

# The Anglo-Saxon Foot: a computerized assessment

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*THE DEVELOPMENT of a computer program which can allow identification of units of measurement in buildings offers the opportunity of objective assessment of possible ancient units of measurement, including the Anglo-Saxon foot.*

From time to time attempts have been made to establish the length of the foot used by the Anglo-Saxons. Such investigations relate to the general problem of archaic units of measurement, and it is useful to look at the wider issues before concentrating on the specific. Any study of measurements consists of two main aspects, one being the collection and choice of data, and the other the method of analysis. The latter is at the discretion of the researcher, while the former is largely determined by the artefacts available to him and whether their dimensions are sufficiently clearly defined for accurate measurements to be made. Different periods of study yield different numbers of artefacts which are susceptible to accurate measurement. An appreciation of the problems of defining and maintaining standards of measurement will give a perspective for the assessment of the accuracy of the results of a measurement study. These problems are bound up with the technology available at the time and the tolerances allowed by the defined standard.

## THE PROBLEM OF MEASUREMENTS

The value of looking outside the Anglo-Saxon period is clearly shown by K. D. Connor's<sup>2</sup> measurements of nine Roman folding footrules. These yielded values of the Roman foot ranging from 290 to 294.5 mm with an average of 292.9 mm. The spread of 4.5 mm shows a poor level of standardization, either intentionally accepted or else the best technically attainable; the usually accepted value for the Roman foot of 296 mm is not even within the spread of this sample. If Roman technology and administration could not do better than this, then results for less centralized and technically proficient societies may show equal or greater variability. The pitfall of pseudo-accuracy is illustrated by Connor<sup>3</sup> with two cases which, while amusing, need to be kept in mind. In particular it is necessary to guard against the danger of

believing that because analysis has been done electronically all the figures presented by a calculator or computer are correct.

The guidelines for the analysis of measurement data, while not explicitly stated, are clearly illustrated by D. G. Kendall<sup>4</sup> in his work on the megalithic yard. He describes a mathematically rigorous method which uses a computer to search for possible values of the length over a wide range of values. The results are tested for their significance by means of an objective statistical criterion. However, it is not just as a model for analysis that Kendall should be read. He has many useful things to say on the validity and selection of data, and it is worth skipping lightly over the mathematics to find his general points. In particular he points out that either the radius or diameter of the stone circles may be used,<sup>5</sup> and clearly implies that it cannot be both. The necessity for data to be independent is thus clearly shown.

The same general principles of a computer search, guided by a statistical test, are followed by H. and K. Nielsen.<sup>6</sup> They differ from Kendall in the detailed implementation of the search and statistical test, but the approach is remarkably similar. They developed their method as an aid for the 'Analysis of Historical Architecture', and tried it on measurements of structures from the 17th century and Viking construction of about A.D. 1000.

#### THE ANGLO-SAXON FOOT

Turning to the more specific question of the length of the Anglo-Saxon foot, several papers adopt a rather different approach. Birthe Kjolbye-Biddle, in her work on the 7th-century Minster at Winchester,<sup>7</sup> devotes the first part of her paper to establishing a strict geometrical pattern for the plan. From this a table of dimensions is drawn up to be used in the analysis. If the geometrical relationships are true then only two of the dimensions listed can be independent. One of these must be the wall thickness, and the second one can be chosen from the rest of the list. Only these two dimensions may be used to support a case for the length of the Anglo-Saxon foot, and it is difficult to see how so small a sample may be trusted. Although most of the data is thus not independent, it is analysed as though it were. A number of published values for the length of the foot are tried against all the dimensions in the table to see which gives the best fit. No criterion of 'best' is stated, nor is any test used to identify it.

