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Indian traditional knowledge on defence fortification: Investigation to unravel historic subsurface changes in ancient Thanjavur

Natarajan Ramesh Babu[a,*] & R Jayanthi[b]
[a]Department of Architecture, [b]Department of Civil engineering, Periyar Maniammai Institute of Science & Technology, (Deemed to be University), Vallam, Thanjavur, Tamil Nadu 613 403, India
[*]E-mail: rameshbabu@pmu.edu

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Ancient Indian knowledge and wisdom on architecture and town planning, with a focus on fortification, are exemplary and evident in the ancient treatises *Arthashastra* and *Manasara Shilpa Shastra*. Thanjavur, once the capital of the *Chola* dynasty, is an ancient town fortified with a rampart and moat wall that houses the UNESCO-protected monument, the *Brihadisvara* Temple, which dates back to the 11th century. This research manuscript aims to unravel the defence planning, construction techniques, and usage of vernacular materials in the fortification of rampart and moat walls in Ancient Thanjavur town and ascertain its adherence to ancient *Vedic* fortification principles of *Arthasastra's Audaka* or *Jaladurga*. Excavations undertaken for a new construction project under the Smart Cities Mission of the Government of India for Thanjavur City revealed linear composite masonry walls 50 m in length and 3 m in depth, suspected to be the side walls of the *Chola* era moat. At this site, soil was excavated from ground level up to 5.2 m for the proposed construction, and geotechnical investigations using standard penetration tests were conducted up to 24.2 m. The presence of a weak N value of 7 to 6 m below the excavated ground level clarified the existence of a moat that was either deposited or backfilled with soil over time, such that the rampart wall and moat walls remained submerged. This provides evidence of ancient Indian Traditional knowledge on defence planning, use of vernacular materials, and innovative construction techniques for the moat, rampart walls, and foundation during the Great *Chola, Vijayanagar,* and *Maratha* periods.

Keywords: Chola, Fortification, Moat, Rampart, Thanjavur, Vedic

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The Indian knowledge system on architecture, town planning, and defence fortification is ingenious. Although cities have evolved naturally, many ancient Indian cities were created and governed by guiding principles framed during ancient periods. These principles were unique and suited to the natural terrain of the region. Often, the primary purpose of these designed cities was the physical elements of protection that strengthened the kingdom and its rulers. Available natural resources, such as forests, rivers, and mountains, were used in the strategic planning of cities. Vernacular materials and experimental construction techniques were adapted to build temples, forts, and cities. The placement of massive, fortified temples at the center of urban life was a powerful statement of sovereign control, making the king's divine mandate and military strength physically manifest in the landscape of the city. Fortifications were not just passive barriers but active instruments of statecraft, designed to project power, control movement, and organize social space around the central axis of royal and divine authority[1].

In Tamil Nadu, the earlier literary and archaeological studies indicate the map of early Tamil Nadu dotted with around 200 forts, small and big with bigger forts in capitals like Madurai, Vanchi, Kanji which were capitals of *Pandyas*, *Cheras* and *Pallavas,* respectively. The *Chola* towns were characterized by this fusion of defensive and sacred space, with the temple acting as the city's administrative and spiritual centre and requiring strong defence. The dual-purpose construction of large temple complexes, which functioned as fortified urban centres, was a defining feature of *Chola* military architecture. Rajaraja Chola's *Brihadisvara* Temple in Thanjavur, built around 1010 CE, is a prime example of this paradigm[2]. A protective perimeter is created by enormous, several-meter-thick granite enclosure walls that enclose the imposing *vimana*. These walls were not only symbolic; they

[*]Corresponding author

included high parapets, bastions, and gated entrances that could be successfully guarded[2].

The defence fortification systems of the *Chola* period (9^{th} to 13^{th} centuries) in South India represent a sophisticated integration of military architecture, urban planning, and religious symbolism, reflecting the dynasty's immense wealth, administrative capabilities, and strategic vision. Unlike the continuous perimeter walls typical of European medieval castles, *Chola* fortifications often employed a more nuanced approach that leveraged natural geography, monumental temple complexes, and strategically positioned strongholds to secure vast territories across Tamil Nadu and beyond. From a theoretical perspective on fortification as a "technique of power," the *Chola* system aligns with the concept that military architecture intertwines warfare, spatial organization, and political authority[1].

Thanjavur, a city in the south Indian state of Tamil Nadu, is located at 10.79°N 79.14°E. Thanjavur is one of the regional cultural centres established by the Government of India to preserve and promote the cultural heritage of India. The UNESCO World Heritage monument, the *Brihadisvara* Temple, is located in the center of the city. The Ancient city of Thanjavur was ruled by the *Chola* era (9^{th} to 13^{th} century), Madurai *Nayaks* (16^{th} to 17^{th} century), and *Marathas* (17^{th} to 19^{th} century)[3]. This Ancient Thanjavur city is fortified with a Moat and Rampart walls on either side of the moat. The construction of the moat and Rampart wall structure is dated to 850 CE during the reign of Vijayalaya cholan[4]. Further large-scale fortification was carried out during the *Nayaks* period and later expanded by the *Marathas*.

