

Marble-like *chûnnam* in the 18th- and 19th-century Madras Presidency

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Abstract

Lime (calcined limestone), referred as *çûnam* and *çûññam* ('chûnnam') was used in the Indian subcontinent for ages. In the Tamizh country, lime was referred as *çûññāmpu*. The nature and quality *chûnnam* used in the Madras presidency are formally recorded in various published reports by the British either living in or visiting Madras from the 18th century. All of them consistently remark that the quality of *chûnnam* used in building human residences and other buildings was of superior quality than that used for the same purpose elsewhere in India. The limestone for making *chûnnam* was extracted from (i) inland quarries and (ii) beached seashells. The latter was deemed of superior quality. In the Tamizh country in particular, a few other biological materials were added to lime mortar to achieve quicker and better hardening. In the Madras presidency, builders and bricklayers, used to add jaggery solution, egg albumin, clarified butter, and freshly curdled yoghurt, and talc schist (*balapong*) to the lime mortar. Many of the contemporary construction engineers and architects are presently loudly talking on the validity and usefulness of using lime mortar, embellished with plant fibres and plant extracts, supplemented by traditional practice of grinding.

Key words: *Çûññāmbu*, Jaggery, John Smith, *Kaḍukkāi*, Limestone Mortar, Magnesite, Portland Cement, Seashells, Vegetable Material.

1 Introduction

The chief engineer of the Public Works Department of Government of Tamil Nadu, referring to the restoration of an iconic building in Madras city — the *Hūmayūn Mahal* (Figure 1) remarked in the *Hindu* dated 21 September 2019¹ as:

We are planning to use bulls to churn lime

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¹(<https://www.thehindu.com/news/cities/chennai/engineers-hit-rewind-for-heritage-revamp-Humayun-mahal-resto-ration-to-see-revival-of-traditional-construction-techniques/article29472801.ece>, accessed 21 September 2019).

mortar instead of a mixer, for better compressive strength and long-lasting life. We found that structures built with lime mortar achieved more strength as they grew older, compared to concrete buildings that gained strength only up to 50–60 years.

Mohammed Ali Khan Wallajah (1717–1795), the Nawab ruling this part of southern India, desired to build a permanent, palatial residence in Chempauk (coastal segment of Triplicane) and built the Chempauk Palace in 1768. This palace complex consisted of two *mahal*-s: the *Kālsā Mahal* and the *Hūmayūn Mahal* (Figure 1). This palace complex spread over 117 acres, stretching from the Cooum

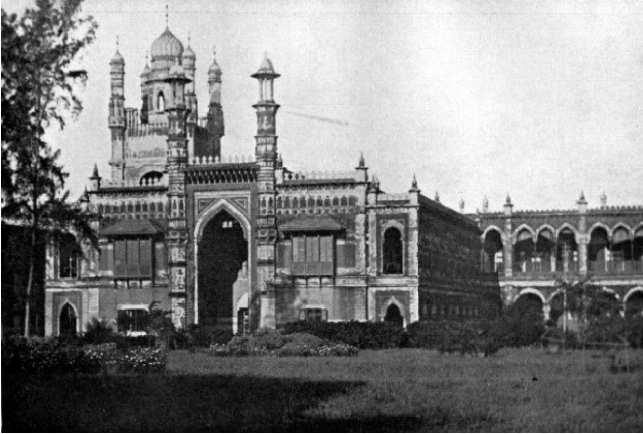


Figure 1 The Chepauk Palace complex. The *Hûmayûn Mahal* with its tower with four minarets is visible in the background, c. 1905 (Source: Courtesy of Special Collections, University of Houston Libraries).²

River in the north to the Pycrofts Road (presently Bharati Salai) in the south. Parts of *Hûmayûn Mahal* were restored by Robert Fellowes Chisholm (1840–1915, Consulting Architect to the Government of Madras) in the mid-19th century (Srinivasachari 1939).

Lime (CaO, Ca[OH]₂, calcined limestone, calcite-including sedimentary rock), referred as *çûnam* and *çûnnam* (hereafter spelt ‘chûnnam’) was used in the Indian subcontinent for ages. In the Tamizh country, lime was referred as *çûnñāmpu*. According to the Merriam-Webster Dictionary *chûnnam* is a ‘cement’ or ‘plaster’ used in India, usually highly polished and decorated with paintings³. Thomas Lehmann (Abteilung Neusprachliche Südasiestudien—Tamil, Süd-Asien-Institut, Universität Heidelberg) explained the etymology of *çûnñāmpu* as follows (email, 13 August 2019):

The word *çûnñāmpu* is first attested in the 12th century war poem *Kalingathu-p-parani*.⁴ According to the Tamil Lexicon of the Uni-

²https://en.wikipedia.org/wiki/Chepauk_Palace#/media/File:\Chepauk_Palace.jpg, public domain.

³<https://www.merriam-webster.com/dictionary/chunam>, accessed 11 August 2019.

