Wooden Boat-building sheets

These documents are extracts from my book on wooden boat construction, "*Construction bois les techniques modernes*" (in French). Though only a very few are presently translated, equivalent information in English is available from other sources and I intend to translate other ones. For example, the websites of epoxy suppliers give comprehensive information in regard to saturation, gluing, filleting, and sheathing. If you need some technical advice, please tell me and I will answer your questions.

The present sheets have been translated into English from the original French version by George Alheid, an american builder of a Seil 18. He doesn't speak French and used Google translation, and corrected the sheets to make them readable. Up to now, I did not have the time to make my own correction, but the document, as it is, will certainly be very valuable for other English speaking builders.
I deeply thank George for this volunteer work that he agrees to make available to all.

Num	Rev	Title	Date	Pages
05	0	Epoxy impregnation	25 sept. 03	2
06	0	Gluing and epoxy fillets	14 octobre 03	2
07	0	Fiberglass on wood	15 novembre 03	4
08	0	Impregnation and bonding: solutions for cold weather	12 novembre 03	3
12	1	Boat rivets	15 novembre 03	2
15	1	Scarfing plywood panesl	9 novembre 03	2
16	0	Glued, laminated parts	30 décembre 03	4
22	0	Assembly of the structure on the strongback	8 avril 04	8
31	1	Strip built hulls	19 juin 04	5
41	0	Spiling planks	30 déc 03	3
42	0	Joining the garboard to the sole	6 octobre 03	1
43	0	Provisional mounting of planks/lapstrakes	6 novembre 03	1
44	1	Lapstrake fitting	3 avril 04	3
51	0	Stitch and glued plywood	8 avril 05	4
62	0	Steam bent frames	28 janvier 03	4
63	2	Frames laminated in place	28 octobre 05	4
71	0	Benches and floors	7 octobre 03	1
72	1	Construction of lifting rudder blades	2 novembre 09	2
73	0	Sliding companion way hatches	6 janvier 2010	3
81	0	Round masts and spars	17 octobre 03	3
82	0	Misanier / high aspect lug rig	10 octobre 03	3
91	0	Paint and varnish	18 novembre 03	3

Outline of epoxy impregnation

Epoxy impregnation can be applied on all plywood parts, on the surface of strips for strip built boats, on cold molded surfaces of boats, and even on individual structural wood pieces.

The impregnation has the effect of reinforcing the surface hardness of the wood and of constituting a barrier against moisture. It thus ensures better durability and reduces maintenance.

It is highly recommended in the following cases:

- For all parts of plywood, particularly “okoume,” a wood that is fairly soft and of medium durability if it is not protected.
- Protection of plywood edges, wherever they are and whatever the type of plywood.
- Protection of plies in small (especially unlaminated) slats/battens to reduce the effects of variations in humidity.
- Preparation of surfaces to be fiberglassed.
- Preparation of surfaces before painting or varnishing, subsequent to verifying the compatibility of the epoxy with subsequent paint or varnish coatings.

Note that it is not necessary to impregnate wooden elements which will be subsequently “oiled” with products such as Deks-Olje or teak oil.

Epoxy is not a flexible material. It is, therefore, not desirable to use it on a wooden structure which flexes in use. Traditional systems of oil painting are more appropriate in such instances.

If one decides to impregnate with epoxy, it must be done everywhere, inside and out, to more or less completely encapsulate the wood and minimize as much as possible variation in internal moisture. In practice, this is only feasible on light structures of moderate thickness.

Recommended products:

The formulation of epoxy is continually under research to improve its properties for particular applications. The best resins for impregnation are of low viscosity (approaching that of water), with smaller molecules allowing better penetration of the wood fibers.

Manufacturers are increasingly developing specific impregnating resins (e.g. Sicomin - Wood Impreg).

Resoltech offers even water based resins (which may be diluted with water for lower viscosities). These have little odor, are pleasant to use and flexible with respect to environmental conditions (i.e. temperature, humidity). Note that this resin is only suitable for impregnation or as a primer, with other products required for bonding and fiberglassing and/or lamination.

Except for boats regularly sheltered, of for area of the boat not exposed to light (e.g. buoyancy tanks, cabin areas) Impregnated surfaces must always be covered with a varnish or paint specifically to shield the epoxy which is deteriorates on extended exposure to UV light.

General conditions for the use of epoxy resins:

The advice provided here is only general and should be supplemented by a careful reading of the documentation provided by the supplier of a selected product.

- Strictly observe the temperature and humidity conditions specified. While manufacturers generally strive to make their products more tolerant to variations, 18ºC is the usual minimum temperature and the maximum humidity is generally 70%. A higher temperature ensures a lower viscosity for the resin and better wettability. It is strongly advised to place a thermometer and hygrometer in the workplace.
- Caution should be taken to avoid an increase in temperature during polymerization of the resin. This can result in small bubbles. It is better to warm the area and materials (resin, wood) before impregnation and allow the temperature to slowly decrease afterwards.
- The specified proportions of the resin-hardener mixture should be strictly adhered to. A small electronic kitchen or postal scale is a good tool for measuring small quantities. For larger amounts graduated cylinders may be appropriate. Metering pumps are also offered by some suppliers. A small scale can be made with a simple wooden batten suspended at its midpoint. At each end a steel wire is arranged in a loop for suspending a disposable plastic cup. Screws or bolts are placed in one side and the resin and hardener in the other. The number of screws added to the cup is selected to match the desired proportions of resin and hardener.
- The resin-hardener mixture undergoes an exothermic reaction. Flat containers should be used to minimize the depth of the mixture and prevent rapid heating and a consequent reduction of the working time (pot life). Do not throw the reacting resin-hardener mixture in a waste container since the temperature in a confined space may be sufficient to ignite the waste. Nor should the reacting mixture be confined to a plastic container which may melt.

Applying impregnation:

- For plywood, especially when this is supplied as part of a pre-cut kit, it is highly preferable to impregnate the plywood parts prior to assembly of the boat. For example, once assembled it might otherwise be necessary to work horizontally in confined or minimal spaces.
- For the first impregnation, use a small spatula about 15 cm wide to spread, and help the resin penetrate the wood. Thereafter, work with a disposable short pile roller.
- Apply the number of layers recommended by the manufacturer and with the recommended thickness. This will significantly reduce the subsequent tedious sanding necessary. Do not apply thick layers creating excessive resin thickness that are difficult to remove and which provide surfaces to which paints or varnish poorly adhere.
- In general, the sequence of impregnation-paint or impregnation-varnish should be adopted that limits the necessity for later sanding. The latter is very time consuming and never fun.
- Impregnate the edges of plywood very thoroughly with a small brush, especially for hatches.

Organization:
Epoxy work requires good organization and planning, both at the level of the entire project (seasons should be taken into account) as well as at the level of detailed assemblies. Mix epoxy only when all equipment is ready and close at hand. Keep everything clean.

Security:

Epoxies are hazardous products which are both toxic and allergenic, Observe the manufacturers recommendations with respect to personal cleanliness, gloves, respirators and adequate ventilation.

Introduction: epoxy resins

The relatively recent development of epoxy resins has considerably impacted wooden construction. Boats made of plywood or small strips use impregnation by epoxy (section 05), with bonding at joints and more or less where areas are reinforced by fiberglass layers.

Each resin manufactured has its own specific characteristics and it is always necessary to carefully read the accompanying technical information. Only general rules are given here to aid in the choice of products to purchase, and in their particular use in the construction of boats according to the accompanying plans.

Section 05 (epoxy impregnation) should be read for general recommendations in the use of epoxy.

A virtue of epoxy adhesives is their tolerance of mediocre assemblies, sometimes to the point of discouraging the amateur from striving for well done joinery. However, epoxy is much more expensive than wood. One should always bear in mind that good wood-epoxy construction should only entail a moderate consumption of resin.

Bonding:

In order to fill gaps and cavities, while maintaining good mechanical properties, reinforcing fillers can be added to the resin. For bonding, these fillers are mainly based on microfibers (when used to fill defects and to give mechanical strength), and / or colloidal silica (to thicken and avoids drips). These fillers are offered by resin manufacturers. You can also (for economy) retrieve the contents of your sander's collection bag provided you are sure of its contents.

You must be careful that the resin always penetrates the wood. It is often preferable, especially for plywood scarfs,to first impregnate the parts to be assembled and after allowing approximately 15 minutes, apply the resin to the parts with a spatula or brush with subsequent assembly.

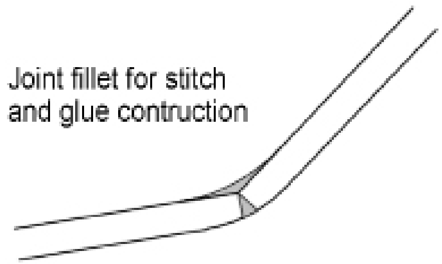
It is not necessary to clamp the parts tightly together. They should be joined sufficiently to avoid any cavity that is not filled with glue, but not to much so that all the glue / resin is expelled from the joint. Clamps, screws, nails may be used to appose the pieces to be joined. The screws and nails may be temporary and removed once the epoxy has set and the joint is strong.

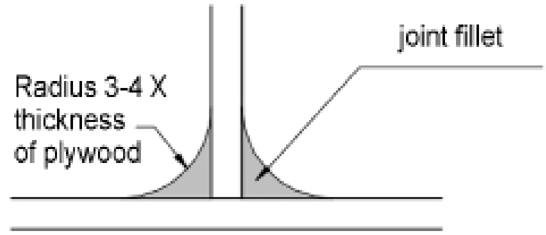
Note that the wood has only limited resistance in the direction transverse to the fibers. Accordingly, mechanical components (screws, bolts, rivets) remain indispensable in reinforcing all bonded joints that are loaded or susceptible to shocks.

Fillets:

Filled joints make it possible to reinforce the connections between two elements when the bonding surface is insufficient to ensure adequate strength in the assembled parts. In practice, this takes the place of battens (ribands, logs, ..) which were used to mechanically fasten two pieces of plywood. The construction plan indicates the main joints to be reinforced with fillets. Some joints will also be reinforced by local application of fiberglass.

- The main instances for the use of fillets on the plans are:
- Connections between partitions,
- Connection of shells to each other (laminated plywood)
- Drift wells, foundation structures,
- Buoyancy tanks





Do not over-fill filleted joints with resin, especially in areas that are visible. If you finish the wood “bright” these areas are not always discreet after varnishing. Generally, rounded corners once painted also give the impression of a “plastic boat.”

The fillet is made by adding specific fillers to the resin, either reinforcing fillers as for bonding, or “lightening” fillers (hollow microspheres). The latter provide low density fillets and are not justified for a boat where one uses only moderate sized fillet joints.

The application process:

- Immobilize the parts to be assembled,
- Sand, clean, degrease, dust,
- Apply fillet resin either with a spatula or with a thick plastic bag containg the prepared resin, from which an angled opening has been cut from the corner.
- Smooth with a round spatula (with the targeted radius of the joint fillet). A spoon back, a small piece of PVC tube, or a dental spatula may serve to smooth and shape the radius of the fillet.
- Using a painter’s knife remove the excess resin from the edges of the fillet.

If the joint is to be fiberglassed, it is best to do so in series with forming the fillet. Wait until the fillet starts to harden, before laying on the resin impregnated fiberglass tape.

A biaxial fiberglass strip is preferable. That is, the fibers of the tape are oriented at plus and minus 45^{o}. If only a small quantity of fiberglass reinforced joints are to be made, We can use ordinary fiberglass cloth cut on a diagonal to use as the joint tape.

Section 07 details epoxy lamination of wood.

Areas of use:

Fiberglass surfacing of wood is mainly used in the following cases:

- Outer lamination of hulls constructed with laminated plywood,
- Inner lamination of laminated plywood hulls. In this case fiberglassing may be total, or limited to fiberglass strips (tape) covering each chine,
- External and possibly inner layering of hulls made with strip construction,
- Fiberglassing of the bottom of a flat keel or sole (up to the chine or waterline),
- Fiberglassing for local reinforcement, for example at the ends of plywood or other exposed grain, on a mast in the area of the mast partner etc.
- Fiberglassing over fillet joints to reinforce a bond (for example in closed buoyancy tanks),
- Repairs

The fiberglass covering fills one of the following functions:

- Ensuring better sealing of the hull,
- Improve resistance to abrasion and shock,
- Increase the mechanical strength of the hull globally or locally (e.g. stitch and glue joints, strip built hulls etc.

An epoxy fiberglass lamination is transparent as long as it does not exceed non-structural thicknesses (as set forth below). It is quite possible to cover the fiberglass with a varnish and to have a very beautiful finish where the presence of the fiberglass cloth is almost undetectable. There are even specialized epoxy resins formulated for transparency and for UV resistance.

Two cases arise at the level of implementing fiberglass:

- More or less large area fiberglass surfacing using fiberglass cloth,
- Fiberglass reinforcement of joints using strips or tapes of fiberglass.

Choice of resin:

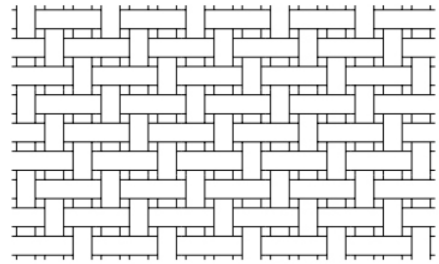
Epoxy can be used without hesitation even if it is more expensive. Polyester, in comparison, has poor adhesion to wood. With the latter resin superficial tensions are created which over time lead to delamination of the fiberglass from the wood substrate. For example, the “Mirror” a small English plywood dinghy designed in 1963 with over 70,000 examples built, called for stitch and glue construction with polyester lamination. Today epoxy repair kits are sold for the existing Mirrors built with this original specification.

A resin with a low viscosity suitable for marine applications should be used. Resins sold in hardware stores are often more viscous and are a generally a poor fit for the program of boat construction. The required resin weight (excluding prior impregnation) is about1.3 times the weight of the fiberglass cloth/tape. This ratio, which varies with different products and the application conditions, is only a general estimate of the quantity of resin to be prepared.

Refer to section 05 (epoxy impregnation) for general information on epoxy resins. Note that it is advantageous to use a slow hardener to preclude a too short pot life (i.e. useful working time for the resin).

Choice of fabric:

We only envisage the use of fiberglass on boats where wood remains the basic structural material. Modern materials used for fabrics, such as carbon fiber or Kevlar, are more difficult to implement and are, therefore, not taken into account. Essentially, ordinary fiberglass roving, called glass E is used in practice. In contrast, fiberglass “mat” made of non-woven fibers is not suitable here. There is a wide variety of weaving fashions available (e.g. taffeta, twill, satin, biaxial) but again the basic woven fiberglass products are sufficient. The mode of weaving of “twill” is a good compromise between resistance, flexibility – to adapt to the curvature of the hull – and ease of implementation. A better solution, if available, is biaxial woven glass cloth, whose fibers are oriented in a ± 45^{o} angle.



The fabric thickness will be 200 g/m^2 for a kayak or an ultra-light boat, and about 300 g/m^2 where the objective is surface protection. For fiberglass tape, it is generally sufficient to cut bands out of glass fabric for applications restricted to small quantities. In this instance, it is better to cut at 45o in a twill woven fabric to obtain a band approximating a biaxial weave. Fiberglass tapes, as far as possible should be obtained with a biaxial weave for more systematic use. Biaxial strips, are much more flexible and easier to install and adhere better to angles. It seems that suppliers often offer the biaxial tape obtained by cutting the desired width from a roll of biaxial fabric. As a caution, not all commercial fiberglass fabrics are suitable for use with epoxy resin. For example, you may buy glass fabric in a hardware store for very small applications (for example to reinforce the tip of an oar) bur for surface fiberglassing it is better to rely on the resin retailer or a specialized retailer for fiberglass fabric.

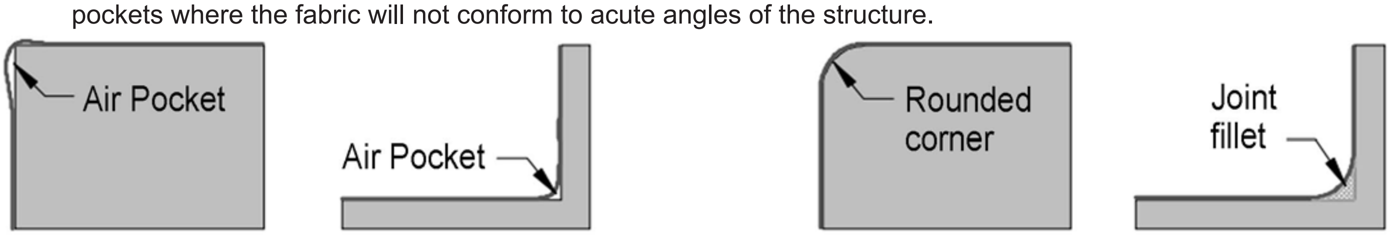
In addition to the fabric constituting the surface fiberglass, a “peel ply” film may be used. Placed on the surface of the wetted out fiberglass, it is removed after curing and leaves a smooth surface that reduces sanding work. Of course, it is mainly justified for large level or gently curved surfaces and more particularly for cases where a complete fiberglassing of the hull outside surface is performed.

Preparation of the surface to be fiberglassed:

Respect for a rigorous procedure is essential for achieving an impeccable fiberglass surface. This is normally the sought after objective especially where external fiberglassing of the hull is to subsequently varnished or lacquered. A good method can also significantly reduce the workload of sanding and or fairing a hull which often represents an important part of the work to be carried out and is never a pleasure. Epoxy is hard. If you have extra (unnecessary) thickness, it will always be painful to have to remove this.

Some precautions must be taken before fiberglassing:

- Round all corners of the surface to be fiberglassed, otherwise the stiffness of the fabric will create resin-free air pockets where the fabric will not conform to acute angles of the structure.



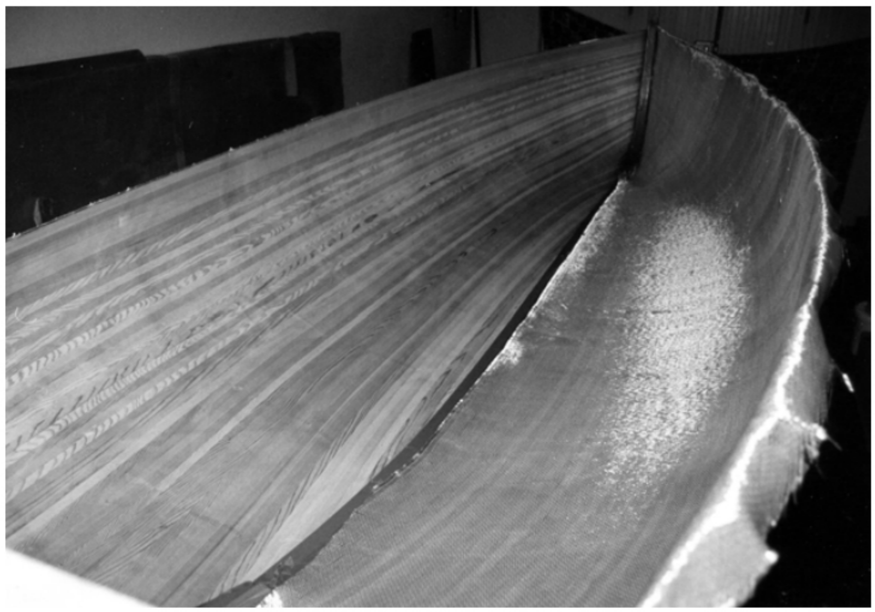
- On fiberglassing a surface, reserve the installation of the appendages, false keels, protective stgrips, soft strips etc … which can be attached after fiberglassing.
- Fill all holes, and even coat and sand any surface irregularities.
- Thoroughly sand the surface to be laminated and finish with a good cleaning to remove any dust.
- Perform a pre-impregnation. The aim is that the laminating resin should not absorbed by the wood to the extent that the fabric is starved for resin. This is particularly a risk with certain substrates such as okoume plywood or red cedar. If impregnation of the plywood / wood was performed at the beginning of the project, it is much better. Otherwise, pre-impregnation should immediately precede fiberglassing as indicated below.

Preparing for fiberglassing:

Here we describe particularly the case of external fiberglassing. Other instances, generally simpler, can be deduced. We assume, of course, that the boat is upside down. Note that if the size of the boat allows, tilt the hull by doing one side and then the other. It is easier to work on surfaces that are close to the horizontal than on vertical surfaces where gravity causes the resin to run.

By working on site, cut the fabric pieces in advance with margins at the edges. On a small hull, it will be one fabric piece per side and one for the keel or sole. On a single chine hull, we can locate a seal between fabric pieces near the bilge. For more sizable hulls, more pieces will be placed along the boat length with joints between pieces. Once cut, roll the pieces, label them and place them where they are ready to serve when needed.

After the fiberglass fabric is prepared, pieces are cross-checked to assure butt joints with little or no overlap. These joints should never be on a very rounded part of the hull or near a corner. For chine, or adjacent to the sole, the connecting joint should be about 3 cm from the angle. Note where fiberglassing contributes to structural strength, overlapping joints will be required, at a cost of additional filling and sanding later. At the bow of the boat one of the fabric edges will turn aft for a few centimeters on the opposite side. If the vessel has a false bow insert, of laminated or solid wood, the fiberglass fabric may be stopped at the line of the rebate. We can in this way retain the angular character of the stem for a conventional wooden boat. The bow may then be protected by a soft metal band. Note that for a skeg or rudder, it is possible to overlap the fabric edges at the fore end of the part which are subject to high wear.



Placing the fabric before fiberglassing inside an Aber hull made with strip contruction.

All necessary equipment (brushes, rollers, bubble traps, cutters, peel ply, disposable gloves, ….) for fiberglassing must be ready before starting to mix the resin. Siumiularly think carefully about the order of implementing the operations. The pot life of the mixed resin is short, so it is important not waste any time once the fiberglassing has begun. Whenever possible, two persons should work together to do the job (and more on a large boat).

Implementation of fiberglassing:

Applying a resin layer. If the wood has not been previously impregnated and the resin is absorbed to a matte finish, it may be allowed to cure before sanding again. If sanding does seem essential for a good finish, a second layer of resin can be applied in the wake of the first, without the wait for complete curing (refer also to the supplier's manual for the resin). However, this second approach entails more risk and you need to choose this option when you already have a little experience.

If a glossy surface remains after the resin application, the fabric is wetted out, rerolled, placed on the hull, and unrolled into position (using fabric specific for epoxy fiberglassing). The fabric is positioned starting from the keel and moving toward the sheer. Warning! This is the tricky part. We can use a wall paper brush to spread the fabric and the more hands to manipulate the fabric the better it is. If you do it for the first time, start with small areas to develop a bit of facility with the process. Also avoid “ironing” the roll as this may create bubbles in the resin. When two pieces of fabric overlap, cut the two plies with a cutter. Remove the overlapping waste and then lift the cloth to remove the underlying waste edge and re-apply the two pieces of fabric as cleanly as possible with both pieces closely apposed to one another.

