TECHNICAL TEXTILE TOOLS REPORT

GENERAL INTRODUCTION

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Preface

We thank you for your cooperation in the first part of the Tools and Textiles – Texts and Contexts (TTTC) research programme and we look forward to your reactions to our tool analysis and the technical report. A synthesis of all technical reports will be published in 2012 (Andersson, E. and Nosch, M-L. *Tools, Textiles, and Contexts*, Oxbow Books, Oxford).

This technical report is written for you. It forms the basis of your context description which we look forward to receiving. In future research, you are most welcome to use the results of the report in other publications and articles about your site and textile production. Please remember to quote the Danish National Research Foundation's Centre for Textile Research.

Copenhagen

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INTRODUCTION

One of the main objectives of the TTTC research program has been to record as many textile tools from as many types of sites as possible within our target area and date: The Eastern Mediterranean in the Bronze Age. The majority of the registered tools are spindle whorls and loom weights, but other tools such as needles, shuttles, and spinning bowls have been recorded (a category termed 'uncertain' has been reserved for possible or unidentified textile tools).

The initial goal was to create a database to gather information on such diverse topics as textile tools in the neo-palatial and post-palatial periods, changes in loom weight shapes at a specific site, spindle whorls from different contexts in a particular period, and so on.

We have now processed the data from the sites investigated. The next step will be for all collaborators to incorporate the results in their individual site context description. After that, we will be able to attain the research program's primary aim: to elucidate the economic and cultural impact of textiles and the textile manufactures in Bronze Age Aegean and Near Eastern societies.

It is our hope that this will create new knowledge and also demonstrate the possibilities in this research field and encourage scholars to continue the work. This is the beginning, not the end.

This report is based solely on the information gathered from the textile tools, giving you the results of our analyses, which concern the physical material – its dimensions, material and find context: we have only given our interpretation from a "tool and textile craft perspective". It is up to you how you interpret this information and incorporate it into your context description.

While processing the data we have compiled all functional parameters, i.e. such parameters that affect textile production according to our experiments and knowledge. We have then compiled and compared the results chronologically and contextually. Following the main body of text you will find a short summary and our interpretation of the textile production based on your recordings, on the analyses of the material in the database, and on the site contexts.

As our interpretation is also based on different experiments you will in the beginning of the report find a short summary of the five experimental tests that have been conducted at CTR in the TTTC research program. For more detailed information please refer to the Experimental Archaeological TTTC reports that have been published on our webpage (www.hum.ku.dk/ctr).

In the new database file, which you receive with this report, you will find comments on tools that we have excluded as textile tools (in those cases they are also marked with a question mark in the field *Find Category*. Sometimes the data you provided, e.g. *the maximum length* or *weight,* is not plausible. This is also commented upon, and in those cases we have changed your recordings and written what we have done and why. If you have sent us pictures and/or drawings they are now linked to the database. To open them you have to click on *Picture.*

The questions we have processed in the database are saved in tables. You will find them under *Table,* but please note that they are not linked with the original tables. In this report you will find several tables and diagrams, and they are also available in the enclosed excel file.

Should there be any questions, please contact Eva, who will be happy to help.

Definitions

Spindle whorls

For the different types of spindle whorls please see the CTR Database Manual. Spindle whorl is abbreviated *SpW* in diagrams and tables. The spindle whorl measurements are presented in graphs. If both weight and diameter are recorded, these parameters are presented in the same diagram. In some cases the parameters are presented in separate diagrams (for example, if just the weight is recorded).

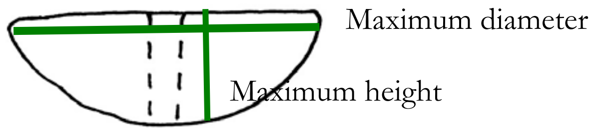

Figure 1. A spindle whorl demonstrating maximum diameter and height.

Loom weights

For the different types of loom weights please see CTR Database Manual. Loom weight is abbreviated *LW* in diagrams and tables. The loom weight measurements will be presented in diagrams. If both weight and thickness are recorded, these parameters will be presented in the same diagram. In some cases the parameters could be presented in separate diagrams (for example, if just the weight or the thickness is recorded).

