MODULES IN BUILDINGS - TWO CASE-STUDIES APPLYING HOLM'S MEASURE OF MODULE FIT

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ABSTRACT

This paper presents a framework for module studies in prehistoric buildings. It falls in three parts, a methodological point of departure, a presentation of two case-studies, and a short evaluation. For the module search Holm's (1987) NAA 1987/354 measure of module fit is used. The material for the case-studies is Early Byzantine churches, synagogues and chapels in Illyricum (mostly Balkan) and a set of measures from the Oelandic ring fort Eketorps borg. A foot, Illyric, and an ell, Oelandic, are reconstructed.

Introduction

This paper presents a framework for module studies in prehistoric buildings. It falls in three parts, a methodological point of departure, a presentation of two case-studies, and a short concluding discussion. The procedure is designed to bridge a cultural situation in which modules are already know to be used, with a similar situation in which it is not quite as obvious. For that reason Roman material is compared to South Scandinavian measures, as an introduction to studies that may in the future be made on the fast growing number of house remains.

The point of departure

Trying to reconstruct the way in which a building was planned, you are forced to define points that were once thought to make up the end points of a certain distance. What distances then, eg in figure 1, would it be reasonable to measure?

Besides the x-, and y-coordinates there are several dimensions defining a point. One of these covers the varying connections of the point to empirical observation. A point could have been essential in the head of the planner or on whatever sketches he might have made, but in the field the point may never have existed. Likewise some points, that in their turn defined others, have perhaps been used only when marking out the building, and some points have probably been affected or created during the work of the mason.

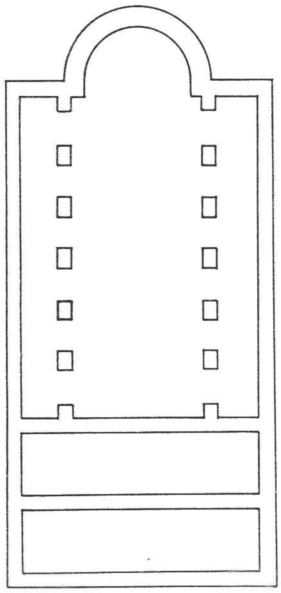

Fig 1. Plan of the basilica in Suvodol (Spremo-Petrovic 1971 no 4).

The principles that govern the persons engaged in these tasks constitutes another dimension. On that dimension one might say that the will to apply geometrically created proportions drops off while modules tend to be more practical. The architect may have used the dynamic triangles (Hambridge 1924) or Pythagorean triangles (Junecke 1983), and the latter ones might also have been used when marking out the building. In that situation - and many buildings have never had any pre marking out planning - even semi Pythagorean triangles (fig 2 a-b) or (Herschend 1989) could have been convenient. Lastly features like the breadth of the walls were affected by the mason's rod and those rules of the

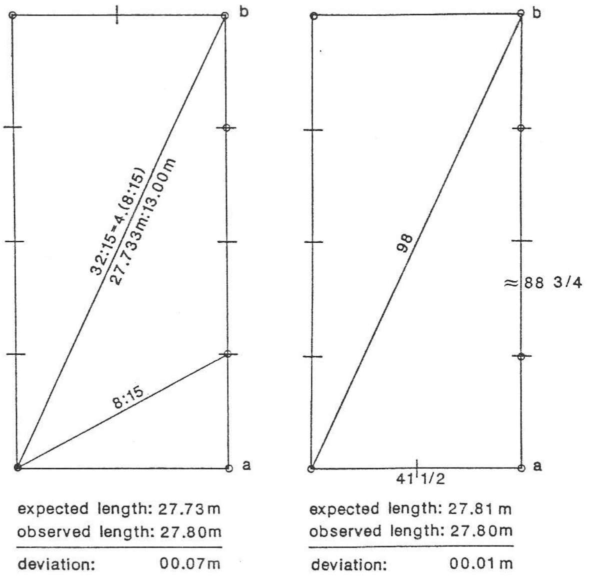

Fig 2a-b. Two reconstructions of the intended length of the basilica in Suvodol, fig 1. a, combining four Pythagorean triangles (Junecke 1983;13 ff). b, using a Semi Pythagorean triangle (Herschend 1989;137).

thumb that he applied when building a wall of the type in question.