Then position peel ply that can be removed just after hardening or even several days later. This improves the surface of the fiberglass and adsorbs excess resin. This largely compensates for the time spent in positioning the peel ply. In addition, the peel ply protects the surface from contamination until it is painted or varnished. If you do not wish to use peel ply, some resin providers recommend applying an additional layer of resin after installation of the fabric and before complete curing of the resin, in order to coat the fabric. This coating remains to be seen by everyone, and its appearance depends on the resin used, the thickness applied before laying the fabric and the paint or varnish which is subsequently applied, etc…

In practice many variations are possible in these procedures, depending on the circumstances. It also depends on the compromise between the time spent and the quality desired. The more thin layers applied at either the impregnation stage or fiberglassing stage, the fewer drips/runs and the better the quality of the finish. It is especially important for fiberglassing on a vertical surface. Another caution worth repeating: avoid excess resin. It unnecessarily increases the thickness and often results in the need for “excess” sanding. Where the surface cover is important, it should be applied step by step. Apply the resin with an edge, present the glass cloth, apply the resin on the other side of the fabric etc..

Dry method:

If you want to work with less stress by the time taken for the resin to harden, it is also possible to use a “dry” fiberglass application. First the fabric is laid in place and held in position by adhesive tape at the edges. The resin is then applied. The application of the resin through the fabric is more difficult, but you have more time. This method is suitable for someone working alone on level work, but should not be attempted for vertical surfaces.

In summary, before moving to the wet method, which is more productive and more universal in application, a beginner should be interested in working through step by step, even if the overall work is increased.

- Complete impregnation followed by sanding,
- Dry fiberglass method then tilting the hull if necessary to work close to the horizontal.

An alternative is to start the laying of the dry fabric while the last impregnation layer is still a bit tacky. The fabric adheres slightly but can still be repositioned if necessary. Then according to advocates of this method, the fabric does not slide while the resin is applied on top.

Note: It seems that there is almost as many methods as resin sellers. I have tried to present those here that are the most recognized and best suited to amateurs building boats according to my plans.

Coating for smoothing:

For fiberglass surfaces laid as a base for painting, those who want a superb finish can apply a coating to remove surface defects. For this purpose, epoxy loaded with hollow glass microspheres can be used to form a light coating which is easy to apply and sand. As a warning you do not wish to overdo this, everyone will think you have a plastic boat!

Introduction

Epoxy is currently an excellent and versatile solution for impregnation, bonding, joint sealing and fiberglass reinforcement within the construction of a wooden boat. But a major fault is that it imposes a minimum working temperature of about 18ºC (or sometimes less, as providers are working to lower this threshold). However, most manufacturing and most small craft projects may be handicapped by this temperature restriction. Here we deal with methods and product suitable for building in an unheated room.

Construction planning

A boat home build often takes place over a long period of about a year. It is, therefore, possible to carefully plan the construction, taking into consideration the following ideas:

- Making some pieces at the bench; e.g. ribs and a glued bow, prefabricated rudder and centerboard, rudder and skeg fiberglasing ….. Note: I assume no responsibility for family consequences!
- Make during the summer all operations for which there is no good alternative, especially surface fiberglassing.

Wood storage

Solid wood and plywood should not be wet during bonding. It is imperative that they are stored in a dry and ventilated area. If possible, the wood should be heated before use by leaving inside for about fifteen days in a heated storage area, especially before impregnation and fiberglassing.

Use in cold weather

Above all, have a thermometer and hygrometer in the room.

Use the right products for the workplace temperature range. There are often several hardeners ranging from slow to fast. For work in cold temperatures choose the one that gives the fastest polymerization.

For impregnation, us Resolcoat “1010 Resoltech”, diluted with water, which can be used at temperatures as low as 10ºC.

For bonding and joint sealing, you can work in cold weather by using the following:

- Stock resin, hardener, and additives in a heated room (preferably at 25ºC) until needed. It is indeed important that the mixture is well done with the lower viscosity warmed fluids. Some manufacturers even recommend placing the resin containing bottles in hot water before mixing and use.
- Heat the working area. This can be done with a plastic sheet covering the part concerned and a heater that may be limited to a single lamp. Caution is still needed to insure that you do not cause a fire. Note that epoxy emits little in the way of solvents. The warming method would be dangerous with many other products.
- Wait before removing clamps: in the cold polymerization will take longer but will be as strong when complete

For fiberglassing, especially with large surfaces (e.g. planking) the problem is more difficult. The risk is that bubbles may form in the epoxy as it cures resulting in an inner whitish veil. The problem remains the same for impregnation with standard epoxy resins. Especially if you intend to varnish afterwards, you must arrange it so the impregnation is done in the summer or the workspace must be temporarily heated to a satisfactory temperature on a day that is not too cold. When a painted finish is anticipated, one can, with cautious regard for adequate bonding, work in suboptimal weather conditions. Similarly laying reinforcing tapes might be more easily accomplished in cooler weather since it is nominally simpler to heat the zone where the work is performed. Only a careful reading of the package insert for the specific resin used, will allow an estimate of an acceptable temperature threshold. In general, major problems in applying epoxy will not occur for temperatures above 15°C for a reputable product specified for use above 18°C.

In the case of impregnation or fiberglass lamination under marginal conditions, one may observe a film on the surface that is not removed by solvents. In this case wash the surface with water by rubbing with a scouring pad and sand before moving on to the next step.

Polyurethane adhesives

The polyurethane adhesives (PPU 100 in France, 100 Balcotan in Britain) are available in hardware stores, and have properties that seem equivalent to the PPU 100 found in ship's chandlers. This may be applied at minimum temperatures of 5-10oC. Characteristicly, these products foam where underlying gaps are present. The foam does not, however, have the same mechanical strength as a sealing coat properly applied. The wooden parts to be joined must be adjusted for a close fit and strongly clamped to avoid gaps that result in foaming. If these conditions are not met, the bonding will be inferior and will eventually yield. I have had the experience with one of my boats where detachment started at the end of ten years; this was even more rapid for highly stressed parts.

Nonetheless, with attention to close fitting joints and increasing the supporting mechanical connections (pins, screws, bolts, rivets), one can achieve a strength and quality on a par with boat construction using epoxy. As with epoxy, if the wood is porous (including planed plywood at scarfs and edges) pre-impregnate with two adhesive layers at approximately 30 minute intervals. Then wait 30 minutes, to insure than the wood will not absorb more adhesive, before final gluing of parts for assembly.

Polyurethane has a big advantage in that it is a single component and therefore very easy to use. In some instances it is an interesting alternative to epoxy insofar as it has fewer problems with temperature. I would refer, in particular to its use in strip built hulls, especially where the outer hull is subsequently (epoxy) fiberglassed. The polyurethane may be used for assembly of the individual strips, thus avoiding the necessity of repeatedly mixing a two part adhesive while gluing the strips in place.

Polyurethane adhesive is also a good solution for installing large area reinforcements, for example, on a bridge deck. If there are areas where the joint between two pieces of plywood is not properly fit, resulting spaces will be filled by the foaming polyurethane adhesive. It was Jean-Jaques Herbulot who originally promoted PPU adhesives for boat construction and he adapted several of his famous designs for planning dinghies (Vaurien, Capri, Figaro) for the use of polyurethane glue.

One should beware that polyurethane adhesives do not last more than a few months in their original packaging, and last much less with frequent opening of the container. Therefore, for small projects spread over time, it will always be cheaper to use one product for everything. It is, therefore, clear that for such cases, epoxy is the current champion.

Polyurethane mastic adhesive

Sold as cartridges to apply as a spray, the best known brand is Sikaflex 291 and 292, but other brands market equivalent products. Check that these are polyurethane or silicone sealants because other formulations are intended for specific needs. Unlike other adhesives mentioned already, the polyurethane sealants are viscous; the seal requires a certain thickness that must be taken into account. These sealants are and alternative to PPU where the latter is unsuitable, particularly for assemblies where the joints are not perfectly matched. There must be powerful means of clamping available, for the product spreads everywhere filling and getting out of the joint. The work must also be completed fast enough because the product cures quickly. Sikaflex 291 is appropriate if it is backed up by mechanical linkages; this is usually the case. Sikaflex 292 is a true structural adhesive and one may dispense with screws or the like. It is especially useful for wood-polymer bonding, but this is off our main topic. As with the polyurethane glues, the mastic adhesives may be used at temperatures as low as 5°C.

These are well suited for large structural assemblies (e.g. keels, centerboard, sawn frames etc) where the joints are never well enough aligned. I also use these adhesives for bonding lapstrake planks that are tightly fastened by rivets. The main drawback is that the application from the cartridges using a hand powered caulking gun is long and one tires quickly. In addition, the product, which is used in large quantities, is expensive. It is, therefore, better to consider the polyurethane cartridge sealants/adhesives as a complementary solution when neither epoxy nor the polyurethane glues are readily applicable.

Resorcinol

Very much in use before the advent of epoxy, resorcinol is supplied as two components including a powder. It’s color is reddish brown when cured. I state this from memory, since this product is now difficult to obtain (the most common brand is Aerodux 185). I think the interest of the amateur might be for a rather large hull size. Professionals still use resorcinol because it retains some advantages, not the least of which is the cleaning up of drip simply using water.

Copper Boat Rivets

Builders wishing to give a traditional touch to their boat may choose to use spot fastening bordered by copper bolt rivets. This approach also has the advantage of reducing the necessity for epoxy resin manipulation.

Use the appropriate rivet diameter to thickness of the hull.

Gage	Diameter	Length	Application	Spacing
JP 14	2.2 mm	30 to 40 mm	Border 6 mm	8 to 10 cm
JP 16	2.7 mm	50 to 60 mm	Lined 9 mm	12 to 14 mm
JP 18	3.4 mm	60 to 80 mm	Ribs	

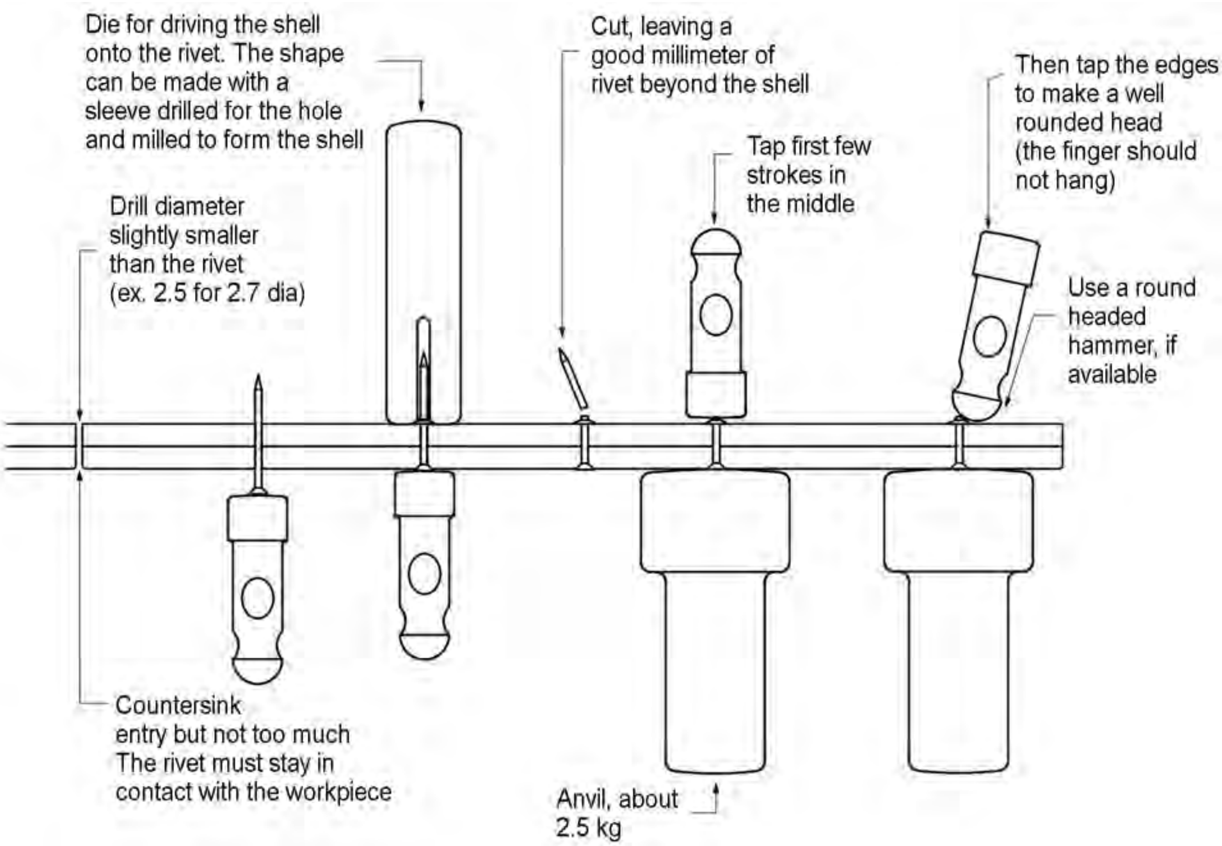
The rivets are ordinary round tipped copper used with washers or curved shells which strengthen the tip. Rivets are also available that are square in section. The latter are uncommon and used as specialized hardware in traditional mail boats.

Rivets, round and square and shells

The use of rivets in lap strake construction

On boats with plywood joints, sole-garboard joints, there is little value in fastening by use of rivets. Other strakes are placed dry (without glue except at the deck and the stem or the ?hobby?) and riveted with spacing as described in the preceding table. It is important to mark in advance the position of the rivets which must not fall on locations where there are frames or bulkheads. This is for aesthetic reasons, to ensure that the spacing of the rivets are as regular as possible, and to insure that the partitions and/or ribs fall halfway between rivets. In the case of narrow spacing with bent or laminated ribs in situ, we set a rivet which binds to both planks and ribs. In this case, the corresponding rivet is to be taken into account in marking the location of rivets, but is placed later with the installation of the rib.

The strake to be placed (from above) is drilled and slightly countersunk in advance (depending on the hardness of the wood) so that the head of the rivet does not extend above the finished surface of the work. The holes are countersunk before the final finish ensuring perfect depth. It remains to set the rivets as shown in the figure on the next page. We can wait until after turning the hull to complete the setting of the rivets.

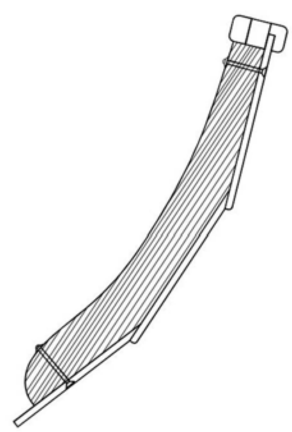


In the “dry” method, when the hull is assembled epoxy resin is applied to the joint. The resin will “spin” in the gasket and sealing and complement glued bonding. You have to go up several layers refusal, the hull upside down, then hull at the location (or vice versa). During the same operation, we took theopportunity to coat the plywood songs. It is necessary that the setting of the rivets is fully completed before impregnation.

Other uses of rivets

Copper rivets are well suited to building of traditional open boats. They may also be used for:

- Fastening ribs that are steamed and edged.
- Fastening sawn frames to prevent the wood from breaking (see drawing) if there are no timber “twists” (non-rectilinear fibers).
- Fastening the floors on sleepers, or cross-tree that are below (see section 71).
- Fastening small deck fittings



Vocabulary

- A scarf is an adhesive bond between two pieces of wood fitted with an oblique joint
- The hull refers to the “outer skin” of the boat, reinforced internally by bulwarks, frames, ribs etrc..
- A plank is a longitudinal element from which the strake is derived
- A strake is a irregular curved board extending from fore to aft of the boat.

Plywood boards in standard shapes

Scarfs are made necessary by standard lengths used for plywood manufacture: 2.5 or 3.1 meters (8 or 10 feet). Warning: Still available on the global market (abroad) are 8 foot long panels that are only 2.44 m in width. The missing 6 + cm can be a problem.

Beginning

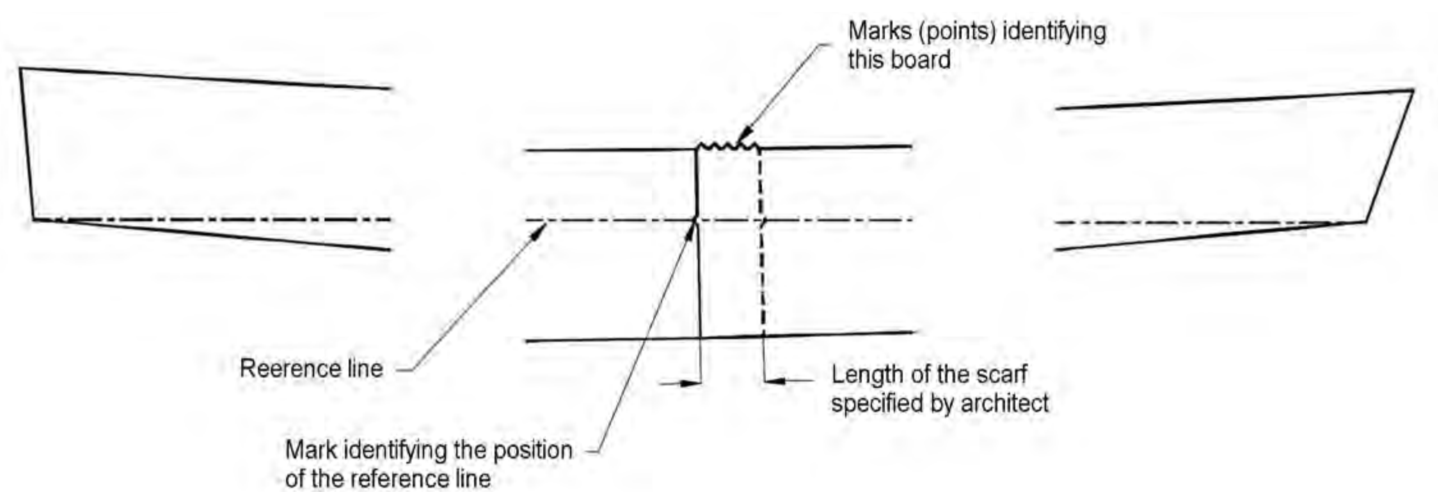
Plywood parts which can be scarfed are essentially planks (hull strakes or plates for chine hulls) or the plywood panels used as the basis of these planks, providing a simpler method in the latter cases.

In the case of pre-cut strakes (delivered as part of a kit, or cut manually from tabulated values, or from a full-size plan of the part), the objective is to form continuous strakes from parts whose length is limited by the standard sizes of plywood.

Warning: it is best to place the completed scarf oriented as a “fish scale” and therefore planing of scarfs (before bonding) should be in opposite directions depending on whether the plank is to be placed on the port or starboard side. Take enough time to mark the scarf direction in advance since errors are common.

Aligning planks

It is essential, during bonding to carefully align the planks constituting a strake. A small angular error at the scarf will result in several millimeters or centimeters of error at the fore and aft ends of the boat. The error could be irretrievable.

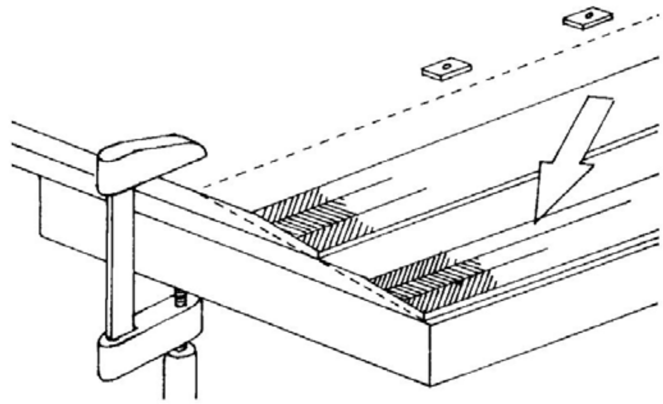


To this end, a guideline for each tracing is provided (marked by “spikes” on strakes cut digitally). For a correct strake, the guidelines must all be aligned when the scarfs are glued.

The length of the scarf is specified by the architect. In general, this is usually eight times the thickness of the plywood.

Planing the scarfs

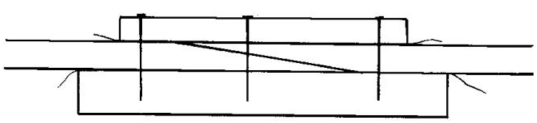
It begins with planing the scarf to the specified length. To this end, superimpose the two panels and assemble them in the correct position by nailing them to a rigid and level support, with the sides of the panels aligned. The planing direction is shown in the figure by the arrow.



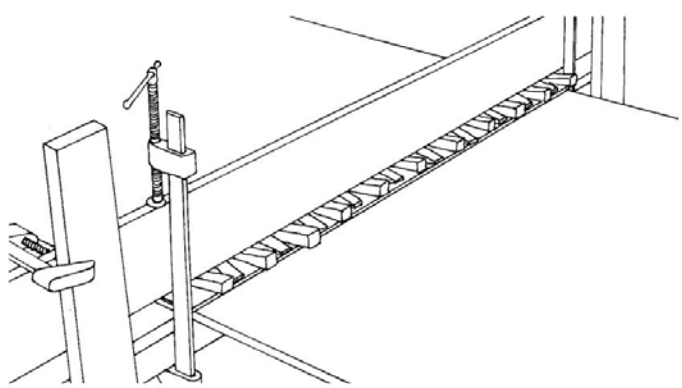
Bonding the scarf

Use the following approach:

- Present the panels horizontally (e,g, on benches or an assembly site) with thick plywood or hardwood beneath (to take firm clamping). Be sure to place a sheet of cellophane to prevent the adhesive from adhering to the support.
- Glue in two stages (impregnation and bonding) because the planed plywood will adsorb much of the glue. Be sure to position the two panels exactly one above the other. Prevent slippage of the scarf while setting by nails at some points outside the area of the joint.
- Cover the top of the joint with cellophane then place a light piece of plywood over the joint and tighten the clamps. If needed some nails are used to insure the scarf is aligned and glued properly everywhere. Any holes made will be resealed thereafter, with an epoxy sealant.



- In the case of whole panels, the need for pins or screws is inevitable. For smaller thicknesses a weight may also be used. If we wish to avoid holes the clamping arrangement shown in the figure may be used.



As when assembling strakes, mark the panels with their number and side (port or starboard) as well as the face (interior or exterior). There is, indeed, a significant risk of error (for example producing a bevel on the wrong side).

Applications

One can choose to apply the lamination technique to elements such as floors, frames, curved benches, square decks … they will be stronger or will get by if the wood used is not strong enough if used by itself. For ribs a strong single element can be created that would otherwise require several parts, when assembled with conventional construction methods.

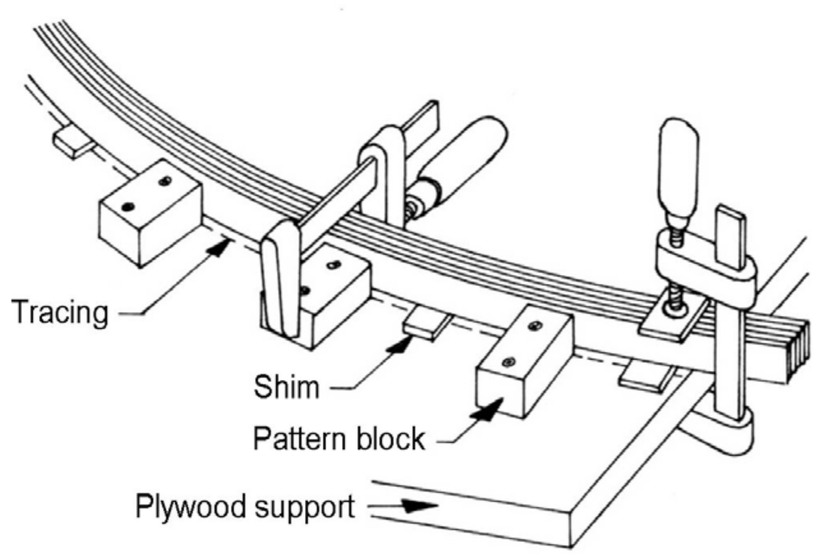
In general, epoxy (sections 05 and 06), or possibly polyurethane glue may be used.