⁴*Kalingathu-p-parani* is a war poem composed by *Jayamkondār* in celebration of the grand victory of *Kulōtunga Çōlā I* (1070–1120 CE, of the later *Çōlā* dynasty) and his commander *Karunakara-t-Fōndaiman* over *Anantavarman Chōdaganga Devā*, king of Kalinga Dēsā (most of modern Orissa and some of northern coastal Andhra

versity of Madras *çûnñāmpu* is derived from *çûññā* (Prākṛit). It is possible that the word *çûnñāmpu* was in use before the 12th century. Lime was used in the Tamizh country in the first millennium, but maybe with another name.⁵

The Mandagapattu cave temple inscription of Mahēndra Varmā I (c. 7th century CE) articulates that the rock-cut shrine made in Madagapattu (12° 6′ N, 79° 27′ E, Villupuram District) by King Vicitracita for the Hindu Divine Trinity was constructed without bricks, timber, metal, and mortar. This articulation confirms that the people in Tamizh country of the 7th century knew and built temples and shrines using brick, timber, metal, and mortar (Ramaswami 1971, Balaji 2017).

Large city-like congregations of Harappa (c. 2600 BCE) included sophisticated sanitation networks (Lal 1997). The mortars used in constructing those networks were of mud paste. They also seem to have known and made use of *vajralēpa*. *Varāhamihira* (6th century CE) explains *vajralēpa*⁶ in *Bṛhatsamhitā* as an adamantine glue made as a composite paste, prepared by grinding various biological and mineral substances. It included resinous secretions of plants, e.g., *Commiphora wightii* [= *C. mukul*], Bursaceae) and of animals, e.g., *Kerria lacca* (Insecta: Kerridae) in addition to metals, such as mercury (Sastri and Bhat 1946). *Vajralēpa* was used primarily in temples⁷ and palaces, implying that it was affordable to the wealthy. To fix the idol onto the pedestal, *vajralēpa* was applied at the installation points (*brahmasthāna*-s) in

Pradesh and inland Telengana, and parts of Chhattisgarh) in the 12th century.

⁵The term *sutai* was used to imply lime (CaCO₃) and lime mortar in the Tamizh country before the 12th century. *Çankam*-period poetry, e.g., *Aka-nānūru*, *Pura-nānūru*, *Nēdunālvāдай* (1st century BCE—2nd century CE) use the word *sutai* indicating that the Tamizh people knew of CaCO₃ and CaCO₃ mortar. Because of the enormous heat, the lime kilns, it seems, were used as torture rooms. In *Çēkkizhār’s Pēriya Purānam* (also 12th century CE) verses 1360–1368 (<https://shaivam.org/devotees/the-puranam-of-thirunavukkarasar>, accessed 15 August 2019) refer to the admonishment of *Firunāvuk-karasar* (6th–7th centuries), a Śaiva Saint, for seven days to a lime kiln by *Mahēndra Varma I* of the *Pallava* dynasty (r. 600–630 CE) ruling from *Kāncīpuram*. Only literary evidence exists for this claim (personal communication, Venkat Prakash, Indologie, Institut Français de Pondichéry, email, 14 August 2019).

⁶*Vajralēpa* (Sanskrit): *vajra* — diamond, *lēpa* — paste, glue

⁷Use of *vajralēpa* in ancient Hindu temples is explained in Raddock (2011, p. 114, footnote 680).

temples (Chakrabarti 1998, Indorf 2004). Its high tensile and compression strength is currently established as 100 kPa (Atalkar et al. 2006).

Mahmud Shah (*r.* 1538–1554), the ruler of Ahmedabad (modern Gujarat), on being repeatedly harassed by the Portuguese in Surat, instructed his army commander Safi Agā to build an extra-strong fort there in the 16th century. Safi Agā built the Surat fort in 1540–1546, surrounded by two — each 20 yards (18.3 m) wide — water-filled moats. Walls of the fort and the moats were built using stone, chūnnam mortar, and burnt brick (Elliott 1873, p. 575). Stone grinders pulled by either single or a pair of bulls to grind lime mortar were usually used. Stunning details of the different mortars used in building the *Bibi-ka-Maqbara* in Aurangabad by Aurangzeb in memory of his principal wife Dilras Banu in 1660 are available (Singh et al. 2014).

1.1 Lime mortar elsewhere and the Portland cement

Romans of the later Roman Republic (*c.* 500–0 BCE) used a composite, referred as the Roman concrete (RoC, *opus caementicum*) to construct submerged pillars in harbours and walls of aqueducts (Lamprecht 2008). This was a hydraulic-setting material, which hardened within minutes after application under water. Volcanic ash in RoC prevented cracks in built structures. By the mid-1st century RoC was used extensively in Rome and other nearby nations, with a few minor changes made to its composition in later years (Courland 2011, p. 396). The pyramids of ancient Egypt are yet another remarkable landmark in the use of mortars: the Egyptians used limestone–gypsum mortars (Davidovits 2006, p. 284; Jana 2007).

