Medieval foot unit

Adapted from *Avista Forum*, ix 1995, 12-14; plus extracts from *Divide me a Circle: a history of measure*, MS Sydney, 1975.

Though the records give us the names of medieval units, and occasional metal rods provide exact lengths, little is known of most of the lengths being used. In the 1790s the French Metric Commission surveyed the units of measure used in France before creating the metric system. They found thousands of units currently employed, with separate lengths and names for measuring cloth, tin, gold, firewood and scantling. Even within the one town there could be five separate units in use, with each being displayed on metal bars fixed to the - jambs of the gates into the town.[1]

The variety of units employed in the twelfth century may have been similar. Anyone trading in the medieval world had to handle proportional computation to survive. No two medieval towns had the same foot unit, and within a town few industries shared the same foot either. The measure for cloth was different to the measure for wood. If a Florentine merchant travelled to Milan to buy cloth, not only were the measurements different, but so was the money. He would only know he were getting a good buy if he could sort out the ratios between the different measures and moneys. There were no calculators and fractions were not easy to work out. We do something similar when we travel and convert pounds weight to grams and dollars to francs - but we have had years of schooling to equip us for this.

Medieval measures were, on the whole, debased versions of the units used in Classical times, with ranges that were scattered across the full scan of lengths.[2] Therefore to try to apply the few established foot units to a building is not a secure method. It is better to analyse the geometry and extract the foot, for then at least we can have some relationship between the ratios used the origin. For the greatest certainty we need to unearthed the whole of the geometry underlying the design of a building.

I have found again and again units that had no relationship to any in the literature.[3] Scholars will in general look for documented foot units, and hope to base their analysis on something already named.[4] This approach is limiting, and I would think it more advisable to let the geometry itself provide the foot.

The question was how to determine whether any particular length was the master's foot unit, or span or cubit used in the design process.[5] Sometimes it became obvious when a number of elements built by the one master disclosed a common unit, but not always.

As a general rule of thumb, and after spending some months researching in the British Museum, I concluded that a foot unit was most likely to be in the range of 280 to 370 mm, a span from 190 to 280 mm and the cubit 420 to almost 600 mm. These lengths form an almost continuous range of measurements, with the largest span being the same as the Roman Foot. With such a range it becomes a matter of convenience whether we call some lengths span or foot or cubit.[6]

Most masters shown in drawings or on tombs carry a rod. Hues Libergier's measured 1,571 mm.[7] We could make mechanical divisions – say into five feet each of 314.2 mm – were there not lines on the rod that suggest that a more complex set of ratios may be contained in his rod. A more detailed analysis suggests that his foot unit was in fact 302.7 mm.[8]

It would seem that the foot ruler was a precious object, at least from the surviving wills from the later middle ages in which a dying master leaves his tools, each carefully defined, to his successor. Handing the object on ensued that its length would be maintained over the generations. It was obviously of some real value. In their training every apprentice came to know the master's manner and foot units, and would naturally take them over on his death or retirement. The evidence from Chartres suggests that the foot remained unchanged over many decades, and remained constant in spite of changes in the masters who led the crew.[9]

Not every element is set out from the master's foot, but may be evolved from the work already built below as in the towers and many of the windows. But where a foot is clearly used to begin the operation, or to set out any part of it not determinable by geometric methods alone, then it appears to remain consistent over the whole job. In individual geometric analyses I found errors of only ±0.5 mm in a crew's foot measure.

When there was a change in the masters there was no change in the foot unit being used, in Bronze's case from at least 1190 to his last time on the site around 1242. The length of the foot was one of the main features used to identify the crew. Each time a team reappeared they produced the same foot unit they had used before. On leaving the job they obviously took their foot with them.

In analysing the geometry, the foot unit is seldom obvious it is in most cases buried in the geometric complexity. For example, in most windows the foot unit may be the first step in the geometry, but is never reflected in any of the final dimensions.[10] This is so common that I suspect that the starting point, the unit itself, was meant to remain concealed.

This unit would often be disclosed in small items, such as doors and corbels and some wall thicknesses. In others the first step in setting out the element would be a length that was close to a foot. Simple rules at times were applied to ordinary things, such as the four doors at Chartres.[11]

But in larger and more complex items that related across the building, such as buttresses, piers and windows, the proportions were often the result of earlier geometric steps in some larger part of the church so that no unit was used. For example, the heights to the string courses on the interior were made by taking the height of the lowest string and forming a series of squares to determine the heights to the next string and the springing point above that,[12] or in using the height of the triforium plinth to extend upwards for the centre of the clerestory rose windows.[13]

At Chartres each master used his own unit and only that unit. Though there was no uniformity of measure each template-maker rigorously kept to his own preferred unit. Occasionally he may have used more than one, but in each case the units had a clear proportional relationship to one another. Scarlet, the first master, used the Roman Foot and a unit called in Classical times the Ped Manualis. For him his measures were 294.4 and 353.3 mm which form the ratio of 5:6. It is interesting that in spite of the great variation found in ex-Roman measures at that time (293-298 mm), Scarlet's foot unit was only 1 mm less than the average for the ancient Roman foot first measured by Graves in the eighteenth century.

