The Becoming of Boats. Craft Practices in Southern Norwegian boatbuilding (1050 – 1700 CE)

Excerpt from thesis (Chapter 3) to explain the categorisation of the data table.

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Chapter 3. Material and Method.

Definitions of the properties selected for systematisation

Introduction

This excerpt from the thesis only contains the first section, as it is meant as a substrate to understand the categorisation of the data in the binary matrix table. To refer to this text:

Falck, T. (2024). *The Becoming of Boats. Craft Practices in Southern Norwegian Boatbuilding (1050—1700 CE)* [Doctoral thesis. Stockholm Studies in Archaeology 86.]. Stockholm University.

This chapter is divided into two main parts:

- The first section presents the selection of variables used to systematise the archaeological boats and ships in this thesis. This systematisation was designed for application in a multivariate statistical analysis (MCA). It provides definitions of key concepts and connects them to the Viken material.
- The second section delves into the statistical method, presenting and evaluating the results. This section is not to be found here, but in the main document (Falck 2024).

As underlined elsewhere, the choice of properties is not arbitrary but of significant importance. It is based on the system Bill applied in his analysis of Danish material (Bill 1997, 2009). Because his systematisation was structured to include material from the Viking period, issues concerning biases will be examined and commented on. Also, the material in this thesis comprises vessels from the 17th century, meaning that some features typical of early modern shipbuilding must be addressed. This mainly concerns the larger carvel-built ships dating from the 1600s. They fit less well into the scheme developed by Bill, and their role in the results is minor. My primary interest is the lapstrake-built vessels, meaning I have not gone further to try to make the systematisation work for the larger, early

modern ships. This is a methodical issue to be aware of when assessing the results, underscoring the importance of the chosen properties.

There are 112 vessels in the analysis, systematised on 64 properties (Appendix I – IV). The properties are systematised in 11 categories, meaning that the features are organised to belong to specific functions in the vessel's construction. Aspects like the century of building, (exact) building date, the provenance of timber, and overall length are recorded, but are not activated in the statistics. This applies to the main building methods as well.

Main building method

The category 'main building method' consists of three practices: lapstrake, carvel, and carvel_lapstrake. It is important to note that the statistical analysis was conducted treating the main building methods as both active and passive variables. In the final analysis, it was treated as passive. Carvel_lapstrake refers to vessels constructed with a flush-laid bottom and overlapping planks on the sides of the hull, a typical feature in the construction of medieval cogs, as discussed earlier. Some lapstrake-built vessels also feature an outer layer of carvel planking (double-planked, converted). These are recorded as both lapstrake and carvel, and are represented as double-planked in Figure 9.

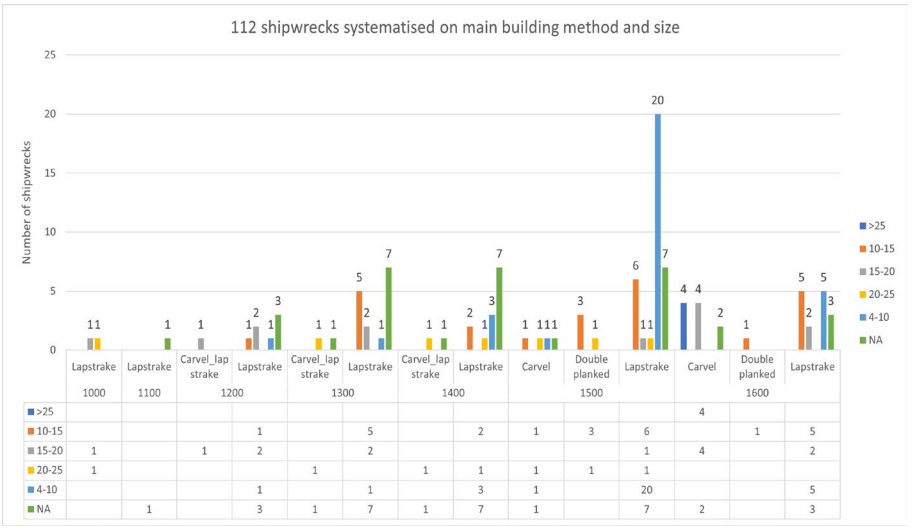


Figure 1 Main building methods of 112 vessels sorted on overall size and date. 88 finds are registered as lapstrake-built and 14 as carvel-built. Five vessels have a flush-laid bottom and lapstrake-built sides (cog-like vessels). Five vessels are sorted in the group 'double planked'. One of these is an anomaly, a lapstrake-built vessel with strakes laid as a 'lock panel' above the waterline (Barcode 5).

This rough division already produces an overview of the material in the dataset. Concerning size, one option is to use sorting based on a continuous range of values into intervals, like Ravn has done (Ravn 2016, 14) (Table 1) (see Figure 10). This system is only helpful to a certain degree, and its reductive outcome will be commented on below. The diagram shows that the material from the 1500s is dominant (43); most frequent amongst these are the small lapstrake-built vessels of 4 – 10 m in length (boats) (20). This is 17.9 % of the total. The vessels measuring 10 – 15 m are also common (small ships), with eight from the 1500s and seven from the 1600s, including the double-planked vessel. Small ships from the 1300s are also worth noting as a distinct category (five). The distribution illustrates well the choice of focus in this thesis. I will use the neutral term *vessel* when not considering type or size.

Table 1 Designations based on vessel length. Based on Ravn 2016, 14.

Length (in metres)	**Type**
<10	Boat
10–14	Small ship
14–20	Medium-sized ship
>20	Large ship

Some qualities in the material might be lost using this system. The distinction between boats, small ships, and medium-sized ships is more complex than the metric divisions suggest. It is difficult to argue that the 7.6-metre-long vessel, Barcode 6 (Planke & Stålegård, 2014), is significantly different from the contemporary 10-metre-long Barcode 8 (Grue & Vangstad 2023) or the 11–12-metre-long Bispevika 16 (Rodum in prep.) in terms of main construction, propulsion, and function. All three are lapstrake-built, open vessels with two masts differing primarily in size and cargo capacity. However, examining the details, we see they also contain individual particularities. They are not technically identical. When analysing the size categories, it seems coherent to classify small vessels with oars as their primary means of propulsion as boats. Other divisions might also be worth considering. For instance, the size of the crew needed to operate a vessel is a relevant factor. Although there is a risk of imposing modern perspectives on the medieval and early modern context, the practicalities of managing a vessel using a small crew may have influenced the choice of vessel size. Also, size categories look different in terms of perspective. In Karel Vlierman's recent work on cogs, he operates with large cogs, typically of over 20 m, and small cogs between 11–17 m (Vlierman 2021, 26ff).

Some concepts related to shipbuilding practices should be introduced, including *shell first*, *skeleton first*, and *bottom-based* construction. Frederick M. Hocker describes the shell-skeleton dichotomy as 'perhaps one of the most influential

theoretical ideas to emerge from the study of ancient ships in the last half century' (Hocker 2004, 65). However, he also highlights the limitations of this simplistic classification, as many vessels do not easily or convincingly fit into either the shell or skeleton category. These concepts are more complex than can be fully explored in this section. Broadly speaking, shell-first construction is associated with lapstrake (or clinker) building, while skeleton first refers to carvel building. Bottom-based construction adds further nuance to these distinctions, offering a more accurate connection to actual building practices.

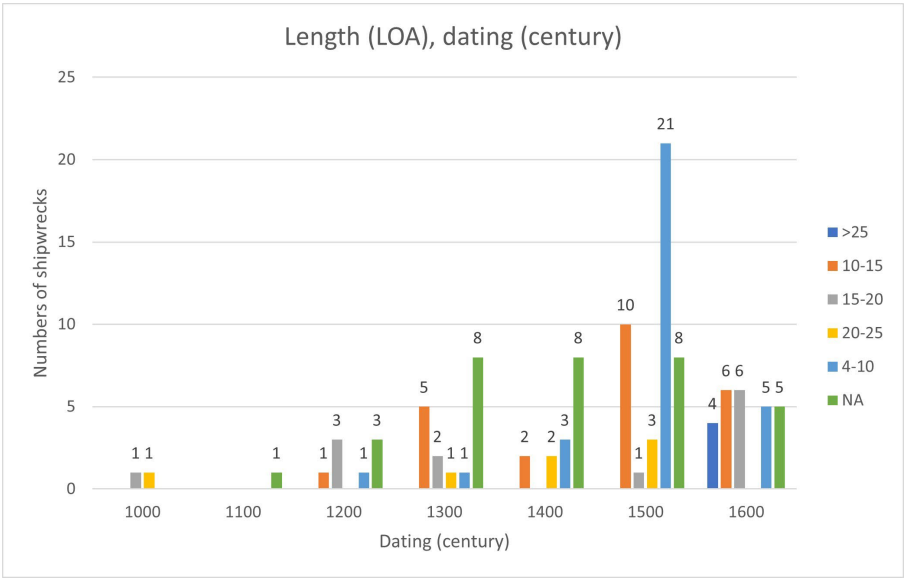


Figure 2 Overall length of shipwrecks in the dataset sorted on dating by century. Continuous range of values into intervals: 4–10 m, 10–15 m, 15–20 m, 20–25 m >25 m. Not available data is shown in the diagram.

This is why J. Richard Steffy's definition of skeletal construction is 'A modern (sometimes misleading) term used to describe the procedure in which hulls were constructed by first erecting frames and then attaching the outer skin of planking to them' (Steffy 2011, 1146). Hocker points out that it is more accurate to adjust the concepts slightly and talk about shell-*based* or skeleton-*based* rather than shell- or skeleton-*first* (Hocker 2004b, 6).

In a *lapstrake-built* vessel, the individual shaping and assembling of planks are the procedures that create the hull shape and, therefore, much of the technical performance of the vessel. This means that the structural timbers (frames in particular) play a strengthening role in the construction. This defines the *shell first* (or *shell based*) principle (Adams 2013, 213; Hasslöf 1970, 43, 48). The definition of the opposite technique, the *skeleton based*, implies that a set of keyframes define the hull's shape, of which the *flush-laid* strakes are mounted to create a watertight structure. Already, Hasslöf, via his ethnological approach (1970, 59ff), pointed

out the shortcomings of a template-like presentation of the two techniques. He refers to vessels with flush-laid planking built in a shell-first manner, and shipbuilders applying both lapstrake and carvel techniques in the same ship, often called half carvels (also see Eriksson 2010) Hocker (Hocker 1991, iii) (Hocker, 2004a; 1991, iii) has shown that the tradition of bottom-built crafts dominates in North-Western Europe, back to the Roman period. This means that in the early sequence of the building, the bottom planks are temporally fastened to each other without the aid of frame stations (keyframes). Not until the bottom is shaped are the temporary fastenings replaced by floor timbers, and the sides completed. In the medieval period, this is how the cogs were constructed, and later, this is also how the early carvel-built ships in Northern Europe were built, comprising of what Maarlevelt (2013) has discussed under the concept of Dutch flush building. In his 1991 thesis, Hocker claims that the Dutch continued to build cogs, but eliminated the overlaps (between planks) (Hocker 1991, 174). This Dutch (north) manner of building is also described in contemporary sources, in Nicolaes Witsen's elaborate treatise from the last half of the 1600s (Witsen 1690, 168, first published in 1671, see Hoving 2012; Maarleveld 2013). It differs conceptually from a method where a set of keyframes followed the erection of the keel and stem/stern, which is associated with shipbuilding in France and England.

I will not go deeper into this discussion here; I will only point out that this reminds us how the manner of building boats and ships are connected across vast areas and over time, but should be understood in their specific context and practice. When Åke Classen Rålamb depicts clinker-building practices on a Swedish shipyard in the late 1600s (Rålamb 1943) (Figure 68), he shows a shell-first situation of assembling planks, using clamps to keep the planking temporarily together. This feature is normally connected to Dutch flush carvel building in archaeological research (for example Maarleveld 2013). Again, this illustrates that building cargo vessels in Northern Europe in the medieval and early modern period belongs to an 'international' domain, with local variations and adaptations considered. In a Danish context, this applies from circa 1350, according to Bill (Bill 2009, 430). This is not to claim that boatbuilding practices were not connected over vast areas before, but it points towards an understanding of this as accelerating. The following sections provide definitions of the applied variables.

Lapstrake

Lapstrake building is the assembling technique for strakes, where the planks overlap, creating a stepped surface. It is often termed *clinker building*, which is descriptive, but that conceals the fact that the assembling of overlapping planks comprises different methods concerning the element that holds them together. 'Clinker refers to the securing of metal fastening by deforming the end so it cannot work loose or pull out' (Adams 2013, 208). This connotation makes the term lapstrake a more precise concept. The operational chain is defined as a shell-

based building technique, meaning that the shaping of the hull is primarily done via the planking.

The different assembling techniques are defined in a separate category called 'Joining of strakes' (below), where the main divisions are between rivets with roves, (double)hooked nails (or twice-bent nails), and treenails. A fourth known method is sewing, which is not present in the material and will not be dealt with here (see Cederlund 1978). Figure 9 shows that the lapstrake and shell-based building method dominates the Norwegian material.

Carvel (and second carvel layer)

As indicated earlier, the carvel building technique is considered conceptually different to the lapstrake building method. The strakes do not overlap but are arranged edge to edge, creating a *flush* surface. The Oxford Handbook of Maritime Archaeology defines carvel building as 'planked so that the seams are smooth, or aligned, as opposed to clinker-built' (Steffy 2011, 1114). The term is believed to derive from the Portuguese caravelle. According to Richard Unger (Unger 1995, 47), the caravelle appears in mid-thirteenth-century documents as a coastal fishing boat, but became a generic term due to its wide use. The conceptual confusion increased with the use of the term carvel or karveel in Northern Europe (Adams 2013, 207). The *skeleton-first* (or *frame-first*) principle implies that pre-modelled frames are attached to the keel, stem and stern, and strakes are added edge to edge. The frames are then the prime creator of the shape of the hull. That said, it is more correct to claim that frames determine the shape of some of the hull and limit the choices of the rest. This was commented on above by introducing the terms shell-based or skeleton-based to add nuance. This is an important note that was already argued by Olof Hasslöf, but that tends to disappear when presenting the techniques on an introductory level.

