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Length And Area Measurement System In India Through The Ages

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Abstract: ***Throughout history the ability to make measurement has been instrumental in the progress of mankind. The comparison of dimensions of historical monuments with informal and official units establishes the continuity of India's engineering tradition through the ages for as long as 4000 years. Before the introduction of metric system in India there were various units for variety of length and area measurements. In this article, attempt has been made to highlights the length measurement system of ancient India during different periods.***

I. INTRODUCTION

We make measurements to increase our knowledge and understanding of the world we live in and to use that knowledge to help us to have better life. Measurement science is the basis of modern science and technology and consequently of modern civilization. Length is the most necessary measurement in every walk of life. Early measuring methods for length were based on the use of human body parts. Lengths and width of fingers, thumbs, hands, hand spans, cubits and body spans seems to have been popular choices. But there will be considerable variation in the length of the body parts of different person so the use of a piece of stick of wooden or other material as unit of length was one of the bright ideas for length measurement. The unit of length used in ancient India included dhanus (bow), the krosha and the yojana. Many civilization and emperors produced their own measurement standards that were accepted throughout their nation.

II. INDUS VALLEY CIVILIZATION (3000 B.C. -1500 B.C.)

Indus Valley Civilization which spread over an area covering most of the north-west India, shows an excellent example of town planning and architecture. For the construction of buildings and wells, bricks of rectangular shape were used. All over the region the bricks had one size, the length, breadth and thickness being in the ratio of 4:2:1. At Mohenjo-Daro a broken piece of shell, which have been a linear measure, has been found. This broken piece is a remarkably well finished piece of shell about 15.7 mm wide, 6.9 mm thick and the length of broken piece is 152.9 mm. Two small circles are marked on it, one an open circle and the other a full circle. Between these two circles, the centre of which are at a distance of 33.53 mm there are five divisions at equal distances. It is clear that there must have been another circle after five divisions. From this one may conclude that this piece must have been a linear measure and that people during the Mohenjo-Daro period had a sense of decimal system. Uniform units of length were used in the planning of towns. Rulers calibrated to about $^{1}/_{16}$ inch (1.6 mm) made from Ivory were in use by the Indus Valley Civilization. The Mohenjo-Daro ruler was divided into units corresponding to 1.32 inches (33.5 mm) and these are marked out in decimal subdivisions with amazing accuracy within 0.005 of an inch. Ancient bricks found throughout the region have dimensions that correspond to these units. The Indus civilization unit of length, widely known as Indus Inch was 1.32 inches which is exactly equal to 2 angulas of 16.764 mm each. The height of the corbelled drain forming the outlet of Mohenjo-Daro's Great Bath is about 1.8 m, which is equal to a dhanusha of 108 angulas of 16.764 mm each.

Two engravings on a wall of the temple at Tiruputtkali (12^{th} Century A.D.) near Kanchipuram, show two scales one measuring 7.24 meters in length, with marking dividing the scale into 4 equal parts. It may be observed that each division of the first scale is precisely equal to a dhanusha of 108 angulas of 16.764 mm each. The second one measuring 5.69

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metres in length and markings dividing the scale into 4 equal parts interestingly, the second scale is precisely equal to π times dhanusha i.e., equal to circumferences of a circle with one dhanusha as its diameter. It is interesting to note that at Mohenjo-Daro, a lane and a doorway having both a width of 1.42m, which is precisely equal to one division of the second scale at the Tiruputtkali Temple, indicating that both the scales were prevalent in Indus-Saraswati civilization as well as in south India. Kalibangam, a city in the Indus-Saraswati Civilization(in Rajasthan, India) had street width of 1.8 m, 3.6m, 5.4m and 7.2m i.e., built to the standard dimensions being equal to 1 dhanusha, 2 dhanusha, 3 dhanusha and 4 Dhanusha respectively. Such widths are found in other sites also. Bigger streets of Banawali another town of Indus–Saraswati civilization (in Haryana, India) measure 5.4m, i.e., 3 dhanushas.

III. MAURYA PERIOD (322 B.C. - 187 B.C.)

During Maurya Empire, Chanakya (Kautilya) in his famous book 'Arthashashtra' laid down the units of weights and measures and principles of enforcement i.e., legal metrology. The measurements include those of length, divided into several series, rising from those below the standard aṅgula, defined as the 'middle joint of the middle finger of a man of average size'; to those above, including the span and the cubit, and ending with the rod (danda) or bow (dhanus) of around 180 cm and above this measurement of longer distance, the goruta or krosa and the yojana. The elements of measurement system and definition of some of the units of length may be written as

8 parmanu =1 rajahkan (dust particle coming from the wheel of a chariot)

8 rajahkan = 1 liksha (egg of lice)