John Smeaton (1724–1792), a British engineer and builder, first established the scientific relevance of hydraulic lime by improving the previously known lime mortar, by adding aggregates of pebbles and brick powder that hardened more quickly on combining with water than the mortars used previously. Smeaton fired the limestone-including clay, until it turned into a stony residue, which was then fine ground. He used the pulverized material in rebuilding the Eddystone lighthouse (Cornwall, England) in 1756.⁸ This was remarkable be-

cause the hydraulic lime he used, set rapidly securing the stone blocks laid under water (Adams 189, p. 380). Smeaton's work paved the foundation for developing concrete in later years. In 1894, Joseph Aspdin (1778–1855), a British bricklayer, invented the modern cement (Rinde 2015) and named it 'Portland cement' after burning thin-ground chalk and clay in a kiln until all the included CO₂ was completely removed. Aspdin was the first to heat Al- and Si-including materials to the point of vitrification, enabling fusion among the different minerals in the composite. He improved the procedure by rectifying the proportions of limestone and clay before powdering and burning to residue, and finally grinding that into finished cement (Crider 1907).⁹

The Portland cement (PC) and concrete are incredible materials that changed the complexion of the present human society. Besides acknowledging the fact that growth and performance of construction industry are major and critical indices of economic growth and development (Ofori 2015), construction of humongous buildings represent superb science and fascinating technology (*e.g.*, *Burj Khalifa*, Dubai). Such super-tall buildings exemplify the brilliance of human intellect, since many natural forces need to be factored and countered while carrying out such challenging tasks. The *c.* 500 m tall *Taipei 101* (built in 2004), stands majestically in Taipei, withstanding the periodical earthquakes and tropical storms in Taiwan. One scientific marvel in *Taipei 101* is the inclusion of a *c.* 650 tonne steel ball suspended in the centre from the 92nd to the 87th floor — the tuned-mass damper — to mitigate vibration and maintain stability especially during strong winds (Tuan and Shang 2014).

Industrial-scale production of PC started first in India in the South-India Industrials Limited in Washermanpet (*Vannār-péttai*, 13° 6' N, 80° 17' E) in 1904, which produced 10,000 metric tonnes of PC annually. Seashells were the principal raw material. Three other PC factories concurrently commenced in Porbandar (Gujarat), Katni (Madhya Pradesh), and Bundi (Rajasthan) a decade later

⁹Aspdin named this material after Portland, since it closely resembled the high-quality limestone of Portland, England. A copy of his patent application entitled *Aspdin's improvements in the mode of producing an artificial stone and approval by the British Chancery* ([https://en.wikipedia.org/wiki/Joseph_Aspdin#/media/File: Joseph_Aspdin-BP_5022_2.jpg](https://en.wikipedia.org/wiki/Joseph_Aspdin#/media/File:Joseph_Aspdin-BP_5022_2.jpg)) is freely accessible.

⁸First built by Henry Winstanley (1644–1709) in 1696–1699. John Ruyard re-built it in 1708–1709. Smeaton's effort was the third.

(Bagchi 1939, p. 482). Massey & Company Limited¹⁰ on the Cochrane Canal Road, North Madras, marketed <Johnson's Elephant Brand Cement> in 1910 (Playne et al. 1914–1915, p. 161). What is not clear is whether the Elephant Brand cement was the one produced by South-India Industrials or was imported from elsewhere and marketed by Massey & Co. Unfortunately, no further details of the South-India Industrials Limited are trackable.

2 Madras Chûnnam in the 18th Century

2.1 On its apparent quality

The nature and quality of chûnnam used in the Madras presidency are formally recorded in various published reports by the British either living in or visiting Madras from the 18th century. All of them consistently remark that the quality of this material used in building human residences and other buildings was of superior quality than that used for the same purpose elsewhere in India. A few illustrative examples are supplied below.

James Anderson of Hermiston¹¹ comments in the article on chûnnam by James Anderson of Madras (1799, p. 7):

No cement for building hath as yet been discovered in Europe that can be compared with the fine Chunam of India for closeness, toughness, durability, and beauty. It sets as quickly as stucco, and at the same time acquires a hardness greatly superior to our best lime mortar, and is alike proper for works underwater, as for those that are exposed to the air; so that it

supersedes the use alike of gypsum and of puzzuolana, or terras.

Reverend James Cordiner, a teacher at the Male Military Orphan Asylum in Madras¹² between June 1798 and April 1799, and later Chaplain at the Government House, Colombo (Sri Lanka), while returning to Britain in 1802 from Colombo via Madras, comments appreciatively on the quality of chûnnam used in the then newly constructed Banqueting Hall¹³ and a few other new buildings in Madras. He also clarifies that the sparkling chûnnam was made by mixing lime and unrefined sugar — the jaggery¹⁴ — in particular proportions, so that the chûnnam-finished walls were beautiful, enduring, and sparkled like marble.

Walter Hamilton in his travelogue — the *Geographical, Statistical, and Historical Description of Hindostan, and the Adjacent Countries* (1820, p. 193) — says:

Chunam, or lime, occurs in extensive quantities among the boundary hills, and accessible during the rains, from whence it is transported by the inland navigation to the most distant parts of Bengal; but it is greatly inferior to the beautiful shell-chunam of Madras. A commerce in chunam, wax, ivory, and other

¹⁰Massey & Company Limited and Crompton Engineering Company were two engineering production and marketing firms in Madras, their Head Offices located in London. Both Massey & Company and Crompton Engineering Company survived because of works contracted to them by the railway and public works departments of the Government in Madras.

¹¹A clarification of James Anderson (J. A.) as 'J. A. of Hermiston' (Edinburgh, also referred as 'James Anderson, LL.D.') and James Anderson (J. A.) of Madras is necessary. J. A. of Madras, a medical doctor, served with the Madras Medical Corps. J. A. of Madras is referred as 'James Anderson, M. D.' Both J. A.-s were born in Hermiston: J. A. of Hermiston in 1739, J. A. of Madras in 1738. They were close friends (some suggest 'cousins') and intellectuals. Curiously, both died in 1809, one in Hermiston and the other in Madras. A life-size marble statue of J. A. of Madras exists in St. George's Cathedral, Cathedral Road, Chennai (Raman 2011, 2014).

