A medieval dock at Waltham Abbey, and a consideration of medieval measurements

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A research excavation was carried out by Waltham Abbey Historical Society, from 1996 to 1998, across an ancient waterway called Longpool (Fig. 1). It was suspected that a pound lock had existed at the east end of Longpool when there was a navigable route down the Cornmill Stream, through the pound lock, along Longpool and so into the River Lea and south to the Thames. The sole purpose of the excavation was to see what remained of the waterway and to try to date its period of use. It was a complete surprise to discover a great timber-framed and planked dock.

Being a depression in the water meadows, the site was extremely wet. Only selected small trenches were dug, in which it was possible to control the water by almost continuous pumping. When water entered the trenches by draining from the surface, the excavation had to be abandoned.

As can be seen from Fig. 2, the main area of the dock was rectangular with a trapezoidal-shaped eastern end. The main ground beams were huge; it was soon realised that some of them measured nearer 13 inches than 12, when the latter might have been expected. Besides the main ground beams, there were smaller joists running east to west. The whole area had been covered with planks fixed to the beams and joists by massive iron nails of 5, 6 or 7 inches length .

All the timbers were of elm. One purpose of offering this paper is to see if anyone in the dendrochronology fraternity would like to work on the tree rings. The question to be asked is not open-ended. Rather it is to determine whether the timbers are likely to be dated about 1177. This is the probable date of building of the dock when the Augustinian monastery was begun. The stonemason's yard is reckoned to be under the present Romeland or Roomland, just to the south of the dock. The amount of the building material coming in was staggering. Enough lead was purchased in the years from 1177 to 1184 to cover a floor area of up to 31,000 square feet (2900 sq m). With tons of stone and timber arriving, this must have been a bustling place.

The sides of the dock had, in the first phase, timber retaining fences so that the length of boats which could be pulled around in the turning bay at the east would be about 26 ft (8 m). A great mooring post can be seen there. At the entrance into the dock from the west, the ground beam was protected from damage by the laden boats, by the provision of an iron bar nailed to its surface.

Several phases of use can be defined. The first phase was the simple dock as defined. In the second phase, the western end was narrowed down a bit, so as to leave a distinct berth on the south side. The third phase was the use as a through route to the pound lock to the east; this necessitated removing the central part of the turning bay by cutting off the halved joint of the angled ground beam, fortunately leaving evidence of its length; this was necessary because the timbers of the turning bay were slightly higher in

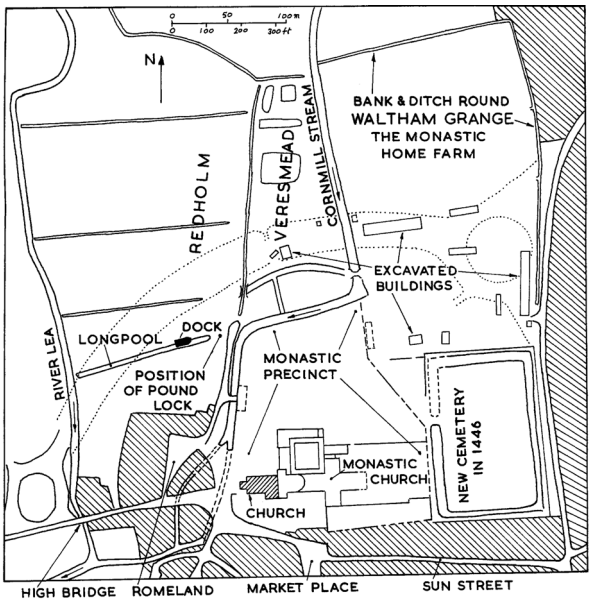

Fig. 1: Waltham Abbey, Essex. Simplified site map, showing the dock, Longpool, and the position of the pound lock of *c.* 1576.

the ground. The fourth phase was the use of the old waterway as a watercress bed.