These two dimensions are strongly influenced by the way in which the monument has been preserved, but also by metaphysical concepts used to define the impact on the building of such things as, aesthetics, technique, economy or function. Due to the last type of dimensions it becomes virtually impossible to define two arbitrary points in a building as the end points of a distance that in theory represents, either a number of once common modules, the square root of the number three, some side in a Pythagorean triangle or the like. The method used by Junecke (1983) favouring the approach that leads to the smallest deviation from the observed reality cannot unconditionally, although it is sound, be used as a guiding principle.

In figure 2a-b two methods compete for the best definition of some probably essential points in a building plan. The one using the Semi Pythagorean triangle gives the result most equal to the measured distances. The differences are, however, small and it is quite possible that the architect used the method of figure 2a with arbitrary modules, while the men marking out the building used the method of figure 2b. There are in other word many ways of creating the practical result recorded by us, and only fragments of a theory of planning and fragments of a theory of application are to be found in the lay-out of the building. These fragments are not sufficient for reconstructing the planning in any detail. Papers discussing proportional and modular planning show this, since they cannot make up the background for a theory that demonstrates how these two forms of planning exclude each other, eg (Thieme 1985, Dufaij 1985).

For mathematical reasons the existence of a module cannot be proved if the material to be analysed is blurred by measures referring to several modules or several non modular geometrical principles with different degrees of precision. Initially the only proof worthwhile is none the less mathematical and therefore the point must be to find a sample of measures mainly governed by a theoretical idea of general consequence in the society that produced the building, rather than in the arts of that society. This idea should in itself imply a modular solution to a problem.

Ideas about the costs of the buildings and the functions they are to fulfil have the dignity necessary to produce rules that may lead to a definition of some measures as equal to a number of modules. In the two case-studies below the right to use a certain part of a common street or square is the main point. It is obviously connected with an idea of the value of a façade. That, in its turn, is a matter of the breadth of the lot and its boundaries in connection with a possibility easily to prove these measures to be correct or within limits. In such matters the need for a standardized or normalized procedure is obvious, and a firm relation to modules helps out. One might in other words hope that the theory of the module, and the application of it, go hand in hand in such a way that although it is only a social obligation it might also grow into a natural part of the unspecified theory of planning.

The first sample

Measurements of Late Roman and Early Byzantine churches, synagogues and chapels make up the material behind the sample. It has been found in Spremo-Petrovic (1971), in Bersu (1938), and in Barnea (1948 & 1958). In these basilicas there are 4 essential breadth measures as sketched in figure 3. According to the theory, modules should be most obvious in the A-, B-measures while the C-, D-measures may also mirror smaller fractions or measures with a secondary link to modules. The breadth of the mid aisle might or might not be the result of the breadth of the side aisle, but the C-, D-measures could also lack any link with modules what so ever. Eventually one shall have to split the first sample, but to begin with it consists of 138 measures (fig 4).

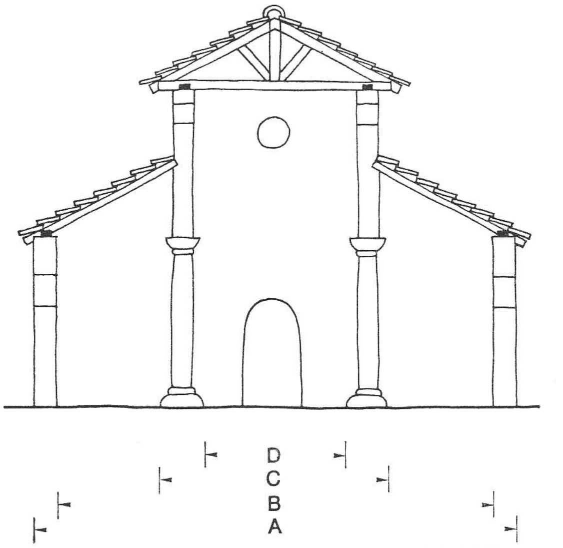

Fig 3. A sketch of a basilica section defining the A-, B-, C- and D-measures.