¹²The Male Military Orphan Asylum was established in Madras in 1789 to support the orphaned boys of Eurasian (Anglo-Indian) descent and provide some basic life skills to them (Penny 1904). This asylum trained them in various capabilities such as printing and minding military horses. Rev. Andrew Bell was the first Superintendent of this Asylum located in Egmore–Chintadaripet area of Madras city from 1789 to 1796. Bell pioneered in the monitorial method of teaching, which came to be known later as the 'Madras System of Education'. After Bell's return to Britain in 1796, this system of teaching and empowering was adopted in various schools in Britain. The Madras College (St. Andrews, Scotland) was established by Andrew Bell himself in St. Andrews, Scotland, implementing the Madras System of Education in 1833. The Madras College is operational today.

¹³The Banqueting Hall is a spacious building, presently known as the Rajaji Hall. This was built during the Governorship of Edward Clive (son of Robert Clive), by the well-known astronomer—engineer of Madras John Goldingham (Raman 2012) in honour of the victory of the British over Tipu in Mysore, between 1800–1802.

¹⁴Jaggery is the unbleached, raw sugar from sugarcane juice (*Saccharum officinarum*, Poaceae). Jaggery is also made from Asian Palmyra (*Borassus flabellifer*, Arecaceae) by extracting and boiling the sap that oozes from the cut end of either the shoot bud or the inflorescence. It is the most abundantly available sugar source widely used by the less well-off rural people of India (Playne et al., 1914–1915).

articles, is carried on with the Cosseahs¹⁵ and other mountaineers on the eastern frontiers of Bengal.

The *Universal Technological Dictionary* (Crabb 1833, Appendix, p. 8) indicates: ‘Madras chunam, made from calcined shells, is the best.’ Maria Callcott, a popular British writer and traveller of the 19th century and one who lived in Madras and Bombay in 1809–1811, describes in her book the *Essays towards the History of Painting* (1836, p. 220):

Panænus¹⁶ (the brother of Phidias) used a plaster or stucco in the Temple of Minerva at Elis, Southern Greece, mixed with milk. This should be something like the beautiful marble-like stucco or chunam-work of India, I once saw a floor laid at Madras, among the materials of which were jaggree (jaggery) or coarse sugar, water and milk.

Because of its quality and shine, the Madras chûnnam was preferentially chosen for use in several buildings in Singapore in the mid-19th century. The Government House and St. Andrew’s Cathedral are two classic examples. To carry out this task, convicts deported from Madras, who were familiar with the technology, were used as labour (Tan 2016) (Figure 2).

2.2 The Madras terrace roofs, unique construction using chûnnam

Madras chûnnam was used both for fixing bricks and plastering wall exteriors. A popular component of human residences from the early decades of the 18th-century Madras was the ‘Madras terrace roof’ (MTR). Before the popularity of MTR in the 18th century, houses of middle- and low-income earners were essentially thatch roofed, using interwoven sun-dried plant materials (e.g., grasses and palm foliage) laid tightly on bamboo frames. MTRs were constructed using baked, red bricks (15 × 5 × 1.2 cm, *achi-k-kal*, *arai-k-kal* [Tamizh]) plastered with lime mortar, placed diagonally over 30–45 cm apart-wooden rafters. Wooden rafters held the baked, slender, red half-bricks

(*arai-k-kal*) plastered along their left—right and front—back faces (Figure 3). If considered necessary, the MTRs were supported by wooden pillars (Punmia et al. 2005, Joseph 2018).

Frederick Hemingway (Collector and Magistrate of Trichnopoly [Tiruchirapalli]), comments on the houses in the district Tiruchirapalli in the first decade of the 20th century (1907, p. 81):

The houses of the poor are thatched. Persons of even moderate wealth build themselves terraced or tiled houses. Terraced houses are rare in Namakkal and Udaiyarpalaiyam taluks, where tiles are generally used. Terraced houses, in many other districts, are usually owned only by the wealthy. Two-storied houses are perhaps more common in this than in most other districts. Thatch is made of plaited cocconut leaves covered with straw of various kinds. Occasionally a loft or mud terrace called *kurangu-macchu* (a kind of mezzanine) is built beneath the roof. Houses are generally oblong in shape.

2.3 How Madras chûnnam was made

The limestone for making chûnnam was extracted from (1) inland quarries and (2) beached seashells. The latter was deemed of superior quality.

Pebbles or gravel stones were first pounded with hand-held cylindrical wooden pounders (1–1.5 m long, 5 cm thick) shod with iron crowns (*ûlakkai*, Tamizh) to separate the aluminous clay from them, followed by sorting into ‘white’ or ‘dull-white’ or ‘brown’ quality. The limestone from inland quarries was burnt by laying alternate layers of rock and charcoal in the ratio of 2:1 charcoal: limestone [CaCO_3 (solid) + heat \rightarrow CaO (solid) + CO_2]. The burnt limestone was slacked by heaping them as mounds and adding water [CaO (solid) + H_2O \rightarrow Ca(OH)_2 (solid)]. As soon as the heat generated, the heaped material was thoroughly whisked and blended until it reduced to a dry powder [Ca(OH)_2 (solid) + CO_2 \rightarrow CaCO_3 (solid, powder lime) + H_2O] (Smith 1837).