This study attempts to relate the defence fortification of ancient Thanjavur with *Vedic* town planning principles as outlined in ancient treatises. Furthermore, the study appreciates the vernacular construction materials and techniques used in fortification elements in continuation of the subsurface exploration conducted to assess the soil strength for the proposed construction.

Literature review

The study consists of an extensive literature review on traditional manuscripts on town planning principles in ancient India. Further literature studies are on defence planning and fortification in ancient India.

Traditional literature on town planning principles in Ancient India

Traditional town planning principles in India flourished during the *Vedic* period between 1500 and 500 CE. The *Vedic* town planning principles of ancient India provide insights into the aspects and approaches of city planning and urban design originating from the *Vedic* philosophies and principles. These principles are documented in texts and treaties, such as the *Vedas*, *Puranas*, and *Shastra*s. The "*Manasara shilpa shastra*," an ancient *Vedic* treatise dating to 700 CE, recommends various town forms to be used for town plans and street layouts. This provides a way to harmonize human habitation, environmental aspects, urban lifestyles, and the well-being of the dwellers. These town planning principles emphasize the cognition of architecture, community life, and the spatial organization required for the same, which is relevant in modern urban planning as well. Based on the purpose of establishment, nature of activities, and location, shape, components, and various parameters, there have been various treaties that have categorized settlements. *Sthapatya Veda* deals with city layout, and *Smriti Shastra* explains the street layout at the micro and macro levels. While *Vastu Shastra* deals with site selection, building orientation, building design and planning, service layout, and landscaping, *Mayamuni* deals with categories of small settlements. *Vishvakarma Vastu Shastra* documents on types of towns. In ancient India, there was no difference between a town and a village in terms of planning. *Manasara Shilpa Shastra* under chapter 9 named Grama classifies the Village/town forms. The eight types of planning forms listed are *Dandaka, Sarvathobadra, Nandyavarta, Padmaka, Swatika, Prastara, Karmuka,* and *Chaturmukha,* based on the shape and size of the town, city fortification, location of entrance gateways, Royal Palace, residence, public building, markets, and alignment of streets[5,6]. The laying of cities, forts, temples, and houses using 81 square grids, as suggested by *Agni Purana* in chapter 105 for the prosperity of society, emphasizes the concept of spirituality as the foundation of settlement or city planning[7]. Ancient Indian town planning includes a diverse array of components, such as temples (*devalaya*), markets (*apana*), royal and civilian dwellings (*sarvvajana-grhavasa*), water stations (*prapa*), thoroughfares and passageways, reservoirs, drainage systems, and recreational gardens (*aramagyha*)[8].

The *Arthashastra*, an ancient Indian foundational treatise on political economy and statecraft attributed to Kautilya, is believed to have been composed around the 3rd century BCE. The *Arthashastra* deals with systematic and scientific approaches to town planning, bye laws, and control measures concentrating on privacy, built ratio, walkability, fire safety, etc. *Manasara Shipa Shastra* in 5 chapters inculcates insight on overall planning and design of architectural elements at the settlement level and also describes on 8 categories on village settlement[5].

Traditional literature on defence fortification in ancient India

The principal idea of fortification in ancient India was to protect against natural disasters and foreign invaders. Megasthenes describes the ancient city of Pataliputra as a fortified city 800 stadion long and 15 stadion broad (1 stadion = 490 and 690 ft) with a ditch in the front for defence[9]. Research on the Nayak period villages (1600 - 1800 AD), *Siddavvanadurga* and *Uchchangipura*, in the southern state of Karnataka, India, reveals the presence of ditches as a significant defensive feature that runs parallel to the line of fortification walls[10].

An archaeological report on excavations at Harappa by Dr. Mortimer Wheeler in 1946 revealed the existence of massive mud brick fortifications, 40 ft wide and 40 ft high, faced externally by a wall of burnt brick. He related the structure to terms used in the *Rigveda: pur* meant a rampart, stronghold, or fort, broad (*prithvi*), and wide (*urvi*)[11]. According to ancient technical treatises, the three primary components of the defence system are gates, flanking towers, and rampart-ditches. The rampart-ditch, also known as *prakara-parikha*, is the initial component of the defence system[12]. It is created by the same process, which involves excavating the ground and throwing up the earth behind it to create an embankment supported by a wall (Fig. 1). Next, the projecting sections of the rampart, which create quadrangular towers, are connected to the main enclosure at regular intervals and are frequently reachable via ramps or stairs[12]. Lastly, the imposing gates, whose number is frequently stated (usually, there is one in the middle of each face and sometimes more)

The treatises were verified by excavations[12]. The part through the Ancient Indian city's defensive system illustrates what the ancient scriptures say about a high and thick bund equating to a deep and broad ditch (Fig. 1). This contradiction is also demonstrated by the excavations done at other locations, with the exception of those where they weren't necessary. In order to create actual ramparts that were more suited to the military technology of the day, the embankments were then simply raised and reinforced with masonry works. These ramparts were then revetted with brick or stone. Water from nearby rivers or recurring downpours was delivered to the ditches via canals[12]. The chapter 3 of *Arthashastra's* book "the duties of government superintendents" elaborately outlines the construction of forts[13]. *Arthashastra* describes various types of fortifications based on the geography of the region.

