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Units of Length In 17th–18th Century Bengal Temples: Context Bishnupur

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Abstract

Shubhankari is an almost-forgotten mathematical treatise of Bengal that was widely used in the pre-colonial era. It consists of verses, called arjyas, which deal with everyday computations like weights and measures, land measurement and so on. The arjyas list various units of length measures, like the angula (finger), muth (fist), hath (hand) and the relation among these units. The same types of units have been found in Monu Mistiri's handbook on construction of temples, of which only a few pages survive. The author conducted in-depth research and realised that these units of length were used in India since the Harappan times and have been mentioned in ancient treatises of architecture like Arthashastra, Brihatsamhita, Mayamata, Manasara and Bhubanapradipa. These units of length also matched the units used in the ancient world viz. the cubit and the digit. To find out whether the ek-ratna temples of Bishnupur were constructed using these length measures, the author measured ten such temples and collected on-site data. These dimensions were then converted to hath-angula units and matched with the Shubhankari system of measurements. The results showed that there was a very good match, establishing that these units of length were used in the 17th–18th century temples of Bishnupur.

Keywords: Bengal temples, *ek-ratna* temples, mesopotamian civilization, egyptian, ancient treatises

INTRODUCTION

Since the dawn of civilization, human societies have used the units of measurement for their day-to-day activities. It enabled people to calculate length, area, volume, mass, currency and time for land measurement, house construction, trade, agriculture and so on. For the measurement of lengths, people had universally used human body dimensions as the basic units, e.g., finger width, palm, fist, handspan - which has been mentioned in the ancient religious books (The Old Testament, Vedas etc) and other sources. In the field of architecture, cubit (length from the elbow to the tip of the middle finger) had played a special role in planning, designing, and constructing buildings in the past. The cubit had variations, though not widely, due to the anthropometric differences arising out of the various ethnographical contexts. When trade developed between far-away places like Indus-Saraswati Valley and Mesopotamia, there arose a necessity of a common standard of measurement.

This article will focus on the units of length used in the *ek-ratna* temples of Bishnupur, Bengal, constructed over a period of two hundred years between 17th–18th century CE. The units of measurement for planning, designing and construction of *ratna* temples must have been based on the prevailing practice in the vernacular and classical religious architecture. This article investigates the units of length in the existing *arjyas* e.g., *hath, angula, muth and bighat* and so on, which were used in temple building and the rural Bengal tradition of house construction. These have been tallied with the dimensions of ten existing *ek-ratna* temples of Bishnupur to see if the *hath-angula* were

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indeed the units of length measurement in these temples. The paper begins with a comparative analysis of the length units used in the ancient world and in Indian treatises, to situate the Bengal units of length in the global and national context.

UNITS OF LENGTH MEASUREMENTS ACROSS THE WORLD

Length is the most necessary measurement in the daily life of any society. Since time immemorial, the human figure (mostly male) has been used for establishing various units of length for two reasons. To begin with the measurements of a human body was approximately the same in any culture. Moreover, these measures would always be with a person, wherever he went. An added advantage of this practice is that this system of measurements has an inherent proportionality since the human body parts are all proportionate to each other. The inch, foot, cubit, yard and so on are all multiples of the basic unit–the digit, which is the breadth of the middle finger. The architect's rod, or staff, was always a cubit long–equal to 24 digits. Often, the proportions of a royal figure or a nobleman would be taken as the standard to eliminate person to person variation. Of all these measurements, the cubit has been in use in architecture since the Biblical times. Two of many such instances are the descriptions of the Noah's Ark and King Solomon's Temple, as illustrated here.

"... Make thee an ark of gopher wood; rooms shalt thou make in the ark, and shalt pitch it within and without with pitch. And this is the fashion which thou shalt make it of: The length of the ark shall be three hundred cubits, the breadth of it fifty cubits, and the height of it thirty cubits."
…Genesis [1].

"... And the house which King Solomon built for the Lord, the length thereof was threescore cubits, and the breadth thereof twenty cubits, and the height thereof thirty cubits. And the porch before the temple of the house, twenty cubits was the length thereof, according to the breadth of the house;- and ten cubits was the breadth thereof before the house [1].

The ancient Egyptian hieroglyph for the cubit is a forearm. The royal cubit has been used in the construction of the Step Pyramid of Djoser as early as about 2700 BCE [2]. It seems to have been composed of 7 palms of 4 digits each, totaling 28 parts, and was about 524mm in length. Stone also mentions that the Egyptian cubit was probably the standard measure of length in the Biblical period. This unit of length probably travelled to other lands like Israel due to the Biblical exodus and war. Trade also facilitated the transfer of the units from the ancient civilizations to other regions. The cubit was an early and important unit of the Mesopotamian civilization as well. Stone writes that the cubit has been mentioned in the Epic of Gilgamesh where the unit has been used to describe a flood similar to, but predating, the flood of Genesis [2,3].

The Greeks mostly used a 24-digit cubit, but it varied according to the different digit measures from different Greek city-states. The Greeks and Romans probably continued to use the Egyptian foot [2]. The Roman foot was divided into 12 *unciae* (inches) Leonardo da Vinci's drawing of the '*Vitruvian* Man' is a record of the Roman length measures. Da Vinci notes that, during the Roman times, the lengths of body parts of an ideal man were canonized as being exactly proportionate to one another [4]. So, 4 fingers equaled one palm, 4 palms equaled one foot, 6 palms made one cubit and 4 cubits (24 palms) equaled a man's height.