Variations in the performance are also connected to regional shipbuilding. The method of Dutch flush building implies that the builders, after erecting the keel and stems, build the bottom without attaching keyframes. This is done using temporary clamps, or cleats, to hold the planks together before the floor timbers are adjusted and positioned (Maarleveld 1992, 164). The use of cleats in Dutch shipbuilding is described in books from the late 17th century by Nicolaes Witsen (Witsen 1690, 168 (plan), see Hoving 2012; Maarleveld 2013). This process can be detected archaeologically by the identification of 'spijkerpennen', which are holes in the hull that, after the removal of the cleats, have been refilled with wooden pegs (to make it watertight) (in relation to cogs: Hocker 1991, 125, 2004a, 77). The Dutch flush method is not, conceptually, radically different from the lapstrake, shell-based, building in its use of the planks as the primary shaping of the hull. Systematisation done for the dataset does not divide between these variations within carvel construction. Maarleveld suggests that the situation in the Baltic and Scandinavian countries is similar to that of the Dutch tradition. This seems plausible regarding the two early carvel-built ships from Oslo, the

Bispevika 8 (circa 1557–1558 CE) (Fawsitt et al., 2024) and the Paléhaven 1 (1636 – 1643 CE) (Borvik et al. 2015). Both vessels are part of the dataset. In Hendrik Lettany's revised research on the Dutch-built Scheurrak SO1, he points out the notable presence of an early-built Dutch flush vessel in Norway, built with Southern Norwegian oak timber (Lettany 2024, 180).

The mention of the large merchantman Scheurrak SO1 (circa 1580 CE) is also relevant here for another reason. It is an example of the presence in the Dutch material of applying a double layer of planking, often called double Dutch (Maarleveld 1992, 166, Lettany 2024). In the dataset, double layering is present with vessels where a lapstrake hull has been added to an outer layer of flush-laid planking (Bispevika 16, Bispevika 19, and Masthamnen 3). Also, two examples of hulls with a more randomly added sheeting are recorded (Bispevika 4 and Masthamnen 2). They are both in the early stages of reporting, meaning that not all details are yet fully described (Grue & Vangstad In prep.; Gutehall 2022)(Grue and Vangstad in prep.; Gutehall 2022). These 'hybrid' techniques also raise questions concerning the operational chain. One such fundamental question is whether this results from an original manner of building, or conversions done in the vessel's lifetime. This will be more thoroughly discussed in Chapter 4, meaning I will leave it here.

A rare technique is the use of what has creatively been named 'lock panel' (Eriksson 2004, 14ff), coined after its similarities with standard planking techniques in house building (also Hansson & Sundberg 2014, 40; von Arbin, 2015, 14). This means that the upper part of the hull is assembled like planking in a house wall, where planks are alternating every second on the inside and outside of each other. Supposedly, this phenomenon occurs in attempts to make the hulls higher, as interpreted in the upper part of the hull in Barcode 5 (late 1500s, early 1600s) (Steen In prep.). The findings in the above-listed sources (Eriksson, Hansson & Sundberg, von Arbin) are all from the 1700s and later, making Barcode 5 an early example of this technique. This feature (lock panel) is not defined as a property in the investigation, but Barcode 5 is identified as having this feature. The mixing of features and techniques will play an essential role in the discussions in this thesis, and will be presented more thoroughly later. The Barcode 5 is interpreted as a converted (modified) vessel.

Carvel lapstrake

This particular method of building ships in the medieval period combines the two main assembling techniques. They are typically built to a sharp angle at both ends, and almost flat amidships. The mid-bottom is flush-laid (carvel), while the sides are lapstrake-built, most commonly assembled using double-hooked nails. The building technique is typical in cogs, usually constructed bottom-based/shell-based. Since the precise definition of a cog is debated, and most of the material in the dataset contains limited information, it will be handled as a

feature that primarily represents something distinct from the method of lapstrake or carvel building.

There are few cases of this technique in the Norwegian material, and including Western Swedish (Bohuslän) data has been very useful. The Dyngö (1233 – 1240 CE) (von Arbin 2022) and Mollösund (1356 CE) (von Arbin & Daly 2012) cogs are well documented, and valuable as early comparative material for medieval and early modern lapstrake-built vessels. Also, the Skeppstad vessel in the dataset (from Kville in Jorefjord) could be constructed in this manner. Still, the lack of a documented bottom makes it difficult to be confident (von Arbin 2011). It is dated from the second half of the 13th century, on continental oak (the Ardennes) (von Arbin & Carlsson, 2021, 18; also von Arbin, 2024). From the Norwegian side, the Ny-Hellesund wreck (circa 1450 CE) was excavated in the mid-1980s (Nævestad 1999, 188ff). The ship has never been reconstructed, but the use of a flush-laid bottom and lapstrake-built sides is well established. It is fully documented on foil in 1:1, making a potential reconstruction within reach. Also, the much lesser-known Leirviken vessel (1400s – 1600s) is worth mentioning, as the bottom planks are flush-laid with wooden pegs put sideways into the planks (Teisen, 1992; Nævestad 1999, 188). More than anything, this reminds of the use of mortise-and-tenon, known from Mediterranean shipbuilding, and reckoned an uncommon feature in a North European context.

Confirmed building phases

The vessels with confirmed building phases are also grouped within the category of *main building methods*. While this is essential information about a vessel's biography and function, and helps contextualise the building methods, it is not considered valid data in the statistics. This is mainly because identifying building phases can assert many different things. It is also very dependent on the level of documentation of the vessel, which varies significantly. However, the observations will be important when discussing the results, and have implications for the theoretical aspects of building, modification, rebuilding and maintaining vessels. Also, the social and technical significance of the converted lapstrake-built vessels is relevant, as this shows the knowledge of both lapstrake and carvel practice in the same vessel.

The most common modification is applying additional strakes to increase a vessel's height (and volume). Also, there are examples of the prolongation of vessels. This might be defined as a rebuild, since it will dramatically change the vessel. Another modification, though rare, is adding a transom in a vessel formerly pointed at both ends. The well-documented, fully reconstructed Barcode 6 boat (a. 1596 CE) is an example of this feature in the dataset (Falck 2014; Falck et al. 2014).

Techniques of conversion

This category defines the primary methods for converting a log into a plank. Its importance touches upon qualitative and processual factors of building. It concerns the quality of the planks relating to building techniques, an understanding of the wood's materiality, and the processes of procurement and pre-producing of the timbers (see Ravn 2016, 25ff on the procurement and production concerning Viking ships).

The conversion techniques can be identified by a visual inspection of the cut section and the grain structure on the surface of the plank (Figure 11) (see Rich et al., 2017). The planks show either a radially or tangentially cut section. A radial section shows that the timber has been cut into halves, quarters and eights (even sixteenths) to produce planks. The centre of the timber (pith) will be found along one edge, while the softwood will be along the other (ideally speaking). Tangentially cut planks are cut lengthwise (instead of halves) and produce planks from different parts of the timber log. Some will be from the core, while others will be from the outer parts.

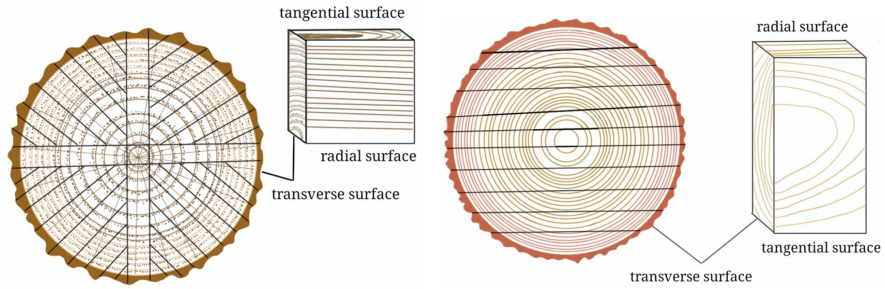


Figure 3 Schematic diagram showing radial conversion of oak and tangential conversion of coniferous wood. After Sara Rich 2017, 19–20.

When documenting boat timbers, it is essential to be aware that tangentially cut planks can be prepared with wedges and axes and by saw. To help identify the techniques, one can look for tool marks on the surface of the planks. Saw marks can indicate that the log has been tangentially converted, either with a water-powered saw or other hand-driven saws (frame saw/pit saw/hand saw). Identification is further complicated by the use of saws to remove excess wood from both radially and tangentially cleft planks. While the difference between saw marks from a hand saw and a water-powered saw can be easy to divide, other types of saw marks are more difficult to distinguish.

An observation of ceiling planks from vessels from the 16th and 17th centuries, often made from pine and only a little prepared before being used in the boat, is that they tend to have undisputable marks after the blade from the water-

powered saw. The marks are straight and occur with a regular pattern and distance, patterns that are rarely this clear in planks used as strakes. The two cases in this thesis, the Bispevika 16 and the Portørenga boat, are both illustrative examples of the use of a saw when preparing the planks. The secondary layer of carvel planking in the Bispevika 16 shows clear marks of the use of the water-powered saw, while the marks on the lapstrake planking are more vague. In Portørenga, the lapstrake planking has very clear marks of a water-powered saw (Figure 65). When systematising whether it has used sawn or cleft timbers, it is vital to know that these techniques are often combined for rational reasons. Shaping the bottom planks with an axe to create the desired hull shape is not a practice that disappears when the more efficient water-powered saw is introduced. This means that a combination of techniques is used to reach specific qualities in one and the same vessel.

Planks radially split

Englert (2015, 306) defines radially cleft timbers as 'components produced by splitting the log along the medullary rays, producing wedge-sectioned pieces of great strength and stability'. Even though the cleaving of timber (for planks) is only one of many stages in preparing the wood for building, it is defined as a property in the statistics for mainly two reasons. As suggested in the definition above, it impacts the planks' quality. Secondly, it is a feature that can be identified by visually inspecting the timbers, making it suitable for the analysis (Figure 11, Figure 12).

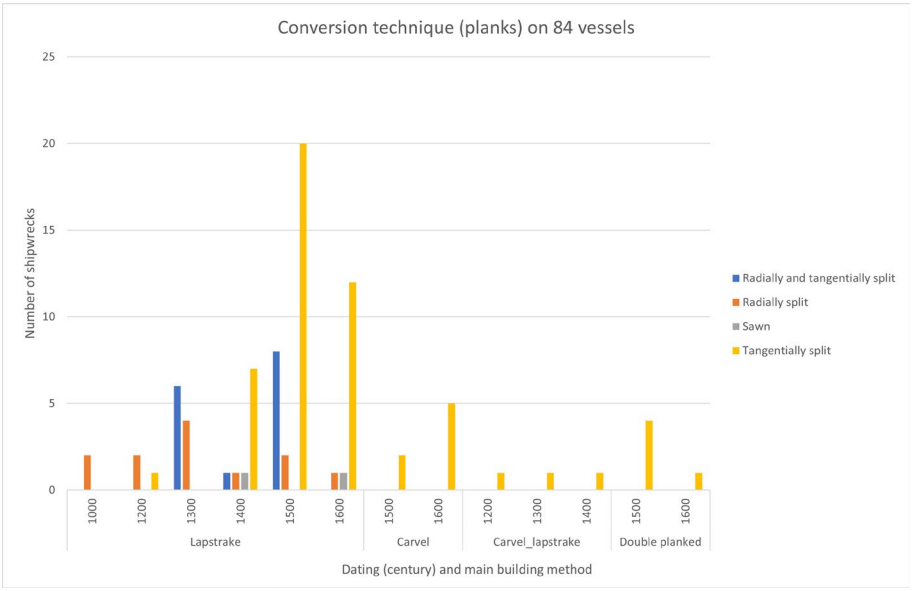


Figure 4 Diagram shows vessels sorted by main building method against observations of plank conversion. The data is from 84 of the 112 wrecks in the investigation. It does not show NA data.

In Viking Age boatbuilding, plank strength is vital, as thin planks in flexible hulls are assembled in short scarfs without lips (flush scarfs) (Ravn, 2016, 26). But as the material from the medieval and even early modern period shows, the use of radially cleft timbers continues long after the strengthening of the hull is apprehended by other means than primarily in the shell construction. The bulky Barcode 8 vessel (a. 1595 CE) is an excellent example (Grue & Vangstad 2023). It contains many 'modern features' (for example, double-hooked nails and a transom), but the strakes are mainly from radially cleft timbers). In the documentation report, Christian Rodum states that only the sheer strake is tangentially cut, which also has clear marks from the use of a handsaw (Rodum In prep.). The strakes are otherwise shaped mainly by the use of an axe. Variation can be evident within the same vessel, and raises questions about the boatbuilders' preferences, differences in traditions and practices, and material provision. Sometimes, the different uses within the same vessel can be related to repairs and building phases; in other cases, they cannot. There is evidence to show that radially and tangentially converted timbers have been combined in the original building. A source of error here is our ability to identify the different conversion methods when interpreting the wood, and to what degree the identification has been done systematically in the cataloguing process.

Planks tangentially split

Englert (2015, 308) defines tangentially converted (cleft) timbers as 'components produced by splitting the log in half and splitting or hewing off the round sides to produce a small number of wide planks'. The definition is connected to medieval shipbuilding. A problem with using this feature as a property in the statistics arises because identifying the sections as tangential (as opposed to radial) does not distinguish between the process of cleaving or sawing. In many cases, the dressing of the plank will remove traces of saw marks, leaving the identification of the section as the sole clue to categorisation between tangentially cleft or sawn timbers. In other cases, decomposition in the surface due to post-depositional processes will have the same effect. Sometimes, the conversion method are identified solely based on information in the dendrochronological report. Therefore, the division between radial and tangential conversion is not valid for defining the conversion techniques alone. This is also why identifying saw marks is important when cataloguing and describing archaeological timbers. A fair concern is that (tangentially) cleft and sawn timber have different properties. When it is not systematised as such, it is because of the lack of evidence to do this with necessary stringency.

Planks sawn

As mentioned, saw marks on a plank can help identify the conversion and timber reduction method that has been applied. The bulk of the material in this thesis is from the 16th century, which implies that it was built after the introduction of the water-powered saw in Scandinavia. Much of the timber from the late medieval and early modern periods has saw marks. While the marks from the use of a water-powered saw are often easily distinguished, the use of other types of saw (frame saw/pit saw/hand saw) is more complicated. The use of a saw is registered in the dataset, but there are issues concerning the cause of the saw marks. It should be used with caution.

Joining of strakes

Ole Crumlin-Pedersen has held up the fastening of strakes as a particularly useful tool to study regional variations in shipbuilding (Crumlin-Pedersen 1991, 70). This category consists of five properties, all describing techniques of assembling planks in lapstrake-built vessels. It concerns how overlapping planks are held together with rivets (with roves), (double)hooked nails or treenails (Figure 13). Regarding using iron nails/spikes, it also divides between square and round shanks. This division is not very useful for the analysis, as the round nails are nearly absent in the material analysed. Several researchers have confirmed this to be a feature connected to the Nordic clinker tradition in the Viking Age (Bill 1994, 1997, 35; Ravn, 2016a, 21). The rationale and social aspects relating to this change are interesting, making it worthwhile to describe the techniques, despite the minor use of round shanks in the material.