The powder lime was used by the builders. Seashell chûnnam was produced nearly in the same manner, except that it was cleaned in a dry state by manually winnowing it against the wind. The burning process differed slightly. Charcoal was mixed with the shells and burnt

¹⁵Cosseahs — people belonging to the Khasi Hills of the Shillong Plateau, Meghalaya (Nongsiej 2002).

¹⁶Panænus: a painter in ancient Greece (c. 500 BCE) (Leake 1821).



Figure 2 Mortar mill used while building the Government House, Singapore. (Source: McNair and Bayliss, 1899).



Figure 3 Inside view of Madras-terrace roof. (Source: <https://www.pinterest.com.au/pin/36697306-9635001123>).

in large open kilns with grated bottoms and longitudinal flues. These kilns communicated to the exterior usually with four, occasionally more, lateral windows to extract the finished product (Rāz 1834).

Thinly diluted *chūnnam* was used for whitewashing interiors of a house, which, rendered the washed walls marble-like, usually after three coats (Smith 1837). The

lime extracted from well-washed seashells were calcined in designated kilns (*ūlai* — National Centre for Safety of Heritage Structures [NCSHS] c/o- Indian Institute of Technology, Madras)¹⁷ during which the artisans took care to see that the brilliance of the lime remained unblemished. They made the plaster by mixing the burnt lime and river sand in the ratio of 1:1.5. They preferred river sand, because of its whiteness. The sand from other sources — they considered — would ruin brilliance. When white sand was not procurable, they ground locally available crystalline soil and pebbles (Benza 1837, Malcolmson 1838) into a fine powder and used.

Grinding was done in a large stone bowl (mortar) intended for this purpose. The ingredients were dumped into the bowl and as the grinding by a massive stone pestle went on, pulled either by humans or by using animal (usually, bulls) power, periodical moistening was done. However, moistening was scrupulous, since excess water damaged the preferred constitution of the ground paste. When the stone bowls and pestles were inaccessible, humans hand pounded the material using the *ūlakkai*. The ground plaster was scooped from the stone bowl and heaped as cones, which was a clever way of stor-

¹⁷<http://www.ncshs.org/events/workshop/lectures/2>. Lime Burning in India.pdf, accessed 19 August 2019.

ing the freshly ground plaster, because that method of storage retained moisture in the stored mortar at the desired level for relatively long periods (Mehta and Barker 1994). Whenever the mortar had to be stored for longer than usual periods, a pit was dug at the apex of the conical stockpile, through which measured quantities of water were periodically added. That water, percolating through the stockpile, retained moisture (Holman 1840).

The main deity (*mūlavar*) of *Ananta-śayana Mahā Viśnu* in *Sri Ranganātha* temple, Srirangam, near Tiruchirapalli, is not made of granite as in temples dedicated to *Mahādēva* (*Śiva*) in southern India, but of stucco — a unique combination of *chūnnam* and baked bricks, plastered with a specially prepared balm (*tailam*) consisting of musk, camphor, honey, jaggery, and sandal.¹⁸ The *chūnnam*, intended for delicate ornate work, particularly in the *vimānā*-s and *gōpurā*-s (towers) in southern-Indian Hindu temples (Figures 4, 5) was hand ground, in small quantities, on a stone metate.¹⁹ The 3-storey tower in Figure 5 bears beautiful *çunnāmpu* sculptures (*suthai-çirpangal*, Tamizh). This practice of incorporating stucco figures extended further with time across to other parts of southern India. For example, the *prākārā* (cloister) in *Virupākṣa Kṣetra* (*Pampā Kṣetra*) in Hampi (Vijayanagara Empire, 13th–15th centuries) is ornate with several elegant stucco figures (Balasundaram 1948, Singh et al. 2018).

Jaggery was one key ingredient in preparing the *chūnnam*, especially that was used in plastering. Jaggery, because of its high-sugar content, was intentionally used to achieve intimate fusion of the coarse particles of lime (Rāz 1834).

3 Engineer John Thomas Smith and the Lime Mortar of Madras

John Smith (1805–1882), chief engineer with the Madras Engineers Corps (MEC), is immortalized in Madras for designing and building the Grecian-Doric column lighthouse in 1838–1839 (Raman 2016). Smith explored the

¹⁸UNESCO, n.d., <https://whc.unesco.org/en/tentativelists/5894/>, accessed 3 September 2019.

¹⁹Read as either ‘metātee or metāté (Spanish). A rectangular, granite block usually with a flat top. On the flat top, a heavy, hand-held granite mano (= a kind of rolling pin) is rolled repeatedly in a forward—backward motion grinding the material.