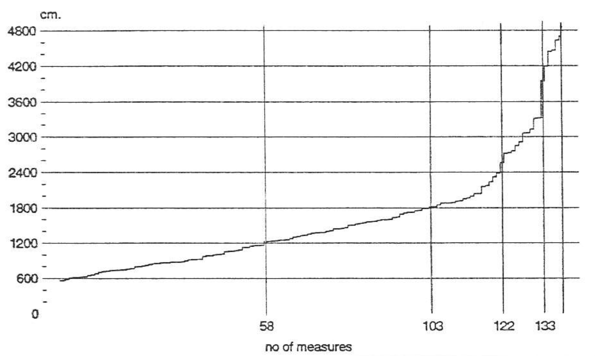

Fig 4. The sample of 138 measures from the Illyric material.

The second sample

Measurements from the Eketorp ring fort on Öland form the second sample. Falling back on studies made by Hannerberg (1955) and Göransson (1971) an ell of c 47 cm can be expected to occur in the material. Hannerberg suggested that this ell was of East Roman or Greek origin, but Göransson (1976) and (1988) has doubted Hannerberg's interpretation. Hannerberg did not explicitly discuss why the ell must have been a loan, and Göransson's examples of a foot corresponding to this ell and of equally short ells in other parts of Scandinavia, speak in favour of its being an old local measure. There is on the other hand some very definite loans in the Oelandic culture, and two of these relate to the Roman Empire - the metrology used in connection with payment rings and the portcullis gate in the second Eketorp ring fort. Even a sketch of the overall idea of the planning of the ring fort (Herschend 1989) could indicate a connection, and justify a comparison as the one attempted here.

Planning the fort is a matter of planning a periphery. In the first ring fort the inner face of the rampart was the periphery to be sectioned and in the second the same circle made up the façade of the radial houses. Bearing in mind the state of preservation, the type of distances that can be measured with reasonable security on the photogrametric scale 1:50 plans, are indicated on figure 5.

In the second ring fort the walls are approximately 0.95 m wide and some of the radial ones were built as detached walls later to be supplied with short ends that stretched between two entrances in the façade, making them look like T's (fig 5a). The distances between these primary radial walls are reasonable measures. The same type of measure can be found between the radial walls of the first ring fort where they abut on the rampart (fig 5b).

There are no actual outer house breadths to be measured with confidence in the second ring fort and several of the inner breadth measures are difficult to define due to corners being rounded or faceted by the masons. Where the walls meet in definite angels these distances are, however, reasonable measures (fig 5c).

The sample is still relatively small and therefore it has been completed with those measures that are a result of the demand for a minimum street breadth. These measures are found in the gates and in those places where the demand has affected the form of a house (fig 5d).

All 75 measures (fig 6) correspond closely to the theory above, but contrary to those of the first sample they are fewer, they relate to one monument only and some distances are very much more frequent than others. The measures should thus be used with caution although the advantage of being theoretically comparable to the Illyric measures favour the comparison.

The methodical steps

When Holm's (1987) measure of module fit is applied to a sample, the fitness of the suggested module is expressed as a measure of concentration deviating from an expected value. This difference between the observed and the expected can be translated into standard deviations.