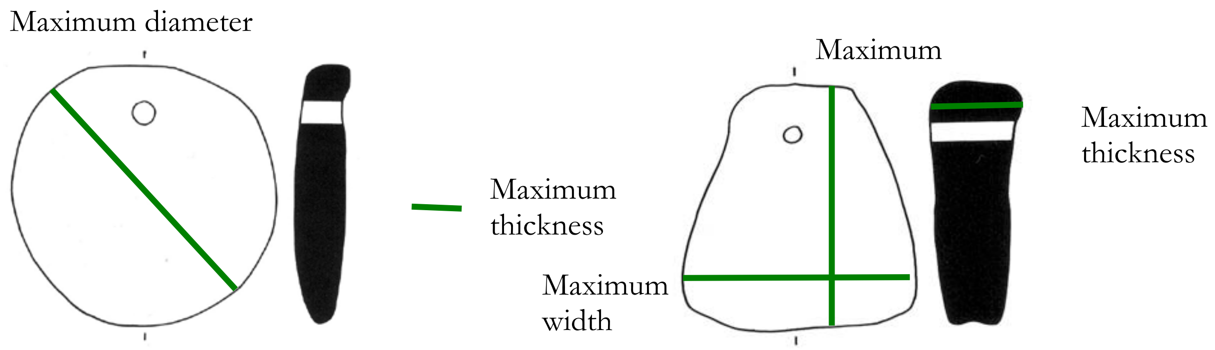

Figure 2. Two loom weights demonstrating maximum diameter, thickness and width.

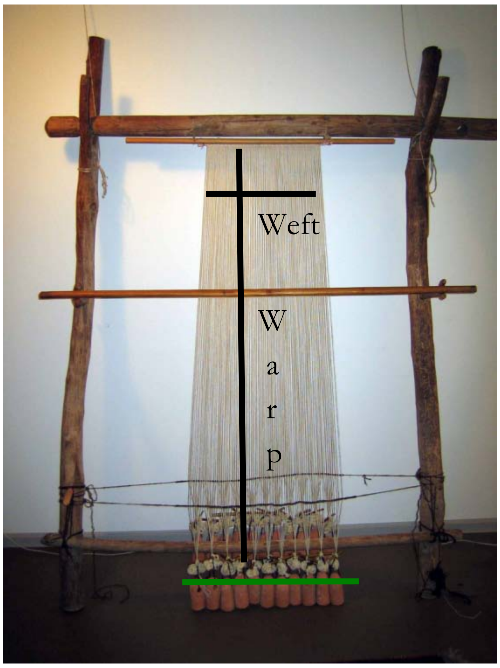

Figure 3. Warp weighted loom with the total width of loom weights in a setup.

WEAVING TECHNIQUES

Different types of weaving techniques will also be discussed. The figures below demonstrate different technical expressions and techniques mentioned in the text. Evidence of tabby weaving exists from Bronze Age Crete. Since tabby weaving is considered the most common weaving technique during the Bronze Age, we have based our calculations on this type of fabric. A balanced tabby has more or less the same number of threads and the same type of threads in both warp and weft (figure 4a, 4c, 4d and 4e). A weft faced tabby is when the weft is covering the warp threads and there are more weft threads than warp threads (figure 4b). A fabric can also be open (figure 4a) or closed (figure 4d). However, one must bear in mind that there is an infinite amount of different types of tabbies. To our knowledge, the only preserved examples of twill (see figure 4f) are fragments from Alishar in Turkey dated to the late 4th millennium (Fogelberg and Kendall, 1937, 334-35; Barber 1991, 167-168).

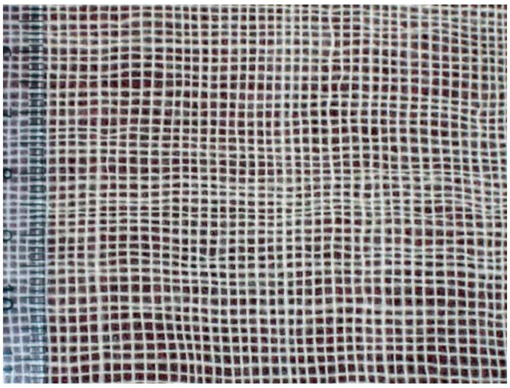

Figure 4a. Balanced open tabby, with an average of 6.1 warp threads and 7.4 weft threads per cm (wool fabric).