The measurements

The overall measurements of the dock, from plans drawn over the three seasons, are as follows: the width was 27 ft 9 in (8.46 m). The length of the rectangular part was 43 ft 6 in (13.3 m). The additional length of the turning bay was 11 ft (3.35 m). This latter measurement of 11 ft, where one might have expected a round 10 ft, is a clue that the medieval rod or perch may have been used in the design of the dock.

This medieval rod or perch, which is still in world-wide use, as a quarter of the length of a cricket pitch, at 5½ yards or 16 ft 6 in (5.03 m), is an awkward measurement. It must have come about as a compromise between fitting a well-established small measure into an equally well-established large measure. So two measuring systems must have been in use, presumably having been employed for different purposes, or by different peoples, which had to be amalgamated into this awkward relationship in the 13th-century Statute for Measuring Land.

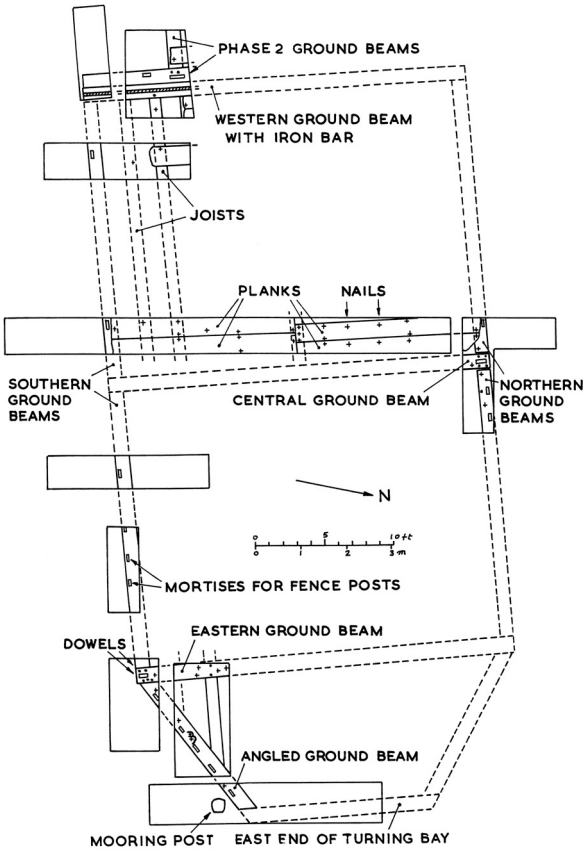

Fig. 2: Waltham Abbey, Essex. Plan of the dock, entrance from the west, showing the main features.

A few people now accept that our medieval rod or perch of 16 ft 6 in (5.03 m) was in use in parts of England back into the Anglo-Saxon period. This was first noted by Warwick Rodwell and the author in excavations at Rivenhall[1] and Nazingbury,[2] both in Essex. It was also realised at both places that the primary division of the perch was into thirds, which in modern terms is 5 ft 6 in (1.68 m). Thus 2/3 of a rod or perch equals the 11 ft we met above.

It was Margaret Jones who encouraged the author to study the Anglo-Saxon post-hole building plans at Mucking on the Thames estuary. It was clear that some, but certainly not the majority, of the buildings were set out in terms of this rod and its thirds.[3] Fortunately, some buildings were of proportions 2:1, length:width, and with a length of 1 2/3 units the width must have been 5/6 of the rod or perch. So the next sub-division of the third was its half, or the sixth of a rod. This sub-division could have been realised by the use of a hinged measuring instrument. Since the Latin word *pertica* means measuring stick and flail, which was hinged, this idea makes sense.

Clearly, the third and sixth of a rod or perch do not have the feel of a round or whole number measurement. But in terms of some measure, other than the modern foot, they might have. Since the rod or perch is divisible by three, one might expect it to be divided into either 15 or 18 feet of some sort; the larger of these 'feet' seems the more likely as we are able to offer a very likely contender.