The level of preservation should be commented on. In most shipfinds deposited on the seabed, the iron is decayed. The shape of the nail holes interprets the section of the nail shanks. This presents an almost opposite situation to vessel remains found in graves, where the timber is (most often) deteriorated, only leaving the nails or corroded remains of the nails (see Kimball et al. 2024 for a method to document a grave context based on its rivets). If iron is used, the production of iron and the craft of smithing are of great importance in understanding the operational chain. As for the sail and rigging, the iron constitutes a considerable cost and labour effort. It is also a specialised skill. Bill underlines these objects' (strictly) functional character and how function influences their morphology (Bill 1994, 55). While this is true, it is also important to keep in mind that the demand from the boatbuilder and the social and economic circumstances surrounding the relation with the provider, the blacksmiths, have also influenced the fasteners' morphological qualities. These social aspects might be just as important when analysing the chronological changes and local and regional developments in the material as *pure function*. This is also a central part of Bill's explanation of the change *back* to square-shaped shanks, which he connects to the

appearance of feudalism in Europe and even an emblematic Scandinavian acceptance of the European reality in early medieval Scandinavia. These reflections illustrate that the concept of pure or strict function comes short in explaining technical change and variabilities in the material.

In this chapter, the focus is on defining the objects' morphological character for systematisation. Still, mentioning the complex social aspects of making these seemingly mundane objects is worthwhile. Ravn (Ravn 2016b, 35ff) investigated these processes in his analysis of resource management in 11th-century Denmark. He goes through the necessary steps to produce iron for rivets and spikes, from bog ore to finished iron products. Also, he emphasises that the blacksmiths would have chosen different qualities of iron in connection with making tools and other iron objects, which underscores the knowledge and practical application of this in producing iron objects (Ravn 2016b, 37). While Ravn is discussing this from a Danish perspective, boatbuilders in Eastern Norway and Western Sweden would have been closer to more specialised production sites than the Danish, and metallurgical analysis has also shown that Danish Viking Age communities imported iron in bar form from outside the Danish realm. Metallurgical analysis has also revealed differences in the purity of the iron and the content of phosphorus, which can relate to different performances of the material for various purposes.

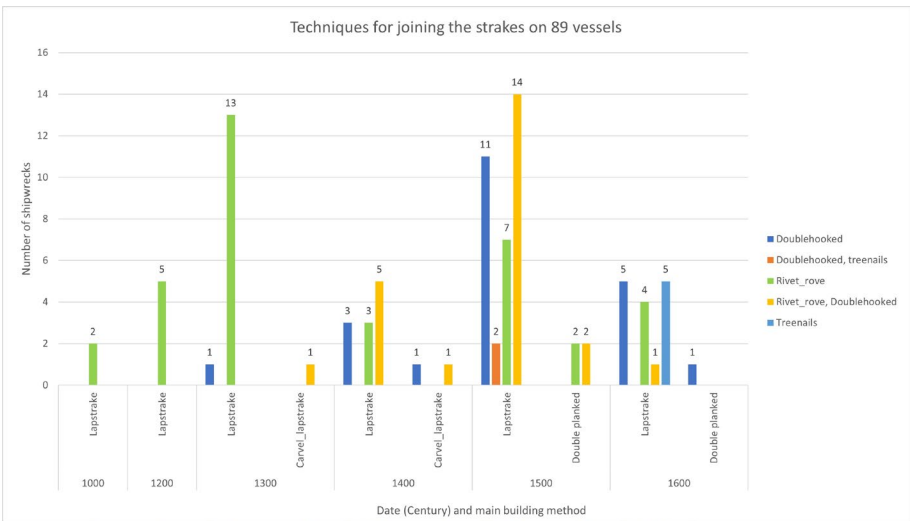


Figure 5 Vessels sorted by main building method and century of building against observations of techniques for joining the strakes (using rivets, doublehooked nails, or treenails). The data is from 89 of the 112 wrecks in the investigation. It does not show NA data.

Round and square rivet shanks

A rivet or spike consists of three structural elements: the head, the shaft and the apex (Bill 1994, 55). This section will discuss the shape of the rivet shanks, despite

the lack of rounded shanks in the material. Round shanks imply that they are made round in the smithing process. Detecting round shanks can pose a problem when interpreting material where the iron is gone. It has been common to drill holes to prevent cracking (using an auger), meaning that all holes had been round before hammering the spike, whatever shape, through the hole. Since the diameter of the spike should be just bigger than the drilled hole (for sealing), it is easy to detect the remains of a square spike, while a more rounded hole can also be caused by wear and tear or post-depositional decomposition.

Regarding the blacksmith's working process, it is crucial to know that all nails are produced squarely and that round shanks mean they have been hammered and shaped during the smithing process (Bill 1997, 35). According to Bill, the change from round to square shanks occurred during the 12th century, which explains why the round-shanked rivets are (close to) absent in the dataset. It was only confirmed on the Klåstad ship, which, together with the Äskekärr, is older than the main material, both dating from around 1000 CE. During the systematisation process, I was not able to confirm the section of the shanks in the Äskekärr ship, but Englert has categorised them as round (Englert 2015, 270). The material in the dataset confirms that the more time-consuming process of making round rivets disappears. Still, in this minuscule technical detail, it is interesting to regard the complexity in the chronological development behind this simplification. Bill has shown that in the early phase of clinker-building (before 500 CE), the shapes of the shanks vary. They are round, multifaceted, and different kinds of square-shaped (Bill 1994, 57). In the following period, the round shanks became more uniformly standard (500 – 1100 CE). After 1100, he identified a pronounced change, where the round shanks disappeared, leaving square-shaped shanks as the dominant practice in Scandinavian and Northern European boatbuilding.

Round shanks are recorded in the Roskilde 7 (1270 CE) (Englert 2015, 72) and Bill points towards the Aber Wrac'h vessel from the 15th century as an exception, which still makes recording this feature worthwhile. This was followed up in his own work (Bill 1997, 2009), confirming the pattern already laid out in his paper from 1994. With reference to Björn Varenius' thesis from 1992 (Varenius 1992), Bill links the use of round shanks in Viking Age vessels to the choice to invest labour and resources to achieve (marginal?) improvements in technical performances. This, again, is related to the ideological function of the ship as an important religious and political symbol that fades in the process of Christianisation (combined with economic changes). While the two authors seem to disagree to some extent on how, why, when and at what speed these changes happen (for example, symbolic versus economic explanations), what is important to consider from a craft perspective is the assumed changes in relations between the blacksmith as the provider of nails, and the stakeholders in the ordering of the ship (client, owner, boatbuilder, and so on). This requires a broad perspective on the crafts, their actors and the resources involved, and the organisation of blacksmithing in towns versus rural areas over time (for instance, Hansen et al., 2015).

It is also unclear *what* the marginally improved performance of a round shank consists of (personal communication, Arne Emil Christensen, 12.12.2022). There might be reasons why the feature was considered important for (Viking period) boatbuilders that we are not able to understand today.

As Gunilla Larsson has shown in her dissertation (Larsson 2007), there is also reason to be aware of the geographical distribution of practices, as she questions that the Swedish finds from the Viking Age have spikes with round shanks. Instead, she connects the material from Sweden to the Eastern area, with the Baltic Sea and the Russian rivers. This is against a western and predominantly Danish and (Southern) Norwegian area.

Another feature not defined as a property in the statistics is barbs and grooves beneath the rivet heads (Ravn 2016a, 225). It is not looked for systematically in the Norwegian material but is a known feature from, for instance, the Bøle ship (1380 CE). It is also known from the Copper Wreck from Gdansk, Poland, from the first half of the 1400s (Ravn 2016a, 226). The reason for preparing rivets with such a feature is not fully explained, but it is yet another craft practice that complicates the production of rivets when it comes to investment in time and equipment.

Rivet rove

Englert (2015, 306) defines the rove as a 'small, pierced metal plate over which the point of a clinker nail is clenched or peened'. As for the nails themselves, the iron has mostly decayed in shipfinds deposited underwater. This means that roves are identified as impressions on the surface of the planks. They can be rhomboids or rectangular/square-shaped. The rivet is usually hammered in from the outside, and the tip is peened over the rove on the inside. This implies that when looking at a singular plank, the impressions of the roves normally tell you this is the upper, inside edge of the plank.

(Double)hooked nails

I have been applying the definitions in Anton Englert's book concerning ships in the early medieval period for the previous properties in this category. When he defines a double bent nail as a 'nail driven through two or more elements, with the point turned back and driven into the wood, typical of cog and other non-Nordic clinker construction' (Englert 2015, 303), it is necessary to comment on his reference to type and geographical distinctions. With the bulk of the dataset being from the late medieval and early modern period, this feature is so common that it can hardly be defined as foreign when assuming the vessels were built locally. That said, it is an example of a feature that most likely has entered the local practices via external influence.

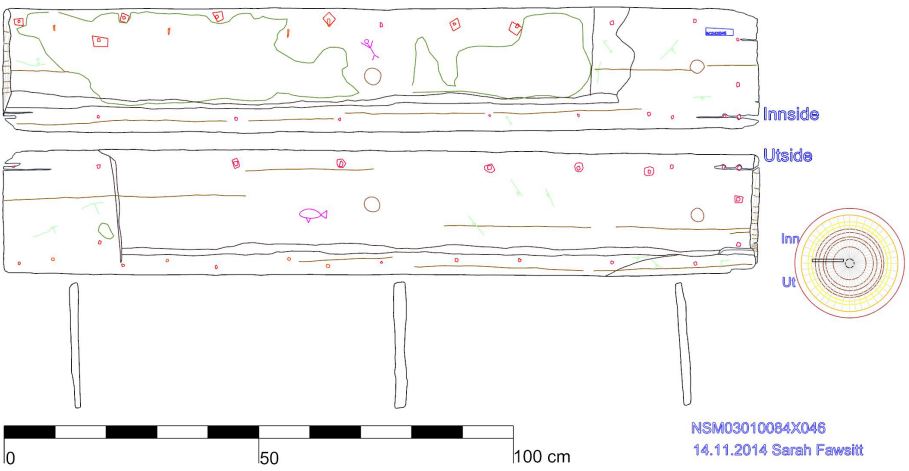


Figure 6 Example of a plank with rivets with roves, and doublehooked nails. The plank is from the Barcode 4 (1572 – 1586 CE), and also shows long scarfs with a lip. The original drawing is by S. Fawsitt, NMM, processed by T. Falck.

I put 'double' in parentheses because there are examples where hooked nails have only been bent back and not secured with the tip hook. This can be considered a less solid fastening. Since this is not documented systematically, all hooked nails are considered the same property for statistical purposes. It is quite a common phenomenon, even if one should be aware that some of its use can be traced to repairs and secondary functions. There are also examples of repairs of vessels originally built with doublehooked nails, using rivets with roves.

Treenails

Treenails for assembling planks are used in seven vessels in the investigation, with the aforementioned Barcode 6 as the earliest (a. 1595 CE) and the Portørenga boat (a. 1660 CE) as the latest. Using treenails implies the production of treenails with heads and wedges. They are typically hammered into drilled holes from the outside, and wedges are inserted from the inside. The wedges expand the treenail and thereby lock inside the hole, just as they do when fastening frames to the strakes. Often, but certainly not always, there is a match between the nail's head and a recess in the hole entrance. This makes the nail heads lay flush with the surface of the plank. Also, the material used varies for both the nails and the wedges. The cost of a total assessment of the wood type of treenails makes it common to do only a few analyses per vessel. This makes the wood type in treenails a not-so-useful category to analyse the choice of resources.

While this feature is considered to belong to traditions originating on the south coast of the Baltic (Crumlin-Pedersen 1991, 71) (9th – 14th centuries), its

presence in the dataset dates to the late 1500s and 16th century. Its presence is interesting, considering the high costs of producing iron rivets for a vessel. Treenails are low-cost resource-wise and require marginal skills to make. However, investigating traditional boatbuilding techniques displays knowledge of material and production that is useful as a reference (Godal 2001, 111).

Waterproofing

The category 'waterproofing' refers to the kind of material the boatbuilders choose to make overlaps between parts watertight. It mainly concerns lands between planks. It is also a significant maintenance feature, often resulting in various techniques being used in the same vessel over time (see Christensen, 1992, 64ff, for a discussion on maintenance on traditional boats). The statistics do not divide original and secondary material. According to J. Richard Steffy, caulk means to drive oakum, moss, animal hair, or other fibrous material into the planking seams 'and cover it with pitch to make the seams watertight' (Steffy 2011, 1115).

Morten Ravn (2016b, 125-126) divides between inlaid versus driven caulking. Christian Rodum (2013, 5) in his master thesis on the caulking techniques in Scandinavian boatbuilding, chose the neutral term 'waterproofing'. Underneath this, various techniques are found, which are valuable in analysing craft practices. For instance, Rodum mentions that Ole Magnus (2005) has suggested that the making of wool threads (no: *sisnor*) for waterproofing has been a way to provide extra income for farmers who had direct access to the raw material (wool from sheep).

Another important archaeological aspect is that waterproofing is an archive for macrofossils and pollen, that has a great potential for revealing information on both the production site and the biography of the vessel. Both plant fibres (mosses and other plants) and animal hair can be analysed using scientific methods to discuss provenance. It must also be considered a technical preference of the craftsperson, although one needs to divide between material accidentally ending up in the caulking and material chosen for its qualities. Rodum is also correct in pointing out that just because animal hair is reckoned to be common in the Viking Age and early medieval boatbuilding, it should not be taken for granted as the only choice. An excellent example of this is the Klåstad ship, which is mentioned as waterproofed using animal hair in Crumlin-Pedersen's book from 1997 (Viking-Age ships and shipbuilding in Hedeby/Haithabu and Schleswig) (Crumlin-Pedersen 1997), while Christensen and Leiro's publication (Christensen & Leiro 1976) does not establish anything about the type of material. A sample analysed in 2011 showed that it was waterproofed using plant material (NMM archive).

The statistical analysis only divides between whether *animal hair* or *plant* material has been used, if the material is *inlaid* (lapstrake), and if *laths* have been

used to secure the stability of the material. The caulking in carvel-built ships, driven between planks, is only captured in the statistics as the absence of inlaid material and the presence of flush-laid planks. Figure 15 shows the distribution in the dataset. It is worth noting the mixed use of fibres in the 1500s.