Materials and Methods

Under the Smart City Mission, the Thanjavur old city is undergoing development into a smart city by improving infrastructure facilities. The development of a modern commercial complex building was proposed among the identified smart city projects within the limits of Thanjavur City Municipal Corporation. The project falls within the Area Based Development zone of Thanjavur city, which is apparently the old Thanjavur city. The identified site in the Thanjavur old city was excavated for the construction of a basement from Ground Level up to 5.2 m. The excavation revealed a stretch of moat wall that was submerged and not visible. To understand and appreciate the structure, the study was carried out in four stages: preliminary investigation, experimental

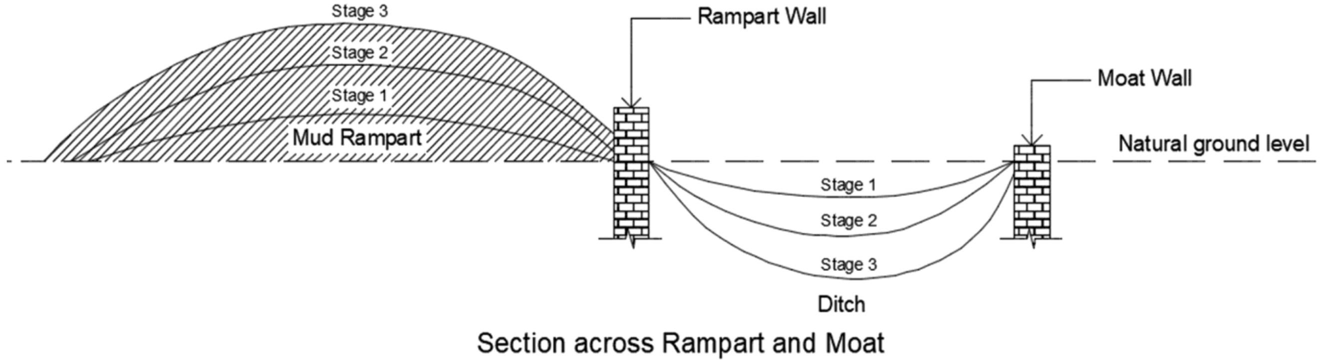


Fig. 1 — Typical dichotomy rampart-ditch in ancient India

work, post-experimental testing, and data analysis (Fig. 2).

In the preliminary stage, reconnaissance and site investigations were undertaken to understand the present terrain of the study area from a holistic perspective. A comprehensive literature review was conducted on ancient treatise *Arthasastra*, *Manasara shilpa shastra*, *Mayamuni* and notes of Megasthenes to understand India's ancient knowledge on water management systems, town planning, vernacular construction materials, and the defence systems of Thanjavur city during the Chola dynasty. A preliminary survey using a total station was conducted to obtain basic spatial data, and plans were formulated for soil testing to identify the strength characteristics and geotechnical properties of the underlying soil layers. In turn, the presence of a historical moat and the structural characteristics of the moat wall were indicated.

In the experimental stage, a detailed topographic survey was conducted to determine the distances and reduced levels of the site. The Standard Penetration Test (SPT), an *in-situ* test, was conducted as per IS 2131:1981[14] at selected locations, and testing boreholes were selected far away from the walls without disturbing the entire stretch. Test holes with a clear size of 75 mm were executed by setting the tripod and test assembly unit together. A thick-walled sampler tube with outside and inside diameters of 50.8 mm and 35 mm, respectively, and a length of 650 mm, was attached to the drill rod and placed on the drill point. A hammer weighing 63.5 kg was dropped repeatedly to drive the sampler for a depth of 15 cm as a seating drive. The number of blows were noted for each 15 cm of penetration and the sampler was driven for another 30 cm. The samplers were then lifted from the boreholes. Undisturbed samples were collected at each meter depth. The borehole was advanced to a depth of 24.2 m from the ground level. The samples were sealed in polyethylene bags with identification tags to prevent moisture loss and were taken to laboratories for further tests. The tests were conducted as per the procedures laid down in IS 2131-1981[14] Method for Standard Penetration Test for soils. Casing mud was used at depths of 9.2 m and 12.2 m because the bore holes tended to fall due to the presence of loose deposits. Disturbed and undisturbed soil samples were collected up to a depth of 24.2 m from an excavation level of 5 m below ground level. Using the values of N, the penetration resistance number, the strength, and density of the soils were empirically correlated.

Non-destructive testing using a rebound hammer was conducted on the entire stretch of the exposed rampart wall to estimate the strength of the composite masonry wall. Five test locations were selected at one-meter intervals along the wall, including the midpoint of the wall section. The rebound hammer test was conducted horizontally on the vertical surface of the wall by positioning the hammer at designated test points. After releasing the hammer, the rebound index readings were recorded to determine the rebound energy of the surface. The rebound index values obtained were subsequently correlated with the equivalent compressive strength of the material using standard conversion charts.