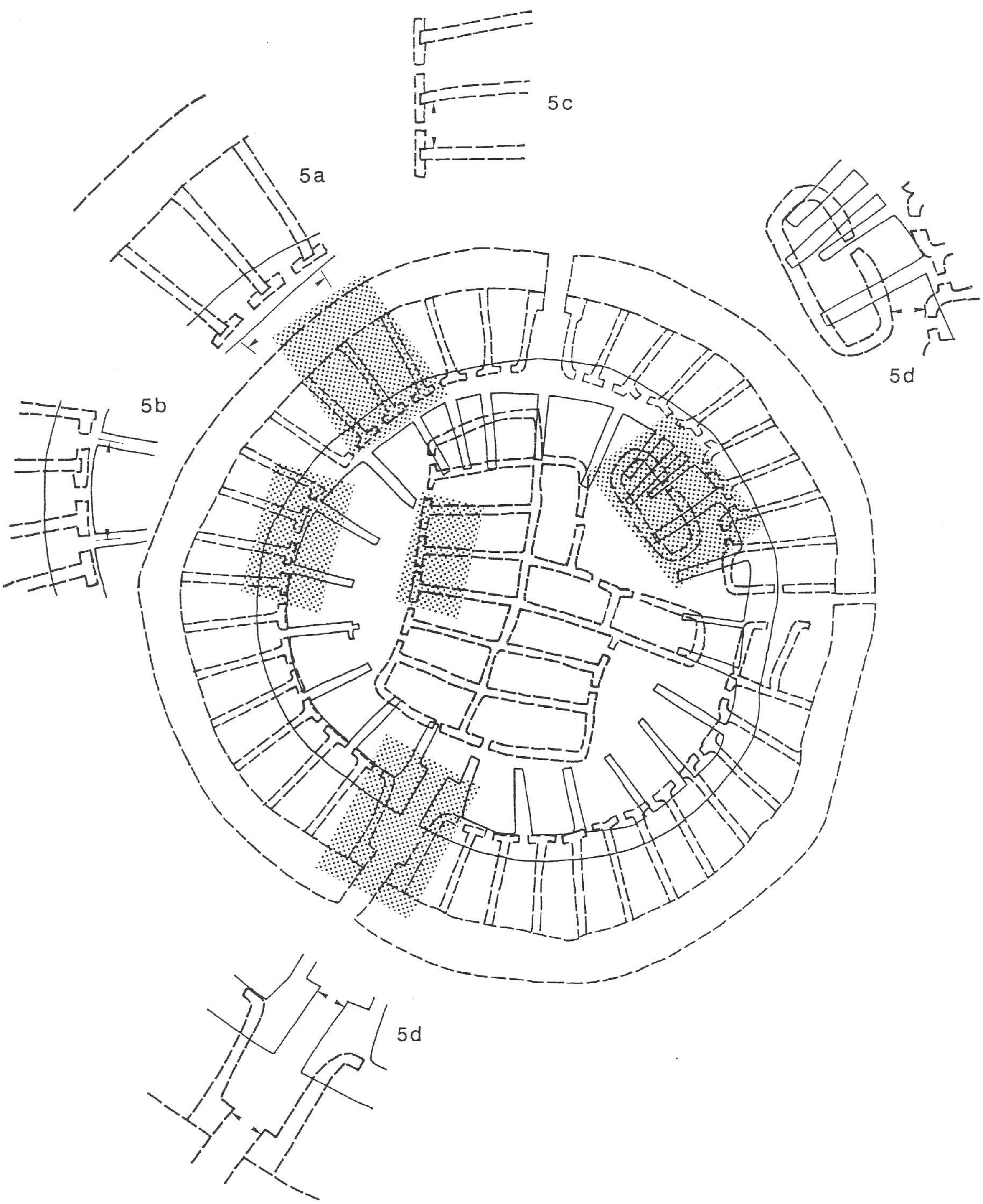

Fig 5. Sketches of the first and second Eketorp ring fort, showing the type of measures used.