There are several mentions in the English and Continental literature of the foot measured by hand; some of them are: the *manupes, manupedes, manupedem, pes manualis, pedes manualis, pedes ad manus hominem, pied manual, pied de main, pedem manum*, and *pie main*; these range from 8th-century Italy to 13th-century England. There are also references to the perch measured by hand such as the *pertica manualis, perticam continentem pes manupedes* and *perticam pedes manuales*; these range from 9th-century France to 12th-century England.

The *manupes* is made up of two *shaftment*, where the latter is the width of the hand to the outstretched thumb, so that a timber could be gripped, or the girth of a tree measured, by passing one hand over the other in sequence. It is an ideal measure for a carpenter. Several references could be quoted. In a 9th-century Carolingian manuscript, the *Pauca de Mensuris*, we read:

"For it must be known that feet have two meanings according to the customs of the ancients. One, that which is the natural foot; the other, improperly taking the name of the foot measured off with the hands, for the manual foot exceeds the natural foot to the extent of the thumb extended lengthwise."

For the author, in spite of the length of the thumb being a bit imprecise, this formula works well.

There is a reference to the so-called 'Drusian foot' in the records of the Roman field measurer named Hyginus. He wrote about a measure, not a Roman one, in use in Germania near Liège; this is in the territory of the Belgae. This local foot was longer than the Roman foot by 1½ inches. We cannot tell how accurate this estimation is, but if we assume it is 1½ rather than 1¼ or 1¾, meaning we accept a doubt of 1/8 in, and taking the Roman foot as 29.57 cm, we arrive at a range of lengths for the Drusian foot of 32.96 to 33.57 cm, or between 13.0 and 13.2 modern inches. So this reference to a measure in the land of the Belgae looks as if it was the *manupes* or foot measured by hand; and where might they have taken it?

There is no definitive statement that the medieval rod or perch contained 15 *manupes*, but if it did, a *manupes* would measure 13.2 in (33.5 cm). The present author, a typical example of the mid- to northern European race, must admit an obsession with the *manupes*. Not only is it a very practical measure for a carpenter and other tradesmen, but his hands are the right size; his *manupes* measures 13.2 modern inches and the shaftment 6.6 in. For people whose hands were not the right size, they could learn to add or subtract a thumb or finger width. The *manupes* would have been a convenient measure over the area of Europe where people were of a certain stature. It has, for instance, been detected in the setting out of the Viking camps in Denmark.[4]

So far we have considered one of the two postulated systems which we reason must have been amalgamated in the 13th century. The other system may be evident in the majority of the Anglo-Saxon buildings at Mucking. The shorter rod there was assessed to measure 4.65 m (15 ft 3 in modern terms). This can be compared with extant rods measured by Meitzen in the Elbe-Weser area of the Saxon homeland,[5] where ten such rods had an average length of 4.63 m. If we follow Francis Pryor, in his recent TV series, we are not supposed to believe in the movement of Saxon people to England. However, Mucking may be an exception to this new idea.

Analysis of the Mucking buildings set out to the 4.65 m rod again showed the sub-division into thirds and sixths. Smaller measurements could not be detected, but if this rod too was made up of 15 'feet', each would measure 12.2 modern inches. One might just wonder if the compromise made in the Statute for Measuring Land was to fit this 'foot' into the larger medieval rod or perch, with the result that a slightly shorter new foot and yard were defined, measures which were in common use until recently. This is fairly speculative, but may just explain the sort of thing that happened.

Measurements of a third of a rod were encountered by Eric Fernie in his analysis of the plans of Ely Cathedral.[6] Across the internal width of the nave were the following measurements in units of 5½ English feet, starting at one side: an aisle width of 3 units, an arcade wall of 1 unit, an internal nave width of 6 units, an arcade width of 1 unit, and on the other side, an aisle width of 3 units. These seem reasonable as direct measurements of the rod and its thirds. But Fernie rejected the use of the English perch at Ely with the comment that:

"It suffers the disadvantage of translating the 77 ft overall width into four and two-thirds units."