Subsequently, laboratory tests were conducted to classify the soil samples and determine their geotechnical properties, and vertical borehole logs were prepared. The collected data, including soil characteristics, SPT resistance (N) values, borehole logs, and non-destructive test results, were analysed to identify the subsurface conditions, confirm the presence of loose deposits associated with the ancient moat, and evaluate the characteristics of the vernacular construction materials.

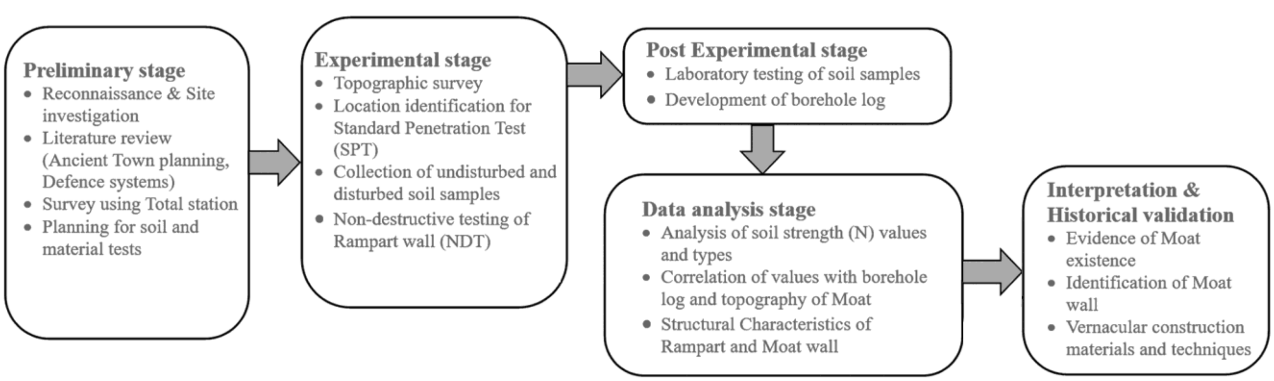


Fig. 2 — Methodology of the study

Results and Discussion

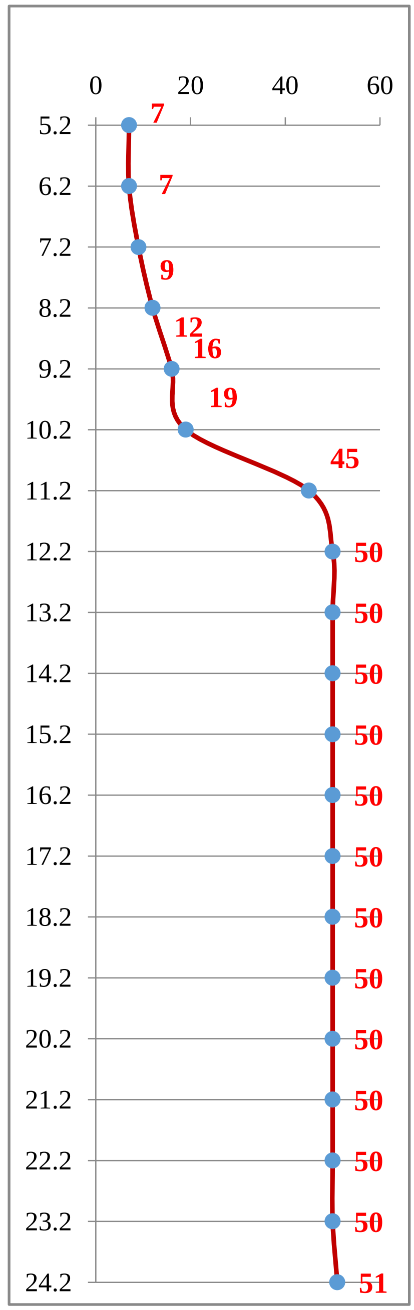
During sampling at a depth of 8 m and again at 12 m loose deposits were identified consisting of broken bricks. Well-graded sand was available till 24 m after which hard rock was encountered, and the bore holes were terminated after 24 m as the N value reached 50 (Table 1).

The Standard Penetration Test (SPT) results obtained from depths ranging between 5.2 m and 24.2 m below the ground level were analysed. The soil stratum between 5.2 and 8.2 m consisted of *kankar*, characterized by the presence of calcium carbonate nodules. The corrected N-values for this layer, after

Table 1 — Borehole log of the site

Depth	Description of Sub-soil stratum	Legend	Type of sample	SPT - Test No. of blows recorded I[st] 15 cm N1	2[nd] 15 cm N2	3[rd] 15 cm N3
5.2	Kankar		US	3	3	4
6.2	Kankar		US	3	3	4
7.2	Kankar		US	3	4	5
8.2	Kankar		US	5	5	7
9.2	Deposit		US	7	8	8
10.2	Well graded Silty sand		US	8	10	9
11.2	Well graded Sand		US	20	20	25
12.2	Deposit		US	25	30	20
13.2	Silty soil and small stone with traces of lime		US	25	30	20
14.2	Silty soil with small stone		US	25	30	20
15.2	Well graded Silty soil with small stone		US	25	30	20
16.2	Well graded Silty sand		US	25	30	20
17.2	Well graded Silty sand		US	25	30	20
18.2	Well graded Silty sand		US	25	30	20
19.2	Well graded Silty sand		US	25	30	20
20.2	Well graded Silty sand		US	25	30	20
21.2	Well graded Silty sand		US	25	30	20
22.2	Well graded Sand		US	25	30	20
23.2	Well graded Sand		US	25	30	20
24.2	Hard Rock		US	25	31	20

Profile of SPT: N - Value



applying dilatancy and overburden corrections, ranged between 3 and 7, indicating a very loose soil condition.