Figure 4b. Weft faced tabby, with an average of 5.8 warp threads and 14.8 weft threads per cm (wool fabric).

Figure 4c. Balanced tabby, 9 warp and 9 weft threads per cm (wool fabric).

Figure 4d. Balanced tabby, 14 warp and 14 weft threads per cm (linen fabric).

Figure 4e. Balanced tabby, 10 warp and 8 weft threads per cm (nettle fabric).

Figure 4f. 2/1 twill, 8 warp and 5 weft threads per cm (wool fabric). Note that this figure is only an example of a twill fabric; it is not a reconstruction of the fragment found in Turkey.

SPINNING[1]

The most common archaeological evidence for spinning consists of spindle whorls[2] and by analysing them one can gain knowledge of what types of yarn could be produced. Spindle whorls are generally used when working with a suspended spindle (figure 5).

The spinning experiments with suspended spindles conducted in the TTTC program have confirmed that it is primarily the quality of fibres and the weight of the spindle whorl that affect the finished product, i.e. the spun yarn.

The spindle whorls tested in the TTTC experiments weighed 4g, 8g and 18g. The tests confirmed that when spinning with a suspended spindle and a similar type of fibres, the lighter the spindle whorl, the thinner thread will be (Mårtensson *et al.* 2006a; Mårtensson *et al.* 2006b; Mårtensson *et al.* 2006c). Previous tests with heavier spindle whorls have also demonstrated that the heavier the spindle whorl the thicker the thread will be (Holm 1996; Andersson 2003; Andersson and Batzer 1999; Mårtensson 2006).

Figure 5. Textile technician Linda Mårtensson is spinning with an 8g suspended spindle.

[1] For more information, see also Mårtensson *et al.* 2006a; 2006b; 2006c.

[2] It is of course also possible to spin without a whorl, and whorls can be made of perishable materials. The absence of spindle whorls in the archaeological record is thus not an indication of the lack of spinning activity.

If one tries to spin a thin thread with few fibres per metre with a heavy spindle, the thread will break because of the weight of the spindle. On the other hand, if one spins a thick thread on a light spindle, the spindle will only rotate with much effort, and the yarn will not be strong enough to be used in a weave. It should, however, be noted that it is also of greatest importance how the fibres were prepared before spinning.

Sometimes the differences between types of yarn are not visible to the eye. One possibility, though, is to record how many meters of yarn can be produced when spinning identical fibres with different spindle whorls. The TTTC spinning tests clearly demonstrated that the lighter the whorl, the more yarn can be produced (figure 6). In general, a thin thread contains a smaller amount of fibre.