Caulking hair

As Rodum (2013), with reference to Susan Möller-Wiering (2004), has shown, a detailed analysis of the caulking material in boats demands a much more fine-grained systematisation than the category in this thesis allows for. Even animal hair alone has many more properties than covered in this crude systematisation. Möller-Wiering (2004, 114ff) distinguishes between disorganised fibres, which are accumulations of 'disordered' hair (sheep, goat, and cattle) and strands of hair, which means there are loose finds of (different) hair in the caulking. It can be interesting to look for roots or not in the hair samples, as it potentially tells what kind of product the hair results from (for example, carcass versus cut hair. Even wool harvested from living sheep by pulling it out is reported (personal communication, Fred Hocker 29.05.2024)). The next group is fibre strands, loosely spun strands or rolls of fibres, for instance, in a simple S roll. This group consists mainly of sheep's wool, and seems to be produced for this purpose, un

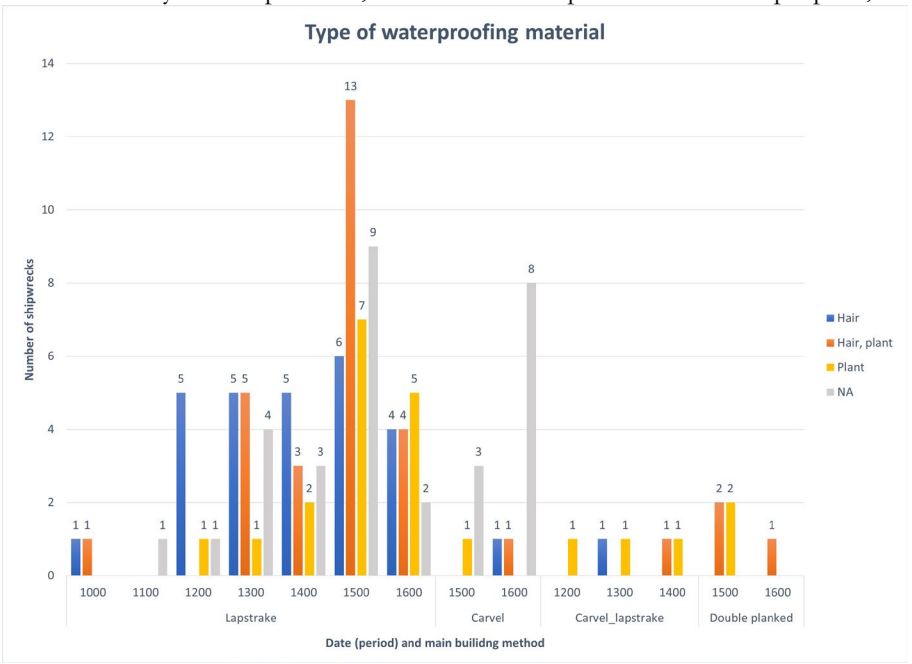


Figure 7 Diagram showing the use of materials for waterproofing (animal or plant fibres) sorted on main building method and century. It also shows data for the not available (NA) information.

like the two previous groups. She refers to the Sjøvollen ship (Christensen 1968, 131, 140) as a medieval and Scandinavian example. The following example is the

use of twine yarn, and SZ spun thread, and she refers to a sample from Halmstad, Sweden, from the 1400s. Möller-Wiering interprets this as secondary material.

The last group is woven and knitted fabrics, also interpreted as secondary uses. They are fabric fragments cut off to be reused as waterproofing in vessels. In addition, Rodum has added two more categories, both processed materials. These are rope and mats/felted material. Ropes are secondary material. Felted mats are wool spread out to cover a larger area and are not spun or woven. An important distinction is where in the boat the waterproofing material is found. For example, woven fabrics are often to be found in repairs. A vital source critical note is made by Möller-Wiering when she addresses the crucial question of what has been published regarding waterproofing material and, at a more fundamental level, what has been documented. Rodum (2013, 17) has organised Müller-Wiering's categories into table form, which is slightly moderated here (Table 2).

Caulking plant

In lapstrake boatbuilding, plant material is used for waterproofing, following the same pattern as animal hair. The plant material can be organised in strands or more randomly applied as fibres mixed with tar. It has been common to denote the preference for using plant fibres in Slavic boatbuilding and Hanseatic cogs (for example, Filipowiak 1994; Vlierman, 1997).

Table 2 Seven types of animal fibres in waterproofing material from archaeological shipfinds, level of pre-processing and primary or secondary use. After Rodum (2013, 17) and Möller-Wiering (2004, 117).

Disorganised fibres	**Strands of hair (loose)**	**Spun strands**	**Felted mats**	**Twine yarn**	**Woven fabrics**	**Ropes**
Not processed		Slightly processed			Fully processed	
Primary				Secondary		

In contrast, the choice of animal hair has been considered Scandinavian (Crumlin-Pedersen 1997, 113-114), but this pattern has chronological and regional variations. Also, the fact that vessels are moving across distances makes it essential to divide between material applied in the process of building (construction phase) and as a result of repairs and maintenance. Different types of mosses have been

preferable over time when using plant material. Also common is the mix of tar and various byproducts from rope or textile making, for example, hemp and flax. This is what is called oakum (Rodum 2013, 35, see definition in Steffy 2011, 1138).

Caulking inlaid

This means that the waterproofing material is placed between planks before assembling them. The concept is used concerning lapstrake-built vessels, where the material (no: *si*) is placed in the overlap (no: *su*), often in a cove (no: *sirand*), before clenching the planks together. Regarding the early modern material in the dataset, it is my impression that the cove is usually missing. Another observation is that waterproofing material is later added (repeatedly) as maintenance by pushing it between and over the meeting planks using tar. According to Bill (Bill, Unpublished manuscript) caulking can also be placed between planks mounted edge to edge (carvel), but this feature is difficult to detect in archaeological material. Instead, the waterproofing in carvel-built vessels is usually driven in between the planks.

Caulking with laths

Englert (2015, 305) defines laths as a 'light batten of wood, laid over the caulking to protect it, and held in place by sewing or iron staples, clamps or sintels'. This definition is suitable for particular lapstrake vessels, but laths are also identified in carvel-built ships. This regards early carvel-built ships in Scandinavia (Eriksson in prep.). The use has been described as a typical feature of cogs (Hocker 1991, 112). It is present in the Dyngö cog (1233 – 1240 CE) and possibly the Mollösund cog (1365 CE) (von Arbin & Daly 2012, 378) found in Bohuslän. It is recognised in the more uncategorised ship Ny-Hellesund (1450 CE), found in the Agder region, but also from other medieval cargo ships (lapstrake-built) like the Bøle ship (1380 CE) (Daly & Nymoen 2008, 156) and the Skjernøysund 3 (1389 CE) (Auer & Maarleveld, 2013).

The use of laths is not common in the bulk of the Norwegian lapstrake-built material from the late medieval and early modern periods. The vessels Bispevika 18 (1567 – 1578 CE) and Bispevika 25 (1421 – 1436 CE) are exceptions (both are unpublished to date) (Figure 16).



Figure 8 The usage of wooden laths above the overlaps between planks on the vessel Bispevika 25, found in Oslo in 2022. Photo: L. B. Kvernberg, NMM.

Bispevika 25 shows a substantial use of laths nailed over the steps of the inside planking. Again, the presence in the Oslo material illustrates the variation that characterises the material, making categorical divisions unwanted. In a Swedish context, it has been documented in early, large, carvel-built warships, like *Mars* (Eriksson & Rönnby 2017, 3) and *Elefanten* (Eriksson in prep.).

Plank joints, scarfs

This category describes the method of joining two plank ends in a strake. Englert (2015, 307) defines a scarf as a joint 'between two long timbers aligned on approximately the same axis'. This definition also includes the joints of other types of timber than planks, which is not embraced in this limited category. Planke and Stålegård (2014, 364) define a scarf as an oblique joint between two plank ends. The statistical category consists of three properties, short and long scarfs, and butt ends. The first two are variations found in lapstrake-built vessels, and the last is the method described as being a defining feature of carvel building (butt ends, end-to-end joints). As with many other properties, they are to be found across these main construction methods. The plank scarfs are normally planned so that the opening between the lands faces aft on the vessel's outside. This prevents water pressure through the scarf opening when the boat moves forward.

The full-scale reconstruction of boats from the medieval and early modern period found in Norway, especially the Barcode 6 (a. 1596 CE), has been beneficial to examining and understanding the methods of joining planks in early modern lapstrake-built vessels (Planke and Stålegård 2014, 363ff). This examination and practical trial show that the technical choices should not be limited to discussing aesthetics or functional rationality. It must be understood as differences in technical choices, made within a conceptual way of thinking around the whole vessel construction.

Flush short scarfs

These scarfs are the overlap between a strake's end edges, accounting for only about 30 % of the plank width. The edges are feather thin (no: *tynnet i null*), creating a flush surface for the two meeting scarfs. While this feature was common in traditional boatbuilding in Norway until recent times (18 – 1900s), it is almost absent in the material for this thesis. An examination of the Sjøvollen material in the storage at the Museum of Cultural History (Oslo) shows that the techniques are more varied than this simple categorisation, meaning that not all scarfs are feather thin or only 30 % of the plank width. As this property is not present in the younger material in the investigation, it is essential to identify and discuss the variation within the second property, the long plank scarfs.

Long plank scarfs

This is the standard property for end joints of planks in the material. It is defined as 'the oblique joint between two plank ends where the two meeting faces have lengths of 50 – 100 % of the standard plank width in the strake' (Bill, Unpublished manuscript). Unlike the flush scarfs, the plank ends are not feather thin but leave a lip or step above the surface (Ravn 2016b, 28). This lip can be of variable thickness. When building the reconstruction of Barcode 6, this technical feature was discussed by the boatbuilders involved (Planke & Stålegård 2014).

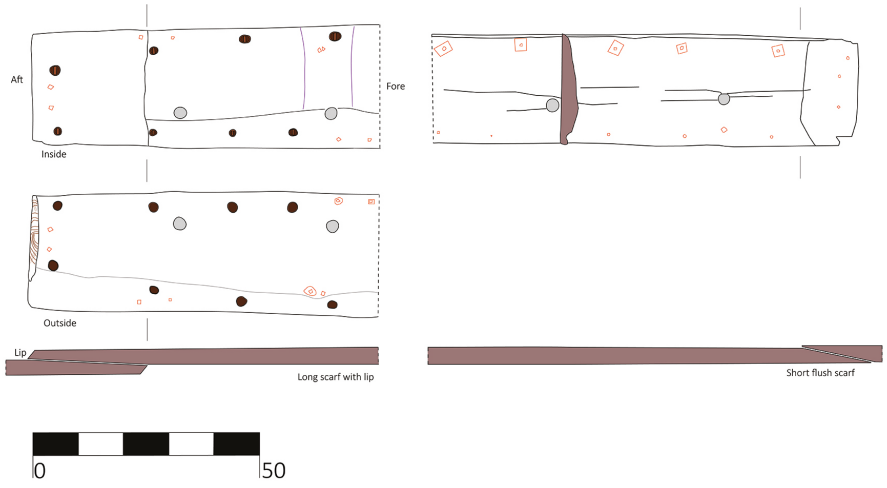


Figure 9 Long plank scarf with a lip to the left and short flush scarf to the right. The illustrations are based on planks from Barcode 6 (a. 1595 CE) and Sjøvollen (1280/90 CE). The sections below are sketched to show the principle. The Barcode 6 is assembled with treenails as (primary) fastening, while the Sjøvollen uses rivets with roves. Illustrations: T. Falck, based on original documentation.

They were trained in traditional (Western) Norwegian boatbuilding and the reconstruction of Viking Age boats, and the manner of making joints with lips is not a familiar feature within any of these practices. They explained that the usual way for them to do it would be to use a plane on all scarfs to create a smooth surface. In Barcode 6, the axe was the standard tool in use, except for some places where the evidence of a scraper (no: *skjøve*) was detected. An axe might make an uneven surface, causing the sealing to be an issue. They did not interpret this as sloppiness on the builders of Barcode 6's behalf, but as a cause of rational considerations within a tradition. It fits within a pattern when regarding it in the more extensive conceptual process of building this vessel. According to them, it showed that when mounting the planks, the fitting of the top edge (no: *å skyte til bordet*) had already been done before fastening it to the lower strake. The lip creates the need to adjust with a notch in the next strake's lower edge, which again causes a gap between the plank ends. They detected a possible use of the lip in the mounting process, concerning the plank's tendency to slip out of the rabbet in the stem. They could use the lip to hammer the plank back in place, a solution impossible with feather-thin plank ends. No identification of damage to the plank ends caused by this procedure has been recorded, though. The lip also strengthens the plank end and may increase its longevity by preventing splitting, damage, or rot.

In a discussion with a boatbuilder trained in Swedish traditional boatbuilding, the quality, technical complexity, and relative time used between making a

short, flush scarf and a long, lipped scarf was questioned (personal communication, Fredrik Leijonhufvud, 13.10.2022). The flush scarf is often taken as a representative of the elegant and technically demanding building of Viking ships. Still, the adjustment towards the next strake with notches can also be considered challenging of skill, as well as time-consuming.

I have referred to this discussion to display how a seemingly small detail, a long plank scarf with a lip, can be put into a more comprehensive building system. It is important to note that the example of Barcode 6 is only one variant of this. It is an important example because it represents techniques quite dominant in the dataset, and well-documented through the reconstruction work of Planke and Stålegård. Bill (1997, 144) places the change from thin and short plank scarfs to long scarfs to around 1200 CE. This date includes other significant technical changes as well. The lack of material from the early medieval period makes it hard to evaluate this in the Norwegian material. Still, it is interesting that the Sjøvollen ship (1280/90 CE) seems to have short, thin scarfs and long(er) scarfs with a lip, amongst other somewhat 'archaic features' (*biti* construction, mast bite, mouldings).

End-to-end joints

The two types of scarfs above are so-called through scarfs, but planks are also joined end to end. This manner of joining planks is typical in carvel-built ships. Examples from the Bispevika 16 (1589 – 1603 CE) and the Paléhaven 1 illustrate the Norwegian material. In the carvel-built Paléhaven 1 (1636 – 1643 CE) (Borvik et al. 2015), the joints of most planks are done with scarfs described as flat scarfs with stopwaters (Steffy 2011, 1128, fig. G11b), or nibbed diagonal scarfs (Lemée 2006, 247) (Figure 18). Exceptions to this are in the first strake on both sides and the third strake on the port side, where the planks are joined with simple butt joints (end-to-end) (Borvik et al. 2015). The outer carvel layer in the lapstrake-built Bispevika 16 (see Chapter 4) shows a similar variation as the later Paléhaven 1.

Considering the material activated in this thesis, the end-to-end joints of planks create an opposition between the carvel and lapstrake technique that commonly apply through scarfs, but it is worth noting that the butt end joints became common in lapstrake building at the latest in the 19th century in the region (see Falck, 2012, 128 for an example from the first half of the 19th century, the BU1).