Upon advancing the borehole to a depth of 9.2 m, the soil was observed to be predominantly composed of deposited material. Further advancement of the borehole for the next 2 m revealed well-graded sand with a medium SPT-N value of approximately 25. Between depths of 11.2 m and 12.2 m, the soil again exhibited characteristics of deposited material. From 12.2 m to 15.2 m depth, the soil layer comprised silty soil mixed with small stones and traces of lime. Between 16.2 and 21.2 m, the soil was identified as well-graded silty sand, followed by well-graded sand between 21.2 and 24.2 m. Hard rock was encountered at a depth of 24.2 m, and the borehole was terminated.

The samples collected from depths of 9.2 m to 17.2 m below ground level exhibited considerable variation in soil type and texture at approximately every meter interval, as presented in Table 1. This variation suggests the presence of loose deposits at the site, which may be anthropogenic or natural in origin. It is inferred that the ground level has been raised over time, up to approximately 17 m, through the dumping of different soil types subsequently from the natural ground surface during that time period. At a depth of approximately 18.2 m, sandy soil was encountered, which may represent the original ground level at the site. The excavation and soil exploration in the study area with a weak N value of 7 till 6m below ground level confirms that the moat was back-filled in loose soil over ages such that the rampart wall and moat walls remain submerged.

Defence fortification in ancient Thanjavur

Ancient India's traditional knowledge of town planning and defence fortification dates back to the *Vedic* period. Cities followed the principles outlined in *Arthashastra*, *Mayamuni*, and *Mansara Shilpa Shastra* to form governance and fortification of boundaries. Temples and palaces were often the nucleus of growth in ancient South Indian cities. In temple cities like Kancheepuram, priests were accommodated in four streets around the temple, which were used for processional purposes[15]. The Srirangam settlement falls under the category of both *Sarvathobadra* and *Kevala Nagara*, having four gates towards the four cardinal points and furnished with *Gopuras* (towers), dotted over with, guard-houses, equipped everywhere with barracks, encircled with markets, filled with temples of various denominations. Furthermore, during the Chola dynasty, fortification was a critical component of their defence strategy, often based on terrain. Although most forts in ancient India were located far from settlements, some were developed around cities in a circular formation, as in the Bhandra fort in Ahmedabad, Gujarat, and the Thanjavur fort[16].

The moat and fortification of the old Thanjavur city are inspired by the *Vedic* plan forms, which describe the fortification of various town forms with rampart walls surrounded by water-filled moats. Figure 3 shows the plan form of the *Swastika. Manasara Shilpa Shastra* under chapter 10 named *Nagara* describe the characteristic features of the cities of all classes of kings, summarizing the details from the *Tantras* - sciences of architecture and also deals with various aspects of town planning. The eight fortified