Instead, Fernie went further and noted various 'proportions' which he related to the square root of two, or 1.414, or just 1.4. He noted that the overall internal width was 14 units (this is 3 + 1 +6 + 1 +3, as quoted above); the distance from one wall to the further arcade wall was 10 units (this is 3 + 1 + 6); he saw the ratio of these two numbers, of 14 to 10, to be some mystical representation of the square root of two. He went still further to note half of 14, from one wall to the centre line of the nave was 7 units; then again

the ratio of 10 to 7, or 1.43, was thought to show a similar mystical quality.

In a later publication[7] Fernie withdrew his reservation about his rejection of the perch with the words:

"Doubt was expressed in that article that the perch as such, rather than the third of a perch, was used at Ely. The evidence from Yeavering renders this reservation unnecessary."

The reason for Fernie's initial rejection of the perch was that he did not like the measurement of the overall width of 77 ft or 4 2/3 of a rod or perch. Had he seen the measurement as 14 thirds of a rod or perch, or as 70 *manupes*, his dislike might have been more muted. It has to be said that he was working before the significance of the third of a rod had been published. Whether his later acceptance of the perch and its thirds, and the realisation that the measurements were just that, direct measurements, would have led him to reconsider the involvement of the square root of two in the layout is not known. Talking of Norwich Cathedral, Fernie felt that:

"The designer was fascinated by the square root of two . . . because of a desire for some form of geometrical unity in complexity."

This is a fascination not shared by the author.

What of the dock measurements?

The measurements of the dock, in modern terms, seem not to suggest any obvious design sizes. But the width of the dock of 27 ft 9 in is 1 2/3 or 5 thirds of the rod to within 3 inches. The length of 43 ft 6 in is 2 2/3 or 8 thirds of a rod to within 6 inches. So there is a difference of up to 1% in the measurements and these suggested design sizes. The extra length of the turning bay at 11 ft is exactly 2/3 of the rod. It remains here to ask if the proportion of 5:8 may have had some special significance.

Students of mathematics will recall that the most beautiful rectangle, the so-called Golden Section, was of proportions 0.618:1, or 1:1.618. This is not the place to pursue this matter, but it is just possible that the proportion of 5:8, or 0.625:1, was the practical, or working man's, expression of the Golden Section.

It was noted that some of the ground beam sizes, admittedly mostly measured under water, were about 13 inches wide and deep. So it is possible that the carpenters were using the *manupes*, their customary measure, out in the forest where the basic trimming-up would have been done.

Suggested geometrical method for setting out

In the case of the dock, all dimensions could have been obtained by direct measurement. Besides the strange fascination with the square root of two, some workers suggest the use of quite complex geometrical methods for setting out. Adrian Gibson has published two attempts to explain the layout of the great timber aisled barns at Cressing Temple in Essex; we will consider briefly his latest ideas for the wheat barn.[9] The construction starts with the drawing of a square, around which a circle is drawn, then a hexagon is drawn inside the circle, and so the principal post positions begin to emerge. A double bay system of design is assumed. The square roots of two and of three are both involved. Finally, the nave width is found to be 1.414 rods or 23.3 ft, and the bay pitch as the square root of three divided by the square root of two, which is 1.22 rods, or 20.2 ft. Actually, the internal nave width is about 21 ft, whereas the bay pitch is about 20 ft; these are both sizes which do not seem to need complex methods to deduce them. So the construction does not work too well. But the crucial issue is why bother, when these sizes could so easily have been measured? Gibson went on:

"The great advantage of the use of strict geometry, as opposed to a system based on measurements . . . Is the precision of intersecting circles and arcs."