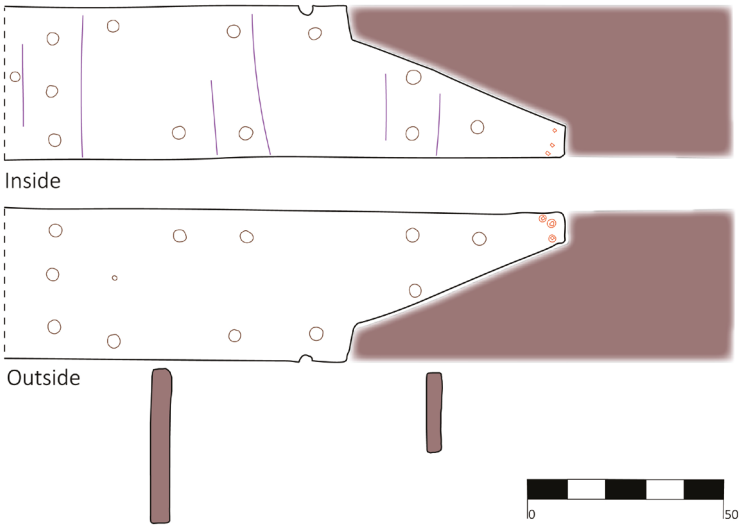


Figure 10 Plank (x69) with a nibbed diagonal scarf from the early 17th-century carvel-built vessel Paléhaven 1. Original drawing by C. Rodum, processed by T. Falck.

Decorative mouldings

Englert (2015, 305) defines mouldings as a 'decorative profile in the edge of a plank or timber, typically made with a shaped scraper, a typical feature of Viking construction'. The mouldings are interesting because they constitute a category that can be interpreted as having a decorative, aesthetic purpose. When used as a line along the seam of the planking, it can also have a practical function as a guide to where to drill the holes for the nails, but the practical usage of this is not settled. In traditional Scandinavian boatbuilding, it is expected to drill the holes for the clinker nails from the inside and out (personal communication, Lars Stålegård, 20.12.2022), which would make the function of a line on the outside less practical.

The dataset shows that mouldings are not a very common property, with only seven confirmed observations (Table 3). The reasons for this are explained chronologically and geographically.

Table 3 Wrecks with observations of mouldings in the dataset. Barcode 9, which was originally interpreted as having mouldings, is withdrawn from the selection based on re-interpretation.

Name	Building date CE	Provenance	Type of moulding	References
Klåstad	1000	NA	Single?	(A. E. Christensen & Leiro 1976)
Tønsberg 1	1260	NA	Single	(Bonde 2009; Molaug 2010)
Sjøvollen	1280	E Denmark, SW-Sweden	Single and multi	(A. E. Christensen 1968; Bonde 2005)
Sørenga 1	1300	S Sweden	Single	(Christensen 1973)
Nordenga 1	1330 – 1340	Poland, Germany	Single and multi	(Paasche et al. 2020)
Barcode 2	1589	W Norway, S Norway, S Sweden	Single	(Fawsitt & Hobberstad 2021; Hobberstad In prep.)
Bj24	After 1625	S Norway	Single	(Falck 2012)

Christensen (1985, 193), in his study of the Bryggen ship fragments, notes that a significant number of the findings exhibit decorative mouldings. This practice continued in Western and Northern Norway until the recent past. This practice is also observed in house timbers and other wooden objects from the medieval period. He categorises the moulding shapes into four distinct groups: 1) a

narrow V-shaped groove, 2) a shallow rounded (U-shaped) groove, 3) a shallow rectangular groove, and 4) a more complex feature, described as a stepped and oblique rectangular groove (Christensen 1985, 196). These grooves can be combined to form various patterns, such as a common type that features a shallow U-shaped groove flanked by two narrow V-grooves (though this pattern is not present in the Bryggen material). Christensen emphasises that this is not merely a Viking Age phenomenon; instead, he argues that the tradition persists through the medieval period and the Renaissance with evolving tools and stylistic preferences. This is even evident in the 19th-century boat BU1, a vessel interpreted as originating from Eastern Norway, mentioned earlier. Christensen is also developing a tentative theory suggesting that the combination of a shallow U-shaped groove flanked by two narrow V-grooves is more prevalent in Eastern Norway. In contrast, the third and fourth types, featuring rectangular grooves, are more common in the West. In his most recent publication, Christensen (2022, 127) illustrated 29 patterns he collected and documented from ships and churches dating from the Viking and medieval periods.

The results of Bill's investigation of Danish material are relevant to the material in this thesis. In his 1997 dissertation (Bill 1997, 144-145), figure 72 gives a good overview of the presence and absence of mouldings. The first two finds in his investigation that appear to have no mouldings are the Skagen and the Kollerup cogs, dated to the 1190s and 1150 CE, respectively. Before the disappearance of mouldings in Danish material, the simplification from multiple to single mouldings seemed to be a parallel running visible pattern. This is in line with Christensen's observations. However, one must remember that mouldings are still present in modern traditional boatbuilding. The 'trajectory' of the presence and absence of mouldings is a telling example of the difficulty of making interpretations based on teleological understandings of technical changes and regional differences.

This makes it appealing to investigate the types of decorative mouldings found in the material and how these can be linked to dating, provenance, and other details of the vessels. There are only three confirmed examples of the use of multiprofiles. These examples are the Klåstad ship (circa 1000 CE) (A. E. Christensen & Leiro 1976), the Sjøvollen ship (1280 CE) (Christensen 1968), and the Nordenga 1 (1330 – 1340 CE) (Brandstrup 2013; Paasche et al. 2020). According to Christensen, the Klåstad ship features a U-shaped cove flanked by a single V-shaped groove on each side—a typical profile associated with Eastern Norway. The Sjøvollen ship exhibits a single rectangular groove along the seam line on some planks, with double rectangular grooves on specific frames (Christensen 1968, 143). Christensen interprets the decoration on the frames as evidence of reuse, as the tool used appears to differ from that applied to the planks. A tool was also used to create a shallow U-shaped cove to secure the inlaid caulking, and Christensen notes that a single scraper tool may have served this dual purpose. The Nordenga 1 boat will be discussed below.

Seven finds have affirmed single profiles. The Klåstad and the Sjøvollen already mentioned above, Tønsberg 1 (1260 CE), Sørenga 1 (1300 CE), Nordenga 1 (1330 – 1340 CE), Barcode 2 (1589 CE), and the very fragmented small boat Bj24 (a. 1625 CE). A few fragments of a small ship were found together with Bispevika 20 (a. 1567 CE), which had decorative mouldings. This boat is not included in the dataset because of lack of information. While this pattern confirms the general idea that this has gone from being a common phenomenon (in the Viking Age) to declining, the material hints at a situation that is ambiguous. The findings point to a situation where a few of the older vessels have this property, while only two or three vessels from the bulk of the post-medieval material are represented. The Tønsberg 1 is documented *in situ* and later covered, meaning that not very much detailed knowledge of the design of the vessel is accessible. Still, in Figure 20 in the excavation report (Molaug 2010, 18), mouldings can be seen on sections of two planks that were sawn for dendrochronological dating. On the 6th starboard strake, the groove can be interpreted as a singular streak, *possibly* rectangular, and placed along the lower edge outside. The nails are placed in the groove.

The Nordenga 1 has also been documented *in situ*. The excavation report discusses decorative mouldings (Paasche et al. 2020, 27ff). It is placed along the seam line on the outside of the strakes and some planks on the inside. It appears like the same tool has been used to make the decorative groove (1.3 cm x 0.2 cm) as the cove for the caulking. On one of the loose planks, probably belonging to the top strakes on the starboard side, and on lower strakes belonging in the aft of the vessel, a multi-profile with a round cove with a v-shaped groove on each side was documented. Regarding Sørenga 1, Christensen (1973, 104) describes the decorative mouldings as décor scraped along the edge of *all* materials.

The next find identified as having decorative mouldings is the complex Barcode 2, dating from the late 16th century (Hobberstad in prep.; see also Fawsitt and Hobberstad 2021). This ship is bigger, has one deck, and has faced extensive modification. The modification is interesting, changing from a pine hull to a mainly oak-built construction. I do not have the opportunity to go into any detail, but some features are essential for the decorative mouldings. Firstly, there are only decorative mouldings in the pine part of the ship, meaning in the original bottom construction. These strakes date back to circa 1589 CE, with a provenance from the northwest coast of Norway (Kirchhefer 2015). The later, oak-built upper part does not have any décor, and the provenance of the timber is from Eastern Norway and Southern Sweden (Daly 2010). The modification is interpreted as taking place shortly after the first building phase. Moreover, the groove on the pine plank is not placed on the lower outside edge of the plank but along the top edge on the inside, where the roves are placed systematically along the line. This placing of the mouldings argues against any decorative function at all. The grooves will be hidden in the bottom of the boat, covered by frames and ceiling planks. This makes it more likely that the groove has a practical function: possibly to aid the boatbuilders in determining where to place the nails

along the edge of the plank. Regarding Stålegårds suggestion, that the drilling of holes for the seam is done from the inside out, it could have had this practical function in this particular vessel. The last boat in the investigation with decorative moulding is the Bj26, represented by one plank with two simple and parallel grooves. This boat is not very suitable for drawing many conclusions. It will not be used here to claim any traditional use of this feature in small boats in the Oslo region in the first half of the 17th century, but as the BU1 mentioned above, the feature is also present in a boat from the first half of the 19th century.

I have spent some time on the mouldings because, unlike other features, it might have an aesthetic value. What is clear from this review is that even though the general trend is a decrease in the use of mouldings from the Viking age through the medieval period, the phenomenon also occurs in the later material. Also, the Danish material seems to follow a different trajectory from the Norwegian concerning this feature. As for other features, this more aesthetic type cannot be structured in a clear regional or chronological order, at least not a simple, straightforward one.

Framing distance

The category 'framing distance' is grouped into seven intervals, all based on average distances between floor timbers using metric data. These are *Less than 35 cm, 35 – 44 cm, 45 – 54 cm, 55 – 64 cm, 65 – 74 cm, 75 – 84 cm,* and *more than 84 cm.* The distances are measured from centre to centre of the floor timbers, but leave out the often-occurring, more lengthy distances at the ends of the vessel, as Bill also did (Bill 2009). Even in poorly preserved vessels, the distance between frames is often possible to reconstruct, making it a valuable category for statistical purposes. In many cases, it can be measured without intact floor timbers, by identifying the nail holes or pressure marks from the frames in planks. The spacing between the frames impacts a vessel's strength, flexibility, and weight, and the tendency of narrower spacing is linked to developing specialised cargo carriers. Technically, it is also linked to changes in the *biti* system.

One problem with this category concerns its consistency when using it on lapstrake-built vessels *and* large carvel-built ships from the early modern period. The large ships are often full-framed, so the frames are positioned at close intervals. The size of the frames will make the distance seem wider than it is when measuring the distances from centre to centre. This source of error should be considered when creating and interpreting the statistics and underlining what has been pointed out earlier, concerning the properties that are less fitting on the carvel-built ships. I have chosen to define all full-framed vessels as having the shortest distance between frames, meaning less than 35 cm.

Transverse-strengthening techniques

This category is diverse and complex. Many of its properties are defined to capture the essential changes in building techniques in the early and high medieval period.

The *biti* construction

Englert (2015, 302) defines the *biti* as 'the lowest beam in a framing unit, directly above the heads of each of the floor timbers and fastened to the sides by standing knees'. It is a common component in 'traditional Nordic construction', and more specifically in Viking ships. Looking at the dataset, it confirms the picture. The property is present in the two late Viking age finds (Äskekärr and Klåstad), and in the high medieval vessels Tønsberg 1 (1260 CE), Sjøvollen (1280 CE), and the Sørenga 1 (circa 1300). These cases seem to be the youngest that can confirm the presence of *biti* construction in the material from the Viken and Skagerrak regions. In Barcode 8 (a. 1595 CE) (Rodum, In prep.; Grue & Vangstad 2023) and Barcode 14 (1574 CE) (Fawsitt, In prep.), singular floor timbers with transverse beams above are recorded. This is similar to the *biti* construction, but their rare presence might suggest that they are a solution to accommodate the access to suitable frame timber (personal communication, Christian Rodum and Sarah Fawsitt, 16.08.2024).

In the small boat tradition of Norway's western and northern coast, building with *bitis* was still a common practice in the 19th century. In the south, the *biti* construction is replaced by other transverse strengthening techniques, first and foremost by more scarfed frames, thereby reducing the number of transverse beams. These less frequent beams are constructed as throughbeams, or just fastened to the sides using a vertical knee. A significant advantage of not building with *biti* is the opening up of the hold of the ship, making space for more cargo. Increasing the number of frames would make the hull more robust and less flexible. Bill suggests that the *biti* was an 'optional feature' for shipbuilders concerning medium-sized cargo ships from the mid-eleventh century onwards (Bill 1997, 139).

Grown stanchion and stanchion board

Englert defines a stanchion as a 'turned or carved post supporting a beam' (2015, 307). It works as a rod that locks the position between the keelson and the beam by its weight. In the dataset, it is only confirmed in the Klåstad ship. What is present in several finds is evidence (indirect) of a plank, a board, that has been placed next to the mast, in front of it, as a support for the mast beam. These are the Hundevika (Figure 21) (Teisen 1994), Teigen, Nordenga 1, Sørenga 1, Sørenga 2, and Bispevika 2. While the Teigen find has an inaccurate dating using

the ^{14}C method from 1280 – 1400, most Oslo finds date to the 14th century, except the Bispevika 2, which dates to 1518 CE.

Keelson chock

This property also locks the keelson without direct fasteners (spikes or treenails). Except for the Sjøvollen ship (1280/90 CE), the property is not identified in the dataset (Figure 22). This feature is called a mastbite by Christensen (see discussion in Chapter 5). Later, another related feature is determined, which in Swedish is termed *björner*, but also supporting buttresses in English (Rönnby & Adams 2002).

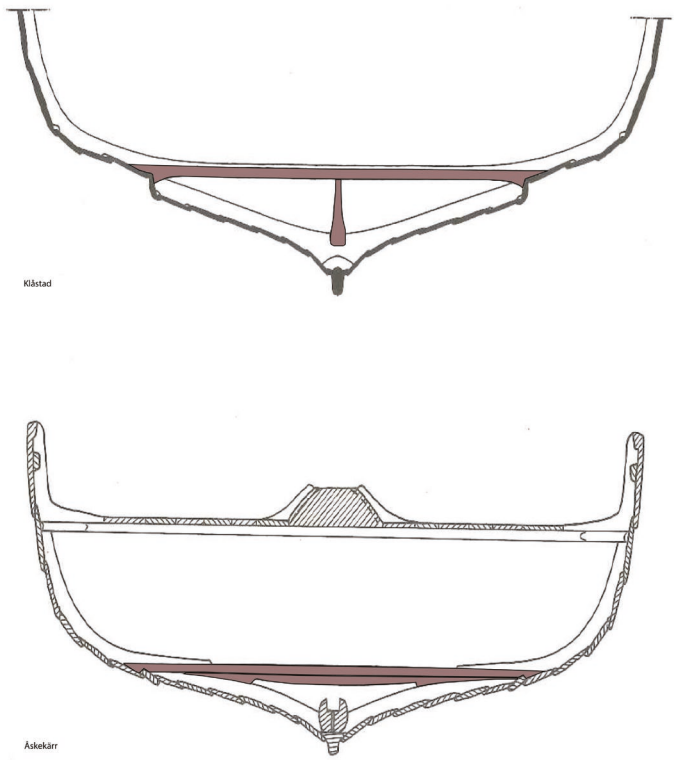


Figure 11 Reconstructions of the Klåstad ship and the Äskekärr ship (according to Christensen and Leiro), with the biti (lowest beam) enhanced. Also, notice the 'snelle', the stanchion/rod, between the biti and the floor timber on the Klåstad ship. Both illustrations from Crumlin-Pedersen 1997, 295. Processed by T. Falck.