In contrast to Kjolbye-Biddle's paper which concentrates on one building at a particular time, the paper by P. Huggins, K. and W. J. Rodwell<sup>8</sup> covers a much wider field and time span. It divides into three parts, namely Anglo-Saxon timber buildings, Viking camps in Denmark and Anglo-Saxon stone buildings. In the interests of brevity only the first and last will be considered here. The data for the timber buildings is taken from sites covering the length and breadth of England and representing a time span of about three centuries. Most of the measurements are scaled from the published plans. The results are presented for the group as a whole without considering whether they are homogeneous. In the analysis each dimension is assigned a presumed design size. The difference between the measured size and the design size is expressed as a percentage of the measured size. All these

percentages show remarkably low values. What is not immediately apparent is that they are not comparable one with another, since each is a percentage of a different measured size. In addition each percentage has an upper limit. This is set in the process of fixing the design sizes, each of which are rounded off to the nearest one-sixth of a Northern rod. The maximum rounding off is thus one-twelfth of a Northern rod, which is 1.25 Northern ft., so the difference between measured size and design size can never be greater than this. For any particular case the maximum possible value of the percentage difference is equal to 1.25 Northern ft. divided by the measured length and so will depend upon that length. For the longest measured length of 33.9 m the maximum possible percentage difference is 1.24. The percentage difference given for this case is 1.0, but all the percentage differences have been rounded-off to the nearest 0.5. The true figure is 1.19, nearly equal to the maximum possible.

Much of the data for the work on stone buildings is taken from H. M. and J. Taylor<sup>9</sup> again by scaling from the published plans. In their introduction Taylor and Taylor specifically deal with the quality of their measurements and do not recommend scaling from the drawings. In the analysis of the data measurements are again rounded off to the nearest one-sixth of a Northern rod, so the maximum rounding-off value is one-twelfth of a Northern rod, 1.25 Northern ft. or 419 mm. At the same time the dimensions chosen on the buildings are either external or wall centre-line whichever seems most appropriate, with the exception of one internal dimension. All Saxon wall widths lie between 660 and 1,090 mm. If a particular building has a wall width of 838 mm, that is twice the rounding-off value, then because of the rounding-off and subsequent conversion to Northern feet either the external dimension or the wall centre-line length will end in 0 or 5 and may be chosen as appropriate. For such buildings the rules of the analysis guarantee the result. For a wall width chosen at random from the range given above there is only a chance of about 1 in 8 of not getting this result.

#### ANALYSIS — METHOD, VALIDATION AND IMPLEMENTATION

The study of the Anglo-Saxon foot is in need of an objective method of analysis, and so a computer program which tests a wide range of values has been developed using the least squares criterion rather than the more mathematically sophisticated test of Kendall. As potential users are more likely to have some knowledge of least squares it is hoped that they will feel more confident about using it. In addition greater flexibility has been introduced by allowing for the possibility of fractions of a unit in the measurements, and these need not be at regular intervals. For example, measurements of details may have originally been intended to be a number of whole units plus a half, quarter or third. Each trial value of the unit length is divided into the measurements and the nearest value of units and specified fractions is found. The variance of the resulting residuals is calculated and reported. It is left to the investigator to use this information to judge if any one or more values of the unit are strong possibilities, and to use any other evidence available to him to reach a decision. The program has been written in Fortran and run on a mainframe

computer, and in Basic and run on a micro-computer. The latter version makes it more immediately available to a wide range of people.

The method of analysis may be tested quite easily by taking measurements in the metric system on a structure which was constructed according to the Imperial system. The structure should be free-standing and well away from its neighbours so that there were no constraints on the original choice of dimensions. If it is made out of stone then the material of construction will not have influenced the choice of dimensions; in this regard there is evidence that in a brick building the sizes of windows, doors and other openings may be chosen to suit the brick size.

At about the time that the proposed method had been developed to the stage at which a controlled test was desirable, the author was in charge of surveying for the excavation at The Hirsal, Coldstream, under the direction of Professor Rosemary Cramp.

The stable block at The Hirsal fulfils the conditions detailed above and so it was chosen for the validation of the method. Constructed in 1900, recorded by a clear inscription over the entrance arch, it is firmly set in the era of Imperial measurements. The stonework is in good condition, allowing accurate measurements to be taken. There were some constraints as to what could be measured, but this is rather like an Anglo-Saxon building in which the amount of original material left to measure is usually very limited. Some duplicate features have the same measurements, for example window openings, but in such cases only one of them was used in the analysis. There are two quite distinctly different features which have the same measurements, and both these were used as they represented two separate decisions on the part of the original designer. The measurements were taken by experienced surveyors, using a steel tape in good condition. Running measurements were taken along walls to pick up the features such as doors and windows, thus preventing the accumulation of minor errors.