The expected value 1, is the mean in a distribution that is at least in its central part a normal distribution. Therefore the standard deviation is a measure of the possibility that the observed concentration is significantly different from the expected (Holm 1987), (Herschend 1987).

In the following the module with the greatest negative deviation from the expected is the most probable one, but the deviation should be greater than minus 2.57 sigma in order to be sufficiently significant.

The procedure is simple enough. The computer tests a lot of modules in series within more and more narrow frames in order to find the optimum module,

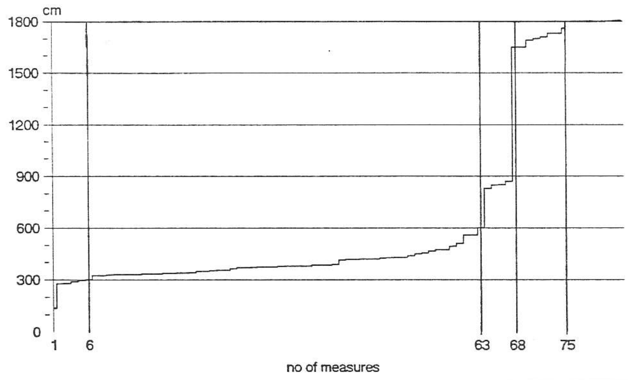

Fig 6. The sample of 75 measures from the Eketorp material.

ie the module resulting in the greatest negative deviation. The module is defined in centimeters down to three decimal places, however rounded off to one decimal place only.

Having found the optimum module the precision of the measures in the sample is tested against this optimum in order to see how the deviations per cent are distributed.

The Illyric case-study

A look at figure 7 shows that there is an optimum to be found at c 31.5. If we compare the A-, B-measures and C-, D-measures (fig 8) then obviously the C-, D-measures lack concentrations that would in their turn indicate a module, and for the rest of the study only the A-, B-measures are used. With these 80 measures the optimum can be defined as, 31.2 (31.236) cm (fig 9). Several units in figure 7 show great positive and negative deviations, and especially on both sides of the optimum there are numbers that fit the sample very badly. These high positive deviations indicate anti modules, ie units not falling in with the rhythm of the measures. The comparison in figure 8 does also reveal that in a sample influenced by a module the oscillation is fast and deviations often great. Naturally there is a tendency for the oscillation to be more moderate as the module grows bigger, but the variations are also due to the existence of a main module, to mathematical relations with this module, and perhaps also to the existence of several related modules.

When a sample is as influenced by a module as the Illyric, then the optimum is not affected very much by measures with no obvious tie to the module. If namely the C-, D-measures had still been part of the sample, then this would only marginally have effected the optimum, changing it from 31.236 to 31.235 cm. But its deviation from the expected would have dropped from c 5.7 to c 4.5 standard deviations.

The precision (fig 10) is good. Circa 60% of the measures are less than ± 3.72 centimeters, ie $\pm 1/8^{th}$ of a foot from total precision. There are some few measures that may reflect measurements in half feet, but otherwise no obvious breaks in the curve. There is, however, a tendency in the deviations to form a plateau just below a step in the graph at c 6.25%. This is perhaps an indication that there was a rule once used by some, saying that a measure should not deviate more than $1/16^{th}$, in the case of this foot ie an inch, if the measure was defined in feet.

The analysis has in other words resulted in a definition of the Greek or the Late Roman foot of the East Roman Empire (Schildbach 1971). That is not surprising, but perhaps the dominating character of the foot is more outspoken that one would have expected after studying Spremo-Petrovic's (1971) analysis.