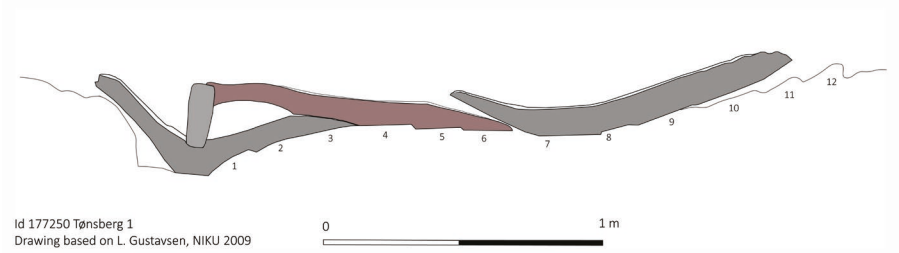


Figure 12 The biti beam (2F) documented in situ on the Tønsberg 1 wreck. The beam is possibly broken towards the keelson and only preserved on the vessel's starboard side. Drawing: L. Gustavsen in Molaug 2010, 14. Processed by T. Falck.

These are timbers that are placed above the bottom construction and support the keelson at the mast step (Åkerlund 1951, 52). *Björner* is present in several Scandinavian found vessels and appears in a few of the finds in the dataset. These are, for example, the Hundevika (Figure 21), Skaftö, Dyngö (cog), Skjernøysund 3, Bispevika 2, 3 and 4.

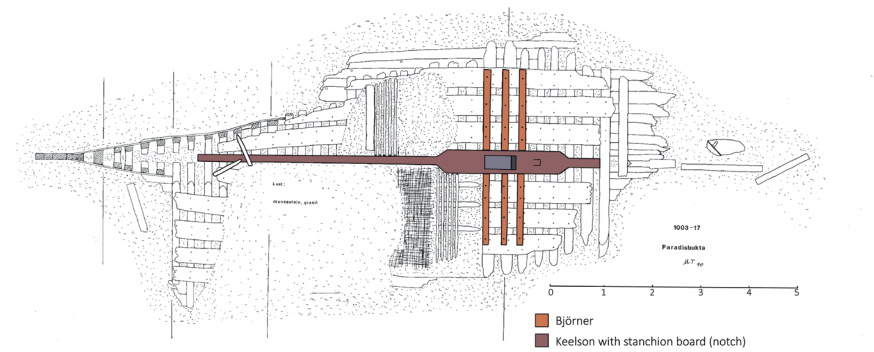


Figure 13 In situ, underwater documentation of the Hundevika wreck (Pardisbukta). The fore is to the right. Drawing by M. Teisen in Teisen 1994, 74. Processed by T. Falck to enhance the keelson with stanchion board and the björner (buttresses).

Other connections between keelson and *biti*

This property is inaccurate but tries to sum up connections other than the above. Since the property is only used in vessels with *biti* construction, it is not very useful for the dataset. For this reason, the property is made passive in the statistics. It is worth noting that in the Tønsberg 1 ship (1260 CE) (Molaug 2010), the keelson is indirectly fastened by the *bitis* that are joggled over it, and this would,

according to Bill's categorisation, belong to the group of other types of indirect fastening systems.

Direct tree or iron nails

This property refers to the fastening arrangements of the keelson directly using primarily wooden pegs and/or iron nails. The practice might affect the ship's potential flexibility (or firmness), but as far as I know, this has not been tested. The indirect methods were presented above as features linked to the *biti* construction. The property is conveyed in the statistics as the absence or presence of direct fastening, and 55 vessels are noted as having this. The actual number is likely much higher, approaching 100% of all vessels that 1) use sails for propulsion and 2) were not constructed with a *biti* system. For this reason, this feature is challenging to work with, primarily because the shift from indirect to direct fastening occurred before the dating of the bulk of the material in the dataset.

This aligns with Bill's observation (Bill 1997, 137), where he notes that of the 12 examples of indirect fastening in his study, 11 date from the 11th and 12th centuries. Interestingly, the most recent vessel in Bill's material displaying this feature is the Bredfjed ship, from the late 1500s (Bill 1997, 83).

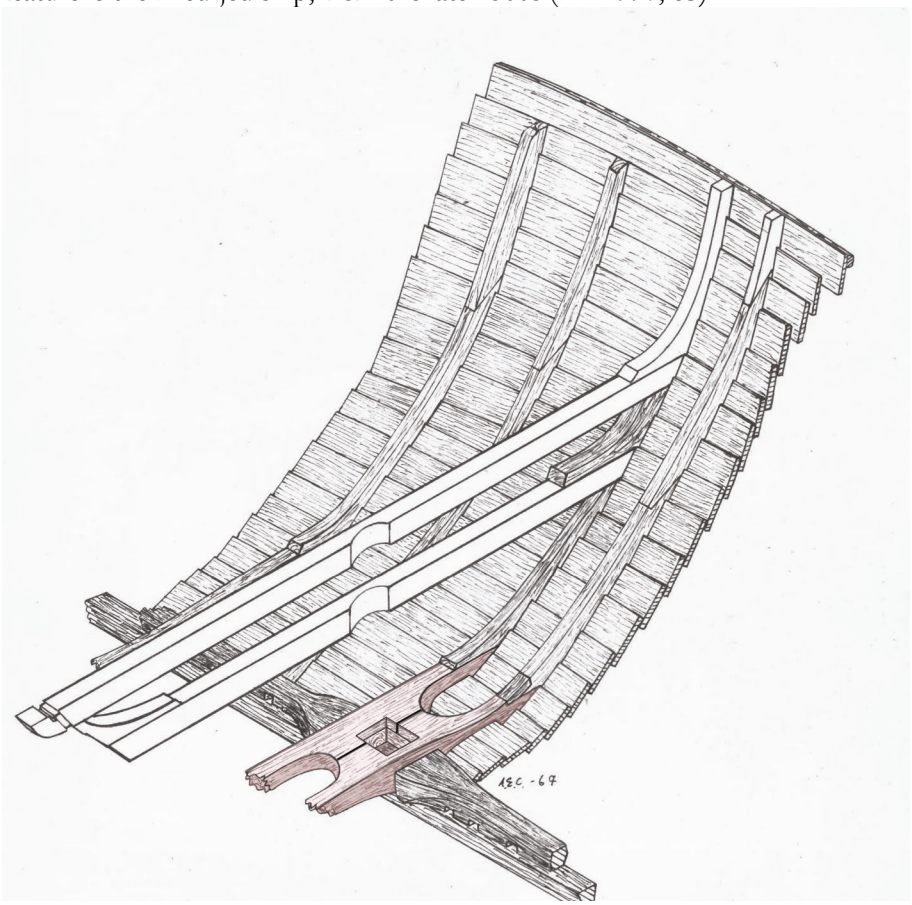


Figure 14 The indirect fastening of the keelson in the Sjøvollen ship, reconstructed by Arne Emil Christensen in 1967 (Christensen 1968). Christensen terms this the masthite. It is a particular construction with two timbers joggled over the keelson at the mast step. The figure also shows the protruding beam head and frame system (scarfed, parallel-sided frames). Drawing processed by T. Falck.

The Bredfjed case makes dismissing the possibility of later findings with indirect fastening techniques difficult. Consequently, many observations are recorded as 'not available' data, though it is highly probable that they employed direct fastening. In the statistics, other vessels marked as *not* having direct fastening lack a keelson altogether, indicating they are rowing boats.

Scarfed frames, parallel-sided

This describes how the frames, composed of several elements, are joined together using scarf joints. It represented the 'new way of doing things' when *biti* construction was no longer a common practice in the region. This method is simpler and, as mentioned earlier, creates a more open hull, providing greater space for cargo. The fact that the frames have parallel sides means that the different parts of the frame stations (typically the floor timber, futtock, and top timber) are constructed with even, parallel sides that are carefully adjusted to fit one another. In the dataset, this characteristic has proven to be redundant. Its definition contrasts with a method known as wing-shaped frames, which involves an elegant and complex shaping process, particularly of the floor timbers. These timbers feature a tall, narrow section over the keel that broadens and flattens, eventually tapering towards the ends of the arms, finishing in a wedge shape. According to Englert (Englert 2015, 72 cf. Bill unpublished), the latest certain evidence of this feature in the Danish material is the Roskilde 5 (1130 CE). It is interesting as a property because it is an example of the elaborate work put into (some) vessels from the Viking era that later was not practised.

Protruding beamheads (throughbeams)

This property concerns the practice of constructing the beams (crossbeams and bitt beams) with the ends through the ship's sides, a feature named 'headbeams' by Christensen (Christensen 1985) and throughbeams elsewhere (for example, F. (Hocker, 2004a). The throughbeams have recesses on the underside fitting the futtocks (or top timbers). While it is common in cogs, lapstrake-built vessels also share the feature. The supposedly oldest documented vessel containing this feature is the Danish-built Kolding cog, dating to 1189 CE (Englert 2015, 269). Together with the Kollerup cog (1150 CE), these are the oldest cog finds dated. Also, it is a documented attribute of some early carvel-built ships in the Baltic (Eriksson et al. 2024, 6).

Concerning the use in lapstrake-built vessels, Bill suggests it to be a device to meet the specific problem of building ships with a high hull, but certainly one

that came into use in an extensive range of vessels (Bill 1997, 139). Christensen already made this point in his publication on the finds from Bryggen in Bergen (Christensen 1985, 200). Amongst other stray finds of beams, the Big Ship, dating from 1179 CE, exhibited this feature (Christensen 1985, 187). Christensen assumed it to be a Scandinavian invention, maybe deriving from tie-beams used in corner-timbered and stave-built houses. It is interesting, particularly regarding the influence the building of large ships in Scandinavia in the early medieval period might have had on constructing cog-like vessels on the continent (Crumlin-Pedersen, 2000, 241). When Åkerlund wrote his book on the findings from Kalmar, he emphasised protruding beams as an unknown and odd phenomenon, but added that this might be caused by the lack of findings from the medieval period to date (Åkerlund 1951, 39). He turned out to be correct. He also discussed that the protruding beamheads create a vulnerable point in the hull in the case of interference with other ships or quays. For this reason, they are often protected by beamhead guides or fairings (Vlierman, 2021b, 578ff, 827 in relation to cogs). Åkerlund also made another observation connected to the protruding beamheads. He suggested that this manner of doing the transverse strengthening of the hull also influenced the process of planning the shell construction. At least for the bigger ships, the frames had to be placed before finishing the strakes (Åkerlund 1951, 135). This suggests that the shell-first or frame-first principle was negotiable and performed with varied practices, as pointed out earlier.

In the material included in this investigation, 11 findings are confirmed as having throughbeams (Table 4). I am confident that more cases are hidden in the non-available data. The earliest in the dataset are the Skeppstad (1260 CE) and Sjøvollen (1280/90 CE), while the latter are the Skaftö (1437 – 1439 CE), the Bispevika 25 (1421-36 CE), as well as the Ny-Hellesund (circa 1450 CE). The Skeppstad and Ny-Hellesund are considered cog-like vessels. In the Oslo material (in addition to Bispevika 25), it is present in the Sørenga 2 (1355 CE) and 3 (1320 CE), Bispevika 28 (a. 1327 CE), Nordenga 1 (1330 – 1340 CE) and Barcode 17 (a. 1353 CE). The 15th-century Bispevika 25 was earlier mentioned because of the use of laths. It might also have a transom, but this will have to be left unanswered here. If this is the case, it will be unusually early. All vessels are cargo vessels, from ships of around 12 m to larger ships of more than 20 m. When the Sjøvollen ship was constructed using throughbeams, this technique was already used for over 100 years.

Table 4 Shipfinds in the dataset built using throughbeams (protruding beamheads).

Name	**Building date CE**	**Provenance, timber**	**Cog or lapstrake**	**Reference**
Skeppstad	1260	Ardennes	Cog	(von Arbin 2011)

Name	Building date CE	Provenance, timber	Cog or lapstrake	Reference
Sjøvollen	1280/90	E Denmark, SW-Sweden	Lapstrake	(A. E. Christensen 1968; Bonde 2005; Daly Daly 2024)
Sørenga 3	1320	W or S Sweden	Lapstrake	1994; Paasche et al. 1995)
Nordenga 1	1330 – 1340	Poland/Germany	Lapstrake	(Brandstrup 2013; Paasche et al. 2020)
Bispevika 28	After 1327	W or S Sweden	Lapstrake	(Daly 2023b)
Barcode 17	After 1353	Poland	Lapstrake	(Daly 2013, 2016; Wickler & Falck 2020)
Sørenga 2	1355	Scania/Øland/Denmark (islands)	Lapstrake	(Eriksen 1994; Nævdal 2001)
Bøle	1380	Poland	Lapstrake	(Daly & Nymoen, 2008; Nymoen, 2005)
Ny-Hellesund	Circa 1450	NA	Cog?	(Nævestad 1999)
Bispevika 25	1421 – 1436 (prelim.)	NA	Lapstrake	(Daly, 2023)
Skaftö	1437 – 1439	C Poland, E Poland	Lapstrake	(Krapiec 2007; von Arbin 2010)

Side timbers

The use of side timbers refers to the practice of increasing the transverse strengthening of the hull by placing standalone frames between the ship's main frame stations. It does not play a significant role in the further analysis, though 12 vessels are recognised as having side timbers.

Horizontal knees and vertical knees/buttresses/keelson riders

The use of knees is generally poorly documented in the material. This makes this property statistically weak and is, for that reason, not activated in the statistical analysis. I have decided to make it passive before running it for the statistics.

Longitudinal strengthening techniques

The longitudinal elements of a vessel consist of the keel, keelson, stringers, stem and stern. The planking is also a significant part of the vessel's strength and is discussed elsewhere. The statistical category does not include the planking but the other important structural features. Together and separately, they play an essential role in the strength and in preventing sagging and other structural damages of the hull, caused by the impact of the movements in water combined with, for instance, heavy cargo. Bill (1997, 136) underlines the role of the plank-built shell in creating strength, particularly in lapstrake-built vessels. Here, the conversion method of planks, the length and thickness of planks, the number of scarfs, and the thickness and wood quality matter.