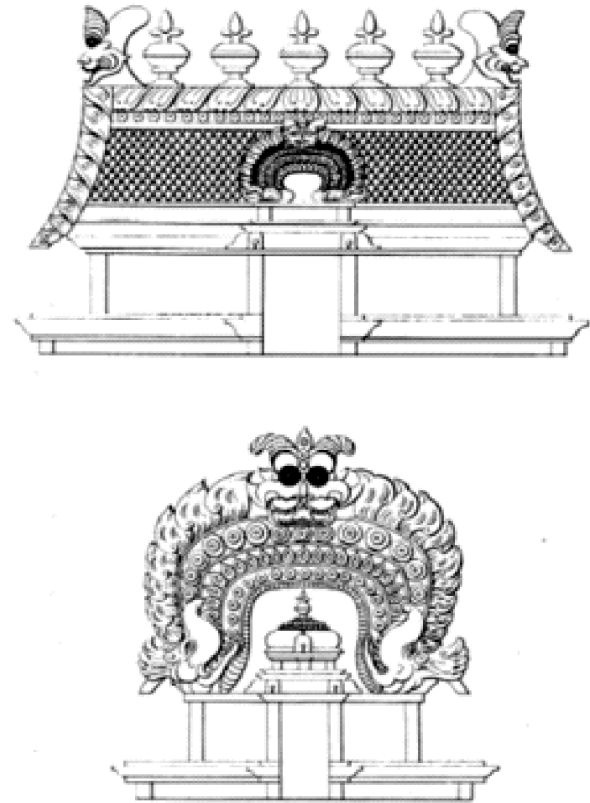


Figure 4 Ornate *chūnnam* work on the *śikhara* of the *vimāna* of a temple in the Madras presidency (Source: Rāz 1834, plate xxvi. Lithograph by William Day and Louis Haghe, London. Artist not identified).

science of limes and lime mortar used as building material. Many of the classy engineering papers and reports submitted to the government at Fort St. George (Madras) by MEC staff were published in the *Reports, Correspondence and Original Papers on Various Professional Subjects Connected with the Duties of the Corps of Engineers Madras Presidency*, edited and published by him from 1839. These papers enlighten us on some of the remarkable science that flourished in Madras. An incredible input Smith made to materials science is the translation of Louis-Joseph Vicat's²⁰ *Résumé des Connaissances Posi-*

²⁰Louis-Joseph Vicat (1786–1861) an engineer in Paris published extensively on the suitability of various limestones for the production of lime. He found that a mortar with hydraulic properties should include lime and either silica or alumina. He invented the method of testing the hydraulic properties of mortar, using the Vicat needle, which measured the setting time of mortars, used even today.



Figure 5 *Neerāzhi mandapam* (the hall in the middle of the temple tank) adjacent to the *Chithira Sabai* of *Tiru-k-kutralanāthar* temple management, Courtallam (8°56'N, 77°16'E). (Photo: A. Raman, July 2018.). Estimated construction was either during the Vijayanagara Empire (14th–17th centuries) or during the reign of the Madurai *Nayak*-s (16th–17th centuries). Recently it was colour-washed because of a festive event in *Tiru-k-kutralanāthar* temple.

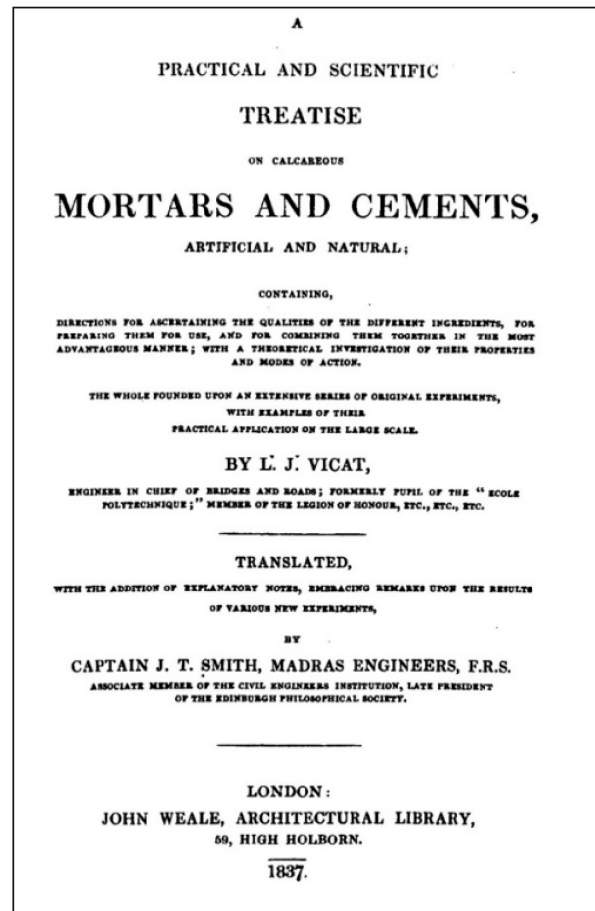


Figure 6 Cover page of the translated edition of Louis Joseph Vicat's book by J. T. Smith (1837).

tives Actuelles sur les Qualités, le Choix et la Convenance Réciproque des Matériaux Propres à la Fabrication des Mortiers et Ciments Calcaires suivi de Notes et Tableaux d'Expériences Justificatives (1828, l'Imprimerie de Firmin Didot, Paris, p. 149) into English (Smith 1837, Figure 6). The translation includes notes and comments on Madras *chūnnam*, based on experiments he made while stationed in Madras.