The Roman mile measured 5000 feet. This became the standard measure in England and other countries that were conquered by the Romans. The yard (measure from the center of a man's body to the tip of the middle finger of an outstretched arm) as a unit of length came later, perhaps as the double cubit; and was divided into the hand-span, palm, finger, and nail. The cubit was, thus, a convenient middle unit between the foot and the yard. It is still used as a way of measuring cloth in many places.

The Arabic basic unit of length-the *dhira* (or *ell* or standard cubit) - was in use around the 9th century CE, perhaps parallel to the growth and spread of Islam [2]. The *al-dhira* or *al-sawda*' (black *ell* or royal cubit) was 540.4mm and was the length from the elbow to the tip of the middle finger of a slave of the Caliph al-Mansur (8th century CE) or the Caliph al-Ma'mun (9th century CE) [5]. In addition to the different norms of the *dhirā*, different *ells* were used by various professionals e.g. by carpenters, cloth-makers, construction workers etc. Moreover, the *ells* used in different cities under the same name differed, e.g. the medieval cloth-*ell* of Damascus (630.35mm) was 1/12 times longer than the cloth-*ell* of Cairo (581.87mm) [5].

The cubit continued to be used as a unit of length, particularly in architecture, all through the Gothic and Renaissance times. Table 1 is the summary of the approximate values of these units in different civilizations of the ancient world. It is evident from the table that 4 digits = 1 palm; 16 digits = 1 foot; and 24 digits = 1 cubit (≈ 450mm). It may also be observed that the digit, palm and hand-span had the least variation across the places, while foot and cubit had relatively more variation. By the time of the French Revolution in the 18th century CE, the cubit and the digit were abandoned in favour of the metric or decimal system [6].

Table 1. Approximate values of digit and cubit in different civilizations of the ancient world (outside India). Table compiled by author based on [2, 4, 5].

Place	EGYPT	ISRAEL	MESOPOTAMIA	GREECE	ROME	ARABIA
DIGIT	18.7mm	18.75mm	19.05mm	19.29mm	18.52mm	19.29mm
PALM	4 digits=74.8mm	4 digits = 75mm		4 digits =77.17mm	--	
HANDSPAN	--	12 digits ≈225mm		12 digits =231.5mm	--	
FOOT	16 digits = 299.2mm	--		--	16 digits ≈ 296.31mm	
CUBIT	24 digits =448.8mm	24 digits =450mm	24 digits =457.2mm	24 digits =463mm	24 digits ≈444.47mm	*Dhira* ≈ 24 digits = 463.03mm
	Royal Cubit 28 digits =524mm	Royal Cubit 28 digits ≈ 525mm	28 digits = 33.4mm			Black *Ell*/ *al-dhira* 28 digits ≈ 540.2mm

UNITS OF LENGTH MEASUREMENTS IN VARIOUS TREATISES IN INDIA

While the previous section focused on the units of length outside India, this section will discuss the units that were used in different parts of this country in ancient and medieval times. The following paragraphs discuss these units and proportions from the Indus-Saraswati Civilization in the 3rd millennium BCE, and treatises like Arthashastra, Brihatsamhita, Mayamata.

In Indus-Saraswati Civilization, the smallest unit of measurement in Lothal was 1.769mm. This is evident from an ivory scale found at Lothal, which has 27 graduations over a length of 46mm. Chattopadhyaya writes that V.B.Mainkar was, perhaps, the first to suggest that ten times the smallest unit in Indus-Saraswati Civilization (17.7mm) was their unit of measurement [7].

Danino's research, based on dimensions of built forms of Indus-Saraswati civilization that have been recorded by the archaeologists, reveals that a general Harappan *angula* = 17.7mm, and a general Harappan dhanus = 1911.6mm [8]. So, in the Indus-Saraswati Civilization, 1 Harappan dhanus = 108 Harappan angula (Angula and dhanus are terms used by Danino in the Harappan context, as these units are very similar to the corresponding units in Arthashastra. This has been discussed later in the article). Danino mentions that there must have been sub-units between the *angula* and the dhanus for ease of measurements of different objects of different sizes. It will be seen in this article that this relation between the Harappan *angula* and the Harappan dhanus continued beyond the period of first urbanization in India. These length- measures survived the collapse of the Indus-Saraswati Civilization and lived on to be canonized by Kautilya in his Arthashastra.

The earliest literary references to length measures in the Indian culture are found in the Sulba-sutras and Arthashastra. The Encyclopedia Britannica states that the Arthashastra was composed by Kautilya in the 3rd century BCE, when he was the Chief Minister of emperor Chandragupta Maurya. It is mentioned in the Encyclopedia that some parts of the text might have been added on later and Mabbett mentions that parts of the treatise could be as late as 3rd century CE [9,10]. The units of length mentioned in the Arthashastra include the *angula*, *dhanurgraha*, *vitasti*, *aratni*, *danda*, *paridesa* and *rajju*. There are at least two dimensions of '*danda*'– first, 1 *danda* (*dhanus*) = 96 *angula* (human span with arms stretched = human height = 4 *aratni*) and second, I *danda (grahapatya dhanus)* = 192 *angulas* (twice the earlier length and used to measure land given to Brahmins). In addition to these, the Arthashastra mentions 4 different units in terms of the *angula* for measuring different lengths, viz. *kishku*, *hasta*, *vyama*, and *grahapatya [11].*

These are as follows:

- *kishku* = 42 *angula* ◊ used by sawyers, blacksmiths to measure army encampment, forts, palaces
- *hasta* = 54 *angula*) ◊ used for measuring timber forests;
- *vyama* = 84 *angula* ◊ used for measuring rope lengths and depth of digging
- *grahapatya dhanus* = 108 *angulas* ◊ used by carpenters (called *grihapati*) to measure roads, fort walls and sacrificial altars.