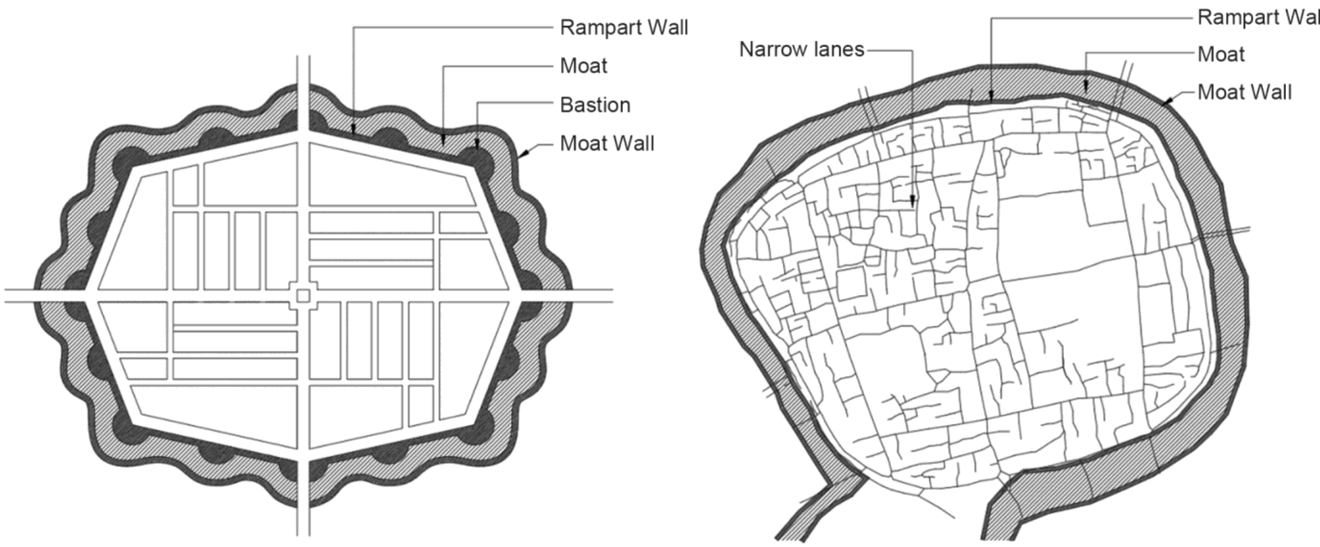


Fig. 3 — Swastika plan form and Thanjavur city form

city categories are *Rajadhaniya Nagara, Kevala Nagara, Pura, Nagarai, Kheta, Kharvata, Kubjaka,* and *Pattana,* based on the type of fortification[5,6].

The circular shape of Thanjavur city possesses a unique geometry with its four main *rajaveethi* (royal streets) used for festival processions and has created a maze of narrower lanes within the square formed[17]. The intentional design of streets in Thanjavur to resemble a maze was intended to deceive strangers or enemies, and the city still lacks way finding or poor intelligibility event today[18]. This arrangement is identical to a quadrant of the *swastika* form of town planning, where navigating this labyrinth of lanes is difficult for strangers as an intentional defensive strategy.

Water management in ancient Thanjavur

In general, water supply or stocking of water within a fortified town was a problem. The *Chola* Empire's advanced water management systems were closely linked to its resilience, which supported its military and architectural accomplishments. Research shows that the *Chola* Empire's ability to adjust to monsoon unpredictability through a vast network of tanks, canals, and reservoirs was closely related to its economic prosperity and capacity to support sizable urban populations and armies[19]. These consisted of irrigation canals and waterways storing excess water by preventing flooding and circulating it for a better defensive system, such as the moat in Thanjavur city. The majority of these massively labor-intensive works were enormous. It follows that their remarkable durability is not surprising, given that they were altered and even rebuilt multiple times. The *Chola* Empire's water management system was evident in the Gingee Fort built during the 13th century, which has two springs with a perennial supply of water and three reservoirs that can store rain water[20].

According to *Vedic* treatises, defence fortifications consist of water fortification (*audaka* or *jaladurga*), a mountainous fortification (*parvata*), a desert (*dhanvana* or *marudurga),* and forest fortification (*vanadurga*)[13]. The fortification in Thanjavur follows the principle of *Arthasastra's audaka* or *jaladurga* type, considering the availability of surplus water. The moat in Thanjavur receives water from the Grand *Anaicut* canal by natural gravity (Fig. 4). Water was allowed to circulate in the moat. The capacity of water that can be accommodated in the moat is approximately 7.5 million cubic meters, which also acts as a water reserve for the city[4]. The ingenious usage of natural terrain to harness natural rivers, canals for cultivation, and storing the surplus water around the fortified city in deep moats, thereby protecting the city and improving the recharge of groundwater, shows the unconventional traditional wisdom of ancient Indian rulers.

This command over water resources provided the agricultural surplus necessary to fund monumental construction projects, including fortifications, and ensured logistical support for a standing army. Thus, the stone walls of *Chola* forts were eventually a product of a broader societal capacity to manage environmental challenges, transforming climatic constraints into a foundation for imperial power[19]. With seasonal rainfall, natural calamities, especially