Thickness of the blades or slats

A simple rule of thumb is to define the thickness of the blade in millimeters equal to the radius of the curve expressed in decimeters. Of course, the flexibility of wood varies significantly from one type to another, so a trial may be necessary in borderline cases. The width of the blades will be determined by taking into account a loss of 2mm for planing the edges and for inevitable misalignment of the blades with one another. For the surface of the slats, it is preferable to cut these using a table saw with a suitable blade for a clean cut. Planing blades should not be used, which have the effect of reducing the ability of the blade to adhere well. Where slats are too smooth they need to be sanded with coarse paper to insure good adhesion of the glue to the surface of the slat.

Creating parts with a mold.

The figure presents an example for creating a laminated part. The procedure is carried out on a thick panel of plywood. When the surface is coated or finished, it is useful to draw directly on the surface of the plywood. If one has a full scale plot on a layer of mylar, it can be affixed to the plywood support and work can proceed on top of it. Cleats, sufficient to control the shape of the part are screwed onto the working surface, then a few shims are placed to prevent direct contact of the part with the supporting panel. The slats are prepared with at least 10 cm of extra length at each end. Make a trial assembly of the slats before moving on to the actual bonding.

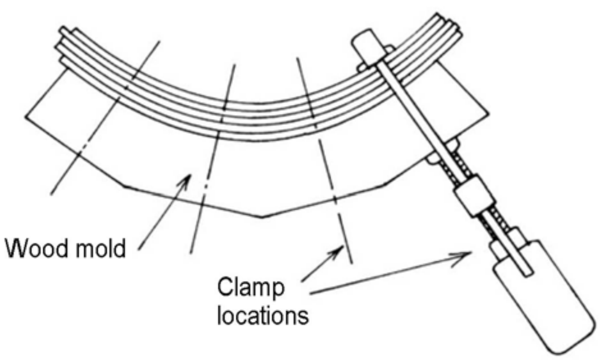


The sized layers are bundled and wrapped in cellophane (it takes practice). Clamps are gradually placed and tightened at each stop to tighten the slats to one another. Clamps are also used to press the part against the panel. If necessary, large diameter holes in the panel are drilled in advance to allow the clamps to slip through. Take note that the slats slide easily over each other as they are being glued. Everything must be kept fully aligned and a clamping force also applied to the width of the constructed part.

It is expected that the glued-laminated part will relax losing some of its camber. We can anticipate this by adjusting the cleats on the mold, but only a test will serve to quantify the amount of relaxation. If you have several pieces to construct (e.g. a batch of frames) commence with the least curved, which can provide a sufficient idea of the corrections to apply to the remaining parts.

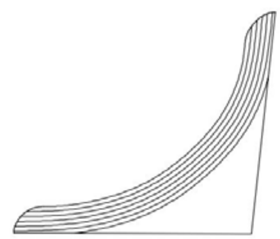
After unpacking the glued laminate remove the glue burrs (prerferably with a belt sander for the well hardened epoxy) and plane each edge to provide a smooth surface. Note that a polyurethane adhesive while requiring close attention to ensuring well clamped slats, is easier to clean. The glue that exits the joints is foam that removed easily with a rasp or microplane.

The photo on the right shows one piece currently wrapped, clamped and bonding, while the piece on the right shows the finished product.



For small parts,it is easier to cut an external profile of the desired shape in a thick plate as demonstrated in the example to the left.

The mold may also be kept as part of the final piece as in the thwart knees in the adjacent figure.



Laminating frames in situ

One may wish to make a laminated piece by directly using the boat hull as the mold. This is particularly useful for laying for laying frames, but also for other parts in contact with the strakes such as a support of a bench or of a bridge deck, or for a false keel or floor.

Described here the particular approach for the frames, a technique that provides an alternative to steam bent frames.

- Prepare the hull: sanding, cleaning, etc…
- Glue the lath beam in place (from one side to the other, with the possible exception of the fore and aft ends or at the level of the daggerboard or centerboard case,
- The laminated part is glued and packaged in cellophane, and tightly held at some points with adhesive tape,
- The frame piece is placed inside the hull by holding temporarily with clamps at each wale,
- Screw the frame to the hul bhy means of temporary Phillips chipboard screws 30 to 35 mm in length and as small in diameter as possible (max. 3mm exernal thread dia.). Start at the keel. For a strip built hull place a screw in one of three strips. In a chine hull, place a screw at the point of contact with the hull plates.
- Before installing each screw, pull the slats together with a small clamp nd drill a pilot hole (matching the outer diameter of the screw) through all the slats (it is practical to use a stop on the drill bit to limit thedepth).

- After setting of the adhesive, disassemble, clean, plane the sides, and bevel the interior angles.
- Mount the frame using boat rivets with a size equal to that made previously for the temporary screws (JP 16 or better JP 18. See section 12 on boat rivets

Note that it is normal that, on both sides of the keel, a gap is left between the frame and the planking. A small fillet can be placed alongside the frame while leaving an area open for the flow of water in the bilge (limber holes). Do not screw through the area of the gap.

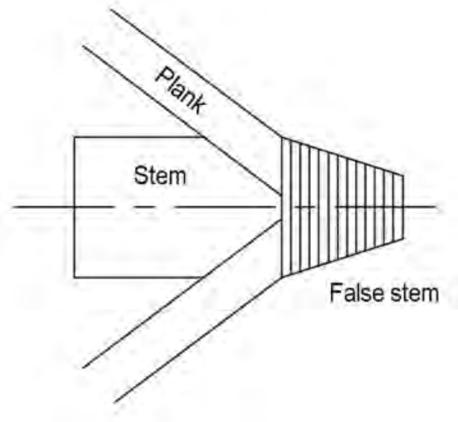
The rivet is the binding mode most suitable for frames. In other cases, or if it is difficult to obtain rivets, screws are used. For parts fixed to the hull, the screws are then placed from the outside of the hull. We will then be obliged to place temporary screws at other points and later cap these holes after the temporary screws are removed.

Photo: An example of laminated ribs made in situ. Note at the second thwart a partial frame that improves the stability of the beam shelf in the area of the thwart. Note also the laminated curved thwart knee.

Laying the skeg or fin

The fin or skeg can be made of solid wood, but without a band saw it is difficult for an amateur to make the cut and adjust it to fit the hull. An alternative is to use lamination to form the skeg. The layers will be 15 to 20 mm in thickness depending on the curvature of the hull. They are laid successively by fixing them with screws or nails with pre-drilling at each screw. Mark the screw positions to avoid collisions between screws from subsequent layers that would require holes to be refilled. It is also warned to leave areas free of screws or nails that will later need to be planed. The use of clamps (photo) at the extension of the skeg beyond the transom can also reduce the need for screws.

Laminated false stem



With modern wooden strip boat building or with strakes, cutting a traditional rabbet may be avoided by creating the stem in two elements: and inner stem which receives the end pieces of the strips or planking and an outer stem or "false sterm" which covers the ends of the planks and lends a more traditional look to the boat.

As much as possible the shaped stem is used prior to installation on the boat, as a mold to produce the false stem. This allows proper planing of each face of the false stem on the workbench. Before laying the false stem, prepare the surface: it must perfectly straight in the transverse direction and regularly curved in the other direction. When layering the false bow, screw alternately from the inside or from the outside (or better with two alternating)).

Laminated false stem in situ

If it has not been possible to mold the false bow to fit the stem on the bench, it remains to be made in situ as follows:

- Prepare the surface that receives the false bow (see above)
- Present and glue the slats successively using nails (stainless or galvanized) or screws (especially at the extremities of the bow). For screws, it is essential to pre-drill. They can subsequently be removed subject to filling the holes. Otherwise, locate their positions to avoid interference by subsequent fasteners. The overlying battens will be decreasing in width to limit the material to be removed in the final finishing.
- Use long screws for the last layer.
- Alternatively, glue the slats in packets held by screws. We must then pre-drill the outer diameter at the application of the slats while ensuring that the chips from drilling do not get stuck between the slats.

Introduction

This section describes the placement of "the boat" on the strongback. This is important because it determines the final three dimensional shape to be built and any errors will be difficult to correct later.

It consists of the following:

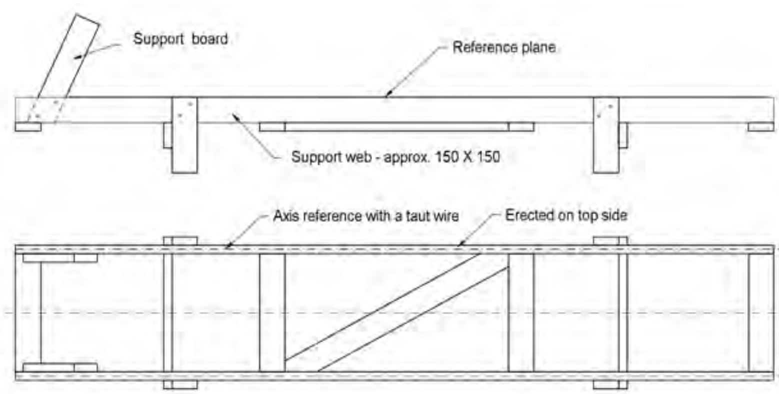
- Constructing the strongback to serve as a rigid support during construction
- Mounting templates, frames, or bulkheads on the strongback
- Position the stem on the strongback
- Position the sole or keel on the strongback
- When present, position the transom on the strongback

In principal all these elements would have been traced, cut out, and prepared in advance, before the strongback takes up valuable space. However, to facilitate understanding of the instructions, we will also in this section discuss making these parts, as they are encountered for mounting on the strongback, in the process disregarding the actual timeline of their construction.

The strongback

This is a timber structure, as rigid as possible, assembled according to the following principles:

A wire stretched on one of the beams of the strongback is used to draw a longitudinal reference line (at a distance fixed from



the central axis of the vessel). Along this line, mark the positonsof the contruction frames, following the shapes on the plan; these are generally equidistant if building on templates. Where the structure includes building on bulkheads and/or frames, the structural plan will indicate the positions for these elements.

Depending on space and available materials, the foundation of the strongback can vary. It is, for example, possible to use cinder blocks beneath the strongback. It can also be glued to the floor (polyurethane adhesive) for good immobilization, allowing a somewhat lighter construction. In extreme cases, the strongback can be placed directly on the ground, but we must think about the need to work at the right height and the ability to access beneath the structure for some later operations (riveting, cleaning of glue drips prior to their polymerization….). Some builder include wheels (possibly retractable) to be able to move the strongback while the vessel is under construction, which can be very useful to better manage available space.

Note that some kits (MInahouet, Laita) include the strongback, precut from ordinary plywood with notches for locating templates and partitions. The geometry is thus completely defined, but it will still be in the best interest of the builder to add solid wood pieces as stiffeners.

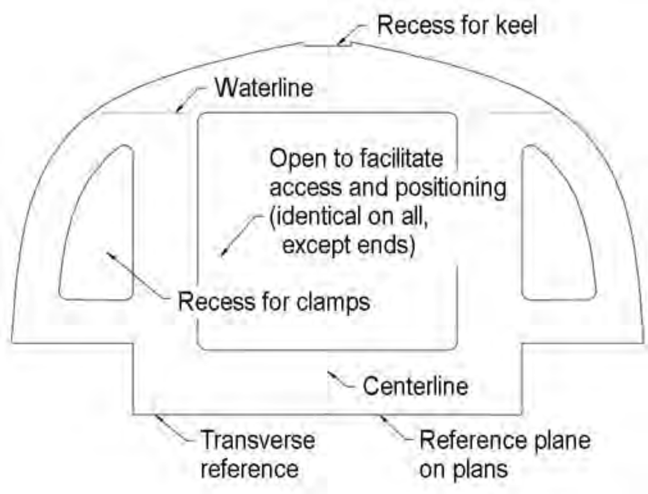
Construction on templates

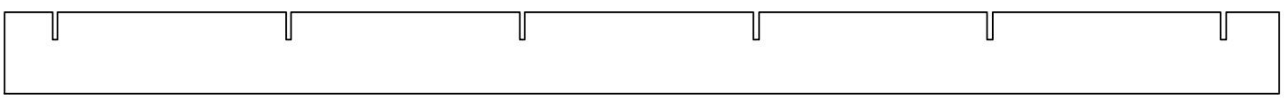
When the boat is constructed on templates the frames are later placed "in situ" within the hull after it is turned over. The templates are not part of the finished boat. The strongback and templates can accordingly be used for subsequent identical constructions. In some cases, especially for open boats, there may be alternating templates and partitions, with the latter being part of the boat. The templates are cut out of ordinary plywood, chipboard, or medium density fiberboard (MDF, a thinner and stronger constituent aggregate). The common thickness used is 10 to 15 mm.

The layout is determined from the plans provided (interior hull "non frames" or from a full size tracing on a sheet of polyester (Mylar), a much preferred solution. We will then plot the maximum number of points: center axis of the boat, waterline, etc ... that will be useful to subsequently align the whole structure.

Openings will be cut in the templates, with respect to:

- Easier access inside the boat during construction,
- To facilitate positioning of clamps for temporarily holding strakes
- To facilitate the alignment of templates by means of spacers (made from wood or plywood) with precisely cut notches for the template location(s).





Attention: it is essential to protect the sides of the templates with adhesive tape of the clear type used for packaging, to prevent the glue used for laying strakes from adhering to the templates and consequently preventing the "demolding" of the boat.

Partitions

Where the boat is built on partitions, they will be made according to the plans and "squared" as we will see for the frames. Partitions must rest on the reference plane, either by extensions that will be cut after the hull has been turned over, or by temporarily attached "cleats."

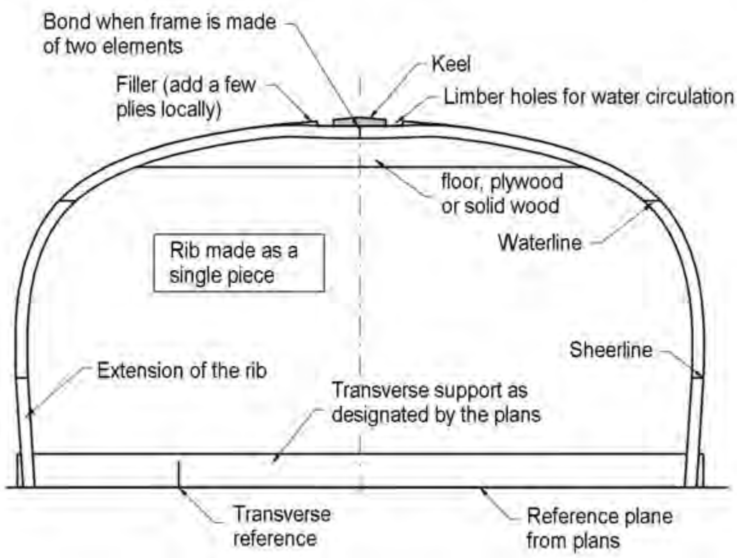
Ribs

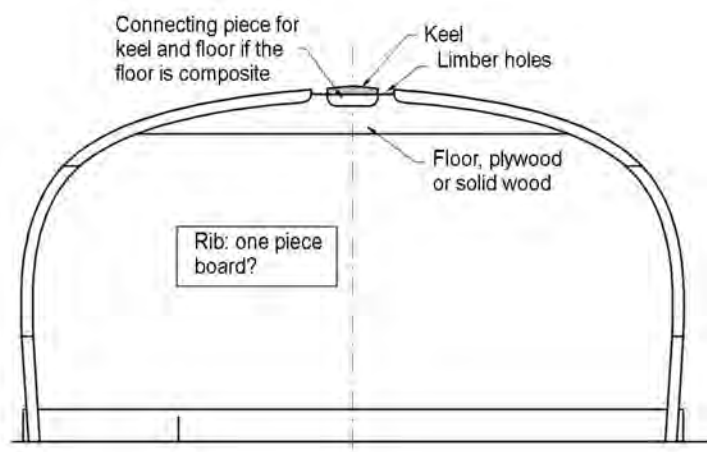
These are most often made as laminated layers (see section 16) as single elements matched to the edge of the preceding, or as several assembled layers matched to the preceding pieces already in place. It's always more accurate to make every layer separately using the same mold. In contrast, the assembly of several layers to form sub parts is likely to weaken the structure and complicate squaring (see below). The figures on the next page show some typical frame types.

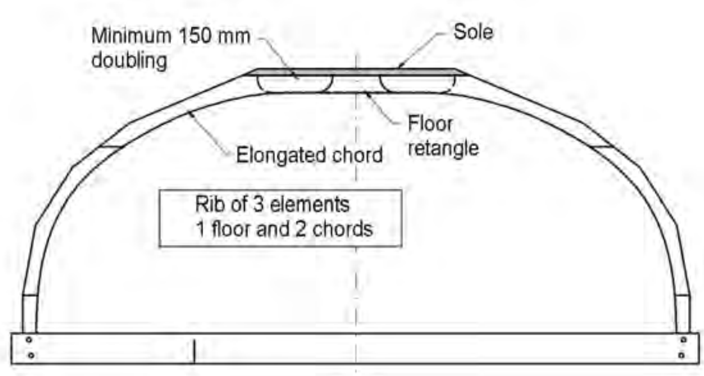
To allow the installation on the strongback, the frames should be extended above the sheer line (top edge of the hull) to the reference plane of the strongback. A cross bar is then firmly attached which is the part that rests on the strongback.

Position the frame-crossbar assemblies according to the tracing (polyester tracing or tracing done on light plywood) to properly adjust the position of each piece and, in particular, the spacing in the transverse plane. It is necessary to be vigilant with laminated-pieces which tend to relax a little after demolding, and the position of crossbar can rectify the correct location and width.

Mark a maximum of reference points (waterline, sheer, etc ...) that can be useful for good alignment of the assembly.

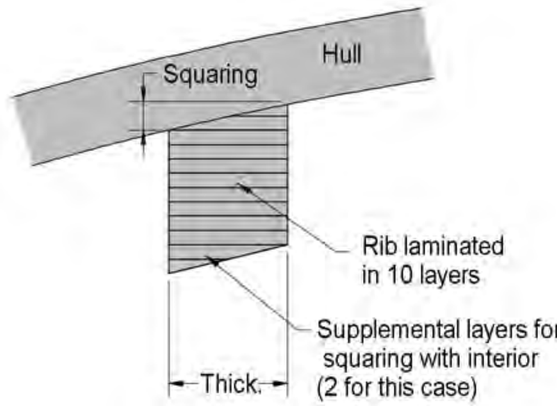

Bond when frame is made of two elements
Keel
Filler (add a few plies locally)
Limber holes for water circulation
floor, plywood or solid wood
Waterline
Rib made as a single piece
Sheerline
Extension of the rib
Transverse support as designated by the plans
Transverse reference
Reference plane from plans


Connecting piece for keel and floor if the floor is composite
Keel
Limber holes
Floor, plywood or solid wood
Rib: one piece board?


Minimum 150 mm doubling
Sole
Floor retangle
Elongated chord
Rib of 3 elements
1 floor and 2 chords

Squaring the frames

The interior of the hull, especially at its fore and aft ends, meets the frames obliquely. It is, therefore, necessary to plane the outer face of the frames to match the angle of the hull. In general, it will be also necessary to square the inner face of the frames to which are attached structural elements such as the bilge pump beam shelf. In addition, the well squared frames will appear more traditional and beautiful.

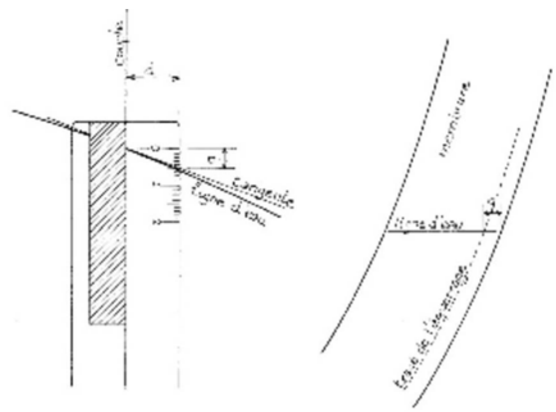


At the stage of making laminated frames, subsequent squaring must be taken into account by adding extra layers at the ends of the bent assembly to insure accurate size after it is planed to fit the hull. When I provide polyester tracings of the frames, an allowance for squaring is indicated. This can be easily marked on the part.

Otherwise, use the following method:

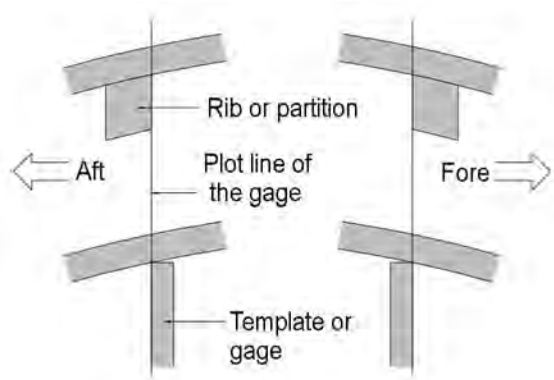
We assume to work first in the upper part of the hull, above the chine, our goal being to define orthogonal dimensions for each member at each water line

- Prepare a transparent ruler with a piece of opaque tape stuck to the bottom in order to measure the depth of the chamfer on the frames (so-called “sampling on the right”).
- Trace on the top view of the frame (on the plans), a tangent to the water line on the right of the station line.
- Place the ruler as shown in the figure, and read the dimension (q) for squaring the frame face.
- Mark this value directly on the face of the frame (supposedly glued and planed and on which we will have traced water lines and longitudinal lines) as shown in the figure. Attention: this mark is made along the waterline.



In the lower part of the hull, this is carried out using the longitudinal lines. We can then mark the reference points for squaring each frame by connection all the defined points. This method is limited in accuracy. It will at least sketch out the squareness. Using a batten on jigs mounted on site, we can complete the work or squaring.

Laying jigs, partitions or chords on site



The positioning of the templates on the one hand, and partitions or frames on the other, differs due to the fact that the former are not squared and the latter are.
The figure opposite shows in either case the position relative to the station line. The station line is that of the face plane of the template. This is normally the one that is listed on the plans.

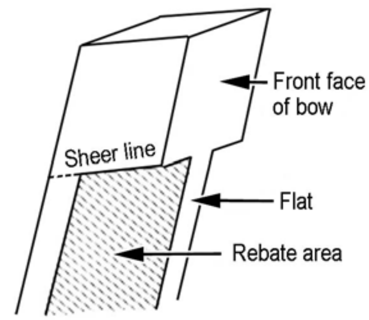
Look carefully at the plans as there may be individual exceptions to this general rule

To set up templates, partitions, or frames, bring cleats, large brackets of plywood or chipboard, and as many clamps as possible. These have the advantage of facilitating the adjustment of position for alignment, and the orthogonality of the assembly. Also place spacer planks spanning the template openings. Note: much of the final quality of the vessel is determined at this stage.