8 liksha = 1 yookamadhya

8 yookamadhya = 1 yavamadhya

8 yuvamadhya = 1angul = 2 cm

8 angul = 1 dhanurmushti = 16 cm

1 angul (approximate width of a finger) = approx (¾) of an inch

4 angul = 1 dhanugraha = 3 inch = 8 cm

8 angul = 1 dhanurmushti = 6 inch

12 angul = 1 vitasti = 9 inch = 24 cm

2 vitasti =1 aratni or hast (or haath) = 18 inch=47 cm

4 aratni (haath) = 1 dand or dhanush (bow) = 6 feet = 48 cm

10 dand = 1 rajju = 60 feet = 19.2 meter

2 rajju = 1 paridesh = 120 feet

2000 dand (dhanush) = 1 krosh (goruta) = 4000 yard = 3840 meter (approx) = 3.6 km

4 krosh (goruta) = 1 yojan = 9 miles =15 km (approx)

Kautilya Arthashastra lays down a scientific and logical system for the unit of length. If we start with angul as his unit of length, then 1/8, $1/8^2$, $1/8^3$, $1/8^4$, $1/8^5$ parts of angul have been identified and given special names viz. yavamadhya, yookamadhya, liksha, rajahkan, parmanu. His scientific approach is clear. He starts with a given length as unit and then subdivided it into 8 equal parts. This subdivision is given a special name and further subdivided into 8 equal parts and is given another special name and so on. Conversely, we could start with parmanu the smallest measure and build multiples up to angul. It is very similar to taking meter as a unit of length in metric system and subdividing it into 1/10, $1/10^2$, $1/10^3$, etc parts, these parts being called respectively decimeter, centimeter, millimeter etc. However, there are two differences from Kautilya's system. First in the Metric system the division is by 10 and its powers, whereas, in Kautilya System, it is by 8 and its powers. Secondly, the prefixes have been given special words viz deci, centi, milli etc. These prefixes can be applied not only to length but to any physical quantity. It is easy to see, why in Arthasashstra 1/8 part was chosen and not 1/10, though the decimal system which originated in India must have been known as is also evident from the broken linear measure from Mohenjo-Daro which is divided in 5 and 10 parts. The reason is that in practice it is easy to divide accurately a given length in eight equal parts as half of half of half but it will not be practically easy to divide a given length in 10 equal parts.

Obviously for measuring longer distances one would need bigger units. Therefore, in Arthasashtra, if we take angul as the unit, other units of length which are multiples of this but not necessarily powers of 8 have been chosen for common use in trade and commerce and everyday life. Thus 4 angul is called one dhanurgraha and 8 angul is called one dhanurmusti etc. likewise separate names have been given to 12, 14, 24, 28 angul. For measuring wood and sizes of pastures suitable units, which are 32, 40, 54 angul have also been named. For measuring the depth of wells a unit 84 angul is given and for longer distances 96,108,192, angul have been named; the last one being called dand. These multiple units go on till yojna which perhaps was roughly equal to 15km.

Incidentally the smallest unit of length was parmanu which was defined as 1/8 of the size of a dust particle. Here care has been taken to standardize this dust particle since their sizes would vary. In the definition, the special dust particle coming from chariot wheel is considered. It should be noted that this rajakan was $1/8^4$ of angul.

If we take angul roughly as one centimeter this dust particle will be about 3 micrometers. We now know that fine dust particles are of nearly this size. The so called parmanu which is $1/8^5$ of angul would be a fraction of micrometer and would be therefore, of the order of wavelength of light. We know that very fine dust particles are of submicron sizes and can be seen by scattering of light. This is the smallest visible particle of parmanu of Arthashashtra.

IV. MUGHAL PERIOD (1526–1857)

The ancient angulam has been found to be equal to 1.763 centimeters. The angula and its multiple Vitasti (12 angula) and dhanus (108 angula) have been used as the unit of measurement right from Harappan times till pre modern era when Taj Mahal was built. In Iron pillar at Qutub Minar complex, it is found that angul and its multiple dhanus were used as the basic unit of length in its design. The total height of the pillar is exactly 4 dhanus. The modular plan of Taj Mahal complex is based on use of grids of sides measuring 60 to 90 vitasti. The Complete Taj Mahal and the river front

columns of Agra, has taken a gaz as equal to 80.5 cm which is precisely equal to half a dhanusha of 96 angulas. The fact that the unit of angul of 1.763 cm could match very well the dimension of historical monuments establishes the continuity of India's engineering tradition through the ages for as long as 3900 years.

During the period of Akbar, there were three standards gaz for linear measurement depending on the object to be measured viz long, middling and short gaz. The long gaz was used for measuring lands, roads, distances, forts, reservoirs, mudwells etc. The middling gaz was used for the measurement of buildings of stone, wood, bamboo built houses, places of worship, wells, garden etc. The short gaz was used for measuring cloth, arms, beds, chairs, palan-quins, carts etc. Each gaz was divided into 24 equal parts and each part was called tassuj. The tassuj of the long gaz is called tassuj of the first kind and was equal to 8 barley corns placed together side by side widthwise. The middling gaz tassuj called tassuj of the second kind and was equal to 7 barley corns placed together side by side widthwise. The short gaz has tassuj of the third kind and was equal to 6 barley corn placed together side by side widthwise.