The Oelandic case-study

Using the Eketorp sample and proceeding the same

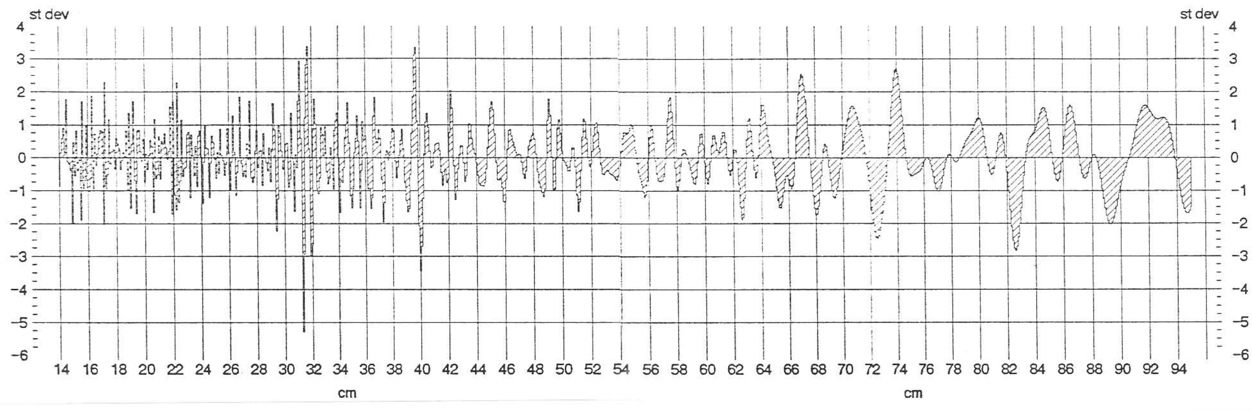

Fig 7. The first module search among the Illyric measures.

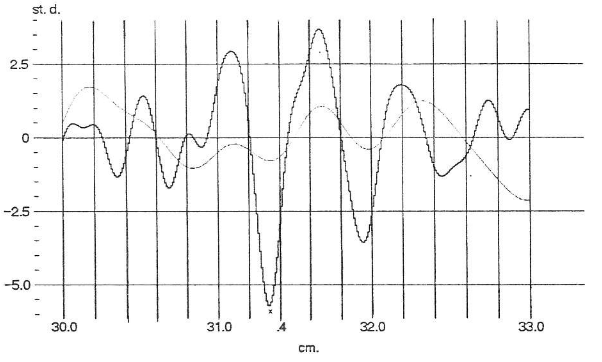

Fig 8. The second module search among the Illyric measures, comparing the significant A-, B-measures (continuous line) to the insignificant D-, C-measures (dotted line).

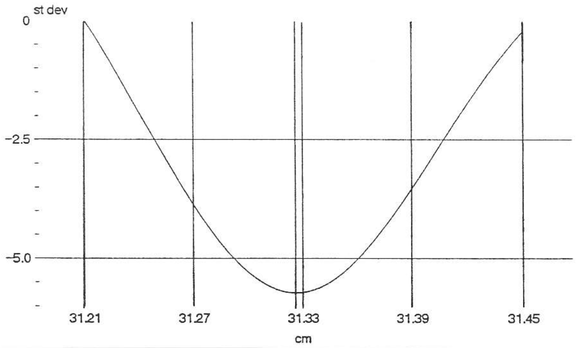

Fig 9. The third module search among the 80 Illyric A-, B-measures (fig 8), determining the optimum foot.

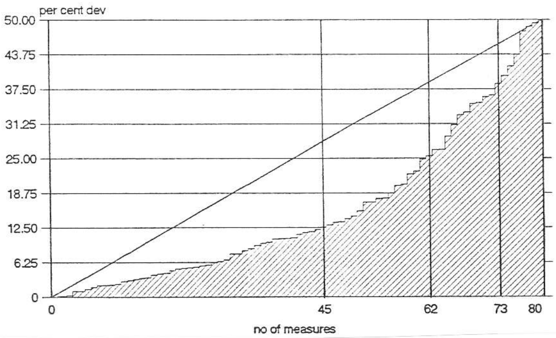

Fig 10. The deviation per cent of the 80 Illyric A-, B-measures from the optimum foot. The diagram shows the relative rigidity with which the foot was applied.

way as above figures 11a-b reveals that there is no foot to be seen in the Eketorp material, but well an ell of 47.1 cm (47.126). This module is not as dominant as the foot in the Illyric material, and the precision is less impressive. Only c. 50% of the measures are within $\pm 1/8^{th}$ of the module, in this case 5.89 cm, compared to 60% of the Illyric measures within the corresponding ± 3.72 cm (fig 12).