Use Phillips head screws (chipboard type) rather than nails for assembly. The shock of a hammer may indeed disrupt the assembly. Some fasteners may be removed subsequently removed if they interfere during installation of the planking.
Do not forget that the hull must be turned over, the strongback and its templates remaining in place. Make sure
all screws to be dismantled remain accessible once the boat is planked. We can use twine to fasten certain links. It will be sufficient to allow the turning

The bow

The bow is made of laminated timber, assembled boards, or as plywood as shown on the plans of the boat. It usually is referenced to the last station line, which facilitates its positioning. I always give a bow squaring plan, this being easy to get when the plan was done on my naval architecture software. Caution: as shown on the drawing, do not square
to the bowhead. Moreover it is often practical to extend the bow upwards until it is resting on a crossbar of the strongback (see photos below).

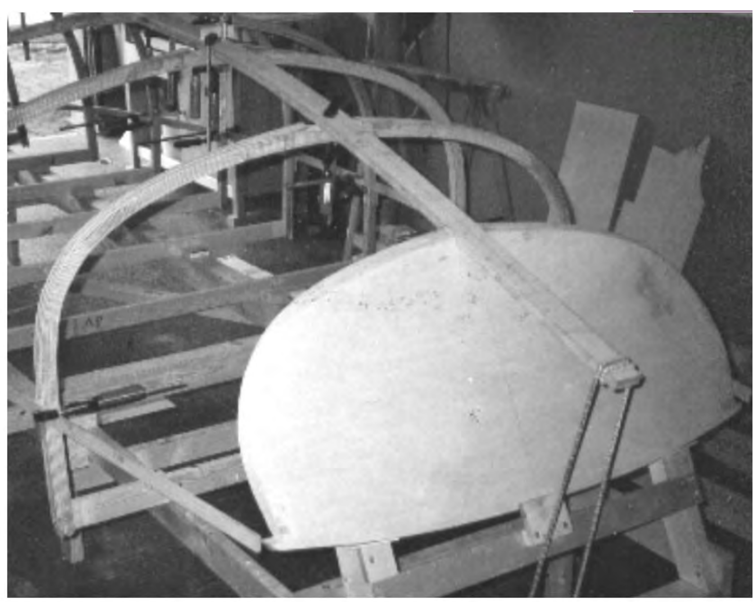


Transom

The transom is less easy to position and so you have to take a lot of care. From the plans of the boat, we can make a square-shaped template that will serve to properly align the two transom supports that we have shown on the strongback on the first page of this section. This template also allows the vertical positioning of the transom.

The curve of the stern is often provided, connecting the keel to the transom. If you have a full scale tracing, its outline is provided. Similarly a template is included in the kits. Otherwise, you have to draw it from the plans, but this may require adjustments.

Make maximum use of connectors. When presenting the keel, we can ensure that all these pieces fit together and then fix them definitely to insure the proper relations between these parts.



A rope forces the keel down, giving it a natural curvature.
This principle can also be applied to the planking.

Photo: Zimmermann (Switzerland).

The transom must also be squared. This squareness is difficult to determine on the plan and it will be defined with a batten resting on the templates and on the transom. The squaring itself will be trimmed with an electric plane, a saw or a chisel. It will be adjusted according to the direction of the wood, with a plane, spokeshave (photo), a rasp or with a belt sander.

Photo: Jean-François Dockes / Nautique Sèvre

The keel or sole

The laying of the keel, or the sole if it is a flat-bottomed boat, completes the setting on the strongback by linking all the elements together. The boat is then ready to be planked.

Note that on some boats, it is planned to insert other elements at this stage, for example a centerboard case. We will also cut in the keel the center board opening, which is much easier to do before planking on the job site.

The keel must be squared on each side to receive the planks. We can define the angle by that on the templates but it will be convenient to take the keel back to the workbench for planing.

The same applies to the sole. It is also only after the laying of the keel that one will be able to square the forefoot (lower part of the stem). We plan this by simulating the planks with a flexible board.

Note on the photo opposite, the adhesive tape placed to prevent the planks from sticking to the edges of the templates.

Photo: Jean-François Dockes / Nautique Sèvres

Example of construction on strongbacks

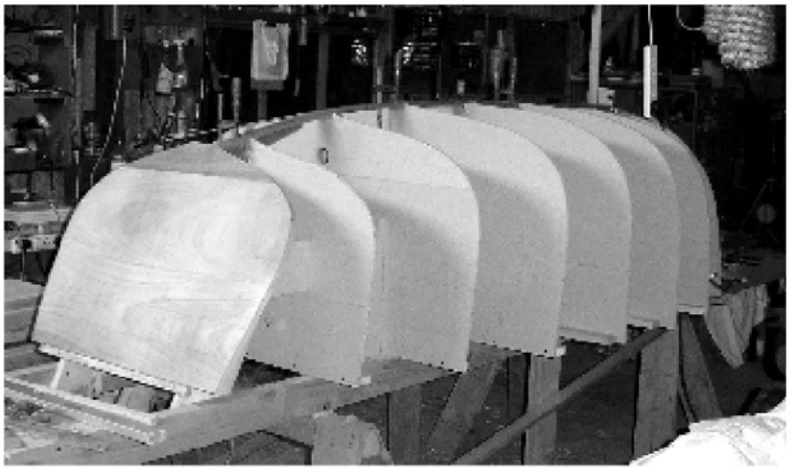
Ebihen being mounted on frames. The partitions attached to the frames are also in place, which helps to stiffen the whole.The layout was made after polyester tracings, which give a high quality fit.

Photo: Clabeck

Aber under construction, also on frames. Bow, keel and transom are in place. We can clearly see the "channels", on both sides of the keel, which ensure the contact between frames and planks in the vicinity of keel.

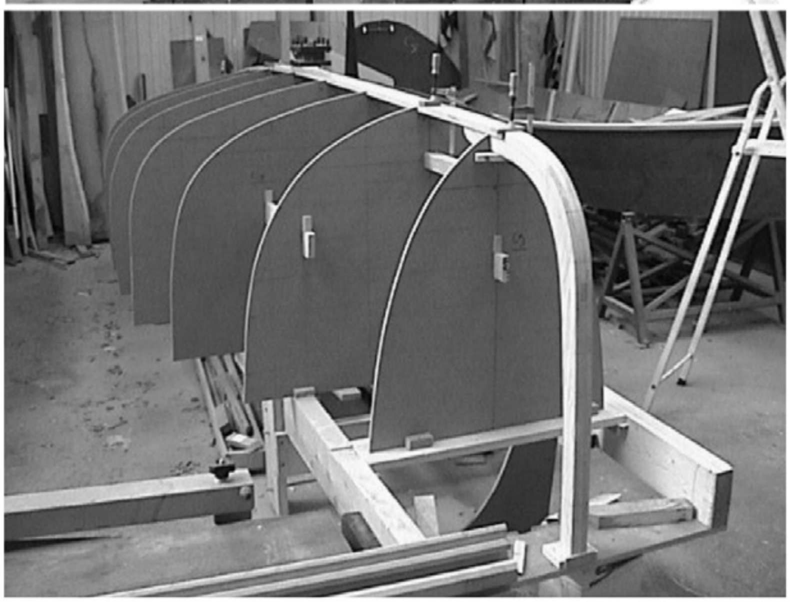
Photo: Zimmermann - Switzerland

Assembly of the structure on the strongback



Template construction for this Kernic which will be strip planked. The transom is solid wood.

Twist Photo - United Kingdom

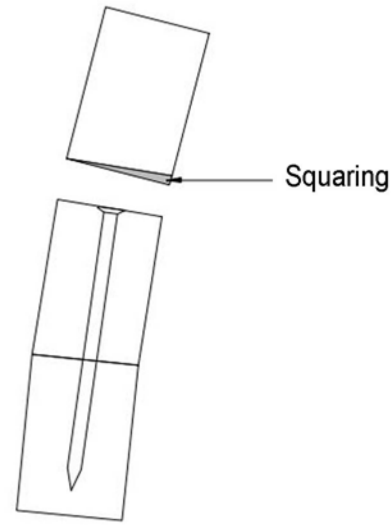


Ilur under construction at the Sèvres Nautical Center. Note the longitudinal boards with notches that cross the templates to maintain the spacing. The bow rests on the front template and on a crossbar. The keel is in place.

Photo Jean-François Dockes /Nautique Sèvres

Youkou-Lili: frame construction with sole. The pointed rear is treated exactly like the bow. A batten is presented to check the squareness of frames and bow

Introduction



Strip plank construction is wherer the whole hull is covered by the simple juxtaposition of wood strips of constant width and thickness. This method eliminates the traditional “spiling” to give a specific shape, more or less a spindle, for each strake.

The only adjustment necessary is the squaring of each strip to ensure a good joint with the previous one (figure). And again, we will see that it is possible to avoid this shaping under certain conditions. This technique has gained value with modern adhesives and resins of the epoxy type that do not require a high clamping pressure, which in this case is difficult to obtain. Indeed only the nailing of a strip to the previous ensures the contact during curing of the glue. Note that some builders use strips that have been routed to an arcuate profile to eliminate the need for squaring between adjacent strips. The effectiveness of epoxy or other glues along with the extra cost of maching all strips, especially for an amateur, do not seem to justify this method, which is, accordingly, not described here.

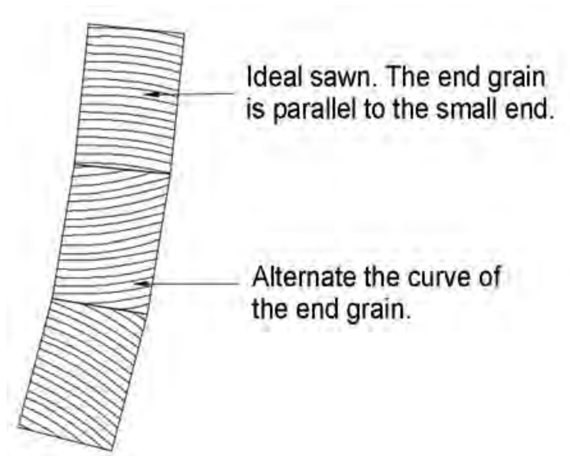
Small slats and strip-planking

In recent years, we have seen widespread use of the technique of “strip planking” the term which is none other than the English translation of “petites lattes.” However, strip planking today mainly refers to a construction method approximating a sandwich: the wood strips act as a core material, which is then covered on both sides with a resistant fiberglass lamination. The result is a light structure, well adapted to efficient boats.

The technique of small strips that we describe remains more traditional. The strips constitute the resistant structure and are not necessarily fiberglassed. If they are, it is particularly to make them more inert vis-a-vis variations of temperature and humidity. Incidentally fiberglassing makes the planking less vulnerable to mechanical damage (essential for a plank in red cedar, a very soft wood). The hull constructed with small strips behaves indeed like a board of great width which will play according to variations in the humidity of the wood. If too dry it can open, too wet it may buckle under pressure. This is why I recommend taking the precautions outlined in the next paragraph.

Recommended Precautions

- Give preference to a wood that works little (African mahogany, sipo, red cedar in particular), cut at a long interval before use,
- Use quarter sawn strips, as shown in the figure and alternate the direction of the grain. The swelling of the wood is indeed lower in the radial direction.
- Before laying the plank, store the wood under conditions of “average” temperature and humidity. Avoid it being too wet in winter, or too dry if you build in the summer. Just before laying the frames, if no fiberglassing has been planned, dampen the bottom of the boat with wet rags for a few days. This area is very often wet, and the frames can prevent the planks from swelling if they are over dry when laid.



- Prefer a construction on glue-laminated frames of varied grain orientation rather than steam-bent frames,
- Fiberglass the exterior (see section 07) to reduce the effects of variations in humidity, especially if the hull is varnished or painted a light color.
- Epoxy impregnate unlaminated surfaces and especially the bottom of the boat on the inside.
- Prefer a light paint to protect the hull from the heat of the sun. Reserve varnish and dark paint for boats either afloat or mostly stored in the shade.

All these recommendations may seem very restrictive. In fact it happens that boats with strip plank construction have aging problems, especially if they are poorly built and poorly maintained. It is not necessary to follow all the recommended precautions, but the closer you adhere to these recommendations, the more the resulting boat will be healthy, durable, and resistant to abuse.

Rightly, the choice of strip planking is often done in order to have a beautiful varnished wood construction. Softwoods (red fir, Oregon pine or Douglas fir) will then give the most aesthetic result. It must be realized, however, that such a construction will have to be carefully maintained and stored most often under shelter, especially for open boats. A very good quality and dry wood (not always easy to find), external fiberglassing, and laminated frames, will then contribute to ensure the longevity of the boat.

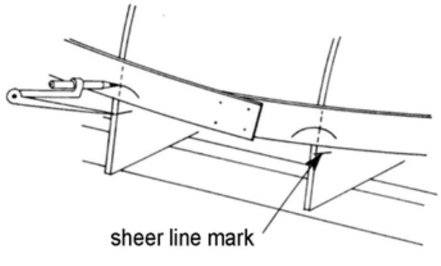
We can make a beautiful boat with a painted hull like this Aven in Pont l'Abbé (see in color on my website!).

Laying the sheer strakes

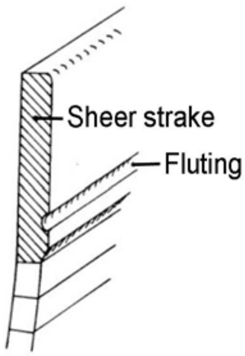
On boats of traditional inspiration, it is aesthetically preferable to place a prominent sheer strake, that is to say, as drawn for traditional construction (painted in dark on the photo of Aven above). This further provides a rigid base for nailing the first strips and the tapered shape of the sheer strake also reduces the curvature of the joint with the adjacent strip. The sheer strake has a greater thickness than the other planks (3 to 5 mm more).

Proceed as follows:

- Prepare three strips of light plywood about 8 cm wide,
- Place them on the frame, at the site of the sheer strake, but without covering the sheer line marks (figure), fix the strips together in their areas of overlap,
- Trace the position of the planks, station lines for the templates or frames, and bow, then mark a constant distance from the sheer line (with a compass for example, following the principle of the figure),
- Remove the assembly and put it on the wooden support on which the sheer strake will be cut, The sheer line is the top line of the hull in the plan
- Mark on this board the position of the sheer line,
- Using a plank batten, draw a regular curve for the sheer line,
- By increasing the width of the gunwale on the form, extend the lower contour and trace with the batten a beautiful spndle form (in general, the width is 65% of the maximum width at the bow, 70% at the transom).



- Cut out the sheer strake, place it and adjust it to satisfaction,
- Trace and cut out the second sheer strake in the same way,
- Plane the thickness at the front end of the sheer strake. Our method of construction (false bow marked) makes it necessary to return the sheer strake to the same thickness as the other planks. Work on the inside, so there will be no visible plane marking. If you want to give some elegance to the boat, dig a groove about 8 mm wide, along the lower edge (Figure 6).



- Plane the outer lower edge of the sheer strake to match the thickness to that of the adjacent plank.
- Glue and screw the sheer strake to the bow and the transom, also ensure a good provisional liaison on the templates.

The positioning of the sheer strake is a very important operation: their outline will depend on the sheer of the boat - and God knows that it takes little for it to be not perfect! The symmetry can also be affected by this operation because the rigidity of the mold is never perfect.

It is possible to simplify the installation of the sheer strakes by applying the principle of small strips described below (strips a little thicker). In this case, the first batten is laid according to the sheerline. The second, identical, is placed next. But the next one and beyond are to be thinned, at their extremities, so that the sheer strake retains its traditional spindle shape. This method should be reserved for the case a painted finish

Gluing the strips

Epoxy bonding

The best product for bonding strips is epoxy. One can even use a mixture totally prepared for bonding and sealing joints. We will just mix two products, without adding each time fillers for thickening the mixture. It is strongly recommended to remove glue dripping before curing. The disadvantage of the epoxy is that we will have to prepare the glue for each joint, which is long and tedious (1 strip on an edge, but perhaps more with good organization). The use of an epoxy filler has the advantage of filling voids. We can, therefore, avoid squaring the strips, except perhaps in certain areas (e.g the chine in the vicinity of the transom). The strips will then joined on the inside, allowing a beautiful varnished finish, and will be slightly spaced outside, which is not a problem if you paint.

We can even use a low density sealant for bonding (e.g. epoxy with microballoons) that flows little and has the advantage of having a hardness equivalent to that of wood. This facilitates the sanding of the hull (i.e. no hard epoxy points). The strength of the bond will then be somewhat less. I did a strength test with Resoltech 8020, a filler for surface finishing, and it was the wood that broke. I still advise in such cases to fiberglass the outside of the hull and to reserve the filler method for relatively soft (coniferous) woods.

Epoxy bonding is limited by minimal tightening. Nails can be arranged that are evenly spaced apart (every 30 to 40 cm), the length of which will only be about 10 mm in the bottom strip. In any case, to ensure better bonding quality, we can pre-impregnate the strips with low viscosity epoxy (formulated especially for porous wood) and / or ensure that the surfaces to be glued are a little rough (the ideal is to have strips cut with a circular saw of good quality not requiring planing).

Other glues

If the temperature conditions are not satisfactory, or if you have an allergy problem, you can use the PPU (see section 08) which is single-component glue. Be careful since this glue stains the wood. For a varnished finish, careful sanding will be necessary (not very easy inside). The PPU adhesive requires a clamping force substantially greater than the epoxy. It will multiply the nails required (every 10 to 15 cm) and take a little longer nails (about 15 mm in the strip below). Furthermore, matching the surface of the adjacent strips is strongly recommended for good bonding.

Resorcinol can also be used for bonding strips, with the same precautions as for the PPU (good joinery for the matching surfaces, good tightening ...).

Evaluation of squareness - © Francis Holveck in Douarnenez

Laying the strips

The principle is simple: strips, of rectangular and constant section, are nailed on (small side) some to the
Lower hull strips others, starting with the one which adjoins the sheer strake. We alternate work on the starboard and port sides to prevent deformation of the hull. We will start by sorting the strips: eliminate those with knots; use the prettier for the higher portions of the hull; reserve the more flexible and straight strips for the chine and the bottom. We use the plane to square if necessary each strip and ensure a good contact with the previous one. The evaluation of squaring is done to the eye with the help of a short piece of strip placed in front of each template (photo).

Stagger the nails from one strip to another (note the position of the nail penciled on the exterior face). We use either grooved stainless steel or galvanized steel nails. The second solution is most often satisfactory, especially if the finished plank is impregnated with resin. More important, galvanized nails grip better than stainless steel, even when the latter are notched.

It is important to orient the nails well and not to split the wood (the risk is maximum for Sipo and Oregon pine or Douglas fir). It will almost always be necessary to pre-drill the strips for gluing. The diameter of the hole will be ½ to ¾ of the diameter of the nails according to the hardness of the wood. We could be led to cut the tip of the nails with the cutting pliers: thus the nail is cut short of the depth of the bottom strip, which avoids the bursting the strips apart. It is advisable to experiment with wood and nails that will be used. We can also test the strength of the bonding, by breaking a zone without nails cut from a prepared sample of bonded strips.

Clamps provide the necessary apposition to the templates during the hardening of the glue. If we build on frames, we can screw to it directly or nail the strips (and glue), which greatly facilitates assembly. Then screw or nail all three pieces. Obviously, if the shell is varnished, it will be necessary to countersink and plug the screws.

At the beginning, the strips of the transom and bow are leveled after the glue has cured. Then, when the strips end on the keel, it is necessary to adjust them before gluing. It is allowed to leave some imperfections, because this joing will be subsequently covered by the false keel.

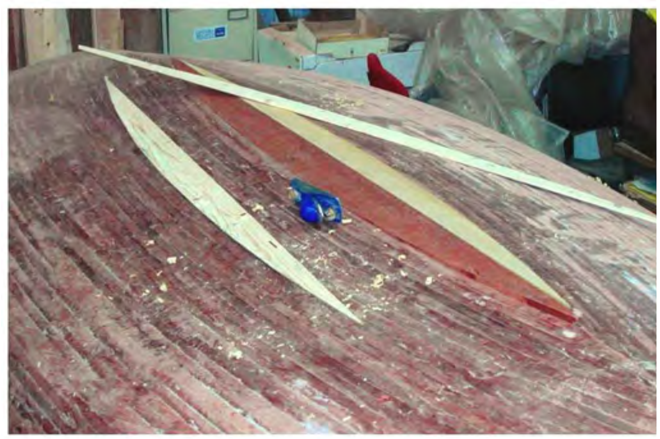
Nailing a strip - © Francis Holveck in Douarnenez

The planking of the chime requires bending the slats, i.e. twisting them with the help of a clamp. The hand of a companion is then desirable. In particular, we will need to force the trimming of the strips at the ends as we see it on the picture opposite.

Wooden levers to facilitate twisting the strips
© Jean-Francois Dockes

Closing the planking

When nothing remains but to close a space of about fifteen centimeters in width, we cut a large plank, which can also be obtained by gluing slats together. This board (closing board) is adjusted leaving, with the last strip mounted, a gap of a few millimeters, slightly open to the outside. This space will be filled with epoxy putty (same product as for a joint bonding - see Section 06). Note that it is also possible to fill this space (and even a larger width according to the forms) by marine plywood (all sapelli, makoré or moabi) of the same thickness as the planking. It will strengthen the structure around the centerboard case, if it exists, and will make the bilge less subject to moisture absorption. It is strongly recommended to impregnate with high viscosity epoxy the edges of the plywood after adjustment, and before gluing in place.



On this Ilur, adjusting the closing plank of solid wood
© Jean-Francois Dockes

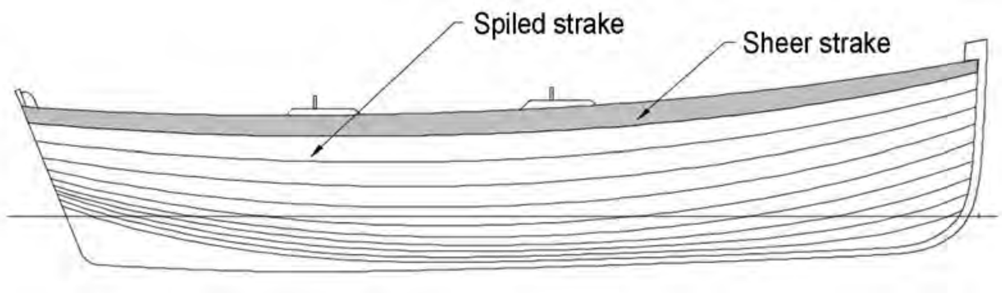
For the record, on the Aven built by the Naval Constructions of Loctudy, the closing plank was caulked with the adjacent strip. Thus, in case of drying of the hulll, the seal opens without damage to the structure. After launching, the hull recovers after 1 or 2 days. It’s a very good method, but should be reserved for those who can caulk and have the appropriate material; ...