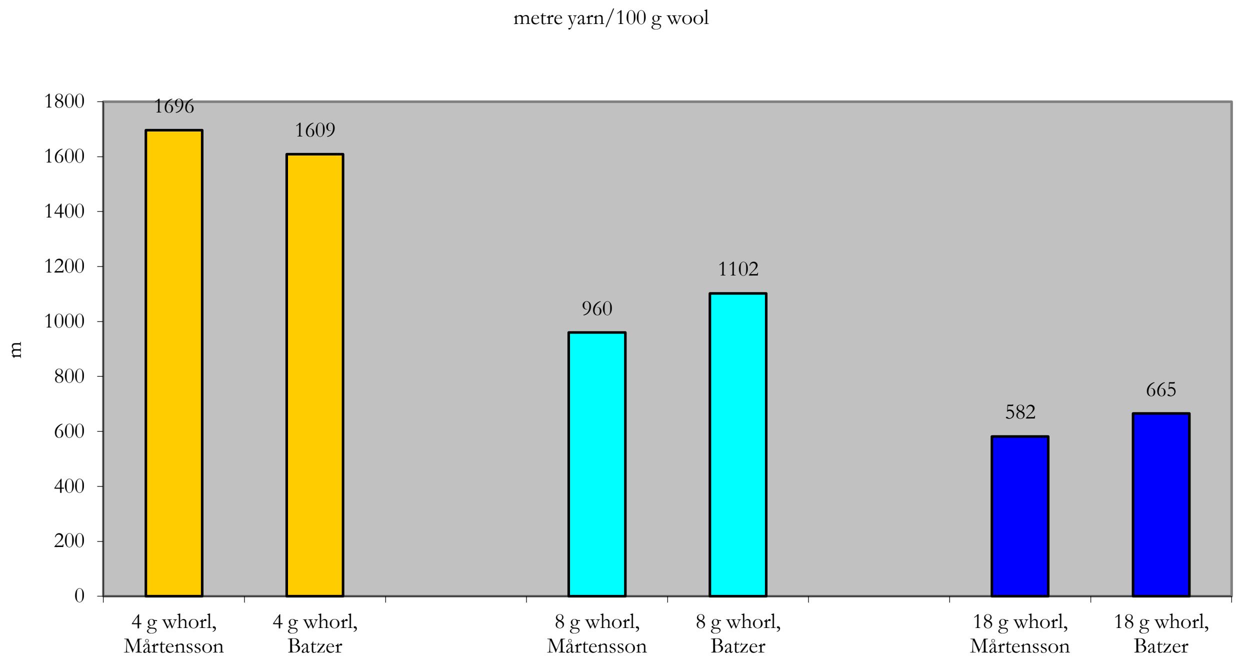

Figure 6. Length of spun yarn obtained from 100g wool, spun on 4g, 8g and 18g whorls respectively. The difference in yarn length can be explained by the fact that there is less fibre per meter in the thread spun with the 4g spindle than the 8g and the 18g spindle. The graph also demonstrates the relatively similar results obtained by the two spinners when using identical tools.

A yarn can be described in far more detailed ways than just as a thin or a coarse thread: as for example: hard or loosely twisted. This can be measured in the yarn twist angle. The twist angle is the angle at which the fibres are positioned in the spun thread, and is a measurement of how hard twisted the yarn is (figure 7). Previous tests have demonstrated that the relation between the weight and the diameter of the spindle whorl can affect the twist angle. If one is working with a light spindle whorl with a large diameter, the thread will be more hard twisted than if the whorl had a smaller diameter. The reason is that the whorl will rotate longer in the first case than in the second. It should, however, be noticed that it is possible to rotate the whorl additionally by hand, although this would take considerably more time (Holm 1996, 113-116). If the thread is loosely twisted, the fabric in general feels soft, and if the thread is very hard twisted the fabric can feel harder. These parameters do of course affect the quality of a fabric but without any textile finds it is difficult to estimate a specific twist angle just by analysing the diameter of the spindle whorls.

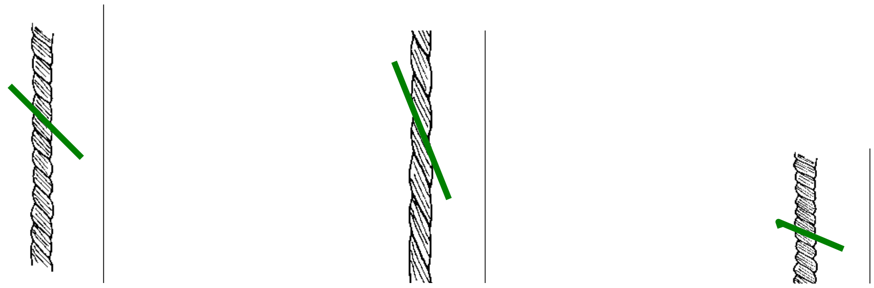

Figure 7. Twist angles.

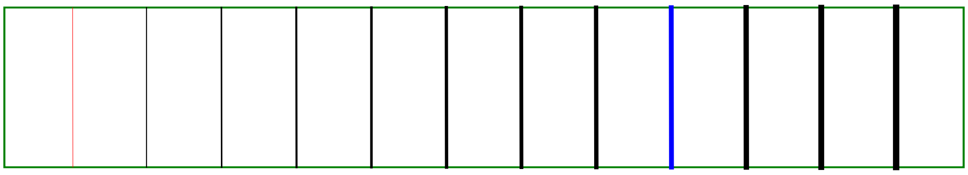

Figure 8. Variations from thinner to thicker "threads". The first line (red left) corresponds to a thread spun with the 4g spindle whorl, while the ninth line (blue) corresponds to a thread spun with a 44g spindle whorl.