Plank keel

A plank keel has a rectangular section and a height less than 75 % of its maximum width (Bill, unpublished manuscript). Englert has suggested less than twice the thickness of the garboard (Englert 2015, 304), and adds that a keel with these qualities will not contribute significantly to longitudinal strength or resistance to leeway. Bill adds that the plank may have a rebate for the garboard strake, but without reducing the width of the bottom of the keel. The available material appears consistent in that the vessels holding this feature are the larger, medieval and 'foreign-built' trading vessels, cogs and other lapstrake-built cargo carriers. It is present in the Mollösunds cog (1365 CE) and the Skaftö wreck (1436 – 1439 CE) on the Swedish side of the border, and the Bøleboen (1380 CE), Selør 2 (1265 – 1385 CE), Skjernøysund 3 (1389 CE), Ny-Hellesund (1450 CE) and Svinør 4 (a. 1550 CE) at the Norwegian side. Their provenance varies between the Baltic area, Poland, Germany, and the Netherlands. The Mollösund cog might have timber from the Danish and German regions (von Arbin & Daly, 2012). The two examples of plank keels in Figure 23 are from the Bøle and Ny-Hellesund wrecks, displaying two variations of plank keels.

T-shaped keel

As suggested in the name, the keel's section is like a capital T, a winged shape, with the angle of the surface for the garboard lap of less than 30 degrees off the horizontal plane (Bill, unpublished manuscript). The shape makes the keel and garboard strake together, creating a flat-bottomed structure, unlike Y-shaped or U-shaped keel constructions that allow for a sharper bottom. The T-shaped keels

narrow in the ends to a Y-shape to facilitate the meeting of the garboard strakes against the stem or stern or a *lot*-piece (also called *kri*). A T-shaped keel is present in 34 of the vessels. It is interesting to investigate further the presence of a T-shaped keel concerning other factors such as provenance, dating, and certainly size.

The keels can also vary in shape, having different degrees of a cigar shape lengthwise, which means they are thicker in the middle and taper towards the ends. The early 16th-century Vaterland 1 boat is an excellent example of this feature (Hobberstad 2012; Stanek 2012; Carrasco & Vangstad 2021, 28) with its distinctly broad wings and almost level angle towards the garboard strake. The small boat Bispevika 14 also has this feature (Fawsitt, In prep.) and will be described in more detail in Chapter 4.

Y-shaped keel

The section is shaped as a capital Y. The garboard lap surface is built at an angle of more than 30 degrees off the horizontal plane (Bill, unpublished manuscript). One should be aware that some keels with a less distinct T-shape (opposite of the Vaterland and Bispevika 14 mentioned above) can be defined as a T-keel in the investigation and the literature. This is a source of error that needs to be considered. Only three finds are systematised with a Y-shaped keel in the analysis: the Äskekärr ship (circa 1000 CE), the Bispevika 28 (a. 1327 CE, newly excavated), and the Bispevika 9 (a. 1520 CE). The dating indicates they are spread out in time. The keel shape in the Äskekärr ship is defined as a Y-shape by Humbla (Humbla 1934, 12ff). He is very particular in describing the keel as different from a typical T-shaped keel, and he does this to establish the ship as a functional sailing ship. Also, Englert (2015, 266) defines it as a Y-shaped keel.

U-shaped keel

Bill defines a U-shape as a rectangular or trapezoid section with a height of at least 75 % of its maximum width. Its lower corners may be rounded. The keel may have rebates for the garboard strake, but they do not affect the width at the bottom of the keel (Bill, unpublished manuscript). This keel design is present in the investigation material from the whole period, with 34 cases. The keel beams most often have a rebate to fasten the garboard strake. This rebate has two main construction methods, and can have a more or less elaborate design. The U- and Y-shaped keel differs from the T-keel in that the garboard strakes, to a more significant degree, function as part of the keel construction, in that they together create a sharper bottom. This results in better steering capacity and less drift.

Joggled and plank-shaped stringers

Stringers are longitudinal timbers fastened inside the hull to strengthen the vessel. The investigation separates joggled (#7) and plank-shaped (#22) stringers, the

last being the most common. The joggled stringers have notches matching the frame stations, and are joggled over these. Concerning the difference in strength provided, there is no doubt that the joggled stringers offer more strength, and are also more elaborate to make.

Beam-shaped or plank-shaped keelson

Englert (2015, 304) defines the keelson as a 'centreline timber on top of the frames, distributing the weight of the mast, often a long timber giving increased longitudinal strength and stiffness to the hull'. The difference between a beam- and a plank-shaped keelson goes along the line of to what degree the timber is similar to a plank or a beam, but in some instances, it can be difficult to categorise precisely. The beam-shaped keelson is the most common with 37 cases, against only five plankshaped. This makes it interesting to look at the varieties a bit closer. The Barcode 7 (1586 – 1596 CE) (Skyaasen In prep.) has a plank-shaped keelson, approximately 21 cm sided and 12 cm molded in the thickest part. The total length is unknown. It has shallow notches underneath, adjusted to joggle above the floor timbers. A 12 x 10 cm rectangular hole makes the mast base.

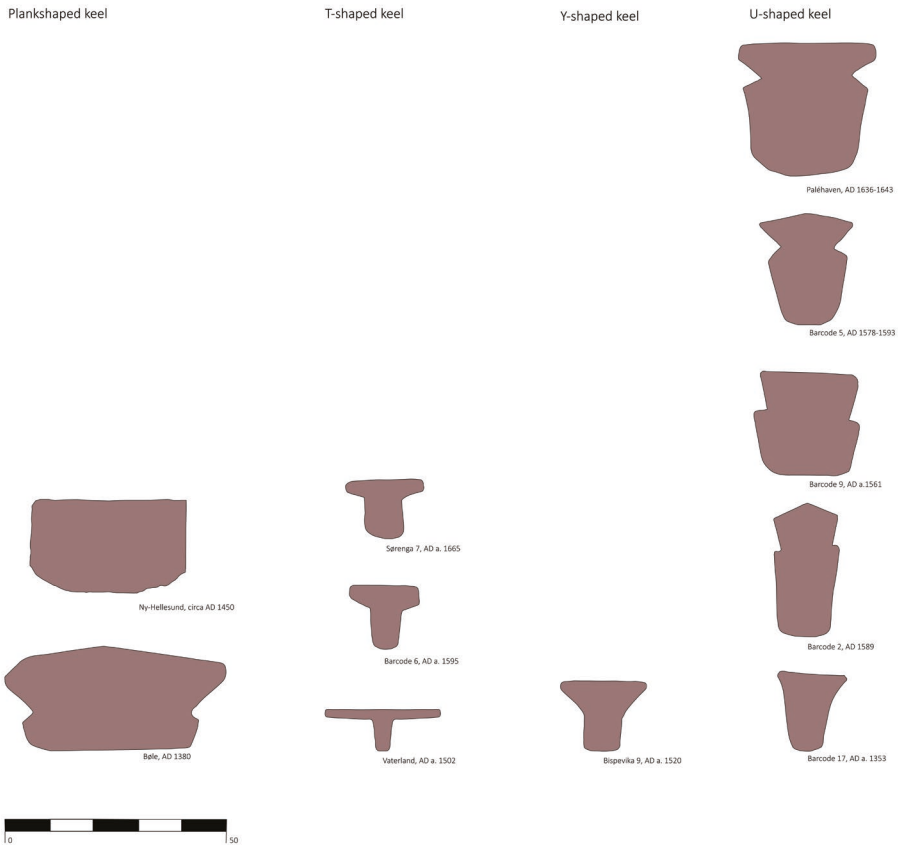


Figure 15 Different shapes of the keels (sections) present in the material. Based on documentation from the archive at NMM. Drawing: T. Falck.

Another similar version of a plank-shaped keelson is from the well-documented Barcode 6 (Planke and Stålegård 2014, a. 1596 CE). The plank is 2.97 m long, 17.5 cm sided, and 3.5 cm molded. In contrast to Barcode 7, it is not joggled over the floor timbers, but just fastened on top using a few treenails (direct fastening). There are some pressure marks on the floor timbers but no cut notches. The base for the mast is an additional rectangular piece fastened on top of the long plank. A similar feature is present in Barcode 3 (1605 – 1618 CE), where the preliminary documentation report suggests that the keelson is part of a secondary building phase, a reuse and/or repair (Rodum In prep.a) (Rodum in prep.a). While the three Barcode finds are from the late 16th and early 17th century, a plank-shaped keelson is also found in the Bispevika 15, dating from the first half of the 16th century. This suggests that it is a practice from at least the 16th century onwards. The beam-shaped keelsons are common throughout the investigation.

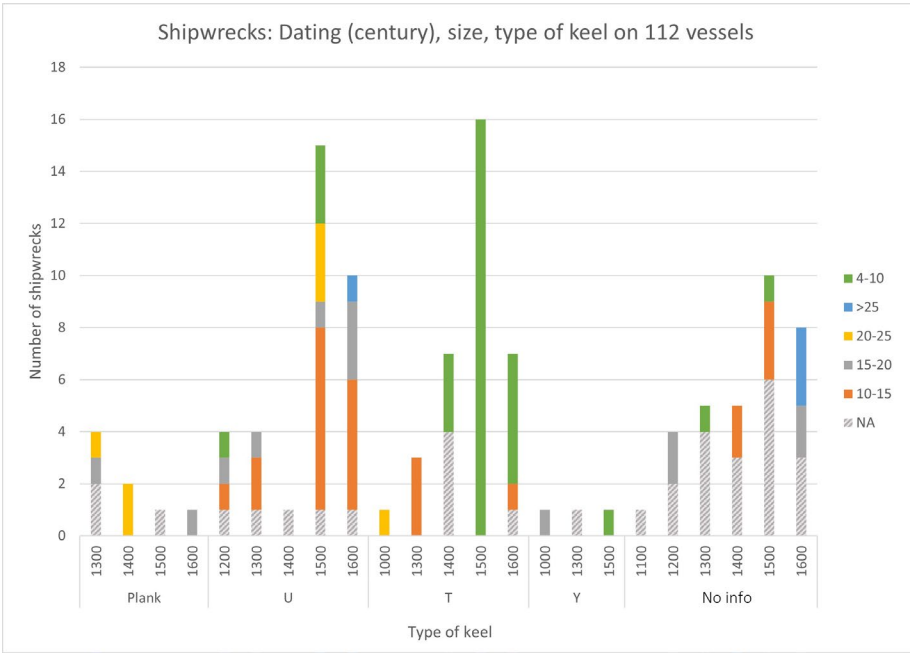


Figure 16 Vessels sorted on keel type, dating and overall length. The keel types are plankshaped, U-shaped, T-shaped and Y-shaped. The diagram also shows not available data (NAs).

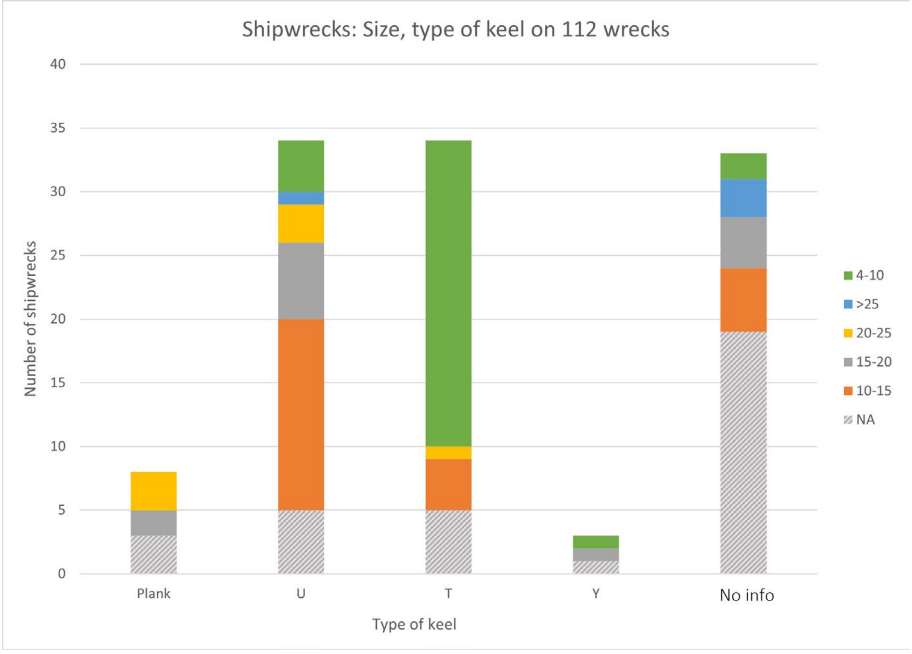


Figure 17 Same information as in the diagram above, without information on date (century).

Keelson joggled over frames or cut into frames

The fact that the keelson is joggled over frames implies that it has notches underneath, adjusted to fit the floor timbers. As discussed above, one plankshaped keelson in the material also had (shallow) notches underneath. For the beam-shaped keelsons, notches seem to be the rule. The joggling creates a sturdy placement of the keelson, a feature that serves the purpose of receiving the great forces from the mast and sail, and adds to the stiffness of the hull structure. The area of the keelson with the mast step is usually more voluminous than the ends, but this shape can vary, from gradually tapering to a more distinct rectangular-shaped feature for the mast step. Attaching the keelson into notches in the frame is a far less common property. It should be added that a high degree of preservation, combined with detailed documentation, is needed to recognise this method. The Bispevika 20 (late 15th century) and Bispevika 4 (1540 CE) are interesting because they are categorised as having both properties. This implies that the keelson is joggled over and sunk into notches in the frames.

Mast step in the frame

Six vessels have the mast fastened directly into a notch in the frame. This regards the Sørenga 1 boat (Christensen, 1973) dated circa 1300 CE. The Barcode 7 (1586 – 1596 CE) (Skyaasen In prep.), which has a plank-shaped keelson, also has a notch in the floor timber underneath for the base of the mast. Bispevika 6 (1572 – 1583 CE) (small boat) has a hole for a mast in a floorboard (no: *tilje*) above the floor timber. This floor timber has a narrow rectangular hole that can be used for a stanchion plank. Its function is possibly similar to the stanchions in some of the older beam-shaped keelsons. Parallel to this, Bispevika 11 (a. 1567 CE) (small boat) has a square notch in the floor timber where the mast has been placed. The floor timber in front of this also has a notch for a possible stanchion. The latest boat in the material showing this feature is the Portørenga boat (Christensen, 1985b) (a. 1660 CE). It has a notch for the mast in a floor timber and a circular hole in the thwart above. Except for Barcode 7, which has both a plank-shaped keelson and a floor timber with a notch for a mast, all others represent small boats with a light and probably flexible mast. There is reason to believe that rowing has been a primary propulsion method, with the sail as complementary.

Stem and stern shapes

This property concerns the way the strakes terminate towards the stem and stern (Figure 26). In a previous analysis (Falck & Dubbini 2024), I only categorised the basic shapes of the stern (for example, straight, curved or transom). Considering the observed variation in the shapes and techniques, four properties were added to the categorisation, flat sides, individual recess, single rebate and covering base.