The list of measurements, in mm, used in the analysis is as follows: 915; 612; 305; 3,023; 1,220; 1,448; 1,449; 1,303; 537; 1,870; 2,670; 24,214. The analysis was set to search for whole units, halves and quarters over the range 250 to 360 mm.

The two lowest values of the variance were equal and corresponded to unit values of 303 and 304 mm (Table 1). These values of the variance were also clearly the lowest. Since the metric length of the Imperial foot is 304.8 mm, the method of analysis described has performed satisfactorily under test.

A study of the Anglo-Saxon foot was first suggested to me by Professor Cramp when I was in charge of the surveying for the excavations at Monkwearmouth and Jarrow Monasteries.<sup>11</sup> When I wanted to run a field test on work of Anglo-Saxon date it was to these two sites that I turned. Standing structures may be measured to the standard of accuracy required for a reliable result. They also have the advantage that others may check the primary data if they wish, without the intervention of secondary stages such as working from other people's drawings.

Some parts of the Anglo-Saxon monastery are still standing at Jarrow. According to Taylor and Taylor,<sup>12</sup> the nave of St Paul's Church was part of the original structure and so this was chosen for a measurement study. The measurement procedure was as described earlier, with the exception of the three small windows

TABLE I  
THE HIRSEL

<i>Length of Unit in mm</i>	<i>Variance *10000</i>						
250	55	278	64	306	31	334	63
251	57	279	60	307	29	335	60
252	64	280	64	308	29	336	63
253	64	281	72	309	35	337	66
254	74	282	83	310	41	338	66
255	65	283	75	311	47	339	60
256	60	284	67	312	58	340	52
257	57	285	61	313	73	341	45
258	58	286	49	314	80	342	38
259	40	287	44	315	80	343	38
260	50	288	33	316	79	344	39
261	34	289	29	317	73	345	35
262	42	290	34	318	70	346	37
263	49	291	48	319	64	347	45
264	54	292	62	320	51	348	60
265	66	293	73	321	43	349	73
266	57	294	72	322	39	350	74
267	58	295	70	323	34	351	71
268	59	296	72	324	29	352	63
269	56	297	74	325	29	353	61
270	65	298	67	326	34	354	53
271	68	299	55	327	42	355	41
272	54	300	42	328	54	356	38
273	37	301	35	329	68	357	42
274	36	302	24	330	81	358	50
275	25	303	19	331	88	359	49
276	29	304	19	332	82	360	53
277	48	305	25	333	72		

high up on the south elevation. For these a base line was set out 15 m from the wall and parallel to it. This was measured once in each direction, the values being 12.065 and 12.061, so the mean length of 12.063 m was used. The angles between the base line and the window openings and the ends of the nave wall were measured at both ends of the base. A simple trigonometrical calculation then gave the values for the window openings and their spacing along the wall.

The list of measurements was scrutinized for any which were not independent and these were rejected. Some of the features of the structure were not part of the original plan, being later additions or alterations. The dimensions of these might not have been decided with the same freedom of choice as the original work. They might

TABLE 2  
JARROW

<i>Length of Unit in mm</i>	<i>Variance *10000</i>	<i>Length of Unit in mm</i>	<i>Variance *10000</i>	<i>Length of Unit in mm</i>	<i>Variance *10000</i>	<i>Length of Unit in mm</i>	<i>Variance *10000</i>
250	31	280	14	310	73	340	46
251	53	281	38	311	41	341	46
252	44	282	49	312	31	342	66
253	36	283	54	313	51	343	53
254	27	284	57	314	42	344	57
255	35	285	68	315	49	345	44
256	45	286	24	316	46	346	38
257	39	287	31	317	78	347	33
258	52	288	64	318	63	348	40
259	30	289	52	319	46	349	35
260	37	290	72	320	38	350	56
261	67	291	74	321	53	351	42
262	42	292	59	322	58	352	40
263	57	293	44	323	55	353	55
264	71	294	47	324	59	354	32
265	38	295	64	325	92	355	46
266	67	296	74	326	64	356	39
267	64	297	48	327	63	357	36
268	53	298	75	328	26	358	46
269	65	299	54	329	52	359	48
270	55	300	44	330	35	360	60
271	59	301	48	331	52		
272	80	302	68	332	45		
273	47	303	68	333	64		
274	33	304	43	334	71		
275	47	305	44	335	61		
276	56	306	56	336	34		
277	42	307	38	337	38		
278	65	308	43	338	30		
279	47	309	53	339	45		