Function

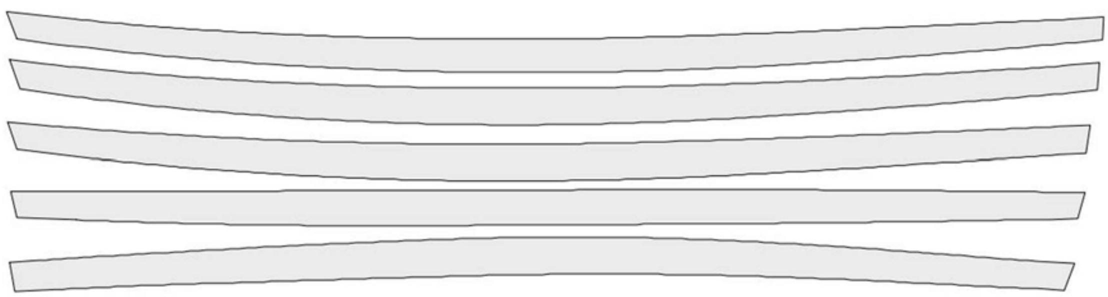
Spiling is the operation of drawing a plank, in other words, to define the exact profile that will come to rest on the hull of the boat. We describe here more particularly the case of spiling a plank for lap strake construction because it is the case where this method will be implemented the most as part of a “modern” wooden boat construction. The method described is similar in principle to that used in a traditional freeboard construction.

Note that on a strip built boat, it is interesting, if only on an aesthetic level, to place a sheer strake (last edge on top) of a traditional spindle form plank, a little thicker than the other strips/planks. This sheer strake will then be spiled in the same way as the case described below.

On a lapstrake boat we can also make the sheer strake solid wood, while the rest of the strakes are painted plywood.



Here are what the strakes look like from the same boat:



The strakes

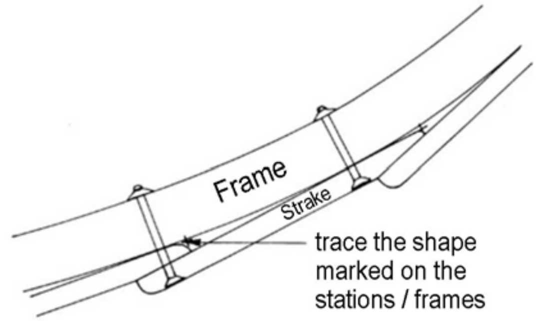
When building a lapstrake boat, it must be borne in mind that it is the shape of the strakes that gives the shape of the boat, in the same way that the shape of a suit stems from the cutting of pieces of fabric which constitute it. Shaping the planking is therefore the essential operation. It must be approached with care and methodically, but, once the first planks are laid, you will find that it is not so difficult as it seems. You be the judge! It also appears that in the past the construction of the lapstrake boat was entrusted to apprentice carpenters.

Laying of the strakes begins with the garbord, the first strake starting at the keel. Repeated operations for each side are:

- Spil the plank, that is to say, obtain the trace of its exact form,
- Cut it out and adjust it,
- Plane/shape the ends, to remove the excess thickness where the strake overlap at the end, on the bow and the transom,
- Put it in place (gluing and / or riveting),
- Plane the chamfer to receive the next plank.

The first two operations are detailed in present section. For subsequent operations, see sections 42, 43 and 44.

Marks on jigs, partitions, or frames

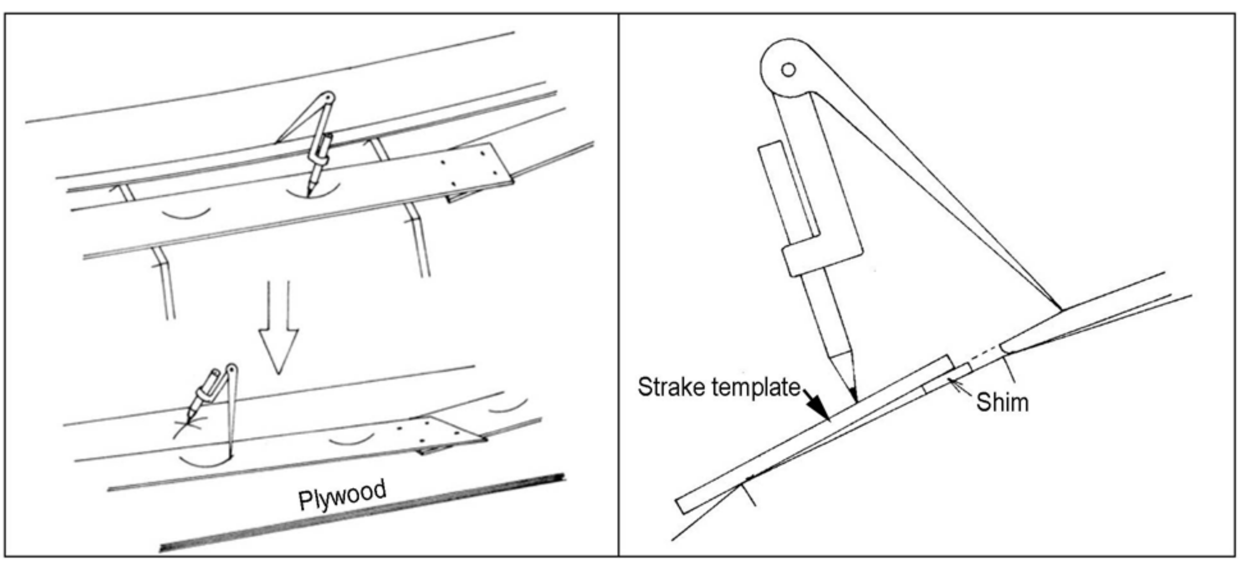


The shape plan of a lapstrake boat is usually represented on the transverse stations in the form of straight segments. It is important to mark well the templates of stations, partitions or frames with the location of each angle. It's based on these marks that the planking is going to be spiled.

The spiling of a plank

Follow the following process:

- Prepare three strips of lightweight plywood approximately 8 cm wide to form a template for planking
- Place them on the frame, at the location of the plank to be laid but without covering the previous strake (left figure),
- Fix the strips together in their overlapping areas in a rigid manner, identify the position of the transom, station templates and bow,
- If necessary, place a small shim between the station template and the strake template so that the latter is in the same plane as the plank to be laid (right figure),
- Draw arcs about every 20 cm (see both figures),
- Place the strake template thus formed on the plywood plank to be shaped (pay attention to the direction of the scarfs and their placement (shifted between adjoining strakes), also take care to avoid dropping the template or plank),
- Mark with the compass the contour of the strake(lower left figure), the position of the stations, and the ends,
- Using a batten, draw a very regular curve (the quality of this line is essential for the aesthetics of the finished boat),
- On each station template, measure the width of the plank, and draw the second contour of the strake,
- Cut the strake and place it in position to check that it fits well to the previous one.



The strake that is put in place must just touch the templates, without deviating or forcing contact. If this is not the case, it is because the spilling is bad. Do not be tempted to force a badly adjusted strake; it would provide hollows and bumps difficult to subsequently remedy.

At first, while we are still unsure of ourselves, we may cut the plank leaving it with an extra centimeter of width, allowing an adjustment. Then trace in place, the final cut when placing the following strake. This cut can be smoothed with the plane. Depending on the accuracy of the tracing, it is usually preferable to smooth the outline of the plank, even if this does not quite respect the markings onf the station templates.

In practice, the garbord (first strake adjacent to the keel) is the most delicate to place. We will use a lot of care. Get help during placement so you do not break it, especially at the most forward templates. If necessary you can soften the plywood by wrapping it for a moment in a cloth soaked in hot water. In this case, it is necessary to fix the strake temporarily and to glue it only after complete drying.

The subsequent strakes are easier.

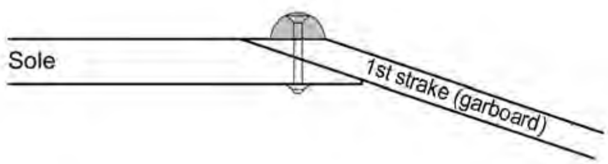
When one is fully satisfied with one’s work, one puts the strake (in the good sense) on the panel of plywood in order to obtain the layout of the symmetrical strake of the opposite side. The hull planking will progress alternately between port and starboard to avoid any overall deformation of the hull.

Vocabulary

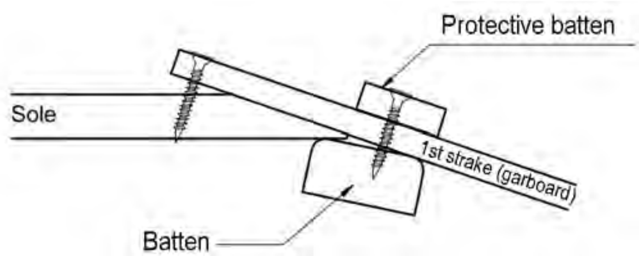
- The sole is the horizontal plank that replaces the keel.
- The galbar is the first trimmed from the bottom, starting from the keel or sole.

Making the joint

The connection with the sole is glued. And fiberglassing then covers at least the sole and the galboard, both to improve the bond, give more impact resistance, and protect the boat when beaching. Finally a soft metal band will be screwed or riveted to protect the sole in the area middle. This finished assembly is as follows (boat shown upside down):



To ensure the tightening during the installation, we use provisional Phillips head screws, making sure to drill a pilot hole in the planking at the outside diameter of the fillets. The alternation of screws on both sides of the joint ensures smooth bonding gaps in the joint. A spacing of about 12 cm is suitable:



Use preferably a glue with a little bit of filler added to fill the voids (also use prior impregnation). After glue is set, the screws are removed, the garboard is planed flat and the screw holes are plugged.

Be careful not to break the screws, especially at disassembly, use an appropriate diameter screw and matching screwdriver bits. Remove them preferably not more than 24 hours after bonding.

The garboard is almost always deformed in the fore part of the hull. To avoid deformation of the bow (when it is made of layers of plywood) it will be useful to glue the first garboard, the second being simultaneously laid dry from the opposite edge. We can then use wires at the front (drill holes where needed) to bring the planks closer and bring them into contact with the stem. Cut if necessary the parts that would be in contact (aft end, in front of the stem).

The soft band is preferably half-round brass (7 X 14 mm for a small sail-rowing boat 10 X 20 mm for a Stir Ven), otherwise flat. It can also be made of wooden slats by considering it as “Consumable” (glued, only to be removed by planing) or for small boats (less than 100 kg approximately) a polypropylene band sold in maritime cooperatives for the production of fishing pots. The attachment is done by small stainless screws if the sole is at least 15 mm thick, by rivets if the sole is less thick (unless you stick a wooden backing for ensure the screws hold).

Temporary mounting of planks/lapstrakes

Object

When making a lapstrake hull, it is necessary to handle complete strakes whose length is that of the boat (even a little more with the curvature), mount them on the strongback for adjusting the contours and chamfers, place them by tightening the connection with the previous strake.

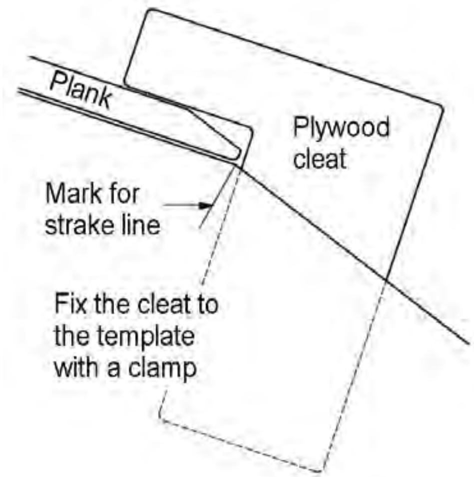
The purpose of this sheet is to provide the corresponding technical solutions.

Holding strakes on the strongback

Except in the case of glued laminated frames, before laying the planks, it will be very difficult to fix the planks directly to the bulkheads or jigs by screws or nails.

The figure to the right shows how to use a cleat cut into plywood and attached to the strongback by a clamp.

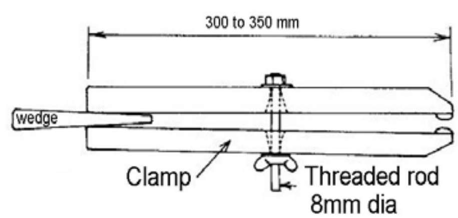
We can also make holes in the station templates and directly pass a clamp that applies the planking against the template.



Holding the planking together

The traditional tool for tightening lapstrakes is the wooden clamp; an easy-to-implement version is shown in the figure, with dimensions for strakes of medium width.

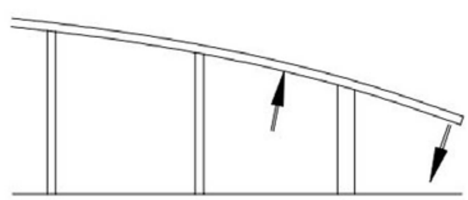
It is not essential, as part of the methods, I propose use provisional screws or rivets. These will do service to complete the tightening in certain areas or to replace clamps in situations where they are not usable



Curvature control

It happens, quite often even, that strakes of plating do not have as regular curvature as one might wish. We can correct, at least in part, these problems, either before the final laying or before laying the next plank.

The ends of the planks always tend to go “straight ahead” while one would like to obtain a regular curvature to the bow (or marotte?) or to the transom. We must first make sure of the definitive squareness of the stem or transom by bending a batten across which serves to check this alignment (as shown on the figure),



Then with twine or wire, constrain the plating while the glue is setting, install rivets (drill holes if needed) using the protruding part (down arrow). In the case of the stem, we can link between them the two symmetrical sides. It is also possible to trap a cleat between two jigs to constrain outward bowing of the planking (upward arrow).

The same methods (pulling with wire, pushing with cleats) are usable everywhere, whenever necessary. If we do it before laying the next strake, we have a chance to remove the defect.

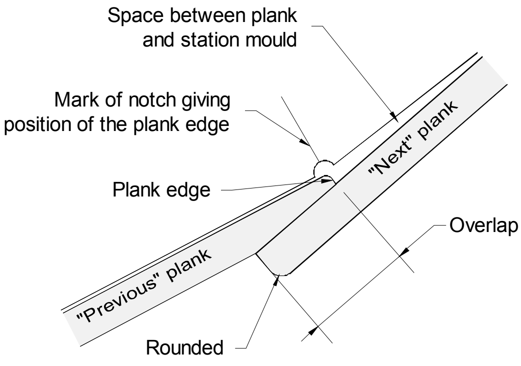
Lapstrake fitting

1 General process

If no pattern of strakes is given, they have to be spiled and cut to shape according to sheet # 41. In case of numerically designed strakes, see § 5 and 6 of this sheet.

The sketch shows the usual clinker or lapstrake joint between two strakes. The « previous » plank is chamfered to receive the « next » one. The boat is planked upside down, starting from keel or sole.

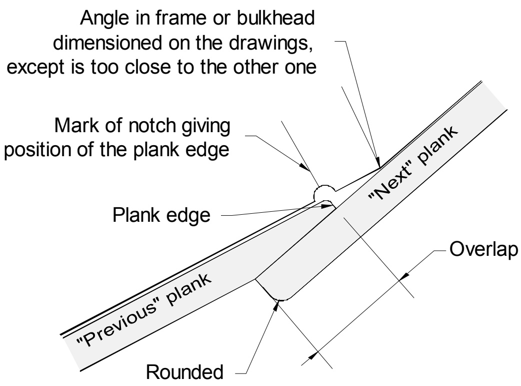
Station moulds or bulkheads drawing or pattern gives the position of the edge of the « previous » plank. In case of NC cutting, a notch or equivalent mean materialize this position.



Planking on station moulds
(usually for narrow strakes boats)

Except in case of high angle between two beside planks, the inner edge keeps a certain width. When building on stations moulds, a small space is left between plank and mould.

When building on frames or plywood bulkheads, avoid this space and cut as shown on the second sketch. Drawing or pattern defines two separate points. Fill up with epoxy putty in case of watertight bulkhead the small remaining space. An other choice is to make a notch into the station mould or bulkhead : see paragraph 5 and 6.

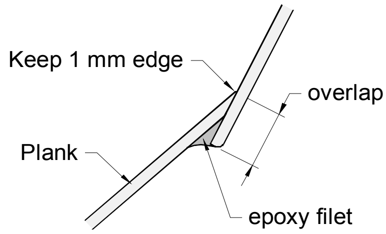


Planking on plywood bulkheads or frames
(usually for wide strakes boats)

The overlap of planks is defined by the architect. It depends on the plank thickness. For plywood planks, the usual overlap is in the range of 2 to 3 times the plank thickness.

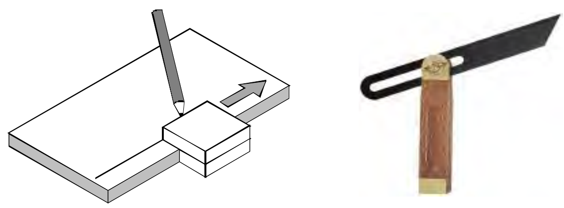
Notice that the inside and outside edges of planks are to be rounded to avoid chafing deterioration and get a better adherence of epoxy impregnation and paint. It is preferable to fully prepare planks on the bench before laying down. Take care that in some specific areas (in particular bilge keels, see § 3) the edge must be kept sharp.

In case of thin plywood and wide strakes, an epoxy filet is made to fill up the space between both planks:



2 Making chamfer

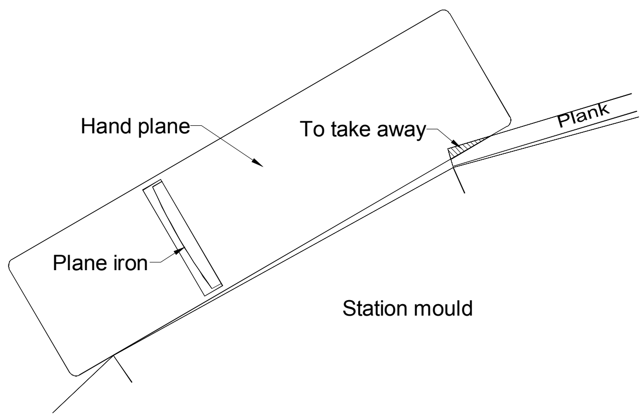
Firstly, be aware to chamfer the right side ! It is easier to plane the chamfer on the bench than on the boat itself but both ways are possible. The first task is to mark the chamfer width. Use a small marking gauge as shown on the sketch. It is made of two plywood pieces, adjusted according to bevel width.



Marking gauge and carpenter bevel

Then planed off the chamfer. Use a carpenter bevel (picture) to copy over the angle measured at each station. For a more precise measurement, and to check the bevel when made, lay down temporarily the strake on the building gig and place a rule or hand plane as shown on the sketch.

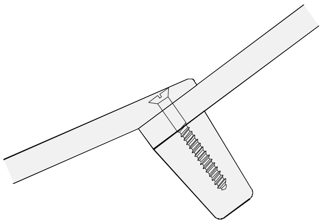
The layers of the plywood help to control the angle which varies along the strake length. If needed, make some chamfer adjustment just before laying down the “next” plank.



If the planks are glued with epoxy, a rough chamfer is convenient. If the planks are dry jointed with rivets (see sheet 12) , make a good quality chamfer using a well sharpened hand plane. The best is to give the plane iron a small convexity.

3 Bilge keels

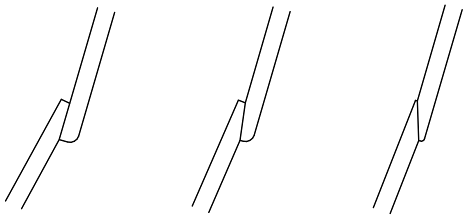
Bilge keels protect the hull when the boat is on ground. Their length is about 25% of the waterline length. Place the bilge keel at the point the hull is touching the ground first. Do not round the outside edge of plank in way of bilge keels.



4 Fore and aft ends

At each end, the overlap extra thickness is to disappear, inside and outside. At bow, it is essential to get a neat external joint between planking and stem. At transom, the inner edges may be kept if notches are cut into the transom. Outside edges may be kept but are more vulnerable.

The sketch shows how chamfer is to be worked out at ends. On the last 30 to 40 cm, chamfer the "below" plank in order to have no edge at end. Fit the "above" plank chamfer to the "below" one.



The picture shows the result on a Minahouet stem (plywood stem). Notice the way the clamp is placed to help keeping the strake against the stem. Many such tricks are useful when planking the hull.

An alternate solution is to work out a rabbet, keeping a small edge up to end (see picture of an Ilur transom). Doing that way reduces the risk to split the wood and is recommended when planking with timber.

Whatever method is used, it is practical to fasten a temporary batten to guide the tools (picture).

Remember that strakes are usually cut with an extra length of 10 cm about in order to help giving the proper curvature. This extra length is to be taken in account when making end chamfer.

5 Numerically designed strakes at final shape

Strakes of boats marketed in kit form are generally cut on numerically controlled cutting machine at the final shape. They need no width adjustment. Only the chamfer is to be made. The same applies with strakes shape printed on polyester patterns. Notice that this method requires a good accuracy when erecting the building gig.

As the shape of strakes cannot be fully perfect, the proposed method is to accept the overlap may vary in the range of 70% to 140% of the theoretical overlap. When to boat is planked, this is not visible and the most important is to get fair and smooth clinker lines.

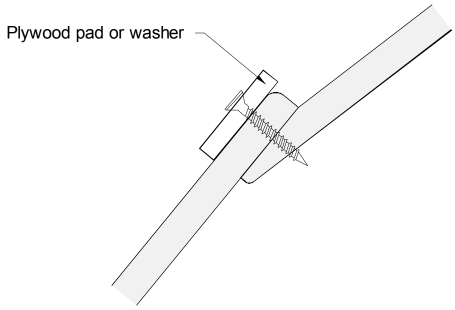
The first step is to lay down the "next" strake, to align the lower side (lower when building upside down) on the moulds / bulkheads marking / notches. Then mark on the "previous" plank the actual overlap and take away the "next" strake. Then, the previous strake is chamfered, either taking it again on the bench or directly on the building gig. The second method is possible with thick plywood and close stations. The first method need to have the plank temporarily fastened only.

6 Numerically designed strakes at near final shape

On some older designs, the strakes are drawn with a transverse margin of 20 mm about. They are only at "near final" shape and need no spiling. The "next" strake is lay down temporarily and marked both sides according to chamfer line of "previous" strake (upper side) and according moulds / bulkheads marking / notches on the lower side. To reduce work, try to have to cut only one side and to make only small adjustments with a hand plane on the other. Be aware to give a fair and smooth profile. Of course the strake of the other side of boat will be cut to the same shape before final lay down.

7 Gluing of planks

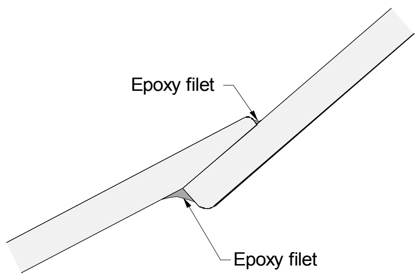
The usual method to fasten planks is gluing. See sheet 12 is you prefer to use rivets. Temporary screws ensure joint tightening. Use small crosshead screws and cordless electric drill. Screws have to be small in diameter but may overshot inside the hull. Drill holes in the outside plank at a larger size than the screw overall diameter. Drill the inside plank as necessary to get enough holding power and not break out the plank.



As far as possible, drill the plank on the bench after marking the station position in order to avoid interferences. Spacing of screw is from 8 to 10 cm for 6 mm thick plywood and 12 to 14 mm for 9 mm and over plywood. If there is frames or thick bulkheads, put down definitive screws.