During Smith's time in Madras, extensive stretches of magnesite (source of $MgCO_3$) were discovered in the Chalk Hills, Salem (11°43' N, 78°7' E) and Tiruchirapalli (10°48' N, 78°41' E). The estimates were that magnesite was available plentifully. Measures were already in place to explore these landscapes for use as a 'cement' source. Benjamin Heyne (1770–1819), a medical doctor and a

noted botanist of India²¹, first discovered the availability of magnesite in the Chalk Hills in the early decades of the 19th century (Blanford 1865). In 1825, Alexander Macleod of the Madras Army established the hydraulic properties of magnesian limestone found in Salem region and brought that finding to Madras government's attention. The magnesia cement (Sorel Cement) of Salem magnesite was considered of superior quality (Cotton 1839). This material came into extensive use in India after John Smith experimentally verified its efficiency in construction work (Smith 1837).

Smith (1837) provides extensive scientific remarks on the physical, chemical, and engineering aspects of chûnnam used in Madras. The following paragraph refers to some of his key remarks.

Three coats were usually applied. The first coat of 1–1.5 cm thickness, intended as wall plaster, involved the application of a mixture of seashell lime and sand, tempered with jaggery solution. On drying, the second, prepared as a thinner solution was applied with the mixture of well-sieved, powdered seashell lime and fine-white sand. The second and the third coats of chûnnam usually did not include the addition of jaggery solution, because its dull-brownness was considered to tarnish the whiteness of the applied chûnnam-wash. The third, usually the last, coat was polished. The third coat chûnnam was prepared with extreme care. Only the whitest seashells with a small proportion of white sand were used. The components intended for the third coat were ground in a circular, granite-base channel in which a massive stone roller rolled grinding the chûnnam ingredients to a uniformly smooth, creamy paste. In a bushel (c. 27 kg) of this paste, a dozen eggs, half a pound (0.227 kg) of ghee (clarified butter), and some freshly curdled yoghurt (quantity not specified) were added. To this composite, some of the master masons (*maistry*) added 110–225 g of balapong (soap-stone, steatite, metamorphic talc-schist), which ensured brilliance of the final coat. However every master

mason had a recipe of his own. The essential ingredients, in addition to the lime and sand, were the albumen of eggs and the ghee. Sometimes an oil (not identified) was used instead of ghee. The final coat was always thin, and was applied usually before the second was fully dry. Because of the dilution and thinness, the third coat dried quickly. The washed walls were then scrubbed using the smooth surface of a hand-held block of either balapong or agate. This procedure was done for several hours followed by wiping with a soft cotton fabric.

In the 'Memorandum of experiments upon the influence of jaghery in chunam' published (1839), Smith describes his experiments to establish the validity of using jaggery solution as a tempering agent while making the Madras chûnnam. He made six trials of mixing the mortar with (i) plain water, (ii) fresh-lime solution, (iii) ¼ lb (113 g) of jaggery mixed in 1 gallon (3.78 L) of limewater, (iv) ½ lb (227 g) of jaggery mixed in 1 gallon (3.78 L) of limewater, (v) 1 lb (453 g) of jaggery mixed in 1 gallon (3.78 L) of limewater, and (vi) 2 lbs (907 g) of jaggery mixed in 1 gallon (3.78 L) of limewater. He concludes that the use of jaggery as an additive to the chûnnam mortar is of special advantage, especially at the first hardening. He concludes that the jaggery is a highly useful material that acts as an efficient cohesive material in achieving a superior level of compaction of the chûnnam mortar, by enhancing the combining affinity of the lime. The proportion of jaggery used is indicated by Smith as follows (p. 129): 'no less than 10–20 lbs (4.53–9.07 kg) of jaggery per parrah²² (of chûnnam mortar) is necessary'. On the cohesive property of jaggery he says (p. 129):

The reason is, that the improvement made in the cohesion of the cement (mortar) depending only on the quantity of jaghery (jaggery) which remains within it after drying, must obviously be determined by the degree of saturation of the fluid of admixture, which regulates the quantity of the sugar which is left behind on desiccation.

²¹<https://plants.jstor.org/stable/10.5555/al.ap.person.bm000336083>, accessed on 1 September 2019

²²Parrah (read as 'parā') was a capacity measure widely used in South Malabar until recent times. One parā equalled approximately 40 lbs of the measured item (Galletti et al., 1911, p. 42).

4 Discussion and Conclusion

The remark that repeatedly occurs in the literature on Madras chûnnam is its marble-like finish. Almost every European, who had occasion to see and feel the chûnnam work in Madras consistently admired for its finished quality. Indeed, chûnnam was used in other parts of India for ages. However, the Madras chûnnam was considered marvellous. The Madras chûnnam was the material of choice in building works in Singapore of the Straits Settlements in the early- and mid-19th century.

Addition of various organic and inorganic materials to lime mortar was practiced elsewhere in the world from ancient times. For instance, in ancient China ground sticky rice²³ was added to lime mortar, which resulted in an organic-inorganic composite. The amylopectin of the sticky rice — the organic source (Yang et al. 2010) — strengthened the mortar. Ancient Greeks supplemented lime mortar with straw and other fibrous materials. The straw as an additive enhanced plasticity and controlled setting rates; it enhanced strength and avoided cracks due to the shrinkage during setting (Moropoulou et al. 2005). Archaeological relics in the erstwhile Roman city of Sagalassos (37° 40' N, 30° 31' E) reveal that the lime used was burnt from local Triassic limestones and prepared by dry slaking. The additives were crushed ceramics and volcanic ash (Degryse et al. 2002).