Table 2 is a summary of the length measures in Arthashastra and their present-day equivalence. Chattopadhyaya writes that though earlier scholars had estimated the traditional *angula* in Arthashastra to be approximately 3/4th of an inch, i.e. 19.05mm, Mainkar's detailed calculations showed that the *angula* equals 17.78mm [7].

Table 2. Comparison of lengths given in Arthashastra. *Table compiled by author based on [7, 11].*

ARTHASHASTRA UNITS	PRESENT DAY UNITS
8 *yavamadhya* = 1 *angula* (*yavamadhya* means width of a middle size barley grain) (*angula* means breadth of the middle joint of the middle finger of a man of medium size)	1 *angula* = 17.78mm
4 *angula*= 1 *dhanurgraha* (bow grip)	1 *dhanurgraha*= 4 *angula* = 71.12mm
3 *dhanurgraha*= 1 *vitasti* (hand-span)	1 *vitasti* = 12 *angula* = 213.36mm
2 *vitasti*= 1 *aratni* (also called *prajapatya hasta*)	1 *aratni* = 24 *angula* = 426.72mm
4 *aratni*= 1 *danda* (also called *dhanus/nalika/ paurush*)	1 *dhanus* = 96 *angula* = 1706.88mm
4.5 *aratni* = 1 *danda* (also called *grahapatya dhanus*)	1 *grahapatya dhanus* = 108 *angula* = 1920.24mm
20 *danda*= 1 *paridesa*	

Mayamata is a Vastushastra from South India, written in 11th century CE during the Chola period, though the oral tradition must have been in practice for a considerably longer time. The fifth chapter of the Mayamata deals with the systems of length measurement [12]. Mayamata specifies the use of units like *angula*, *vitasti*, *hasta* and *yashti* (also called *danda*). The canon mentions that the villages are to be measured in terms of *danda* and houses are to be measured in multiples of *hasta*. The *vitasti* should be used for vehicles and seats of deities, the *angula* for small objects and the *barley grain* for even smaller ones. Mayamata prescribes another unit called *matrangula*, which equals the middle joint of the middle finger of the officiating priest, which should be used for measurements relating to sacrifices and altars. Table 3 shows the inter-relation of the Mayamata units of lengths.

Table 3. Units of lengths in Mayamata. Table compiled by author based on [12].

8 barley grains = 1 *angula* (also called *matra*)
12 *angula*= 1 *vitasti* (hand-span)
2 *vitasti*= 1 *hasta* (also called *kisku/ aratni/ bhuja/ bahu/ kara*)
4 *hasta* = 1 *yashti* (also called *danda*)

Brihatsamhita by Varāhamihira is one of the earliest known Indian texts with dedicated chapters on principles of architecture. It is an ancient Sanskrit text from 6th century CE Ujjain, describing the design and construction of *Nagara* style of Hindu temples. It is mentioned in the text that Viswakarman spoke of three kinds of digits – *prasaya*, of length of eight full grown barley grains; *sadharana*, length of seven barley grains and *sama*, of length of six barley grains. It is further mentioned that the first dimension should be used for the construction of houses. Brihat samhita also mentions that the height of the best type of man is 108 *angulas* of themselves [13]. Manasara is a Sanskrit treatise on architecture and iconography, originating in South India. It is a compilation produced around or after the 10th-11th century CE, based on major treatises from Gupta period and later, that now exist only in fragments [14]. Manasara prescribes a rod (*danda*) of 108 *angula [15]*. Bhubanapradipa, the most popular canon of Odishan temple architecture, also states length measures in terms of *angula* and *hath* [16].

There seems to be some similarities in the units of lengths discussed in the above paragraphs and this section undertakes a comparative analysis of the same. To begin with, there is a remarkable similarity between the Arthashastra and Harappan units. The Harappan *angula* (17.7mm) is almost identical to the traditional *angula in* Arthashastra (17.78mm). Again, the relation of 1 Harappan *dhanus* = 108 Harappan *angula* is found in Arthashastra, where 1 *grahapatya dhanus* = 108 *angula* was a measure used by carpenters (called *grihapati*) to measure roads, fort walls and sacrificial altars. The number 108 is repeated in Brihat samhita (where the height of a man is 108 *angula* of themselves) and Manasara (where 1 *danda* = 108 *angula*). The Mayamata specifies the use of units like *angula*, vitasti, hasta and yashti (also called *danda*), which are the same as those mentioned in Arthashastra. Thus, the similarities among the various treatises are immediately evident. Table 4 is a summary chart of the above discussion and presents the units of measurements found in some of the treatises of ancient India. It shows that these units have been the same across time and place in India. Chattopadhyaya quotes V.B.Mainkar and mentions that the length measures mentioned in Arthashastra are related in some way or the other with the length measures used in later periods in India [7]. At the same time, the striking similarity in one *angula* length in Arthashastra and Indus-Saraswati Civilization stretches back the history of unit lengths in India to 3rd millennium BCE.