have had to comply with fixtures or fittings which have long since disappeared. For this reason these too were rejected. These decisions were based on a study of the work of Taylor and Taylor, helped by the advice of Rosemary Cramp.

The final list of acceptable dimensions, in mm, was as follows: 13,365; 616; 3,295; 690; 630; 11,070; 640; 337; 440; 2,800; 330. This set of data was analysed for whole units, halves and quarters. The length of unit which showed the lowest variance was 280 mm and this was quite an unambiguous result (Table 2).

The amount of data was small, but it was carefully selected to eliminate any doubtful values. Similarly the care taken with the measurements ensured that they

are of high quality. It is safe to say that the unit of measurement used for the initial phase of construction at Jarrow was very close to 280 mm in length. To make a significant change in this value it would be necessary to add quite a number of new measurements all with the same characteristic unit length.

#### CONCLUSION

As compared with some studies of measurement from other periods those dealing with Anglo-Saxon measures have been subjective and lacked analytical rigour. A more objective approach should be undertaken, with the use of better analytical tools such as the proven method of analysis presented here.

The value of 280 mm found for the length of the foot used in the early stage of construction at Jarrow may not agree with other values quoted for the Anglo-Saxon foot, but then, like Connor's Roman foot rules, quoted values may not tell the whole story. The value of the foot used at Yeavinger as given by Hope-Taylor<sup>13</sup> is 281 mm. This is in very close agreement, and interestingly Yeavinger and Jarrow are not all that far apart in time or place. Unfortunately its origin seems to have been just as subjective as the other attempts to find an Anglo-Saxon foot.

#### NOTES

<sup>1</sup> 2 Waleric House, Northumberland Street, Alnmouth, Northumberland NE66 2RS.

<sup>2</sup> K. D. Connor, *The Weights and Measures of England* (London, 1987), 10.

<sup>3</sup> *Ibid.*, xxv.

<sup>4</sup> D. G. Kendall, 'Hunting Quanta', *Phil. Trans. Roy. Soc. London, Series A* 276 (1974), 231-66.

<sup>5</sup> *Ibid.*, 232.

<sup>6</sup> H. Nielsen and K. Nielsen, 'Module Search by Means of a Computer', in K. Kristiansen and C. Pahudán-Muller (eds.), *New Directions in Scandinavian Archaeology — Studies in Scandinavian Prehistory and Early History, Vol. 1* (Copenhagen, 1978).

<sup>7</sup> B. Kjolbye-Biddle, 'The 7th Century Minster at Winchester Interpreted', 196-209 in L. A. S. Butler and R. K. Morris (eds.), *The Anglo-Saxon Church* (C.B.A. Research Report 60, 1986).

<sup>8</sup> P. Huggins, K. Rodwell and W. J. Rodwell, 'Anglo Saxon and Scandinavian Building Measurements', in P. S. Drury (ed.), *Structural Reconstruction* (British Archaeological Reports, British Ser., 110, 1982).

<sup>9</sup> H. M. Taylor and J. Taylor, *Anglo Saxon Architecture*, 2 vols (Cambridge, 1979).

<sup>10</sup> *Ibid.*, Vol. 1, xxvi.

<sup>11</sup> R. C. Cramp, 'Excavations at the Saxon Monastic Sites of Wearmouth and Jarrow', *Medieval Archaeol.*, 13 (1969), 21-66.

<sup>12</sup> Taylor and Taylor, *op. cit.* in note 9, vol. 1, 331.

<sup>13</sup> B. Hope-Taylor, *Yeavinger: an Anglo-British centre of early Northumbria* (London, 1977).