The ell is very close to the ell of one and a half foot formally corresponding to the foot of the Illyric material (Hannerberg 1955;11), (Schildbach 1971). If the Oelandic module is translated to a foot then the difference is 0.29% of the mean foot or 0.90 mm. It cannot yet be known whether this difference is negligible or not, or whether the ell is equally well to be understood as a purely South Scandinavian phenomenon. As often pointed out (eg in the article Fod in Kulturhistorisk lexikon for nordisk medeltid) there is another clue to understanding modules like that in Eketorp as a late Roman ell of one and a half foot.

Most early Scandinavian ells are equal to 2 feet or (16 x 2) = 32 inches and they are subdivided into 4 or 8 parts consisting of 8 or 4 inches each. The late Roman/Greek foot, as indicated above, was equal to 16 inches and divided into 4 parts. The corresponding *pechys* (the 1.5-foot-ell) is consequently divided into 6 parts each consisting of 4 inches. So the first natural fraction of an ell is either a fourth/eighth or a sixth.

Turning to figure 12 it can be seen that there is a limit of precision just a trifle above 16.67%. This probably reflects an idea of precision in the Eketorp monument in as much as it mirrors a tendency to keep distances within $\pm 1/6^{th}$ of the module and perhaps from time to time to correct of faults greater than that. This is a rational behaviour if the first subdivision of the unit is $1/6^{th}$, but not equally rational if the fraction is $1/4^{th}$ or $1/8^{th}$. The Oelandic way of adopting the metrological system is not very strict, and compared to the precision ($1/16^{th}$) disclosed in the Illyric case it could not be called sophisticated. But it is handy and no reason to belittle those who planned the ring fort.

Concluding remarks

From a purely methodical point of view the strength of Holm's measure in relation to the chosen distances, is that the optimum seems to be relatively stable, even if the material contains several measures that are not related to any special module. Contrary to this the significance of the optimum varies considerably, and even in the Illyric material there is a risk, that the inclusion of measures with no particular module connection, will deprive the optimum of its statistical significance. This risk is no doubt greater if the measures reflect a situation in which modular precision is not a major concern.

Sample formation is in other words the decisive step. It stands out as a problem of interpreting the histor-

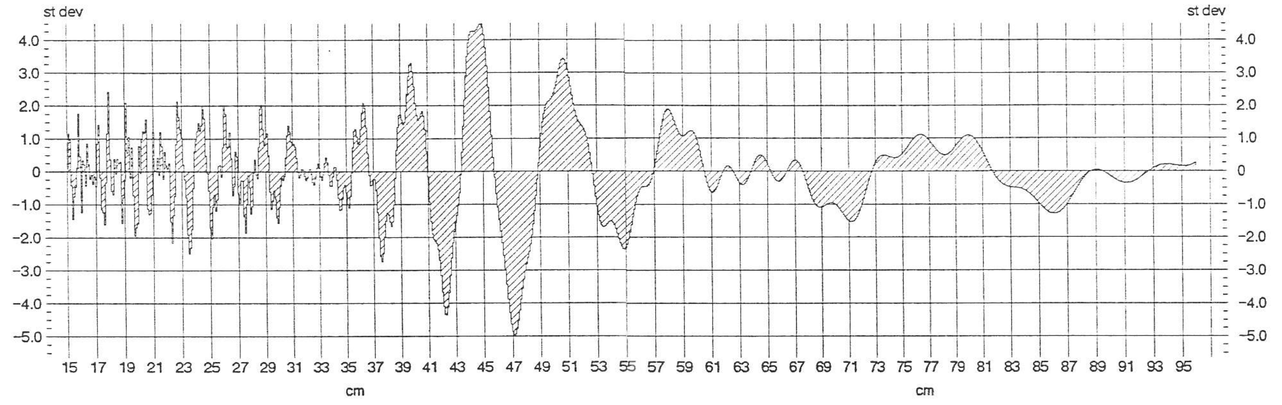

Fig 11a.