Table 4. Summary chart of the units of measurements found in some of the treatises in India. Table compiled by author.

Indus-Saraswati 3rd Millennium BCE	Arthashastra 2nd Century BCE	Mayamata 11th Century CE
10 Lothal units = 1 Harappan *angula* = 17.7mm	8 *yavamadhya* = 1 *angula* = 17.78mm	8 barley grains = 1 *angula*(also called *matra*)
	4 *angula* = 1 *dhanurgraha* =71.12mm	--
	3 *dhanurgraha*= 1 *vitasti* = 12*angula* = 213.36mm	12 *angula* = 1 *vitasti*
	2 *vitasti* = 1 *aratni*(also called *prajapatya hasta*) = 24 *angula* = 426.72mm	2 *vitasti* = 1 *hasta*(also called *aratni*)
	4 *aratni* = 1 *danda*(also called dhanus) = 96 *angula* = 1706.88mm	4 *hasta* = 1 *yashti*(also called *danda*)
1 Lothal *danda/ dhanus* =108 *angula*s = 1911.6mm	4.5 *aratni* = 1 *grahapatya dhanus*= 108 *angula* = 1920.24mm	--

UNITS OF LENGTH MEASUREMENTS IN LATE MEDIEVAL BENGAL TEMPLES

Temple building activity started with a boom in Bishnupur, Bengal in 1600 CE after a gap period of about 400 years. Many types of temples were built during this period, e.g. *chala, ratna, dalan and mancha*. Of these, *ratna* temples were the largest and had achieved an iconic status in Bengal architecture. This section discusses the units of lengths used in this genre of temples.

It is difficult to find literary evidence of the units and proportions used in the late medieval temples of Bishnupur. However, search for the units led to the identification of Manik Lal Singha's book 'Paschim Rarh Tatha Bankurar Sanskriti' [17]. The author mentions about handbooks of architecture (including temple architecture) which were used by masons and preserved as family heirloom in the mason families, because the professional expertise would be passed on from generation to generation. These would be learnt by the apprentices through observation, practice and finally, experience. However, such handbooks are long gone, mostly lost because of neglect, termites and mice, as these ceased to be useful once the modern technologies came into vogue. One such handbook was used by the ancestors of the traditional mason family of Shri Mahendra Sutradhar, who was a mason himself. Singha had recorded the verses which he heard from Monu Mistiri in his above-mentioned book [17]. Saha mentions that these verses, also known as *arjyas,* were used by the masons, though the author or the time of their composition is unknown [18].

These *arjyas* were written in Proto-Bengali language; and close scrutiny revealed that these verses prescribed the dimensions of some parts of the temples and idol-base, based on vernacular units of lengths. *Pal, angula* (digit), *bighat* (hand-span), *gaj*, *muth* (closed fist), *hath* (elbow to tip of middle finger) and a few other units of length have been used frequently in these *arjyas*, out of which some were used by children (viz. *bighat*) in vernacular games until recently. This strongly suggests that traditional units of length were used in temple design and construction. These units were never isolated, but were always part of a system. Thus, the arjyas led to a search for the overall system of lengths and proportions used in the design of Bishnupur temples. While conducting resource mapping for rural housing in Bengal, the author had seen many village masons still used the vernacular units like *hath* and *angula*. They used improvised sticks called *maap-kathi*, which equaled the length of a *hath, muth*, etc. according to the requirement.

To begin with, it is important to understand Shubhankari *arjyas*. Shubhankari has been described as the mathematical treatise of Bengal, and is an almost forgotten tradition that was widely used in pre-colonial Bengal [19]. It consists of a collection of the traditional mathematical knowledge in the form of *ariyas* or verses. These verses deal with computations related to everyday activities like weights and measures, arithmetic in carpentry, agriculture, currency, commerce, land measurement and others. There were two types of verses– first, verses which facilitated calculation in vernacular units of measures and currency and included multiplication tables; and second, mathematical problems in the form of verses [20]. Thus, the first one had to be learnt and memorized to solve the second type of *arjyas*. It must be mentioned here that the traditional Indian culture was to canonize knowledge in verses, as it was easy to memorize, retain and retrieve, even after a long time. The oral tradition or '*shruti*' form of learning has been the Indian way of passing down the knowledge from one generation to the next. Even mathematical knowledge was versified, as seen from the days of Siddhantic Astronomy Era (500-1400 CE) [20].

The Shubhankari was taught to children in *pathshalas* (elementary school in Bengal) as well as at home and consisted mainly of memorizing the *arjyas* by repeated chanting. The stress was on oral counting skills and once understood, memorized and practiced, these *arjyas* would help in doing complex calculations orally and quickly, without using a pen and paper [20].