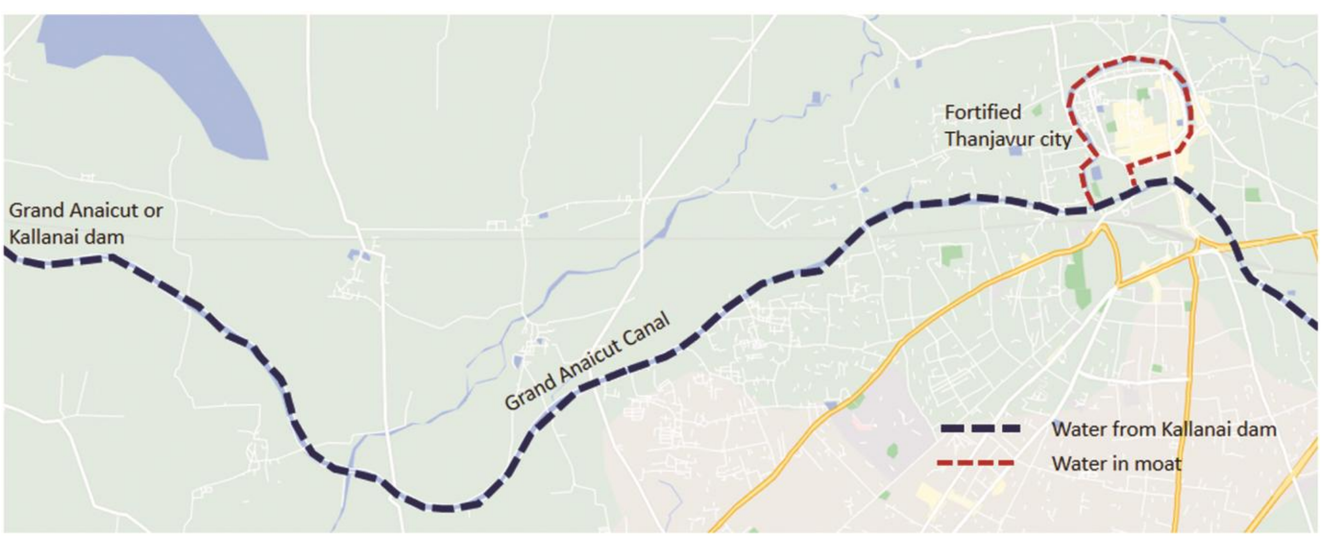


Fig. 4 — Water path from Grand Anaicut to Thanjavur moat (Source: Google map)

frequent floods, have had catastrophic impacts on the Thanjavur district. The construction of the Grand *Anaicut* or Kallanai dam by Chola king Karikalan during the 2nd century reflects Indian traditional wisdom in water management[21].

Physical features of the moat and rampart wall

The moat in Thanjavur city is flanked by a rampart or fort wall on the inner side and a moat wall on the outer side. The depth of the moat is 4 m - 6 m. The rampart wall runs for 4.25 km, with widths varying from 6 m to 24 m. There are two fort walls, one of which is a small fort that surrounds the *Brihadisvara* temple complex, and the big fort protects the entire city (Fig. 5). In Thanjavur city, rampart and moat walls are not visible continuously. Many of the low walls were not visible above ground due to the filling of the moat with debris in recent days. The moat depth has also become shallow. Buildings have been constructed above the backfilled portion over the last 150 years. These buildings include the old Thiruvaiyaru bus stand, a newly constructed bus stand, a theatre named Thiruvalluvar, and an open meeting ground named Thilagar Thidal. The excavated portion of the site (Fig. 6) revealed the moat wall, which confirms the continuity of the submerged moat, intended to maintain the water flow into the Grand Anaicut canal and encircling the entire city.

The physical features of the rampart and moat walls vary in each location due to the terrain. The lengths of the small and big forts are 2.58 and 5.48 km, respectively. The height of the rampart wall ranges from 9 m to 14 m. The width of the wall at the bottom varies from 2.1 to 3.5 m, and the top width varies from 1.2 to 2.1 m (Fig. 7 & Fig. 8). Currently, there are encroached houses above and inside the rampart walls[4].

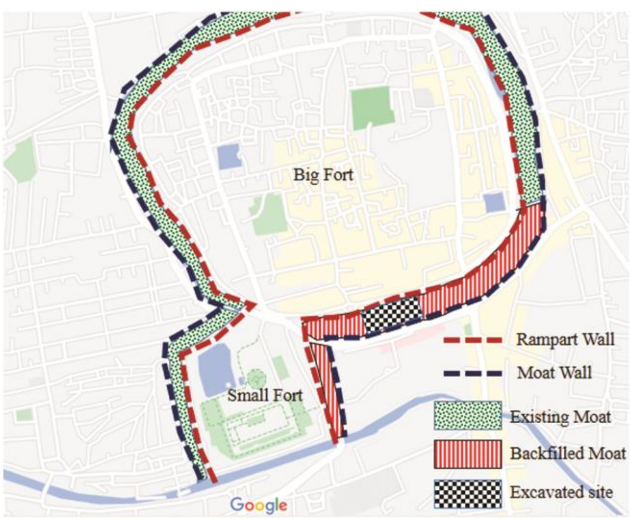


Fig. 5 — Fortification elements of Thanjavur city and excavated site (Source: Google map)

Construction materials and techniques

The fortification walls were built in brick as in alluvial zones or in stone in rocky places, but the fortification principles remained the same. Excavations broadly corroborate the information furnished by literary sources and show that the most