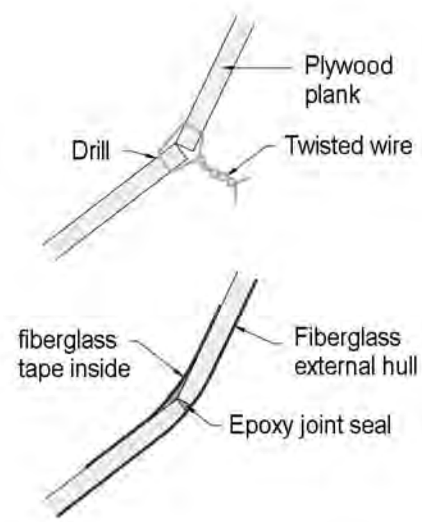
Remind that a good bond with epoxy requires a previous epoxy impregnation, especially on the chamfer which "sucks" the resin.

To add small epoxy fillets outside as well as inside is not essential but reinforces the bond and ease maintenance :



Introduction

The technique of “stitch & glue” is to assemble a boat hull with pieces of pre-cut plywood to the final dimension, to “Sew” these together by means of wire (or other) ties, and finally to fiberglass the joints inside and outside, thus creating a kind of “welding” between two adjacent plates or planks. Originally, this method was used in a spirit of “Plank first,” the frames or partitions being subsequently adjusted and placed inside the hull, But modern computer design tools further improved the method by pre-defining both the geometry of the partitions and that of the planks.



The plans that I propose, like this section, are made to follow this logic. We first mount some partitions, frames or station templates (and the transom if it exists), then we add on the hull plating/planks which are wire tied in position and the joints subsequently reinforced by epoxy-fiberglass tape. All this is essentially the reverse of traditional hull construction.

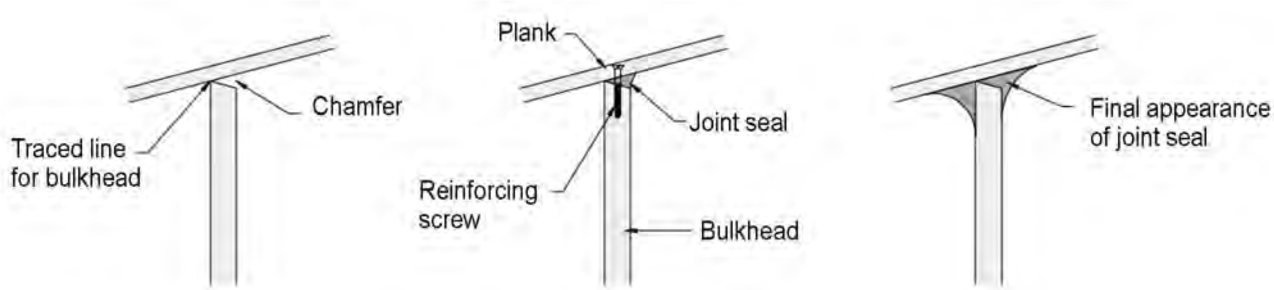
The stitch and glue approach greatly simplifies construction for the amateur: no complicated layout, no joinery, few solid wood assemblies...

It will always be beneficial to use marine plywood that ensures a longer life of the boat. The choice of an okoumé plywood is better for fiberglassing. However, stitch and glue construction has the advantage of protecting the plywood, and also lends itself to the use of an exterior plywood (CTBX in France), especially if we completely fiberglass the interior (for open boats). This helps to make this type of construction economical. A stitch and glue hulll will normally be painted, but it is possible to leave a varnished strip in the higher exterior hull portions, above “stitched” areas, if we want to keep a wood look.

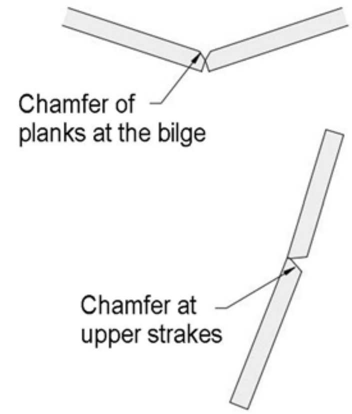
The preparation of the bulkheads

Most often, the construction is done on plywood bulkheads (rather thick). Alternatively, one can build on templates, which are not part of the finished boat. We find this latter method especially on the boats where a priority is light weight. Both techniques may also cohabit the same boat.

In the case of bulkheads, they will be chamfered as shown in the figure (left). This allows, once the planks/panels are positioned, filling the gap with expoxy, ensuring good bonding (middle of the figure). Finally, after flipping (at the location) the hull, we put clean fillet joints (right), possibly reinforced by epoxy-fiberglass tape if indicated by the plans.



The transom will be treated in the same way as the bulkheads. In the bilge, it will be enough to leave the edges without a chamfer, considering the already significant angle between panels and the transom. On the sides of the transom, we can make a chamfer on the inside as were made for bulkheads.

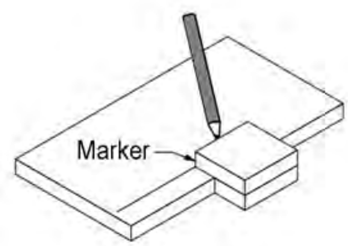


Preparation of the planks/panels

The planks are cut to the right scale, either from a dimensioned plan, e.g. with a pattern traced on polyester being the most appropriate). The planks may also have been provided in a kit after cutting on a CNC machine. When the latter is not used the planks are cut slightly outside the outlines traced on the plywood and the planks planed to obtain a very regular plank edge matching outline. The outline at the second plank/panel edge is obtained by placing planks already cut and planed as drawing guides.

The plank edges can be chamfered to facilitate the alignment of two sides (top of figure on right), while ensuring that there is always an open gap on each side to allow for insertion of the epoxy putty In the joint.

When the planks are closely aligned, a chamfer will have to be made on outside of the plank to provide a gap for insertion of the epoxy putty (bottom of figure).



It is necessary to drill the holes used for the ties. Locate them at a distance from the edge equal to the thickness using a small marking gage (Figure). The interval will be 200 to 300 mm, depending on the importance of strain in the area. In general, ties need to be less closely spaced in the opposite situation where the plans/panels are only slightly deformed.

It is important that the holes are aligned with one another on adjacent panels. For the lined of funds, place them on top of each other and pierce the two together. For adjacent edges, drill one of the two panels/planks and mark the positions or drill directly opposite, on the adjacent panel.

In principle, a strip of fiberglass is epoxied on the outside each bilge joint, then we do a complete fiberglasing of the hull (see below). This creates a risk of creating a small excess thickness on the sides of the tape that will be difficult to fair using only putty and sanding. The most elegant solution that will give an impeccable look to the finished plank is to remove a little thickness (1 small millimeter band) of plywood by means of a router (figure). The width defined according to the fiberglass strips we will subsequently apply, leaving a small margin that will be filled with low density putty.

The ties

You can use wire, copper wire, fishing wire, or the plastic ties used by electricians. But wire remains the most practical to properly adjust the tension for each link. The value of the copper wire is that one can consider leaving it in place, embedded in the resin, after cutting what exceeds. But differences in expansion coefficients are likely to create aging problems and this method is therefore not recommended. The plastic ties of electrician can be useful in specific areas where the bringing together of both sides is difficult, the bow for example. Plastic ties allow for progressive tightening. Wire is the simplest and most economical choice, especially if you find the correct diameter (1 to 2 mm) in the gardening department of your hardware store.

Note that one can make a way to twist the wire with a cordless screwdriver and a hook instead of using pliers.

Ligatures are only a temporary connection. With the potential exception above (with copper wires) you must remove the ties after the initial epoxy has cured but before completing the bonding of joints (filleting, fiberglass tape, etc) and fiberglassing the bilges.

Two methods are possible:

- Epoxy the joints between the ties and once these have hardened, remove the ties before completing the bond of the entire joint.
- Encase the ties in the resin and after hardening remove the wire by heating it from the outside, which has the effect of softening the epoxy. The heating time must be carefully adjusted to avoid damaging or burning the resin (pay attention to the risk of fire).

The first method is my preference, provided that the quality of the epoxy bonding is good (if need be both sides are bonded) because we do not have to subsequently disturb the hardened epoxy when removing the ties.

Laying the planks

Let's go back to the general process of laying the planks. We suppose that bulkheads, templates and transom are in place and properly adjusted. We begin by laying the two garboards or bottom planks together (where there is no sole or flat bottom). We can tie them together flat against each other leaving a sufficient gap in the ties. We can insert a pencil or rod under the ties once they are positioned to have an identical overlap everywhere (top figure).

Bottom planks

Joint arrangement at the transom

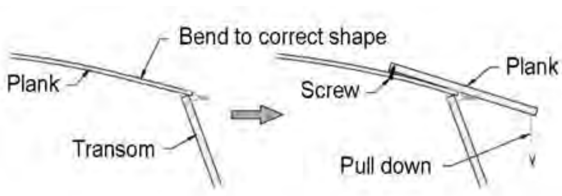
Then open the two panels/planks and position them on the strongback. Set the tension of the ties so the two planks are just in contact and place temporary screws in the bulkhead/templates to immobilize all. Be careful not to over tighten the screws because given the chamfers of the partitions, it would distort the plating.

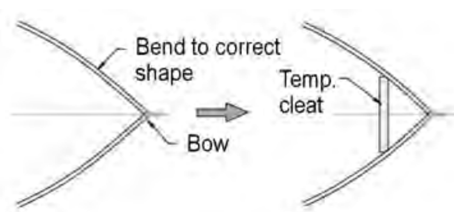
At the transom level, prefer ties (bottom figure) to screws. This will avoid distorting the planking. Note that it is necessary to extend the panels/planking towards the rear for an amount equal to the thickness of the plank, at least in relation to its theoretical arc/path.

Lay the following planks, making the necessary holes at assembly, and so on until you reach the sheer plank (plank at the top).

The curvature adjustment of the planking

At this point, the hull has almost reached its final shape. But defects may occur in curvatures, or otherwise a lack of curvature, and these need to be corrected. The following drawings give two examples of possible devices, one at the transom, the other at the bow. You will notice that vision and touch are the best tools to achieve a perfect hull





You may also need to bring the two sides of the hull closer together. In this case, just drill two holes and to pass a string or a wire which will be tensioned until a satisfactory correction is reached. Be careful to do not overdo it, because a correction in one place can lead to a distortion elsewhere. Be wary of 6mm plywood hulls which are very flexible and therefore more difficult to control. The various corrective devices will have to be left in place until fiberglassing is sufficiently advanced so that the hull keeps its shape. It is important that the sheer curve (upper limit of the hull) is very regular. The subsequent laying of the gunwale (after turning the hull) or beam clamp (decked boat) will help correct any imperfections. But it may be better to stiffen the sheer before fiberglassing. As it is difficult to adjust the gunwale or beam clamp upside down, we can at least temporarily fix (with screws in places that will be hidden later) a first longitudinal element.

Fillets and external fiberglassing

Two types of epoxy putty are used for making a sewn-laminated shell:

- A structural sealant, loaded with fibers, having a good mechanical resistance, for joints leave.
- A smoothing putty, loaded with micro-spheres, to fill surface irregularities before lfiberglassing and before painting.

We also use two types of glass fabrics:

- Fiberglass tape, preferably of the biaxial type to strengthen the bonds.
- Roll fabric, usually twill, for the lamination of the entire outer shell. This fabric can also be used as a finishing layer inside, above the biaxial cloth, as this gives a more finished look (but you have to cut it in a strip).

Once the hull is well adjusted, we insert bonding (epoxy putty) between each tie inside the hull, and outside whenever the bond is not enough, ie whenever the angle between planks is small. When putting structural epoxy on the outside, make sure to do only fill the inside of the V formed by the two planks. In fact, it will be necessary to round off the chime, with the planer and by sanding, and it is necessary to avoid hard points that the epoxy creates which would hinder attaining a smooth and regular bilge.

We also put structural epoxy between bulkhead and planks, between the transom and planking, and between the two planks at the bow.

At this stage the ties are removed carefully, to avoid breaking the still weak and therefore fragile epoxy bonds. The holes are filled with putty.

Once the ties are removed, complete the bonding of joints inside the hull. In principle, we will wait until after flipping the hull to finish the joints fillets and lay the fiberglass strips, in order to make a cleaner job. However, we can already fiberglass the hidden areas (buoyancy chambers, chests, spaces under floors) to consolidate the hull before proceeding to external finishes.

Thoroughly round the chines outside. Finish at first with a plane, for a good longitudinal smoothing, and then with a sanding block. Fill the joints with epoxy putty and sand to obtain a very fair surface. The finishes will be done with a low density mastic (smoothing) whose hardness is close that of wood and which is easier to sand.

Lay a strip of stratification on each chine (see note and sketch above on the preparation of the planks to the router).

Sand, chew and sand again to minimize the edge of the lamination strips.

Finish by a complete stratification of the plating.

Depending on the specific boat, we will have to attach some elements before fiberglassing (false keel, skeg, false bow) and others (runner or stranding keel) after lamination.

In the same way, the temporary screws to the bulkheads or templates will be removed before fiberglassing. We can reinforce the connections with the partitions with stainless steel final screws whose head will be embedded in the plank and covered with epoxy putty.

Attention: once the hull is fiberglassed, we will not be able (in any case it is better avoided) to put screws through. If it is needed to fix interior elements, it must be done before, ie boat upside down, or by turning the boat several times, which is not a problem for a light hull.

Fillets and interior fiberglassing

The hull is turned and rigged, taking care to avoid any distortion (overall twist). The fillet joints are completed and covered with strip of fiberglass as specified on the boat's plans. If there is more than one layer, lay as many strips as possible to hide the edges.

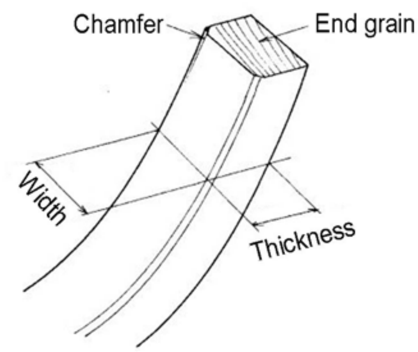
Function

Steam-bent frames are a very traditional solution for ensuring the transverse strength of the hull. The expertise and material for installation of such frames remains quite accessible to the amateur. They can be used on lapstrake hulls, strip built hulls and of course on a classic planking. It is also a quick method. Avoid using them on boats with very hard chines. Even if you manage to place these in the latter type, that's when the boat will age.

The laying is generally done in-situ, i.e. in the hull already established. It is in any case the application that we will describe in this section.

It can be appreciated, that it is also possible to bend frames on a suitable form, to place the bent frames on a form or strongback, and then to lay the planks. Finally, on larger boats, it is the planks which are steamed in heavily worked areas, especially for the garbord at the front.

The timber for bent chords



In France, acacia wood is commonly used for bent frames. In England, where this wood is less common, oak is used. Elm is also a suitable wood, but, a victim of the disease, it is almost impossible to find these days. Ash is also a possibility.

It is advisable to use green wood. Otherwise, it is possible to increase the humidity percentage by leaving the sawn slats in salt water for a few weeks.

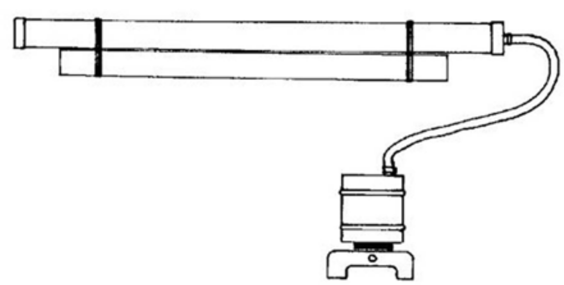
The slats should be sawn parallel to the grain, in any case as close as possible. Otherwise, it is likely that the frames will break when when they are laid. A fortiori, knots are not acceptable, and in any case, the penalty is immediate at placement: it breaks! Do not hesitate to cut redundant frames.

Leave an excess of 20 cm at the ends to facilitate installation. Chamfer inner edges (see figure). To gain time, locate the center of the frame and pre-drilled before steaming (for screwing into the keel). Tie a string at one end of the frame to more easily remove it from the oven.

The oven

To bend the chords, it is necessary to heat them (up to 100 ° C approximately) for a sufficient time so that the wood becomes malleable enough all the way through. The principle is to heat by steam but soaking the wood directly in the water is not excluded. It is therefore necessary to have an oven whose constituents are:

- A good fire, usually based on a gas burner. Camping gas will not suffice, except for small samples (canoe, attachments).
- A container for boiling water: a small casserole, recycled gas bottle (and well emptied of the gas!), can, etc ... Attention! Steam is dangerous, especially when it is under pressure. In practice, we will avoid risks by adopting an assembly with controlled leaks and, therefore, an internal pressure little higher than ambient.

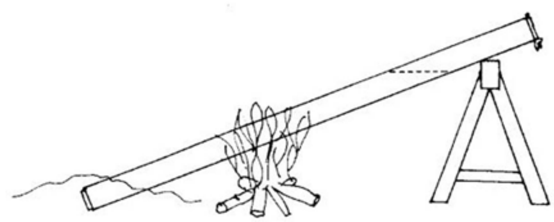


Example of assembly with PVC pipe

- A flexible hose (a type such as an automotive coolant hose) of good diameter (of less than 25 mm), to conduct the steam.
- Finally a tube of sufficient length to contain the frames and to which the steam will be conducted. The tube is closed at one end. On the side where the frames are handled, we close with a stopper (made of wood for example, with a rag around) that is easily removed (so much the better if there are leaks to prevents the rise in pressure). The tube can be made of metal (eg chimney pipes) or PVC, provided the latter is supported on a wooden beam (PVC will soften). Make some holes in the lower part of the tube to evacuate condensation water. You can also make an elongated wooden box. It is advisable to place some supports, inside the oven, which will allow the steam to wrap the frame to be heated.

If the oven is to be used only for a boat, all recycled materials may be used, on the condition that minimum of good sense is demonstrated to avoid accidents. Better to put all this together outside, or in a shed of good height.

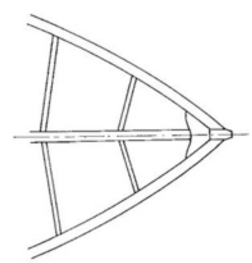
*Example: the tube is made of PVC.
We see the steam escaping in the background.*



*Rustic oven: steel tube full of water on a wood fire.
The lower end is plugged with wood and buried
to prevent burning.*

Preparation of the hull

Before starting to install the frames:



- Remove all glue drips and sand down the entire the hull, which is easier before laying frames,
- Mark the location of the frames with a flexible batten. Whenever possible the frames are in one piece, from one edge to the other. But at the ends, especially at the front, the last can be in two elements not necessarily aligned, to facilitate installation (off-set frames, see figure). If there is a centerboard case, it is also likely that some members will be in two parts. They will then fit into a mortise carved in the cabin of the case. It is useful to form them in one piece and then remove the central part.
- Drill pilot holes in the planks for rivets, screws or nails: every three strakes or at every strake (in the latter case the hole is at the point of contact between plank and the frame). Note that it is normal that, on either side of the keel, there is no contact between frame and plank. This space will allow water to circulate. Do not drill in this area.
- Put in place some transverse tie rods, linking the sheer strakes to each other, which will prevent the opening of the hull when laying the frames (attention, this is important!).

Joining planks to frames

Before laying frames, it is necessary to choose the method of connection between these frames and the planks. The traditional method is the boat rivet (Section 12) and it is undoubtedly the most adapted. Screws can also be used from the outside, provided that the frame has a sufficient thickness on the lath to ensure good holding. The method is faster. In practice, reserve it for boats with a soft chine and therefore frame with large radii. We can marry the two techniques using small screws (designed for chipboard) as temporary connections at the time of installation, then replaced by rivets of greater diameter (than the screws).

On very light craft, rivets can be replaced by nails with the points hammered over.

Restoration of a canoe:
we use nail bent over on very flexible ribs
(lof slender thickness)

Construction of an Ilur with lapstrake and bent frames: peening rivets.
© Francis Holveck in Douarnenez

The laying of the frames

We start with the middle of the boat then work towards the ends. The frames are placed in the oven only when it is hot. Leave them there about 40 minutes (for 16 mm thick), no less, because it is not good to put a frame in the oven for too short a time, but no longer because the frame would become brittle. If we break the frame or we cannot bend it, it will usually be for one of the following reasons: insufficient temperature (we can insulate the oven), too dry wood, or poorly cut wood.

Start with a test with two or three frames.
Make sure we will not be short of water before continuing. The ideal is to place a new frame in the oven whenever another is just taken out to be formed/mounted.

Installing a chord on an Aber - © Francis Holveck in Douarnenez

The laying of the frames must be done in two or even three steps. At the exit of the oven, the now flexible limb is quickly applied against the planking. Press on his in the center, on the keel, then put some clamps against the pre-presses and force the frame to marry the curves of the boat by using some mallet strokes to two ends. Screw the frame on the keel, then continue by alternately screwing each edge working out from the center.

It's good to have a person to be inside of the hull, able to put his foot on the frame and push it against the planks with his hands or knee. For light constructions, which do not allow his weight inside the boat, it may be advantageous to bend the frame with the help of the foot before putting it in place. We can even use a jig for bending which approximates the curvature of the chine.

Laying a chord on an Aber, screwed to the plating
© Francis Holveck in Douarnenez

Introduction

We are dealing here with the laying of glued-laminated members after making the hull, which can be lapstrake, strips, or even cold molded wood. In-situ laminated frames are an alternative to using steamed frames. Two methods are possible, one using the hull directly as a mold, the other using the station templates which were used to build the hull. This second method is more advantageous in terms of ease and quality of work, but can only be applied to frames placed at the location of a template, which is not always the case (I am now referring to my plans).

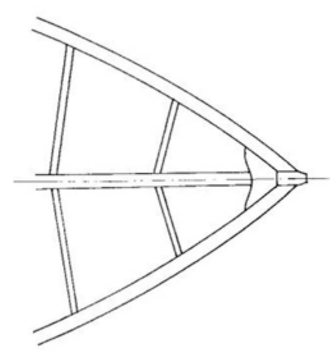
Laminating ribs in the hull

It is in this case the hull itself that serves as a mold and we work at the location where the frame is placed, hence the expression “in-situ.”

Ilur after laying lamellated ribs in-situ
© Jean-François Dockes

Before starting to install the frames:

- Remove all glue drips and sand completely the inside of the hull, which is easier before laying frames.
- Trace the location of the frames with a flexible lath. Whenever possible the frames are in one piece, from one edge to the other. But at the ends, especially at the front, the latter may be in two elements that are not necessarily aligned, to facilitate their installation (see figures). If there is a centerboard case it is also likely that some members will be in two parts. They will then fit into a mortise cut out in the cleat of the case. We can form them in one piece (before installing the case) and then remove the central part.



Deformed frames

- Put in place some transverse tie rods, linking the sheer strakes to each other, which will prevent the opening of the hull when laying the frames (attention, this is important!).

Laying laminated members in the hull

Wood slats are used as for a laminated frame. See Section 16 on the thickness and the orientation of the grain.

In general we will use a supply of slats close in size to the laminated frames, the depth (thickness of slats) being lower than the width.