It is generally accepted that Shubhankari was composed by different people like Shubhankar Das, Bhriguram Das, Dhuldanti, Bisweshwar Das, Harekrishna Ghosh and many others [20]. Since the most renowned of these composers was Shubhankar Das, the name 'Shubhankari' was given to this body of knowledge. According to the researchers, Shubhankar Das lived in Bankura in the late 17th -early 18th century CE. He was employed in the court of Gopala Singha (1712-1748), Malla king of Bishnupur. He summarized complex mathematical computational procedures as simple, easy to memorize verses/ *arjyas* for the children [20]. There is a possibility that he compiled and edited the *arjyas* from traditional knowledge, just like what Euclid did in Greece in 4th century BCE. Sukumar Sen, renowned philologist and expert on Bengali manuscripts, states that some of the Shubhankari verses, including the first few lines of the most famous *arjya*, bear similarities with *abahathta*, which is an ancestor of Modern Bengali language derived from Prakrit and used before 15th century CE. Based on this fact, Sen surmises that Shubhankar, if he was a genuine historical figure, lived before the 15th century CE, wrote in *abahathta* and created a tradition that continued into the 19th century [21]. None of these hypotheses can be proved and Chacraverti mentions that, in any case, almost all the verses available now are modified versions of the original verses. Even if Shubhankari was written down in the 18th century CE (in the court of Gopala Singha), the units must have been in existence for quite some time before that as oral tradition. Moreover, a couple of manuscripts are dated 11th century *Mallabda* (i.e. 18th century CE), which was the calendar system followed in Bishnupur. Use of '*Mallabda*' shows that the Malla kingdom, of which Bishnupur was the capital, was an important centre where Shubahnkari was being written and therefore, definitely practised. Thus, it may be reasonable to say that the units of measurement mentioned in the *arjyas* were used in Bishnupur temple construction in the 17th-18th century CE.

Any architectural design is primarily based on units of length. Hence, though the Shubhankari *arjyas* deal with units of various measures and currency, this paper will focus only on the units of length. These units are primarily gleaned from *arjyas* relating to land measurements and Monu Mistiri's handbook. There were four basic units of length viz. *hath*, *katha*, *bigha*, *chhatak* and six basic units of areas viz. *kalir katha, kalir bigha, kalir chhatak, dhul, ganda, kak*. It is quite evident that *katha*, *bigha* and *chhatak* were units of length and area, and in order to understand which dimension these units represented, one had to understand the context. These units were not on a decimal scale, but on scales dominated by 4, 8, 16 and sometimes 3 or 9 as well. These units were probably used for land measurement. Table 6 shows some subdivisions of 'hath' as mentioned in a few Shubhankari manuscripts and these units were used in architecture, furniture making, vehicle design and the like.

Table 5 and Table 6 present a summary of the various units of length used in the everyday life of Bengal. Table 5 shows the relation among the four basic units of length, all expressed in terms of the '*hath*'. One *hath* equals 450mm and is approximately the same as the cubit of the ancient world [20, 22].

Table 5. Relation of indigenous units with present day units. Table compiled by author based on (17, 18, 20].

Shubhankari units	Conversions from Shubhankari to present day units
4 *hath* = 1 *katha*	1 *katha* = 1.8m
80 *hath* = 20 *katha* = 1 *bigha*	1 *bigha* = 36.0m
¼ *hath* = 1/16 *katha* = 1/320 *bigha* = 1 *chhatak*	1 *chhatak* = 11.5mm

Table 6. Few sub-divisions of *hath*. Table compiled by author based on [17, 18, 20].

Shubhankari units	Conversions from Shubhankari to present day Units
8 *job* (barley seed) = 1 *anguli* (width of middle finger)	1 *angula* = 18.75mm
4 *anguli*= 1 *muth* (closed fist)	1 *muth* = 4 *angula* = 75mm
3 *muth*= 1 *bighat* (hand-span)	1 *bighat* = 12 *angula* = 225mm
2 *bighat*= 1 *hath* (elbow to tip of middle finger)	1 *hath* = 24 *angula* = 450mm

COMPARISION OF THE UNITS OF LENGTH IN BENGAL, INDIA AND THE WORLD

Comparative analysis of the units of lengths used in different parts of India with those found in Bengal show that they are very similar - those mentioned in Bengal Shubhankari are also found in other ancient treatises from other parts of India.

Table 7 demonstrates that Shubhankari and Arthashastra are very similar to each other. The names of the units and the dimensions are different, though the proportional relation among them remain the same. So, one finds that *muth* corresponds to *dhanurgraha*, *bighat* to *vitasti*, *hath* to *aratni* (or *prajapatya hasta*), *katha* to *danda* (or *dhanus*) and *bigha* to *paridesa*. Shubhankari units are related in a similar manner to Mayamata units as well. Now, Arthashastra units and the Indus-Saraswati units are quite closely related and the former seems to be rooted in the latter. Thus, it may be argued that the Shubhankari units, which are extremely similar to those in Arthashastra, are also quite connected to the those in the Indus-Saraswati Civilization as well. This establishes a continuity of length-units from the Indus-Saraswati Civilization, through the Arthashastra and the Mayamata, to the Shubhankari in Bengal. It is remarkable that the units used in late medieval temples of Bengal of the 17th-18th centuries are so similar to the traditional length measures of India.

Table 7. Comparison of units of lengths in various treatises in India. Table compiled by author based on Table 4 and Table 6.