Fig. 6 — Moat wall revealed

Fig. 7 — A 1.2 m wide rampart wall with brick courses in the upper portion

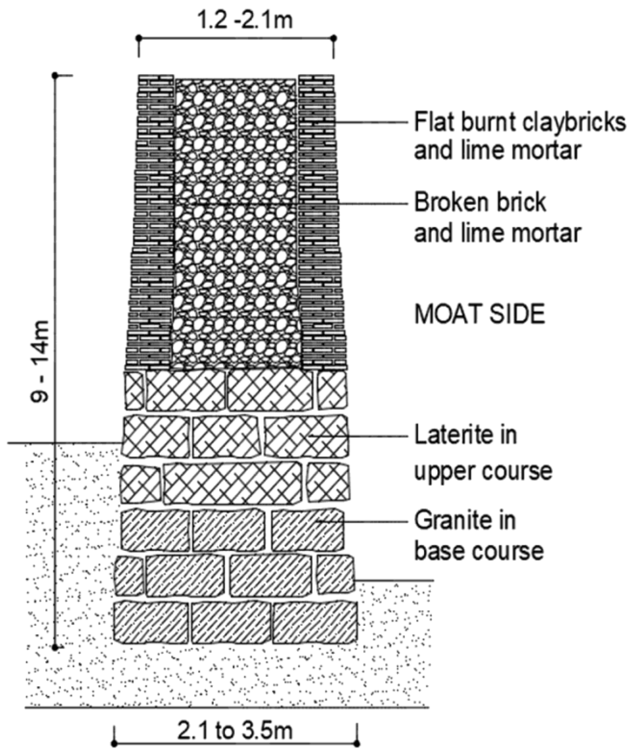


Fig. 8 — Section through a thick rampart wall

persistent features of the early fortifications are massive and compact earthen walls, provided with a baked brick or stone facing, surrounded by wide and deep ditches. In the excavated portion of the moat wall, it was observed that laterite stones were laid as the foundation base course directly upon the hard strata. The upper portion has flat brick courses with lime mortar and plaster (Fig. 6).

In a few areas of Thanjavur city, the revealed portion of a rampart wall with broken bricks and lime plaster was used as a filler between the outer and inner wall courses (Fig. 7 & Fig. 8). This technique was employed to achieve the thickness of the rampart wall, contributing to additional safety and robustness, thereby reducing its vulnerability to breaches. The construction of massive walls was a practice in ancient India to sustain natural calamities apart from defence protection, as seen in Dholavira city, where the wall thicknesses are up to 18 m exists[22]. The ancient knowledge system of fortification involving the use of natural rocks and natural or manmade water channels was common in the *Chola* era.

The fortification during Chatrapathi Shivaji's *Martha* empire involved the creation of fortified settlements in the rocky terrains of central Deccan. In Thanjavur, the materials and construction techniques used in the rampart and moat walls were rational. The materials used were laterite and granite boulders, brick jelly, and unique lime mortars. A study on usage of ancient lime mortar in 1800-year-old ancient temple structures at Cheyyar and Parikkal revealed the presence of organic functional groups (amides and carbohydrates) and demonstrates the incredible knowledge of ancient builders in modifying the properties of mortar by using natural extracts like *Jaggery* (Non-centrifugal cane sugar) and *Kadukkai* (Terminalia chebula)[23]. The lime mortar used in Thanjavur Palace had organic compounds from plant extracts that interacted with bacteria *Bacillus cereus* and *Pseudomonas stutzeri* and produced oxalic acid. This acids on reaction with lime precipitates calcium oxalate that acts as a protective shield against weathering and moisture[24].

The upper course of rampart wall in Thanjavur is constructed with flat burnt clay bricks popularly called *Ramasamy kattalai* bricks, while the footing and bottom course were with laterite blocks (Fig. 7 & Fig. 8). Study on brick samples from Veetrirundha Perumal Temple, Veppathur dated to 400 CE in Thanjavur district exhibited very higher compressive strength up to 2354 KN than conventional clay bricks[25].

The rampart wall widths in the fort area are wider. Wider walls were built for better protection from invaders and floods. To achieve wider walls, two walls, one inner and one outer, were made, and the gaps were filled with broken bricks, stones, lime mortar, and consolidated mud (Fig. 7 & Fig. 8). Weep holes were provided to drain surface water. The thickness of the laterite lining on the outer side of the fort wall is thicker than that on the inner side.

Limitations

The study presents several opportunities for further exploration in India's rich traditional knowledge and wisdom in the field of town planning, water management and defence infrastructure which are regional and diversified throughout the country.

Conclusions

The Indian Knowledge System on fortified town planning developed during the *Mauriyan* Empire and the *Vedic* period. The rich ancient treatises *Arthasastra* and *Manasara Shilpa shastra* outline the various types of forts to be adapted for effective governance and protection. The Indian knowledge system of utilizing natural terrain, vernacular skills, and resources is evident in Thanjavur city and is significant. The elevated location of Thanjavur city and water management within and outside the fortified city are noteworthy examples of the Indian traditional knowledge system. The ancient Fortification system of moats and rampart walls using vernacular materials and achieving structural stability during the *Chola* era is innovative and remarkable. Water management in moats as a defence strategy in Thanjavur city is an extension of the *Jaladurga* type, as depicted in *Arthasastra*. Excavations at the site revealed the presence of a linear composite wall, which was suspected to be the side wall of the *Chola* era moat. The moat and rampart walls at Thanjavur Fort were developed during the *Chola* era and later strengthened during the *Nayak* and *Maratha* periods. This subsurface exploration study provided evidence of the use of innovative vernacular materials and construction techniques for ramparts and moat walls during the Great *Chola* period, achieving stability of the rampart and moat wall even after centuries.

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Author Contributions

RB: Conceptualized and designed the study; acquired, documented, analysed, and interpreted data. Drafted the manuscript and supplementary materials. Managed submissions and coordinated with co-author RJ: Designed the study, interpreted results of soil exploration, and critically revised the manuscript. Ensured methodological rigor, and data integrity.

Conflict of Interests

Authors declare no competing or conflict of interest.

Data Availability

All the data will be available from corresponding author upon reasonable request.

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