They belong to the category of longitudinal strengthening techniques, but will be presented as an independent category. The stem and stern are imperative features in a vessel, and require skill from the boatbuilder. Making the ends of the planks meet in a timber at each end of the boat is a technical performance that contains many risks, and the result significantly impacts on the quality of the vessel. This explains why some boatbuilders in the Viking era were called *stem-smiths*, and held high social status in their communities (Ravn, 2020, 98).

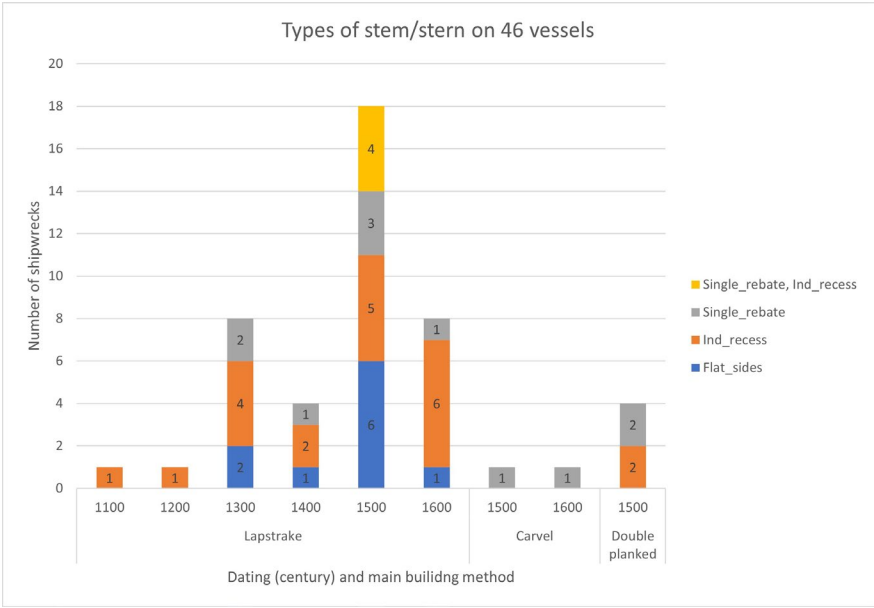


Figure 18 Types of stern posts (single rebate, individual recess and flat sides), on 46 vessels, sorted by date and main building method.

It should be added that the elaborate designs of the so-called winged stems in (some) Viking ships are more demanding and complex structures than timbers, with individual recesses and single rebates, which became the typical design in the medieval and early modern periods. This is also important regarding the social connotations linked to the creation of the stem/stern in previous times. The different types of stern posts are illustrated below (Figure 27 and Figure 28).

Flat sides

The simplest construction is where the stem/stern timbers are designed with flat sides, and the plank ends must be adjusted to meet the smooth surface. It is present in the material in ten cases, but with quite a range, chronologically and in vessel size. To give three examples, it is present in the Bøle ship built with Southern Baltic oak (1380 CE); in the cargo ship Barcode 2 (1589 CE), built with West

Norwegian pine and South Norwegian and South Swedish oak; and in the small vessel from Portørenga, probably locally built with oak around 1660 CE. Based on these findings, it is difficult to explain the feature within a concept of tradition or even regional or functional similarities. Intuitively, it presents itself as a simpler manner of building, but at the same time, making it work without the help of rebates or recesses must have been demanding.

Single rebate

Fifteen vessels are noted with a stem/stern with a single rebate. This means a single, step-shaped recess (rabbet) is carved along the timber to receive the plank ends. The vessels date from the 1300s to the late 17th century, but there are some uncertainties connected to the categorisation of the stems in the two oldest cases (Hesteberget and Sørenga 2). Leaving these two out, it could be argued that it is a phenomenon that occurred from the turn of the 16th century onwards. This might point towards an influence from carvel building, assuming that individual recesses are primarily constructed to receive overlapping planks in lapstrake-built vessels.

Individual recess

Unlike the single rebate, each plank end will meet a countersink in the stem/stern timber when building with individual recesses. As with many other properties, there are no clear-cut divisions between types. For example, a sternpost can be designed with individual recesses for the lower planks, and a single recess for the strakes higher up in the construction. Barcode 14 (1574 CE) is an illustrative example (Figure 27). Twenty-five vessels are noted with individual recess as a feature.

Covering base

Eleven vessels contain a feature where the garboard strake in the aft does not terminate close to the inward edge of the sternpost, but continues towards the end of the outer edge. This is most probably done to use the garboard (and maybe more of the lower planks, depending on the size of the vessel) to strengthen the connection between the keel and the stern. Several Oslo-found vessels from the 16th and early 17th centuries, lapstrake-built and carvel-built vessels, are strengthened in this manner In Gothenburg, the lapstrake-built Göta boat, dating from 1658 – 1662 CE, also has this feature (von Arbin & Olsson 2006, 233). The covering base is a typical feature of Dutch shipbuilding in this period, on both large and small vessels (personal communication, Fred Hocker, 29.05.2024).

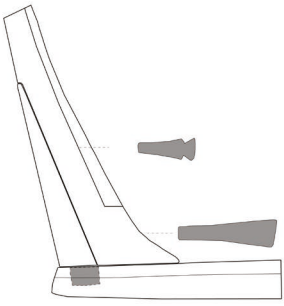
Techniques for joining timbers

This category is created to identify the main techniques for joining timbers. In a complex construction of many single elements, with the demand of being waterproof and resisting the pressure from both outside and inside, the joints of timbers have a crucial function. The plank joints are already systematised in their category (above). This category is designed to embrace the joints between other main structural elements. The keel-stem connection is the most likely to be recognised in the fragmented material. For the statistics, the category only partly functions. The level of preservation and documentation of the findings needs to be high to secure the statistical viability of the category. In many cases, the boatbuilder has also made different choices for different purposes in the same vessel, making it a complex property to work stringently with.

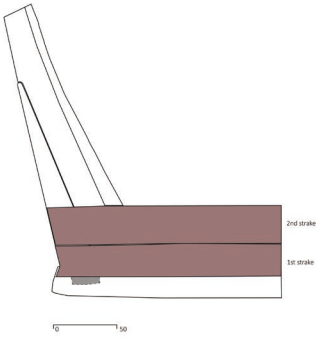
Through scarfs, stopped scarfs, hooked scarfs and mortise-and-tenon

The most common manner is using through scarfs, vertical or horizontal. Using through scarfs to join the keel and stem implies that the only feature that prevents traction and bending damages is the iron and/or treenails that hold the pieces together. Only two surfaces meet. In stopped scarfs, an additional edge, or nib, makes a more robust joint, as the two pieces will also be stopped by the meeting edges. A hooked scarf will lock the joint completely, but no such secure joints have been identified in the material. Compared to stopped scarfs in the material, the presence of through scarfs is 48 to 24, with a few cases noted as having both properties.

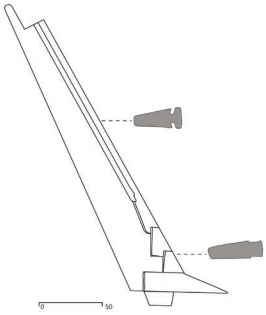
The last property in this category is the 'curious' mortise-and-tenon, a feature not commonly practised, in what is regarded as a traditional Scandinavian lapstrake building. This makes looking at the kind of vessels in the material carrying this property interesting. I have already mentioned the Leirviken ship (Teisen 1992, unpublished report), where the flush-laid bottom planks are attached by using wooden oak pegs (Ø circa 2 cm) added to the sides of the plank, and inserted in corresponding cavities (mortises) in the next. The planks are thick, 5-6 cm, and circa 30 – 35 cm wide. The vessel's sides are lapstrake-built; these planks are thinner (3 cm). These planks are mainly attached using doublehooked nails. The vessel has an imprecise date, only using ^{14}C-method on the timbers, which resulted in a range between 1455 – 1620 CE (1993, Dateringsrapport. T-10785). The second vessel is the small carvel-built vessel called Bratsberg Bruk, also with an inaccurate ^{14}C-dating that makes it difficult to place it chronologically with any certainty (1530 – 1900 CE). The assembling of the planks is described as a technique with squared-shaped wooden pegs between the planks (Nymoen 2008). The two examples show that the only use of mortise-and-tenon occurs in a cog-like flat-bottomed vessel assumably from the 1500s, and a small carvel-built ship with a very uncertain dating, possibly modern.



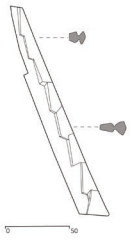
A.1. Single rebate, with covering base.



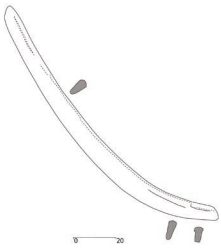
A.2. Single rebate, with covering base. Two first strakes covering the stern.



B. Single rebate, and individual recess for strake two, three and four. First strake covering base.



C. Individual recess.



D. Flat sides, no rebates.

Figure 19 The two illustrations of sterns to the top right are from the carvel-built ship Paléhaven 1, showing a single rebate and covering base (A.1. and A.2). The lowest stern to the right is from the lapstrake-built Barcode 14 (B.), showing individual recess for the lowest strakes and a single rebate for the ones higher up. It also has a covering base for the lowest strake. The next stern (C.) is from the Sørenga 7, showing individual recess for all strakes, and to the left (D.), the stern from Portørenga uses flat sides with no recess. Drawing. T. Falck.

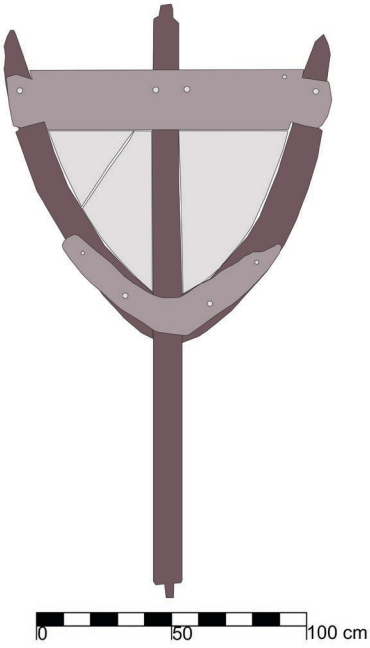


Figure 20 Transom from the vessel Barcode 1 (1598 – 1604 CE). Reconstructed by A. Kerr/NMM, processed by T. Falck.

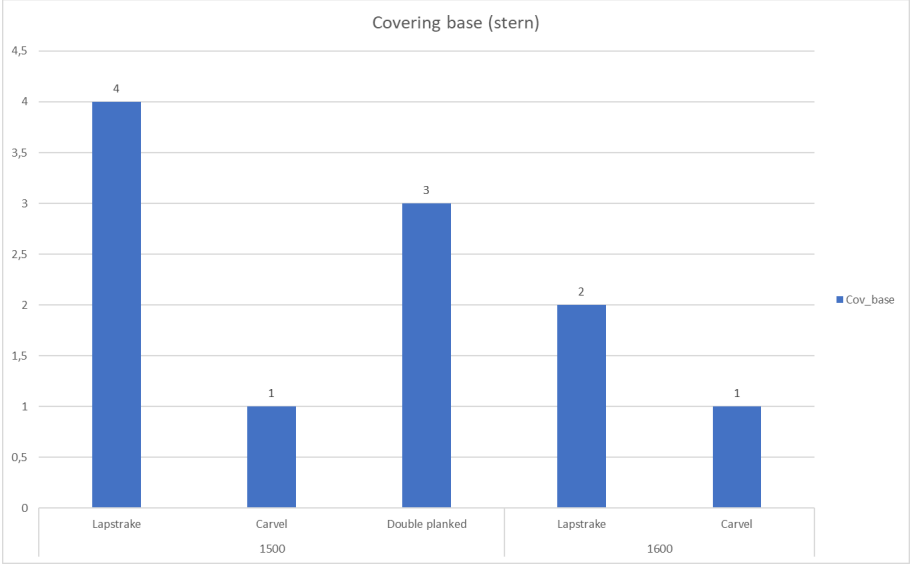


Figure 21 The use of covering base on vessels from the 15- and 1600s, sorted on main building technique. It is worth noting that the covering base is applied to the few double-planked vessels in the investigation (where we have this data), as well as the carvel-built vessels.

Summary of the technical definitions

Some readers may regard this section of the thesis as merely a transport stage, containing technical details that often make maritime, or nautical, archaeology seem inaccessible to those unfamiliar with the specific concepts and terminology. However, engaging with these details is essential for discussing craft practices and understanding the features involved. This has proven an effective way to familiarise myself with the Viken material. Moreover, it has been necessary to highlight certain ambiguities hidden within what may appear to be 'stable facts'. The criteria used to categorise the material have been defined and described, with specific cases from the dataset referenced as illustrations where relevant. This approach allows the reader to grasp the foundation for the comparisons. Broadly speaking, the selection of criteria captures the significant variations and developments in building techniques from the late Viking Age through to the medieval period and the early modern era. I believe the inclusion of the two late Viking Age vessels, the Äskekärr and Klåstad ships, was crucial in strengthening the analysis of the earlier periods. Their inclusion has made certain features, traditionally considered 'archaic', more pronounced. There were undoubtedly significant changes in boatbuilding techniques during the early medieval period, and the few examples dating from before 1300 are less comprehensively documented (except the Sjøvollen ship).

When it comes to the inclusion of large ships from the 1600s, it becomes apparent that the selected properties are less effective in capturing the technical changes that occurred during this period. These were ships constructed in professional shipyards at the behest of the crown, mainly the carvel-built ships intended for naval purposes. Since these ships are not the primary focus of this thesis, I have opted not to adjust the list of properties to address this issue, which may impact the results. The primary focus here is on smaller vessels, or vessels built to serve more mundane activities, such as trade and regional transport. Some of these might have been built in the same shipyards as the larger ships. This raises an important question concerning what we conceive as vernacular and professional building practices.

Taken as a whole, the selected properties and the material are well-suited to illuminating changes in craft practices during the medieval period. However, the most compelling aspect of this collection of vessels pertains to the discussion of the (rapid) changes occurring in building techniques dating from the 15th and 16th centuries. Rather than solely using the term 'change', one might also add 'variation'. I believe that examining the material underscores the varied approaches taken in the construction of otherwise quite similar vessels with regard to their functionalities. The review and definitions of the properties used for systematisation still fall short of providing a robust foundation for a qualitative understanding of these factors. To address this, applying multivariate statistics would create a more solid base for further assessments and interpretations. This,

in turn, will provide a foundation for selecting specific cases that are particularly suitable for an in-depth discussion of the main findings (Chapter 4). In the next section, I will apply the technical properties and categories in a statistical analysis.

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