According to our experience the height of the spindle whorl is of minor importance for the finished product.

As it is practically impossible to determine which types of yarn have been produced, we will just refer to the general categories 'very thin', 'thin', 'thick' or 'very thick' (figure 8).

Different degrees of yarn coarseness also require different weight tension when the yarn is used as a warp on a warp weighted loom. If the tension on the warp threads is too low it will be difficult to change the shed. On the other hand, if the tension is too high the warp threads will break. According to our results a thread spun with a 4g spindle whorl requires a tension of 10g per warp thread and a thread spun with the 8g requires 20g. No weaving test was made in the TTTC program on the thread spun on an 18g spindle whorl, but previous tests confirm that the thicker the thread the more tension is needed. A yarn spun with a 44g spindle whorl needs approximately 40g tension (Batzer pers. com.).

WEAVING[3]

In the Aegean and Central Turkey, the most common archaeological evidence for weaving consists of loom weights used on a warp weighted loom. Since most parts of the vertical warp weighted loom were made of perishable materials they do not usually survive in the archaeological record. It is also possible that other types of looms were used, such as the vertical two beam loom, the back strap loom, or the horizontal loom - but since these types of loom are of completely perishable materials, it is hard to find any archaeological remains. The conclusion is that one cannot *exclude* weaving, when no loom weights are found.

[3] For more information see Mårtensson *et al.* 2006a; 2006b; 2006c; 2007a; 2007b.

Figure 9. Two rows of loom weights.

When producing a tabby weave, the loom weights are hanging from two thread layers (front and back). Every other warp thread is attached to a loom weight in the front layer, and every other warp thread to a loom weight in the back layer.[4] The loom weights in each row are positioned side by side (figure 9).

It is important that the warp threads are hanging vertically and evenly distributed. It is preferable that the row of loom weights has a total width which is identical or slightly larger than the width of the fabric to be produced (figure 10a). If the warp threads are slanting outwards (figure 10b), or inwards (figure 10c), the warp threads will not be evenly distributed, and this will affect the weaving and the resulting fabric negatively (Mårtensson *et al.* 2007a; Mårtensson *et.al.* 2009).

In previous tests (Batzer pers.com.), different scholars have established that the weight of loom weights influences weaving on a warp weighted loom. Different types of yarn need different tension and this limits how many warp threads can be attached to one loom weight. If the yarn needs 20g tension per warp thread, and the loom weight weighs 500g, one can attach approximately 25 warp threads to this loom weight. If, however, one uses a yarn that requires 50g tension, one can only attach 10 warp threads to the loom weight. Likewise, if one uses a loom weight with a weight of 300g, and a yarn that needs a tension of 20g per warp thread, one can attach only 15 warp threads to each loom weight, but if the required tension is 10g per warp thread, then the weaver can attach 30 warp threads.

The experiments conducted in the TTTC program have also clearly demonstrated that the thickness of a loom weight does play an important role when weaving, and hence that the choice of loom weights affects the fabric (Mårtensson *et al.* 2007a; Mårtensson *et al.* 2007b; Mårtensson *et.al.* 2009).

[4] The warp weighted loom can be operated in several ways, depending on for example which weaving technique is employed, such as tabby or twill. The construction of the loom encourages creativity and personal ways of operating. Our assumption is that weaving was well-planned. By this we mean that planning and preparing of weaving as well as the selection of equipment was done consciously. Furthermore, that the weaver was experienced and knew what decisions should be taken in order to facilitate optimal production of textiles and to reach a desired result.

Figure 10a. The warp threads are hanging vertically and are evenly distributed.

Figure 10b. The warp threads are slanting outwards.