Indus-saraswati 3rd Millennium BCE	**Arthashastra 2nd Century BCE**	**Mayamata 11th Century CE**	**Shubhankari 15th Century CE**
10 Lothal units = 1 Harappan *angula* = 17.7mm	8 *yavamadhya* = 1 *angula* = 17.78mm	8 barley grains = 1 *angula*	8 *job* = 1 *anguli* = 19.05mm
--	4 *angula* = 1 *dhanurgraha* = 71.12mm	--	4 *anguli*= 1 *muth* = 76.2mm
--	3 *dhanurgraha*= 1 *vitasti* = 12 *angula* = 213.36mm	1 *vitasti* = 12 *angula*	3 *muth*= 1 *bighat* = 12 *anguli* = 228.6mm
--	2 *vitasti* = 1 *aratni* (or *pr.hasta*) = 24 *angula* = 426.72mm	2 *vitasti* = 1 *hasta* (or *aratni*)	2 *bighat*= 1 *hath* = 24 *angula* = 457.2mm
--	4 *aratni* = 1 *danda* (or *dhanus*) = 96 *angula* = 1706.88mm	4 *hasta* = 1 *yashti* (or *danda*)	4 *hath* = 1 *katha* = 96 *angula* =1 828.8mm
1 Lothal *danda/ dhanus* = 108 *angula*s = 1911.6mm	4.5 *aratni* = 1 *gr. dhanus* = 108 *angula* = 1920.24mm	--	--

If one compares the length measures in the ancient world with those used in India, one finds similarities among the *aratni* of Arthashastra, *hasta* of Mayamata, *hath* of Shubhankari, *dhira* of Arabia and cubit of the ancient world. Each one measures roughly about 450mm. The *angula* of India and digit of the Western world also match, where both refer to the width of the middle finger and approximately equals to 18.75mm. The *angula* (digit) and *hath* (cubit) seem to the basic units of length all across the world. Figure 1 and Figure 2 show the relative dimensions of the digit and the cubit in the ancient world and India.

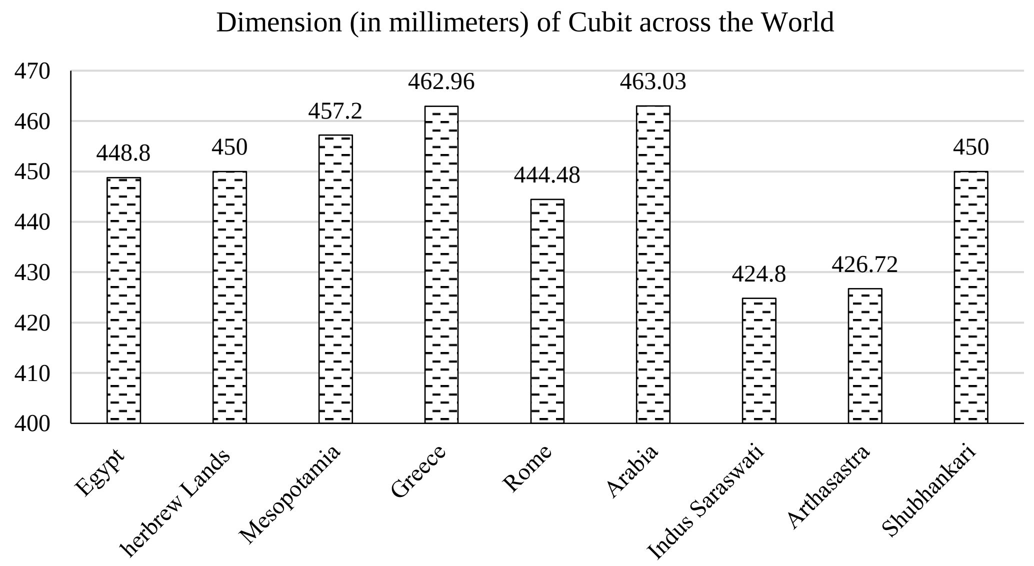

Figure 1. Relative dimensions of the cubit in the ancient world and India.