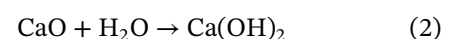
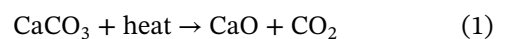
In Southern India in general, and in the Tamizh country in particular, several other biological materials were added to lime mortar to achieve quicker and better carbonation (hardening process). Carbonation renders the lime mortar durable. In the Madras presidency, builders and bricklayers added jaggery solution to limestone mortar. Egg albumin, clarified butter, and freshly curdled yoghurt, and talc schist (balapong) were the other additives, although the proportions of each item added varied with the understanding and experience of the maistry-in-charge of the building work (Smith 1837). Carbonation, a chemical process, depends on the atmospheric temperature, relative humidity, and the concentration of CO₂ present. Carbonation results in the changed mass of the applied lime mortar by transforming the moist mortar into either dry

²³Sticky rice, otherwise known as 'glutinous rice' (*Oryza sativa* var. *glutinosa*, Poaceae) has been in use in China for the last two millennia. This was also grown in many nations in South and South-eastern Asia. This rice includes little amylose and more amylopectins (Li et al. 2017).

calcite or crystalline form of CaCO₃ (argolite) with time. At the end, the applied mortar's mechanical strength enhances considerably and changes water-transport characteristics (Jayasingh and Selvaraj 2018).

Trials made with lime mortars (lime: sand—1:2) laid after 15 days of fermentation added with either extracts of or crushed plants (*Cissus repens* [Vitaceae], *Cochlospermum religiosum* [Bixaceae]), *Persea macrantha* [Lauraceae], *Terminalia chebula* [Combretaceae]) and jaggery made from either *Borassus flabellifer* [Arecaceae, the Asian Palmyra palm] or species of *Saccharum* [Poaceae, sugarcane]) to improve flexure, tension, and compressive strengths. The transverse strength of lime mortar supplemented with 5% plant extracts was 1.6 times greater than the lime mortar supplemented with plain water. Additionally a 3-fold increase in tensile strength occurred because of the elastic nature of plant-material added lime mortar. The compressive strength enhanced up to 2.5 times on the addition of plant extracts (Thirumalini et al. 2011).

Jaggery was added during the preparation of lime mortar, which, as the sugar source (65–80%) enhanced dissolution of lime in water. This was the reason why the maistry-s in the Tamizh country used jaggery solution during slaking process, which restrained the addition of water to lime directly, enabling the conversion of CaO into Ca(OH)₂:



In the sesquicentennial restoration of the Church of Our Lady of Lourdes (St. Joseph's College precinct, Tiruchirappalli, consecrated in 1840) in the late 1990s, the restorers found that the earlier used plastering material included jaggery and *Terminalia chebula*²⁴ (Combretaceae, myrobalan, *kaḍukkāi*—Tamizh) seed extracts, further to extracts of stems of *Ipomoea staphylina* (Convolvulaceae) (Natarajan et al. 2010). Why extracts of *I. staphylina* were

²⁴Many authors incorrectly refer *kaḍukkāi* (*Terminalia chebula*) as 'gall nut(s)'. Gall nuts are dry, woody abnormal growths, referred as 'galls' induced on the leaves of species of *Fagus* (Fagaceae) by certain groups of insects (Cynipidea) and these are usually confined to cool regions of the world (e.g., Northern and Central Europe, Himalaya). They include abundant phenols as the seeds and fruits of *kaḍukkāi* do. *Kaḍukkāi* in popular English is myrobalan and not gall nuts. Images used by most of those authors erroneously indicate the insect-induced galls and not the fruits or seeds of *kaḍukkāi*.

used is mysterious. Use of jaggery solution and extracts of *T. chebula* seeds is also known in the Charminar built by Mohammad Quli Qutb Shah in Hyderabad in 1591 (Singh 1993).

Jaggery and the crushed seeds of *T. chebula* were used as additives to achieve more rapid setting and better stabilization. These materials facilitated the initial consumption of lime altering the pH level, sufficiently high, rendering the available silica and aluminium soluble (James et al. 2018). As lime content increases above the initial consumption of lime, the residual Ca reacts with the soluble silica and aluminium triggering pozzolanic reactions. Such pozzolanic reactions will continue as long as the high-pH and residual Ca remain, leading to the formation of reaction products enhancing the setting and stabilization (Little 1995).

The above narrative brings to light some of the ignored, forgotten details of the plastering materials used in the 18th and 19th century Tamizh country, which impress as a giant leap in construction work, further to impressive sculpture work done using different rock materials. The Airawatésvara temple, 4 km south-west of Kumbhakonam, built by Raja Raja II (1146–1172 CE) of the later Çola dynasty will be one example. That apart, even for buildings human residences, that they made use of sophisticated technology in preparing appropriate paste of chūnam and other materials in the most appropriate manner is indeed remarkable.

It does not surprise at all, therefore, why many of the contemporary construction engineers and architects are loudly talking on the validity and usefulness of using lime mortar, embellished with plant fibres and plant extracts, supplemented by traditional grinding done with bull-pulled stone grinders as referred at the start of this article.

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