Working from some 240 geometric studies I determined a number of the foot units used at Chartres with some accuracy. In millimetres these were 279.6, 282.5, 285, and the Roman Foot of 294.4 mm. There was one close to the English foot of 305.7 and two similar to the Pied du Roi at 322.9 and 325.8 mm. There was also a 336.8 to337.1 Marseilles Foot and the 353.3 Ped Manualis. These lengths are calculated from the average of all occasions where they occurred in the cathedral, within a tolerance of less than ±0.5 mm.

At the same time, I made a survey of all the domestic stone doorways in Chartres for the *Société Archéologique*, many of which seem to have been built by the same building crews, or by some of the gangs within the crews who may have been moonlighting while constructing the cathedral. Among the foot units that could be established from five or more key measurements were 270, 275, 296.4, 326.4, 333.8, 335, 339, 345 and 353.6 mm. In other words, there were no standard unit and each master used whatever was marked on his team's rod. The attempt to find units would seem to be reliant on finding the geometry first, not the other way around.

The whole issue of foot units is, as Eric Fernie states, "unnerving". He invented a series of lengths and through strict analysis came up with two imaginary foot units. From this he argued, correctly, that "even the restriction (of the units applied) to known units is no guarantee of protection."[14] I had a similar experience in studying ancient measures, after which I came up with seven that would seem to have had some degree of certainty over some millennia. This was pretty exciting until I was told that four of these seven measures also turned up, almost to the millimetre, among the first ten numbers in the Cambridge list of computer-generated random numbers - which was equally unnerving.

It would seem that the foot unit was for marking specific lengths, not for more than the most basic subdivisions. In an age when few people could read or write, and when nearly all arithmetic was noted in roman numerals, no master could tell a mason to produce a block of stone x inches by y inches and expect it to be followed with the accuracy of a millimetre. They were not able, for example, to record a length as 8⅝th inches. It was not possible in roman numerals. This old notation was extremely restricting, for only the simplest lengths and ratios could be calculated with it and certainly not fractions nor subdivisions. Villard shows the latter were determined through geometry.[15] But the template with the stone size cut out of it or marked on the face told everything. Nothing more was needed.

However, the masters may have used Arabic notation, Before the year 1000 Abbon of Fleury played with Arabic numbers, and even wrote a little ditty on the subject, *His abbas abaci doctor dat se Abbo quieti.*[16] If a clergyman was this interested, what of the masters who through it were being offered a tool of inestimable benefit?

[1] Jean-Baptiste-Joseph Delambre, *Base du système métrique décimal, etc.* Paris, 1806-10.

[2] Ronald Zupko, *French weights and measures,* Bloomington, 1970.

[3] John James, *The contractors of Chartres*, Wyong, ii vols. 1979-81.

[4] Ellen Shortell, "The Plan of Saint-Quentin", *Ad Quadratum; the practical application of geometry in medieval architecture,* Nancy Wu ed., 2002, Aldershot, 123-138.

[5] Eric Fernie, "Historical Metrology and Architectural History", *Art History*, 1, 1978, 383-399.

[6] Peter Kidson, "A Metrological Investigation", *Journal of the Warbourg and Cpurtauld Institutes*, liii, 1990, 71-97.

[7] John James, "28 Hughes Libergier", *In Search of the unknown in medieval architecture,* 2007, Pindar Press, London.

[8] James, "Libergier".

[9] John James. "19 Master mason as contractor", *In Search of the unknown in medieval architecture,* 2007, Pindar Press, London.

[10] James, *Contractors*, 448, and "30 Four identical windows".

[11] James, *Contractors,* 250.

[12] James, *Contractors, 246.*

[13] James, *Contractors, 480.*

[14] Eric Fernie, "Introduction", *Ad Quadratum; the practical application of geometry in medieval architecture,* Nancy Wu ed., 2002, Aldershot, 4-5.

[15] François Bucher, "A rediscovered tracing by Villard de Honnecourt", *AB*, lix 1977, 7-50.

[16] Christian Pfister, *Etudes sur le règne de Robert le Pieux,* 1885, Paris.