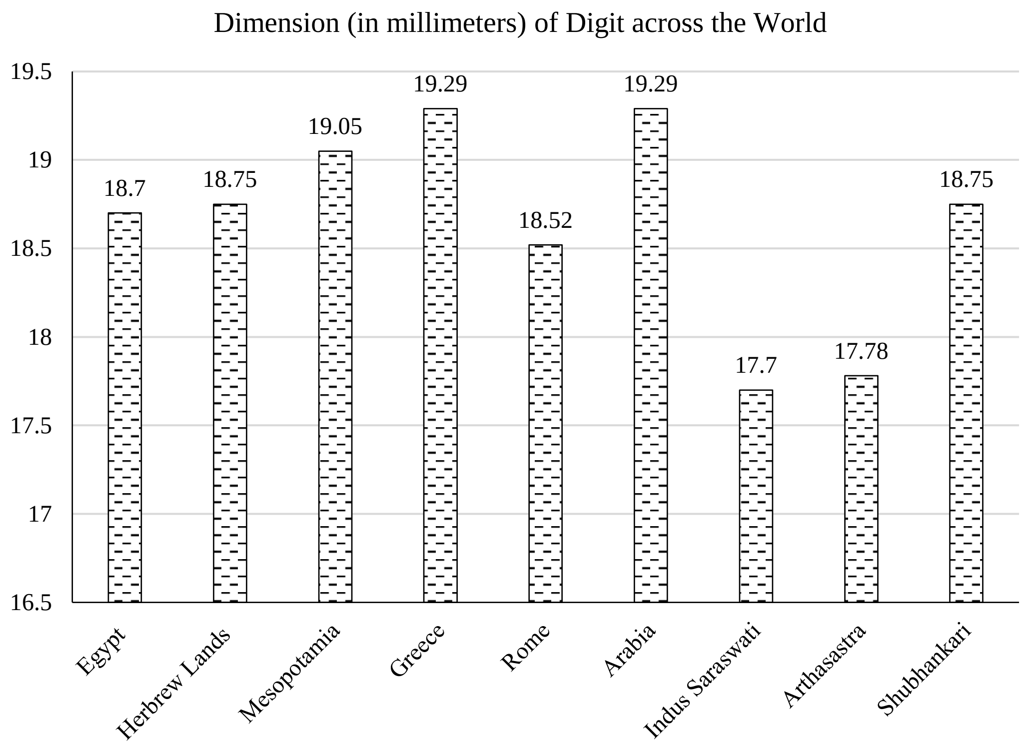

Figure 2. Relative dimensions of the digit in the ancient world and India.

UNITS OF LENGTH USED IN BENGAL *EK-RATNA* TEMPLES OF BISHNUPUR

It has been established in the earlier sections that there is a continuity in length measures used in different parts of India, including Bengal, from the 3rd millennium BCE to Medieval times. In order to examine whether these traditional vernacular units were used in *ek-ratna* temple design and construction, the author did measurements of ten *ek-ratna* temples in Bishnupur. Field study and on-site data analysis revealed that the *ek-ratna* temples of the Hindu Revival period, built in Bishnupur, indeed used the traditional units of length. This has been discussed in detail in the next few paragraphs.

Table 8 shows the average dimensions of the temple parts in *hath-angula* of ten temples. Figure 3 shows the temple parts used in this research. A rule of proportion is immediately evident in these figures. The temple width is almost equal to the temple height and the wall height is more or less equal to the pinnacle height, which is roughly equal to half the overall height of the temple.

Converting any length (in decimal system) to the *hath-angula system* will mostly leave a remainder. The quotients will always be whole numbers, representing the *hath*; while the remainders are the parts, represented by *angulas*. Chacraverti observes that the traditional units of length, viz., *hath-angula*, were on scales dominated by 4, 8, 16 parts and sometimes 3 or 9 parts as well [20]. This means that the *angula* measures were in multiples of these numbers, since the *angula*s are the parts. It is evident that a lot of the dimensions in Table 7 followed this understanding of the Shubhankari *arjyas*. A margin of one *angula* was allowed in all cases. Though one cannot expect all the dimensions to be in terms of the Shubhankari *arjyas*, but it was found that an astonishing 71% actually matched. Thus, there is strong evidence in favour of the use of *hath-angula* in the design of the *ek-ratna* temples. Since these units are very similar to the units of measurements found in the *arjyas*, as well as the traditional Indian treatises, the continuity of Indian traditional wisdom of design and construction in Bishnupur is established.

Table 8. Dimensions of ek-ratna temple components in hath-angula. Table compiled by author based on measurements taken at site.

	Temple width		External wall		Wall height		GG o/o		GG wall thickness		GG width		Pinnacle width		Pinnacle hight		Temple height	
	Hath	Angula	Hath	Angula	Hath	Angula	Hath	Angula	Hath	Angula	Hath	Angula	Hath	Angula	Hath	Angula	Hath	Angula
Kalachand	20	18.79	1.00	12.85	10.00	5.55	12.00	10.79	4.00	1.80	4.00	7.20	10.00	2.47	16.00	19.35	27.00	0.89
Lalji	27	0.82	2.00	9.22	14.00	7.97	15.00	14.80	4.00	15.97	6.00	6.92	8.00	17.08	15.00	23.30	30.00	7.27
Nandalal	22	5.12	1.00	17.99	11.00	8.80	13.00	10.73	4.00	11.19	4.00	12.40	11.00	12.90	16.00	1.33	27.00	10.13
Jora M North	25	17.59	1.00	22.72	12.00	14.35	15.00	22.41	5.00	9.76	5.00	2.97	11.00	14.43	16.00	12.73	29.00	3.08
Jora M Middle	15	9.55	1.00	14.32	9.00	13.41	7.00	19.40	2.00	0.29	3.00	17.24	7.00	3.81	9.00	10.22	18.00	23.63
Jora M South	25	20.47	2.00	0.82	14.00	16.34	16.00	4.45	5.00	12.86	5.00	2.76	12.00	1.42	14.00	10.11	29.00	2.46
Radha Govinda	27	0.29	2.00	4.49	13.00	12.47	15.00	23.73	5.00	0.37	5.00	22.99	11.00	15.35	17.00	4.45	30.00	16.91
Radha Madhav	24	1.43	1.00	23.24	12.00	22.93	14.00	20.54	5.00	1.31	4.00	17.91	12.00	9.03	14.00	21.99	27.00	20.93
Radha Shyam	27	8.69	2.00	8.43	14.00	4.90	16.00	12.64	5.00	13.28	5.00	10.08	11.00	2.99	14.00	3.50	28.00	8.40
Patpur	24	5.89	2.00	4.49	11.00	19.89	15.00	9.61	5.00	6.14	4.00	21.38	8.00	4.82	12.00	9.92	24.00	5.81
Average	23.6	8.87	1.50	11.86	12.00	12.66	13.80	14.91	4.40	7.30	4.50	12.18	10.10	8.43	14.30	11.69	26.90	9.95
Tallied no of angulas as per Bishsnupur-Arjyas		5		7		6		6		8		7		9		8		8