- Glue the bundle of slats,
- Pack it in cellophane and keep it tight with tape at a few points,
- Place it inside the hull, holding it temporarily by clamps on each wale,
- Screw the frame into the planks using temporary Phillips head screws (as used for chipboard) of 30 or 35 mm and a diameter as small as possible (3 mm outside thread). Start with the keel. For a strip built hull, screw in a frame on every third or fourth strip. In a planked hull, screw at the points of contact with the planking.
- Before installing each screw, gather the slats with a small clamp and pre-drill a hole through all layers (it is good to use a stop on the bit) to the outside diameter of the screw. Note that it is normal that, on either side of the keel, there is no contact between frame and plank. This space will allow water to circulate. Do not screw in this area.
- After gluing, disassemble the frame from the hull, clean, plane the sides, and chamfer internal corners.
- Install the frame with boat rivets of the same diameter as the previous drilled holes (JP 16 or better JP 18, see Section 12).
- Alternatively, it is possible to screw from the outside of the plank, having taken care to re-fill the temporary holes and to offset the new screws. If you are a perfectionist, you can also glue an extra layer on the frame to hide the holes.
- On strip built boats, especially when screwing, we will screw the frame to the strips.

At the ends of the boat, it is difficult to place the frames in one piece. We will be able to angle them as shown on the drawing on page 1.

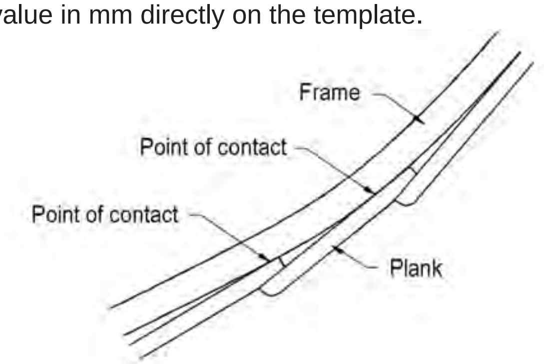
Another solution is to build the plank without seeking complete contact with the planking. After dismantling of the frame, we glue one or two additional layers that subsequently planed parallel with the surface of the hull before the frame is put back in place, as was done on the photo opposite.

Laminating frames on templates

This method is only suitable if the frames are in the same locations as the templates. In principle, the frame and template are on both sides of the theoretical pair of tracings and it is therefore important to make a note of which side of the template the future frame should be placed. Trace the position of the frame on the hull because it needs a guide once it removed and subsequently returned to the hull.

The first step must be done before the hull is turned over. It consists of measuring all the points where the plank is not in contact with the template, which is always more or less the case, depending on the quality of the plan and the construction. Provide good lighting since you have to do this work under the hull. With a graduated ruler, measures the deviations (in the plane of the template and perpendicular to its contour) and write the value in mm directly on the template.

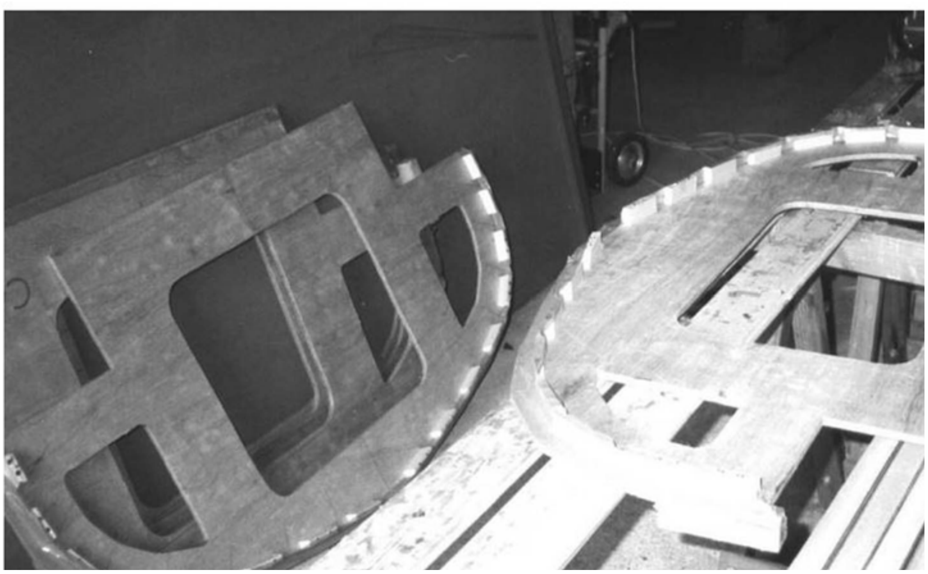
In the case of a lapstrake hull, locate the contact points of the frame on each plank, and it is only here that the gap between template and plank must be measured. If necessary, use a soft shim to better define the point-of-contact.



By means of a piece of wood of the same thickness as that of the frame, it will also be possible to measure the squaring with the angle of the hull.

Once the hull is turned over and the templates removed, we fix the measured wooden cleats at the marked postions on the templates that allow it to be used as a mold for the frames.

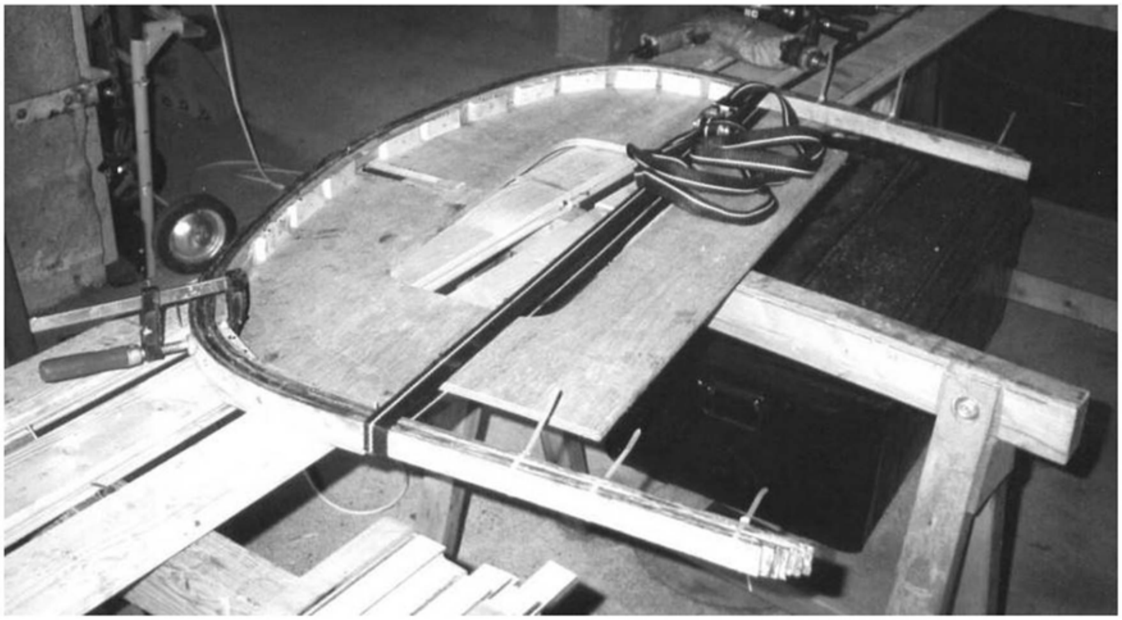
The cleats are placed at a distance from the edge of the template corresponding to the thickness curve on each frame



© Bernard Patural

(including any additional layer for squareness with the hull). This distance is at each location where a gap between plank and template has been measured. In the case of a lapstrake boat (narrow strakes), the cleats are preferably placed at the locations of contact points between the template and the hull.

It only remains then to use this mold to laminate the frames.



© Bernard Patura

Once each frame is glued and planed, the squaring (outside but in principle also to receive structural elements such as bollards) and planing.

During the bonding of the frames, it will be necessary to remove all glue drips and completely sand the inside.

The final adjustment is done when positioning the piece in the boat.

Properly sand the frames before final installation.

Fixing frames with the planking is done with screws (from the outside) or rivets. In the case of a strip built hull, one will glue the frame.

Area of application

Benches (swimming, side, rear) and boat floors for boats partially decked, or with no deck.

Appropriate solid wood

We will preferably use a soft wood of good quality and not too dense (the benches and floors can represent a significant part of the weight estimate): maritime pine, red cedar, Oregon pine. We can also use an African red wood.

For all solid wood benches, place the wood “heart on” to prevent it from forming bowl in aging:

Avoid too wide board widths. 150 mm is a good compromise for floors or decks.

Assembly of benches and floors

Horizontal and subjected to the aggressions of rain, sun, sand, and the feet of the crew, benches and floors are usually varnished or oiled, and require fairly frequent maintenance.

It is, therefore, desirable to mount them as easily removable assemblies, which allows sheltering them over winter, or for reapplying protection (oil or varnish).

Each set will be assembled by means of cleats fixed under the floor or bench. The connection between the floor and cleats can be done in one of the following modes:

- Screwing from above, covering the screw with wooden plugs. The cleat must be at least 25 mm high in a not too soft wood. Note: there are special bits, which can be used with a drill, with which can make your own plugs.
- Screwing from underneath if the board thickness is greater than 18 mm. In this case, be generous with the number of screws and their diameter (5 mm). Pre-drill if necessary to avoid splitting the wood.
- Copper boats rivets

The constructed assembly is then fixed to the boat by the following means which may co-exist:

- Visible screws, preferably in discrete locations (for benches on partially decked boat, one can sometimes screw into a cleat mounted on a partition). Use screws with a diameter of at least 5 mm.
- Wedges under a doubling or cleat attached to a bulkhead, along the centerboard case, or at the transom.
- Wooden or metal turn latches
- Anchor pin/wedge crossing a frame.
- Jumper system (metal, strap or leather) and wedge.

Protection

To avoid a slippery surface, the most suitable protection mode is a Deks-Olje type oil (D1 impregnation only). The only constraint is that it is desirable to add one layer after 6 months spent outdoors, otherwise the wood becomes gray.

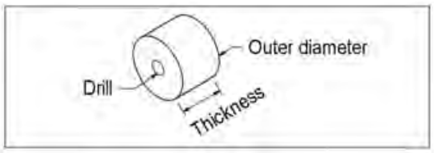
If we prefer to favor the aesthetic of a glossy finish, we can either apply a complete DeksOlje system (D1 + D2) or a system consisting of an epoxy impregnation followed by a high gloss UV resistant varnish, to protect the epoxy (e.g. two-component polyurethane).

1 Vocabulary

The rudder is the entire device allowing steering of the boat, made up, in particular, of the tiller and the blade which is the active part in the water.

2 Features

The rudder and blade is the solution most commonly adopted on my sail-oars and trailerable sailboats. It facilitates beach arrivals and beaching. The blade is weighted with a lead insert. Most often, the blade is simply pushed down in the apparatus. It is raised by means of a small rope which can even to be omitted on the smaller boats (the blade goes back and up only when approaching the beach, or is raised by hand with help a hole provided on the blade).



The axis of rotation is a simple plywood slab on small boats, a flat cylinder made of synthetic material (Delrin, Ertalon ...) or a bronze socket on the larger units (to avoid weakening the blade). It serves at the same time as spacer to maintain the distance between the cheeks, and its thickness must, therefore, be well adjusted to the thickness of the finished blade.

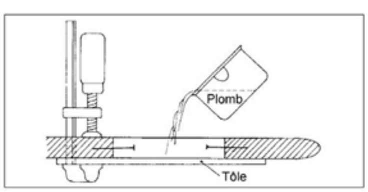
The bushing is traversed by a bolt. The advantage of plywood slabs as bushings is that we can mount them with screws, making it easier to mount the rudder blade to the cheeks. Attention: the rudder with its lead insert and its gudgeons do not float. It is prudent to secure it with a small rope attached to the boat.

3 Lead insert

The lead insert can be cast in situ or can consist of pieces or pellets (shot, lead recovery ...) embedded in epoxy resin.

The figure below shows how to pour lead. The nails inserted on the edges in the mold, cut out of the blade, hold the insert in place. Note that we can then work with a plane to smooth the surface.

Warning: lead is toxic. Operate at minimum in a well ventilated room.



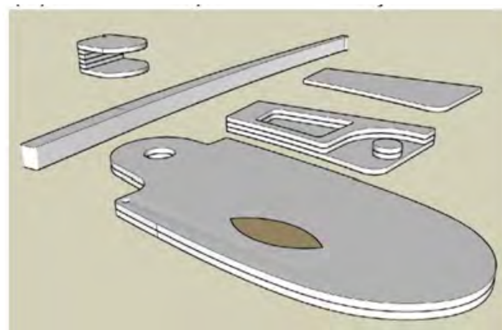
4 Plywood

If possible, use plywood made of hardwood or near hardwood. The ideal is moabi.marine plywood. Otherwise, we can use sipo, sapelli, makore or even birch. Avoid the “exterior plywood” or CTBX, which has significantly poorer mechanical characteristics. If we use okoume marine plywood, it is better to fiberglass the blade to protect it and to increase its resistance to abrasion.

5 Method of assembly

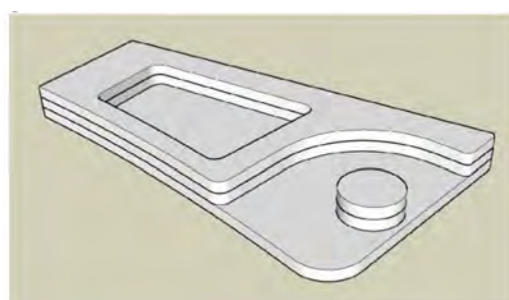
The update of this section is mainly motivated by an evolution of the assembly method allowing better protect ion (paint or varnish) of all the pieces and allow disassembly for maintenance.

The plans of my boats will be adapted to utilize this method. We start by making the various components which can then be permanently painted or varnished.



The blade is shown here not shaped but with its lead insert

The basic piece consists of a cheek and the core of the rudder glued together:

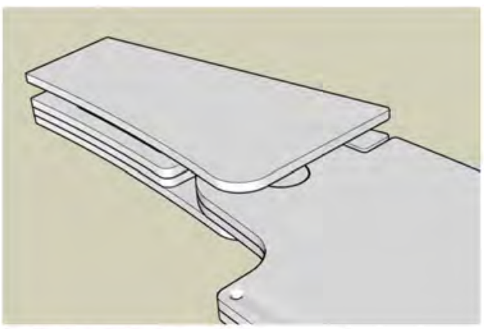


In the case of the figure, we represented a cylinder of plywood layers that serves as the axis for the blade. Reinforce the glue with screws placed across the cheek. The cutout in the core serves as a relief but also allows bolting the rudder plates with the nuts on the inside.

Construction of lifting rudder blades

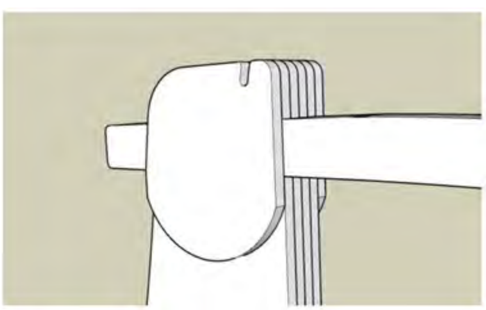
An important point of the assembly is to give the blade just enough clearance so that it can pivot while in the cheeks while still firmly held in the vertical position. For this, it is necessary that the thickness of the core of the rudder is very slightly greater than the rudder blade thickness, including its possible fiberglassing and paint. When it is possible, we can play on the thickness of the plywood (i.e. a core of 10 + 12 mm for a blade of 10 + 10 mm, for example). Otherwise, make the core layers thicker by inserting glass cloth between layers.

The rudder is “closed” by means of the second cheek that mounts to lock in the blade. This cheek is not glued to allow disassembly but is securely screwed, especially on the periphery of the blade.

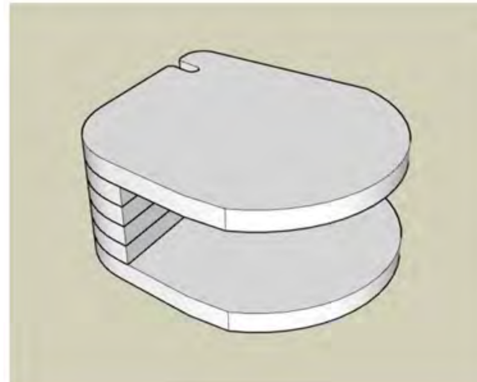


Fixing the tiller on the rudder requires a mortise, either in the bar or in the rudder head. On a lot of my small boat plans, I use a mortise in the tiller apposed to a brass shaft. It is necessary to lift the tiller to release it. This system works satisfactorily provided that a rope or bungee cord secures the tiller to prevent its escape in case of capsize.

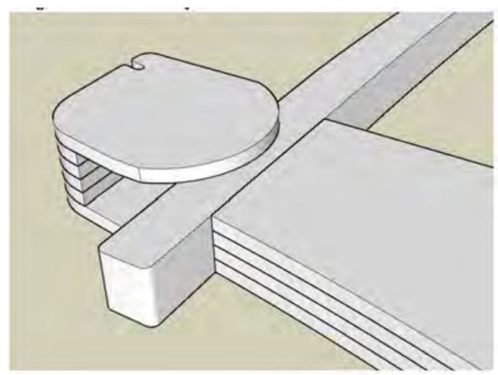
We can substitute the following system, which is easier to make. It’s all about making a stirrup in the helm head:



As for the core of the rudder, one may have to increase the thickness of the stirrup, if only to account the thickness of the paint. The stirrup can include, as on the sketch, a notch to fix the rope used for lifting the blade.



The tiller is given a trapezoidal section (in side view) so that it gets wedged in the stirrup by pushing it backwards. To avoid any laborious adjustment, simply screw the stirrup to the rudder while the bar is inserted.



6 Pintles and Gudgeons

Always have a lower pintle longer than the upper pintle superior to facilitate insertion of the rudder assembly.

On small boats likely to capsize, use a latch (or blade tongue), preferably in stainless steel to prevent the rudder from falling off the pintles.

Sliding companionway hatches

1 General principle

The hatches have a degree of complexity that requires additional specifications beyond those of the structural plans of the boat. By descending panel we mean both the vertical panels that slide in a chute of the opening and the horizontal sliding panel.

This section applies to all hatches of my plans for decked boats:, so far Stir Ven, Béniguet, Koulmig, Méaban, Pen-Hir, Toulinguet, Koalen ...

We have progressively made improvements to the panel design. In case of contradiction between this section and the plans of the boat, it is this section which wins.

To ensure a satisfactory seal, the slides of the sliding panel are placed outside the panel. This allows for uninterrupted cohesion all around the hatch (the word hatch means the opening in the deckhouse).

Overview of the descending panels on a Méaban
The slides are external to the sliding panel
Note the handrails, useful on all boats

A rabbet is made in these slides. Cleat sliders on the panel guide the panel and extend a few millimeters above the deck.

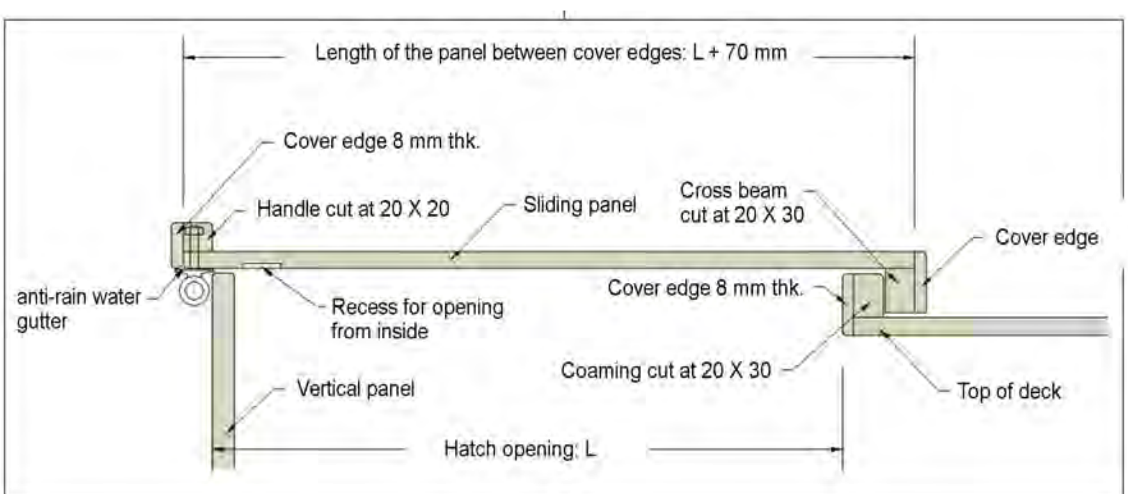
Angle ahead of the hatch showing the continuity of the coaming, which is not interrupted by the slide as is sometimes the case.

2 Geometry

In the transverse direction, the cross sections of the plane of structure give a good definition of the sliding panel.

On the other hand, in the longitudinal direction, it is necessary to take into account the thickness of the front coaming of the hatch and the crown of the cabin decking. In addition, it is necessary to allow an overlap (about 25 mm) at the back end of the closed panel. This avoids rainwater ingress and allows setting a latch for a padlock.

The longitudinal section at the bottom of the page gives a typical example. We have indicated, in this example, the dimensions that normally apply to boats from 6 to 9 meters.



3 Slides and sliding cleats

The panel is provided on each side with two sliding cleats sliding. They are made of hardwood, or better, of a synthetic material. They are screwed firmly into the extension of the panel.

*Sliding cleat made of synthetic material,
here POM-C (polyacetal copolymer) which slides well and wears little.*

A rabbet is made on the inside of the slides. For mainly aesthetic reasons, it is better to interrupt the rabbet at the ends. Allow 1 to 2 mm of play between rabbet and the cleats. It is especially important to position the cleats so that the panel does not rub on the deckhouse, even after a few years of wear. Leave at least 3 mm or more to take account of the fact that the deckhouse itself is not a perfectly cylindrical surface.

As a rule, the deckhouse deck is cylindrical on my plans, unless it is very long (Toulinguet). In this last case, the lower profile of the slides must be cut to the form of the deckhouse. First make a light plywood template.

The circle shows a notch.
The spacing of the notches must be the same as that of sliding cleats.

For ease of maintenance, notches are made halfway along the slides, allowing removal of the sliding panel.

When the panel is in the open position, the padlock latch abuts against the hatch coaming. The ideal is to place the front end of the rabbet so that it stops right before. We can adjust this at the moment of the installation of the sliding cleats.

4 Closing the sliding panel

An eye bolt is placed at the back of the sliding panel. A recess (the mechanics say a countersink) is made on the top of the handle to hold the nut which is then covered with a wooden plug or putty.

A cutout in the top vertical panel allows the passage of the padlock latch. Just put an ordinary padlock in the latch to lock access:

Padlocked descending panel

Open descending panel

You must also be able to open the panel from the inside when it is closed. The simplest device is to make a small cut (40 X 200 mm) in the lower fold of the panel (see longitudinal section). It's very easy if you cut out the layer underneath before gluing up the panel with several layers of plywood. See the longitudinal section on page 1.

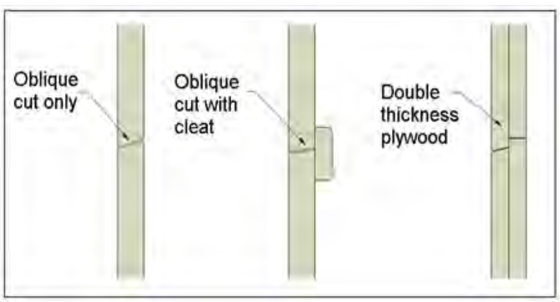
To ensure proper operation of the panel, the best solution is to lubricate with paraffin. Rub a small block of paraffin into the rabbets and check its free play.

5 Vertical Panels

In general, there are 3 overlapping panels, made in plywood. This allows modulation of the airflow through the boat when you sleep on board and facilitates the storage of panels.