The Akbar ShahiGaz of 46 fingers was used as a cloth measure, the Iskandhari gaz was used for cultivated lands and buildings. Thus, there was variety of length measures. The variety of measures was source of inconveniences therefore was abolished and brought the medium gaz named the Ilahigaz (33" to 34") and it is employed by the public for all purposes. For measuring the quantity of land, the measure was beegha which was 60 gaz long and 60 Gaz broad. The Mughal measurement system measured length and land in terms of gaz and beegha with the following relationship.

1 girah= width of 3 fingers (Anguli)
1 hath = 8 girah
1 gaz = 2 hath
1 kathi = 55/6 hath
1 pand = 20 kathi
1 beegha = 20 pand
1 beegha = 20 vishwa
1 viswah = 20 viswansah.

The gaz was widely used till the introduction of the metric system in India in 1956.

V. BRITISH PERIOD (1857-1947)

In June 1864, the government of India recommended inch, foot, yard and mile for linear measurement and acre for area measurement with the following relationships

1 mile = 8 furlongs = 1760 yards
1 furlong = 220 yards
1 acre = 4840 sq. yards = 1/10(furlong)^2
1 sq.yard = 9 sq. ft.
1 sq. mile = 640 acres
1 hectare = 2.47 acres = 10000 sq. m.

The adoption of these linear measures makes the Indian system completely dependent upon the British system. A committee appointed on 10th Oct. 1913 again recommended a system based on the combination of Indian & British systems.

VI. POST INDEPENDENCE (1947- …)

In 1950, mile and furlong were common markers on road in India. The minimum unit of length is one inch. Other linear and land measures are continued with the following relationship.

1 Foot = 12 inch
1 yard = 3 feet
1 furlong = 660 feet
1 mile = 1760 yards or 5280 feet
1 acre = 43560 sq.feet
1 chain = 22 yard
1 acre = (1 chain) x(1 furlong)
1 inch = 2.54 centimeter
1 foot = 30.48 centimeter
1 yard = 0.0914 meter
1 mile = 1.61 kilometer
1 sq. meter = 1.196 square gaz
1 sq.gaz = 0.836126 sq. meter
1 kaththa = 2.5 decimal = 1361.25 sq.ft. = 100 sq.meter
1 beegha = 2304.576036 sq.meter
1 sq. mile = 2.5 sq. km

After independence, it was realized that for fast industrial growth of the country, it would be necessary to establish a modern measurement system in the country. The Lok Sabha in April 1955 resolved: 'This house is of the opinion that the Government of India should take necessary steps to introduce uniform weights and measures throughout the country based on metric system'. The Central Act of 1956 called weights and measure Act 1956 enabled Government of India to establish standards of weight and measures system to introduce metric system. Modernization of the metric system occurred again in 1960 with the creation of the international System of units (S.I.) as a result of a resolution made in the 11th CGPM.

The metric system is an internationally agreed decimal system of measurement. In metric system multiples and submultiples of unit follow a decimal pattern. Length is now defined in terms of the speed of light, assumed to be an exact value (299,792,458 m/s)

The standard unit of length in metric system is the meter.

1 millimeter = 0.001 meter
1 centimeter = 0.01meter
1 decimeter = 0.1 meter
1 kilometer = 1000 meter

VII. PRESENT STRUCTURE OF MEASUREMENT STANDARDS

To introduce the metric system in India the government established National Physical Laboratory (NPL) as the measurement standards laboratory. The standards maintained at NPL are periodically compared with standards maintained at other National Metrological Institutes in the world as well as the BIPM in Paris. This exercise ensures that Indian national standards are equivalent to those of the rest of the world. The standard unit of length, meter, is realized by employing stabilized Helium -Neon laser as a source of light. Its frequency is measured experimentally. From this value of

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frequency and the internationally accepted value of the speed of light (299,792,458 metres/second), the wavelength is determined using the relation: Wavelength = Velocity of light / frequency. The nominal value of wavelength, employed at NPL is 633 nanometer. By a sophisticated instrument, known as an optical interferometer, any length can be measured in terms of the wavelength of laser light. The present level of uncertainty attained at NPL in length measurements is $\pm 3 \times 10^{-9}$. However in most measurements, an uncertainty of $\pm 1 \times 10^{-6}$ is adequate.

VIII. ADOPTION OF METRIC SYSTEM

It appears that some of the traditional units still exist at least in a few situations. In many cases, decimal places become important after conversion into new unit which can't be ignored. For example, 1 foot = 30.48 cm, we can't approximate it as 30.00 cm. Similarly 1 inch = 2.54 cm, we can't approximate as 2.5 cm, otherwise 1 km get shorter by 15.75m. Also 1 mile = 1.609344 km, we can't take it as 1.6 km. In the measurement of floor area of buildings 1sq. m = 10.7639 sq.ft. People are more conversant with numbers without the decimal and prefer rounded-off numbers without any decimal. Different state governments tried to standardize land measuring system by introducing suitable metric system. We should also try to be more serious in sticking to metric system.

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