construction techniques showcase an eco-friendly approach rooted in centuries-old wisdom. On the other hand, modern green construction practices have evolved to address contemporary environmental challenges. Modern green buildings strive to minimize their environmental footprint and enhance energy efficiency and occupant comfort by integrating cutting-edge technologies like solar panels, energy-efficient systems, and sustainable materials. The juxtaposition of Chepauk Palace's historical construction methods with modern green practices highlights the importance of learning from the past while embracing innovative solutions for a sustainable future. By drawing inspiration from the time-tested practices of structures like Chepauk Palace and integrating them with cutting-edge technologies, we can create a harmonious balance between the preservation of heritage and the pursuit of environmentally responsible building practices in the modern era. In essence, the comparison serves as a reminder that sustainable construction is a dynamic, evolving field where the wisdom of the past can inform and enrich contemporary green building practices.

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