Presumably all this geometrical extravaganza was to have been accomplished on the actual site where the building was to be erected. Also, presumably, pegs had to be inserted in the ground at these precisely-located positions; these were very special positions. Then the foundations have to be dug and all the pegs would be lost; they would be dug up. This point alone shows the impracticability of setting out by such geometrical constructions, if the marking-out pegs are going to be dug up just after they have been located. Rather pegs, and a datum line, have to be located somewhere else, such as along the centre-line of the building, where they can be retained throughout the whole erection of the building. It is surely clear that actual

measurements have to be made from these, continually, day by day, as the erection of the timber frame proceeds, and as the posts have to be knocked this way and that to get them all nicely lined up. Of course, all the geometrical procedures could have been done on parchment or on a tracing floor, but then actual measurements would have to be taken, scaled up, and transferred to the building site. In conclusion, one could not proceed to erect an aisled timber barn without making measurements from fixed pegs, and it is the positions of the fixed pegs which have to be chosen.

Another point of concern is of communication between the client, who is paying for the work, and the carpenter, who is doing the work. If set out geometrically, the client would not know what he was paying for until the work was well under way. He would not be satisfied with the knowledge that it would all start with a square of a certain size.

This objection to the use of geometrical methods of layout applies equally well to great cathedrals or monasteries where the work would have gone on for several decades. One cannot imagine the positioning of pegs, by some obscure method of drawing mystical circles or squares, and striking arcs from here and from there, so as to locate particular points, when the pegs have to be dug up to lay the foundations; also complicated geometrical marking-out and checking, when the site is cluttered with piles of building paraphernalia, would seem impracticable. Having decided on particular dimensions of a building, whatever it is, there must be fixed pegs, from which measurements can be made and checked continuously. In the case of stone buildings, such pegs will be necessary until the first course of stonework has been laid. In the case of timber buildings, the pegs will be needed until all the timber framework has been erected and the ground walls constructed. In the case of the dock, everything could have been done by direct measurement.

Final words

Peter Kidson wrote[10] that there is:

"more or less permanent friction between the advocates of bright ideas who seldom try very hard to verify them, and the upholders of proof and probability, who demand firm evidence for every inference . . . the former range from archaeologists in a hurry to make sense of the structures they dig up, to the lunatic fringe which sees order and continuity where everyone else sees only chaos and confusion."

Kidson took one well-respected scholar to task for setting

"a higher premium on caution and scholarship than on historical imagination."

A more satisfying approach might be to search for some order and continuity, to recognise that new people might introduce new methods (if we are to believe that there were new people), that there might be another phase of order and continuity, then there might be a period of compromise with the retention of established working practices. It may be as simple as that.

The carpenter of old could do anything he wanted to do within the limits of his technology. Our brain capacity is the same as that of medieval folk. It should not be beyond us to understand. We cannot be satisfied with the old notion of chaos and confusion.

1. W. J. and K. A. Rodwell 'Excavations at Rivenhall Church, Essex' *Antiq J* **53** (1973) 219–223.
2. P. J. Huggins 'Excavations of Belgic and Romano-British farm with middle-Saxon cemetery and churches at Nazeingbury, Essex, 1975-76' *Essex Archaeol Hist* **10** (1978) 29–117.
3. See P. J. Huggins 'Anglo-Saxon timber building measurements: recent results' *Medieval Archaeol* **35** (1991) 6–28.
4. P. Huggins, K. and W. Rodwell 'Anglo-Saxon and Scandinavian building measurements' in *Structural Reconstruction* BAR Brit Ser 110 (1982) 42–52.
5. A. Meitzen *Seidlung und agrarwesen* **11** (1895) Berlin.
6. E. C. Fernie 'Observations on the Norman plan of Ely Cathedral' *Brit Archaeol Assoc Conference Trans for 1976* **II** (1979) 1–7.
7. E. C. Fernie 'Anglo-Saxon lengths; the Northern system, the perch and the foot' *Archaeol J* **142** (1985) 241–254.
8. E. C. Fernie 'The ground plan of Norwich cathedral and the square root of two' *J Brit Archaeol Soc* **129** (1976) 77–86.
9. A. Gibson 'Further light on the design of the Great Barns at Cressing Temple, Essex' *Essex Archaeol Hist* **27** (1996) 182–187.
10. P. Kidson 'A metrological investigation' *J Warburg and Courtauld Inst* **53** (1990) 71–97.