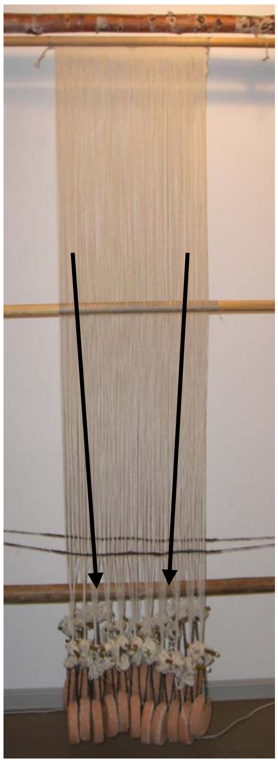

Figure 10c. The warp threads are slanting inwards.

The distribution of warp threads depends on the weight and the thickness of the loom weights. The experiments demonstrate that there is no advantage in attaching more than 30 threads to one loom weight. If more threads are attached, it will create problems during the set up and weaving, thereby affecting the final product. On the other hand, if just a couple of threads are attached to one loom weight, considerably more loom weights will be needed, thus also creating problems.

The weaving tests have confirmed that if the weaver wants to produce an open fabric using thick yarn, (s)he would have to choose heavy and thicker loom weights; if (s)he wants to weave a coarse and dense fabric, (s)he would have to choose heavy but thinner loom weights. On the other hand, if (s)he wanted to produce an open fabric or a weft faced fabric using thin yarn, (s)he would have to choose light and thick loom weights. Finally, if (s)he would like to weave a dense fabric using fine yarn with many threads per cm, she would prefer light and thin loom weights (Mårtensson *et al.* 2007a; Mårtensson *et al.* 2007b; Mårtensson *et.al.* 2009).

In conclusion, recording weight and maximum thickness of loom weights and combining this data with the results of experimental weaving, makes it possible to suggest the kind of textiles that could have been produced with a given yarn quality.

FROM LOOM WEIGHT RESEARCH TO INTERPRETATIONS OF FABRICS.

In this report, we will give some examples of what types of fabric could have been produced with your recorded loom weights. Based on the calculations we have made an evaluation of what we interpret as the most likely choice of tool in relation to fabric. Please note that these suggestions are based on our experience and experiments but are on the other hand conjectural as to what is optimal.

With the loom weights from your site, we have made an assessment of the various types of loom setups and possible resulting fabrics, dividing them into the *TTTC choice*, *Possible*, and *Unlikely*.

- The *TTTC choice* means that 5-30 warp threads per loom weight would be the most functional choice for an optimal production

- *Possible* means that 30-40 or 4 warp threads per loom weight could be possible but not optimal. More than 30 warp threads will create problems during the set up and during weaving. Too many warp threads on one loom weight will make it difficult to distribute the warp threads evenly in the fabric. Less than 4 warp threads per loom weight require very many loom weights in the set up, and here the thickness becomes essential in that consequently only thin loom weights can be accommodated in a row corresponding to the total width of the fabric. Although such scenarios are possible, they remain impractical and hence not optimal.

- *Unlikely* means that attaching more than 40 or less than 4 warp threads to one single loom weight is not functional and even counterproductive; we consider these setups unlikely on a loom.

We will show the results in tables and you will also find a calculation of the fabric, which we consider the most likely to produce with the specific loom weights. We have based our calculations on a warp length of 2 m and a width of 1 m. There is also an estimate of how many loom weights and how many metres of yarn would be needed for such a loom setup. The calculations will illustrate the specific textile production on the site.

However, please note that several loom weights could be used for various types of fabrics and that consequently there can be more than just one *TTTC choice.*

The example below is not based on any archaeological loom weight, but demonstrates how the calculations are made. There is also an estimate of how many loom weights and how many metres of yarn would be needed for such a loom setup. The calculations will illustrate the specific textile production on the site.

To elucidate our interpretation of loom weights and our suggestions of TTTC choice of tools for a fabric you will find an example below.

The following is our interpretation of the fabrics resulting from the use of a loom weight with a weight of 150g and a thickness of 20 mm. The example demonstrates how such a loom weight functions with various types of warp yarn. The weight of the 150g loom weight defines how many warp threads can be attached to it.

If a thread requires 10g warp tension (A), the weaver must attach 15 threads to each loom weight. On the other hand, if a warp thread requires 30g tension (C), the weaver can only attach 5 warp threads to each loom weight.