The interface between the panels can be done in different ways, knowing that it is necessary to prevent rain from entering inside:

- Oblique cut only: facilitates flat storage under mattresses or elsewhere,
- Oblique cut with cleat: we have a grip for remove the panels and a better seal,
- Double thickness panels: heavier but you can make cuts in the inner fold to serve as outlet.



The panels are inserted vertically. The partition is provided with guide cleats on the front and the back. At the bottom, there is only a cleat inside to let the water flow. Plane the joint obliquely to match the adjacent panels.

Solid wood or laminated

The masts and spars of sail-oars or small sailboats can be made, either in one piece of solid wood, or laminated wood.

The first solution will be adopted whenever a wood of good quality is available: no or few knots; properly sawn and dried, avoiding the risk of deformation of the spar.

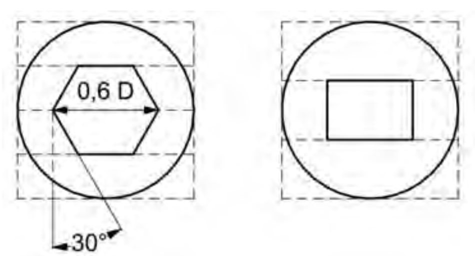
If you want to make a hollow spar to save weight, or simply to be satisfied with a quality wood medium, we will adopt a manufacture in several layers (glue & laminated). It is best to limit the thickness of the layers to about 25 mm. We can also do a spar in two layers only, by putting them in opposition.

The glue will be epoxy. It is important that the whole is laid flat during the gluing, by example using a series of trestles all set at the same height on a stable floor. For the clamping, we can complete the clamps with bungees or any other device, protecting them if need with a plastic film.

The best wood for a small boat is the (European) northern white fir or better still the spruce. But they are hard to find in good quality. Oregon pine is of safer quality but its disadvantage is to be quite dense and therefore heavy. Note that by adopting it, it is possible to reduce the diameter about 4% for equivalent strength.

Hollow spars

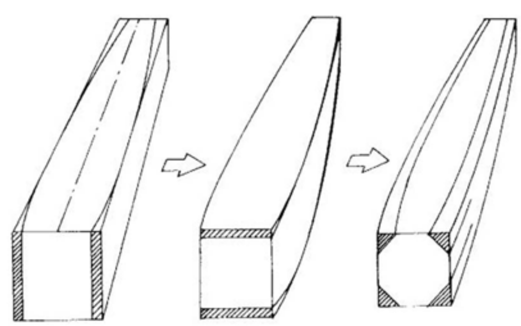
There are many ways to achieve hollow spars. For an amateur who is provided with only limited tools and makes only spars of small dimension, we can stick to the standard sections shown here. Attention: the spar diameter is most often variable and must be taken into account in varying the width of the cut of the hollow. Note that on the drawing on the left, the two middle layers are cut with an inclined jigsaw. In both cases we can only vary the size of the hollow in one direction (the width on the drawing and not the height).



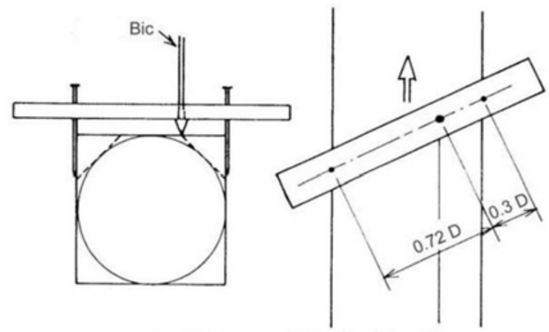
It will be necessary to keep solid the zones working strongly (at the mast partner or hole) and those areas where one will place deck hardware (cleats, sheaves ...)

Rounding up

Contrary to popular belief, it is not not difficult to achieve a round spar. Besides a round spars is much more beautiful than a rectangular or square spar, even with rounded corners. From a piece of wood of square section and whose side is equal to the largest diameter. Draw contours by taking account of reductions in diameter at the ends. Plane the excess while always keeping a square section.



Then trace the edges of an octagon by means of the ?true scan? shown in the figure. Cut down the edges until you get a octagonal section. The rest is done by eye without a trace: move to a polygon of 16 sides, and then remove the facets.



We can save time by using an electric plane. In any case, the final phases are done with a manual plane, preferably one of good length (jointer plane).

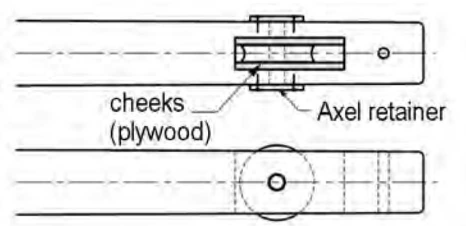
Finish with sandpaper while working transversely if you want a well rounded finish (hold the paper by both ends by making a U-turn on the spar). Note that it is not necessary to try for a perfectly round spar and a perfect finish, which is not justified for a craft having the character of a work boat. For an impeccable finish, for an abrasive use a sanding belt (large size) flipped (abrasive inside) driven by a homemade drum mounted on drill.

Halyard sheaves

We often have a halyard at the mast end (as well as at the bowsprit end). This requires a mortise. If the mast is laminated, the mortise will be done between the layers before gluing them. Pay attention to the orientation of the sheave: according to the plan of the spar, it can be longitudinal or transverse.

Better to start by buying the sheave whose diameter at the bottom of the groove is at least equal to mast diameter at the location of the sheave. Thus we will be sure of the width of the required cage.

The disadvantage of the sheave is that the axis weakens the mast and may cause it to crack under the tension of the halyard. A way to avoid this problem is to glue pieces of plywood inside the cage as shown in the drawing. To retain the sheave axel, we can screw or nail leather, or a small piece of brass, or even glue a small piece of wood.



As a realistic alternative, we can adopt a static system, inspired by the traditional Breton guide. First make the mortise. Then shape the guide that will be epoxy glued into the mortise, which makes it possible to eliminate imperfections in the guide before assembly.

Protection

On boats of the sail-oars type, mast and spars are subject to considerable friction: e.g. from the mast traveler, the yard, or from taking the mast down when rowing ... It is convenient to be satisfied with a oil impregnation e.g. Deks-Olje D1. This very fluid product is applied in many layers “wet on wet” (every 30 minutes or so). The spars will have a matte aspect that is not fragile. Maintenance by applying a new layer from time to time will be sufficient. If one prefers a neater and brilliant finish, the complete Deks-Olje system (D1 + D2) is my preference. I find it more pleasant to apply and maintain than varnish.

Presentation and vocabulary

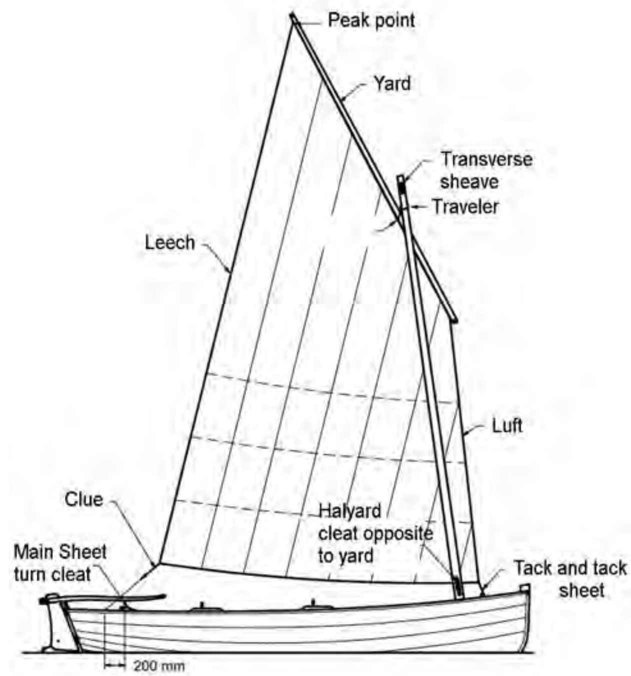
The drawing defines the main terms employed for rigging the “au tiers” (“standing lug”) sail.

We have preferentially referred to the rig as “au tiers” because the halyard is attached to the yard at one-third of its length (in practice it’s a bit less of one third on “au tiers” sails represented in most of my plans).

In Brittany, this rig is also called “Misainier” because historically it evolves with the disappearance of the mainmast and the remaining rig representing a mizzenmast more than the foremast.

The current standing lung sail described here is fixed. That is to say, established on one side of the mast. She there remains whatever the edge from where does the wind. The English call it “standing lug”, which expresses this static character well. The sail can also be attached at its balance point. It’s the “Balance lug” of the English. We will also treat this case here.

A standing lug sail can also be partly lowered when tacking (English “ dipping lug “). The sail is then switched sides at each tacking and the rigging is a little different (especially the head of mast and longitudinally). We will not treat this rig here since it needs a longer explanation.



The mast head sheave

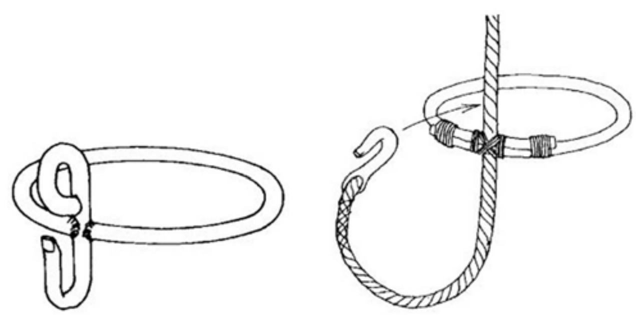
See section 81 dealing with the manufacture of masts and spars.

The mast traveler

The traveler is used to maintain the yard alongside the mast, which is essential especially when the sail is reefed.

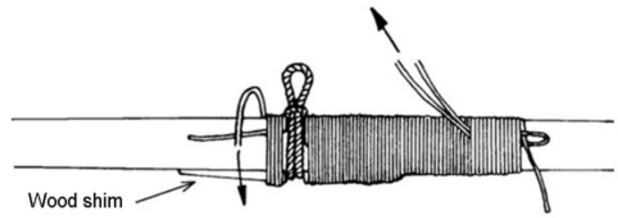
It is found (although with more and more difficulty) made of galvanized steel or bronze (with bar diameters of 8 to 10 mm).

If unavailable, we can make it more traditionally as shown on the drawing at right with a circle formed by a chestnut sapling freshly cut. The same principle can be achieved with a rod of brass or aluminum (2 X 10 mm for example) formed into three or four loops, the whole being seized all the way around its circumferance.



The point of suspension of the yard

It's a question of immobilizing a small suspension strap that attaches to the yard and at the same time providing protection from friction against the mast. The suspension strap should not be too long so that the sail can climb to its proper height on the mast.

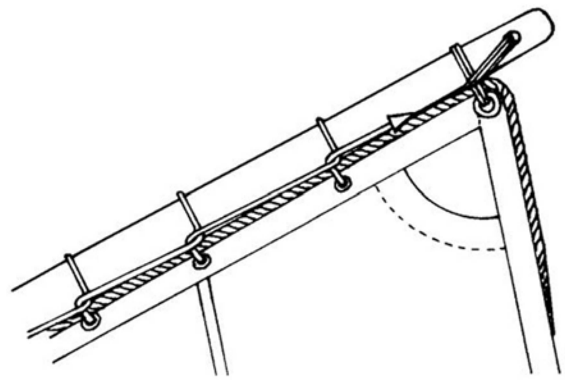


For seizing the strap use a braid of 2 to 3 mm diameter. Place small wooden wedges below to block the strap from sliding along the yard.

The peak of the sail

The drawing shows:

- How to set the peak point of the sail to the yard in a way that does not pull the peak too much against the yard at the risk of damaging the sail.
- The mode of lacing of the sail around the yard, with the lacing attaching to sail grommets.



Tack downhaul

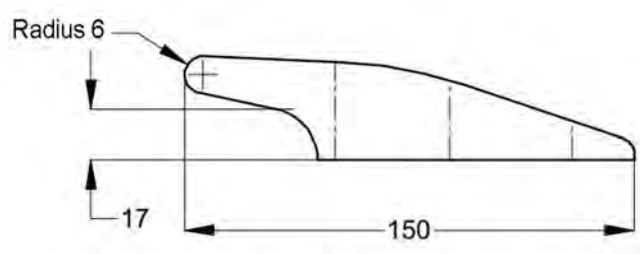
It is located preferably midway between the bow and the mast. Several configurations are possible following the structure of the boat in this area. Build a block and tackle with two or more three stranded lines, which can be maneuvered from as far back in the boat as possible. The ideal is that the line is close to the helmsman but this very often leads to interference with the movements of the crew.

Depending on the wind speed and force, the luff tension of the sail must be easily adjustable. Too often we can see canoes sailing a standing lug with a badly bound tack and a nasty oblique fold between the top of the luff and the clew.

The rigging of the tack should not prevent the sail from being readily lowered. We must also be able to easily degrade and reef the sail by attachment to the other eyelets of the luff.

The main sheet turn cleat

It will be made of hardwood (oak, ash, acacia) according to the attached plan (thickness 22 mm).



As a first approximation, place it on the gunwale at a position is 200 mm forward compared to the theoretical location of the clew on the plans. This is due to the curvature of the sail that is not flat as represented on the two dimensional plan (see figure in page 1).

The cleat shall be securely fastened to the gunwale at the locations indicated, a bolt being preferable at the rear.

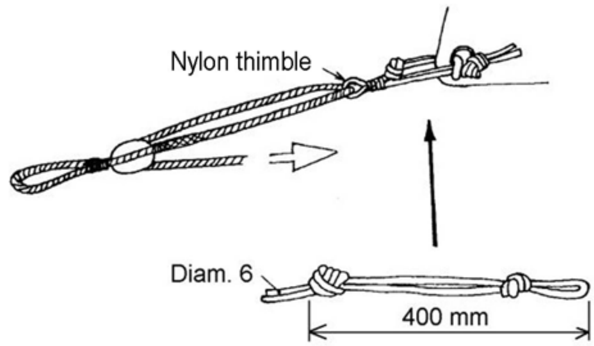
We can do sea trials with the cleat clamp in place until determining the best position.

Clew block

It must be rigged double to tension more easily and at the same time be able to release quickly the sheet in cases where there is a risk of capsizing.

A loop is attached to the block and fastened to the half-cleat. At the tack, the helmsman passes loop from one side to the other.

The sail is fixed to to the block by a “rope hook“, also named a soft shackle, a traditional version of the modern carabiner; the former is less dangerous for the helmsman’s head. This allows reefing down more easily than if the sheet was directly led into the sail eye.

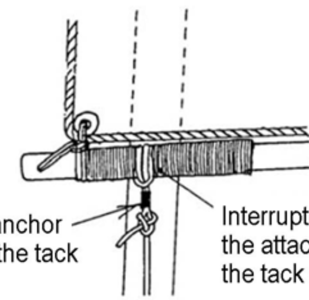


Balanced lug sail.

The most common provision is to have the boom on the same side of the mast, as the yard.

The drawing shows the area of the tack, the boom being covered with seizing in the same way as the yard. A very powerful block must then be provided (3 or 4 strands), as much as possible with a return on the aft end.

Connections will be rigged with the same diversity of solutions as on a modern boat: on the transom, mid-boom length, etc ... Preferably provide a traveler if she is exclusively on the transom. The aft “traveler” can consist of a simple rope.



Paint and varnish

Introduction

This sheet is not meant to say everything on a subject that deserves a book all by itself. Its object is only to help choose the most appropriate system as part of the amateur build of a small wooden boat. There is such a variety of products on the market, such as media and application conditions, that there is no truly universal solution. I give here the main systems that we ourselves have tested. But we can always find other solutions that have their merits. We are not dealing with the implementation itself and we can just say that surface preparation and intermediate sanding, are the keys to success. There are many publications on the subject that we can refer to. We focus here primarily on the protection of exteriors: hull, deck, interior of an open boat.

Paint or varnish?

It is up to everyone to choose between painting or varnishing their boat, or only part of their boat. I simply provide some elements to appreciation and to bear in mind.

- A varnished finish is much more demanding in terms of the finish of the boat: better adjustments, no “catch-up fixes” with epoxy putty, wooden plugs on the screws, strict compliance with the conditions of temperature when impregnating or fiberglassing ...
- It is also more restrictive for the maintenance of the boat. This is not a problem for a small boat stored in a garage after each use. It is, however, insures a regular maintenance for a boat that stays outside, whether it’s afloat or dry.
- Marine plywood is made from unrolled wood that does not have the same appearance as solid wood. A varnished plywood will never have the authenticity of a “real wood”.
- With taste and good observation of traditional boats, one can make real wonders with painting.
- Some construction methods, especially strip building, suffer from excessive heat and it is strongly discouraged from exposing such a hull to the sun on a regular basis, if it is varnished or painted a dark color.

On these bases, and after reading the whole of this section, everyone will be able to decide what he adopts for his boat. It is desirable to make the choice from the start because the building process depends on it (we can easily paint what we planned to varnish, but not always the opposite). In the following we distinguish the recommended systems according to whether the wood has or has not received a epoxy treatment. It is obvious that the same boat is likely to have areas impregnated / fiberglassed, others not, painted areas and varnished areas and that we can standardize the systems used, based first on those that represent the largest surfaces.

Varnish on bare wood, not epoxy impregnated

Two cases arise:

- Movable elements, such as mast, spars, rowing, bar, floors, removable benches
- Fixed elements such as the hull itself or simply flat-boards, strakes, transom, curves, fixed benches, coamings, etc ...

In the case of moving parts, my preference is for the use of a Deks-Olje D1 type oil or equivalent. This very fluid product is applied in many layers “wet on wet” (all about 30 minutes). The wood keeps a matte appearance which is also not very slippery (benches, floors). It is just maintain by applying a layer from time to time. If you prefer a neater and brilliant finish, the system Deks-Olje complete (D1 + D2) is the one that has my preference because it is more pleasant to apply and maintain compared to varnishing.

Because it is very fluid, Deks-Olje is not easy to use on fixed elements. Drips stain the surrounding painted parts. Only exception: a beautiful solid wood boat that will be fully oiled.

In the case of classic solid wood varnish, the most reliable system is composed as follows:

- Optional prior application of a dye that prevents yellowing of redwoods such as mahogany (usually exists in the ranges of varnish manufacturers). In addition this product allows homogenization of the hue if various wood species have been used.
- Preliminary application of a “hard bottom,” preferably two-component. It is an impregnation product quite fluid that is applied in several layers. The result is a hard layer that lends itself well to the finishing layers.
- Layers compatible with the hard bottom in large numbers (at least 5, but can be more). Glossy one component polyurethane is usually the best choice. While more efficient, the disadvantage compared with bi-components, is that it does not change deterioration due to shocks, or at areas of systematic wear, and these products are much more difficult to remove for refurbishment, especially on soft surfaces.

Varnish on impregnated wood or epoxy laminate

If the support is epoxy laminated, the method previously seen no longer applies. We then proceed as following :

- Subject to checking compatibility, the use of a colorant is recommended on bare wood, before any application of epoxy.
- After fiberglassing or after epoxy impregnation in several layers, a varnish is applied compatible with epoxy and having a high ultraviolet filtering capacity. In practice, this varnish will be a two-component polyurethane because it seems that the compatibility of a polyurethane varnish monocomponent is less obvious (it is unfortunately very difficult to obtain guarantees from suppliers, since resin and varnish are not of the same brand). We even start see on the market epoxy varnishes (Resoltech).

This system is obligatory if we have laminated the support (strip built hull, or okoume plywood in particular), with the corresponding advantages (resistance to abrasion, shock ...). Its disadvantage is that it is less validated than the use of more conventional products, in particular vis-à-vis the difficulty of refurbishment that always wins out after a few years. On the other hand, bi-component products are less easy to apply. They are especially well adapted to professionals who work with the gun and can reduce the number of layers required and therefore the labor time.

In the absence of a strong justification for the epoxy impregnation, the use of the more conventional system outlined in the preceding paragraphs seems to me preferable for the amateur.

Paint on bare wood, not epoxy impregnated

If the boat is regularly stored under shelter, or if one is not afraid to do some restoration of paint from time to time, or if we wish to have the aesthetic privilege of a large choice of colors, or finally if the boat is predominantly solid wood, a classic system based on glycerol paint is quite suitable. It is easy to implement, easy to maintain, even if its durability over time is less than the modern products that we will see later. If possible, choose professional-quality paint and take advantage of the opportunity to choose the color of your choice from a color chart. The first layer(s), depending on the absorption capacity of the wood, will be diluted with white spirit or better Rustol. Then apply 2 or 3 topcoats. It is not essential to use multiple layers, if one thinks of adding then regularly. Removing the paint will be necessary when the number of layers or degradation of the film no longer allows satisfactory quality and protection.

If we want to improve the behavior over time, especially for boats staying outside, or if the structure is mainly made of plywood, we will apply a more modern system based on single-component polyurethane paint, preceded by an appropriate primer, as recommended by the manufacturer. There are also several qualities of primers, including epoxy primers.

Paint on impregnated wood or epoxy laminate

As for varnishes, we will use a system compatible with epoxy, generally a mono or bi-component polyurethane base. The difference with the varnish is that we can, following the supplier's advice, first apply a proper primer to the epoxy and then then continue with the finishing layers.

Here too, two-component paints are more efficient but less easy to apply. The One-component polyurethane seems to me to be a good compromise for the amateur having built his boat, and is, a priori, better able to maintain it afterwards

The choice of colors

I would not go into an aesthetic debate here except to recall that a wooden boat can, thanks to the painting or varnish, can become a true work of art. I'm happy with a few remarks:

- Be careful of varnish and the dark colors on strip built hulls. The best way to cause almost irreparable damage is to paint the hull black and then leave it upside down exposed to the sun in summer with water (flowing) next to it.
- On the lapstrake boat, light colors bring out the strakes while the dark colors conceal them.

Working parts

Remember that the working parts of a boat are those submerged parts of the hull. On small boats that are more often out of the water, the use of antifouling is not recommended. A system comparable to that of the hull will be applied. The varnished hulls, except for very small boats such as canoes and kayaks, will preferably be painted below the waterline. On boats that are trailerable but still pass a good part of the season in water, apply a hard matrix antifouling paint, which accepts dry periods and is well resistant to abrasion. The same choice will be made for hulls stranded in tidal ports.

Waterline

Draw a horizontal line. It is unattractive to raise the waterline at the ends as it is sometimes seen. The only interest in doing this a bit is to take into account the variations in the base of light boats (the attitude is the longitudinal inclination of the hull). The waterline edge will be placed several centimeters above the actual waterline. This refines the silhouette of the boat and limits the dirt that is concentrated at this level. In addition, the boats are often deeper than on the architects' plans (in my case, the plan shapes are drawn with a medium displacement, which is neither the light boat nor the fully loaded boat). To draw the waterline, there are some classic methods:

- If the boat is small enough and the ground is fairly flat (leveled concrete), level it as needed by taking dimensions on the plans. Then just take a batten cut at the right height and walk around the hull while marking the position of the waterline.
- If the boat is not horizontal and it is difficult to move it, put trestles at each end at the right height and stretch a wire that is moved to successively mark points along the hull.
- If the boat is horizontal but you cannot use the ground, another solution is to use a clear hose filled with water that is moved around the boat, the other end being maintained at the appropriate height. There are "levels" placed at each end of the pipe that allow a more precise and practical reading.

You can also paint a colored stripe (often white) to separate working and non-working parts of the hull. This is very beautiful but, of course, more work.