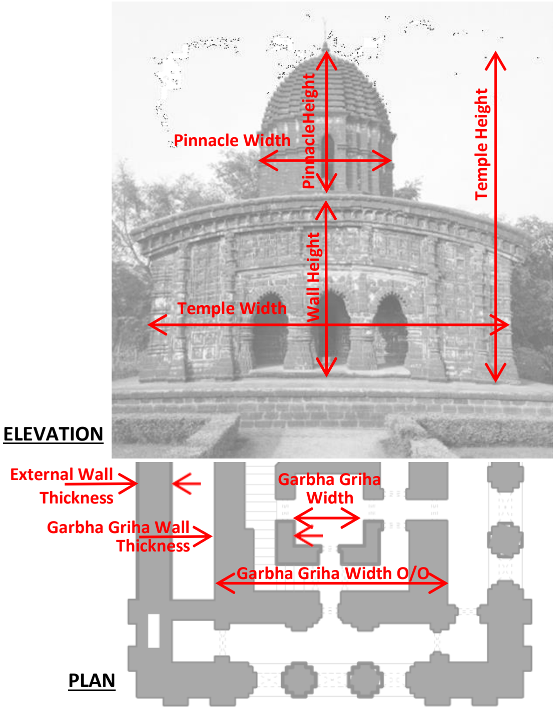

Figure 3. Plan and Elevation of a typical ek- ratna temple, showing the dimensions used in this research

CONCLUSIONS

The objective of this paper is to understand the possible units of lengths adopted in the *ek-ratna* temple building in Bishnupur. Instead of simply exploring the literary sources, this research is based on the actual dimensions of ten *ek-ratna* temples measured at site. The physical dimensions of these temples were compared with several literary sources in general and architectural treatises in particular. This revealed that the system of measurements used in Bishnupur was a continuity of traditional Indian units, albeit with its local nomenclature and very minor variations.

To begin with, the paper explores the units of lengths used in the ancient world. It was long recognized that the human body parts were proportional to each other and could be used for measurements in the daily life. Thus, the inch, foot, cubit, yard and other length measures were all derived from human body dimensions. Some of these, like the yard, are still used today. The cubit was the most common unit used in the ancient world and its value varied from place to place, due to anthropometric differences in different societies. The cubit achieved its standard value of 450 millimeter during the large-scale conquest by the Romans. The royal or a noble man was taken as the anthropometric standard to eliminate variation.

Detail study of the architectural treatises in various parts of India revealed that here too, as in the ancient world, the human body was taken as the basis of length measures. Comparative analysis of the systems of length measurements in the treatises and archaeological remains from various parts of India show that these are essentially the same. Comparison was drawn among the Indus-Sarawati civilization (3rd millennium BCE), Arthashastra (Magadha, 2nd century BCE), Brihatsamhita (Ujjain, 6th century CE), Manansara (South India, 7th-8th century CE), Mayamata (South India, 11th century CE), Bhubanapradipa (Odisha, n.d.). This shows that there was an amazing continuity in the units of length all across India and from the 3rd millennium BCE onwards.

The paper then discusses the units of length used in Bengal temples of 17th-19th century CE. The research led to the identification of Shubhankari, which is a collection of the traditional mathematical knowledge in the form of *arjyas* or verses. These verses deal with computations related to everyday activities like lengths, weights, volumes, carpentry, agriculture, currency, commerce, land measurement and the like and specify various traditional units of measurements like *hath, angula, muth* etc. The masons' handbooks (like Monu Mistiri's handbook) contain *arjyas* which discuss the use of these length-units in the design and construction of the temples of Bishnupur.

This paper also compares the lengths of the digit and cubit of the ancient world with the *angula* and *hath* of Indian treatises, including the Shubhankari and finds that these lengths are quite similar to each other.

The author measured ten *ek-ratna* temples of Bishnupur and studied their dimensions in terms of *hath-angula*. Based on literature review and the primary data collection, this paper shows that these units were indeed used in these temples. Interestingly, the length measurement systems mentioned in Shubhankari are very similar to those mentioned in ancient treatises like Arthashastra, Mayamata and the like; and the similarity extends in the past right upto the Indus-Saraswati civilization, i.e. there exists a continuity in measurement systems from the ancient Indus-Saraswati civilization to the late medieval Bengal.

Thus, it may be concluded that in the Indian context, the ancient concepts of length measurements survived over space and time to become a truly Indian concept, like weight systems, metallurgy, agriculture, craft techniques, numerous religious symbols and food habits.

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Terminology

1. *Arjyas* are verses, which deal with everyday computations like weights and lengths, land measurement and so on.
2. Harappan refers to the Harappan civilization, i.e., Indus-Saraswati Civilization.
3. *Maap* means measure and *kathi* means stick.

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