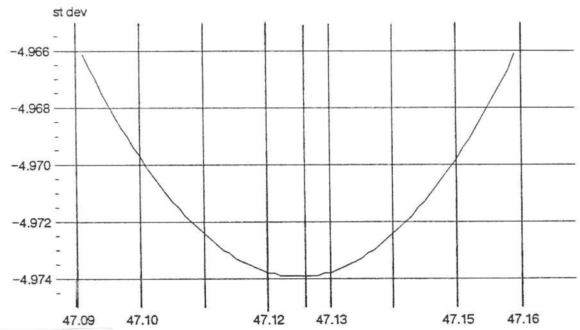

Fig 11b.

Fig 11a-b. a, The first module search among the Oelandic measures. b, The second module search among the Oelandic measures, determining the optimum ell.

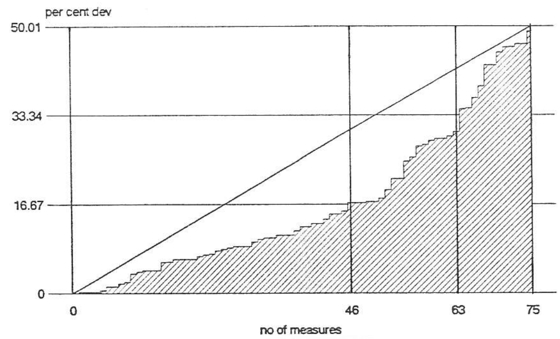

Fig 12. The deviation per cent of the Oelandic measures from the optimum ell. The diagram shows the relative liberty with which the ell was applied.

ic situation in which the measures were needed and used - it is the problem of reconstructing the approach of prehistoric man. With successful sampling from an Iron Age South Scandinavian material, even relatively few measures, 50-75, seem to be enough to disclose a module. This means that measures from one monument or from a small uniform settlement could be enough to make a reasonable study possible. If so, mapping module distributions will eventually be a habit, and even the formation of chronological and geographical units might prove relevant.

The discussion of the suitability of different modules in different situations of planning and construction, is in itself another lane of future research. This is due to the fact, that based on a well defined sample the problem of understanding what the use of a certain module means, has acquired interesting complexity rather than bewildering confusion.

The mathematical correspondence between the modules indicates that there is a fair chance that the ell in Eketorp refers to Late Roman metrology, but the question is far from solved. The ell is a module too big to fit the church builders when defining the breadth of their façades, but it has been used in other situations, eg when marking out fortifications (Herschend 1989). Correspondingly there might have been Oelandic situations in which the foot rather than the ell was the predominant module. This means that future investigations can create complex and more convincing parallels between Oelandic and Late Roman samples.

Most measures used in the Oelandic case-study rely on standard documentation of the monument, and only few were, during the excavation, understood as a certain number of feet or ells. This has created a problem of precision, and the documentation can hardly be used to produce measures with a precision better than ± 2.5 cm, ie measures to the nearest 5 cm. Especially in short measures this is a problem. If the distance is either 60 or 65 cm, then the best foot measure will be either 30 or 32.5 cm, but if the measure is 245 or 250 cm then the best foot will only vary between 30.63 and 31.25 cm. There is in other words a need for a feed-back from the study of modules in buildings to the documentation of them, granted the fact that some measures are more relevant than others and therefore in need of conscious documentation. This is a reason as good as any to carry out module search case-studies.

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