The loom weight has a thickness of 20 mm. In case A, the 15 warp threads from the loom weight in the front layer and the 15 warp threads from the back layer must be packed in the space of 20 mm. The result is a dense fabric with 15 warp threads per cm. In case C, the 5 warp threads in the front layer and the 5 warp threads in the back layer will be packed in the space of 20 mm. The result is an open weave with 5 warp threads per cm.

Loom weight TTTC-XXX: weight 150g, thickness 20 mm				
	A	B	C	D
Warp threads requiring	10g warp tension	20g warp tension	30g warp tension	40g warp tension
Numbers of warp threads per loom weight	15	7.5	5	3
Numbers of warp threads per two loom weight (one in front layer, one in back layer)	30	15	10	6
Warp threads per cm	15	7.5	5	3
TTTCs' evaluation of suitability of the tool	TTTC choice	TTTC choice	TTTC choice	Unlikely

Figure 11. Calculations of loom setups with a loom weight weighing 150g and with a thickness of 20 mm.

As suggested in figure 11 this type of loom weight is suitable when weaving with thin yarn requiring little tension. Both a warp thread with 10g tension (A) and 20g tension (B) would function well but the fabric with the 20g tension will become more open (or weft faced). If the warp thread of 30g tension (C) is used, the weaver can just attach 5 warp threads per loom weight and the fabric will become quite open (or weft faced). Finally, if the weaver chooses a thread with a 40g (D) warp tension, (s)he can only attach 3-4 threads per loom weight and the fabric will be very open. In case D it would have been much easier to choose a heavier and thicker loom weight.

If we focus on the best choice A, we can hypothesise the following loom setup:

Loom setup (calculated on 10g warp tension)

Starting border (width of the fabric): 100 cm

Number of loom weights needed: 100

Numbers of warp threads: 1500 threads, 2 m each = 3000 m

Weft 1: if a balanced tabby = 3000 m

Weft 2: if a weft faced tabby = 6000 m

Total amount of yarn with weft 1 (+ 2%) = 6120 m

Total amount of yarn with weft 2 (+2%) = 9180 m

It is possible to calculate the necessary yarn for producing specific fabrics. The required amount of yarn depends on the number of threads per square cm.

The calculations are all based on a fabric with a length of 2 m and a width of 1 m. If the fabric contains 15 warp threads and 15 weft threads per cm, 3000 m warp threads and 3000 m weft threads is needed, in total 6000 m. However if it is weft faced, the double amount of weft thread is needed, in thus a total 9000 m

A tabby is the result of two thread systems crossing each other at right angels. Even if both the warp and weft threads are taut, the threads will never be fully stretched or lie completely straight since they cross over and under each other. Furthermore, it is not technically possible to weave the last part of the warp, meaning that there will always be some waste warp yarn. For these reasons, one has to add approximately 2-5% more yarn when calculating the need of yarn for one setup. In our calculations, we have chosen to add 2% more yarn for the calculated setups.

The never-ending work with textile production

The time needed to spin a specific amount of yarn is difficult to calculate and it depends on a variety of parameters such as the spinner's skill, the quality of the fibres, and the tool. The TTTC experiments demonstrated that our two technical technicians spun a similar length of wool yarn when using identical tools and fibres. Furthermore, they spun at a similar speed. In average they spun:

- 35 m yarn per hour when spinning with a 4g spindle whorl,
- 40 m yarn per hour when spinning with an 8g spindle whorl, and
- 50 m yarn when spinning with an 18g spindle whorl.

To this the time for sorting wool and preparation of fibres must be added.

The example above (A) demonstrates the substantial requirements of yarn. According to the TTTC experiments, the production of thread for a balanced tabby would take approximately 175 hours to spin on a 4g spindle whorl, and 262 hours to spin the thread on a 4g spindle whorl for a weft faced tabby (Mårtensson *et al.* 2006a; 2006c).

No time study of the weaving process was conducted in the TTTC experiments but earlier experiments state that about 70 cm could be woven per day on a warp weighted loom (Anne Batzer pers.com.). To this must be added time for setting up the loom and for finishing.

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