Guidelines on Improved Boat Building Practices in Sri Lanka

Norad

Ministry of Fisheries and Aquatic Resources in collaboration with the Food and Agriculture Organization of The United Nations and the Norwegian Agency for Development through funds contributed by the Italian Civil Protection Department

Introduction

Sri Lanka has a long tradition in building fishing crafts, especially those in fiberglass reinforced plastics. Although boats built for the export market are constructed to international standard, many boatyards build boats meant for domestic use, of very low standard and under unsafe conditions for the worker and the environment. However, most of these boatyards are thriving as a result of the high demand for low-cost fishing craft to replace those destroyed by the tsunami. To overcome this problem, it is vitally important that boat building safety standards in Sri Lanka be developed, applied and enforced as soon as possible to ensure the safety of the next generation of Sri Lankan boats and fishers.

The Norwegian Agency for Development Cooperation (NORAD) fielded a mission to survey the extent and quality of post-tsunami fisheries rehabilitation in Sri Lanka. In addition, funds contributed by the Italian Civil Protection Department enabled the Food and Agriculture Organization of the United Nations (FAO), in collaboration with the Ministry of Fisheries and Aquatic Resources (MFAR), to engage the services of a Naval Architect who set out to identify current **boat building practices** in Sri Lanka and recommend ways to improve them. A summary of the results of both missions are presented in this booklet.

The term **'boat building practices'** encapsulates five aspects of boat building:

worker safety;
environmental safety;
boatyard (workshop) conditions;
boat building standards and techniques; and
quality control.

Accordingly, this booklet sets out basic concepts in each of these five key areas, so that boat designers, boat builders, fishers, fishing cooperative societies, NGOs and others interested and involved in boat construction in Sri Lanka may adopt better methods for increasing worker and environment safety, improving boat construction and ensuring the safety of fishers at sea.

CURRENT
BAD PRACTICES

- Sub-standard workshop conditions
- Incorrect Laminating Procedure
- Inadequate Laminate Thickness
- Poor details and procedures in construction
- Incorrect repair procedures
- Personal safety and protection
- Careless handling of dangerous and highly inflammable materials
- Issufficient waste disposal

Sub-standard

Workshop Conditions

While boats meant for the export market (Europe and other countries in Asia) are constructed in clean, air conditioned and fully-equipped sections of the boat yards, similar measures are not adopted in areas where boats are built for the domestic market.

- There is no separation between lamination areas and fitting-out sectors.
- Lamination is commonly done in the open air.
- Many yards do not have a proper floor and boats under construction sit on a muddy compound.

A lot of the boatyards building 3.5 tonners and Multi Day Boats have facilities like this one, which actually is no workshop at all!

Although this is not a good workshop, it is better than nothing because it keeps the direct sunlight away from the laminating process. This is very important!

Incorrect Laminating Procedure

The picture shows a bad case of over laminating the frames. The fibre looks white, either because it was contaminated with water or because the polyester was curing too fast to saturate the fibres. Either is wrong. The yellow colour is also some contamination or it's due to the use of too much hardener (catalyser). This causes a high exotherm, overheating and miss colouring in the curing process. The laminate will be weak.

Laminating in the direct sunlight on the sandy ground is not good procedure.

Use of just a brush for application of polyester is slow and leaves dry and aerated spots.

Never walk on a gelcoat surface ready to be over laminated.

First laminate layer must be perfect and free of air and voids. White spots indicate air.

Results of air in laminate

Inadequate Laminate Thickness

One key concern is laminate thickness, if the laminate is too thin then the boat will crack and eventually break due to the stresses of the sea and the shifting catches therein.

It is important that the boatbuilder follow the drawings and directions of the engineer who has constructed the boat! The thickness of the laminate depends on how big the boat is, at what maximum speed is and how close the spacing of the internal frames are.

Bottoms, bows and sterns of boats need thicker laminates.

The laminate of this outrigger canoe is approx. 1mm. Anything less than 3mm is irresponsible.

This boat was given as a replacement for a 6-7m day-boat damaged by the Tsunami. The transom broke after the first use and the boat has been left idle since.

This 6-7m day-boat was used only for a few months when the bottom and the frame broke. The bottom was too thin and the frame too weak. The problem is made worse by the heavy loads taken by these boats to and from the sea.

Sometimes, even if the boat is properly built, it could brake if the engine is bigger than the boat is intended for!

General rules for laminating thickness

- Small canoes should be more than 3mm
- 6-7 multi-day-boats should be more than 5mm
- 28 footers should be at least 6-7mm
  - if these boats are pulled up on the shore, the laminate needs to be thicker
- 35-40 feet boats should be close to 10mm

Poor Details and Procedures in Construction

✗ *Poor joint.*

✓ *Good overlapping the wood and the PVC-pipe of the fender on a 6-7m FRP boat.*

The wooden fender is 2"thick and the scarf is supported by the laminate of the boat.

This is an example of bad workmanship on the framing. The laminate is partly thin and full of air. If using wood for frames - wood must be fully dry.
Seal both wood and plywood properly or it will rot as it gets wet. The same goes for the most PU foams. A better alternative would be to use hollow frames of thicker laminate.

Here the plywood is properly sealed in a good workshop. An even better alternative to plywood, especially in the fish holds, is structural foam. (PVC or likewise with fiberglass laminate on each side)

Incorrect Repair Procedures

- *This way of cutting into the laminate with diamond blade to chisel off the laminate, is quite rough. The cut leaves a weak edge / stress point. A chisel tends to damage the underlaying fresh laminate.*

The main concern here is that the corners of the repair patches should be rounded, and the laminate ground and smoothed out even with the original laminate. There is also too much air and voids in the laminate, and the laminate is rough due to:

- Fiberglass being wet / damp.
- Polyester is too thick (high viscosity), either because the drum has not been mixed properly, and / or it is getting too old.
- Polyester still being fed onto the fibers after it has started to gel (Cure).

✕ *Diesel dripping on the new laminate will weeken the bond.*

Personal Safety and Protection

✗ *This is a typical situation in a Sri Lankan boatyard, where labourers work without any eye, ear, lung or skin protection.*

✓ *Wearing a dust face mask when grinding.*

Everyday dangerous materials are handled by boatyard workers without any protective clothing, gloves, eye shields, etc. The danger of workers inhaling toxic fumes from the lamination process is not adequately addressed, the only masks available in many yards are the basic disposable ones made of cotton for medical use. The glass dust generated by hull sanding or grinding is not controlled by any vacuum cleaning system and goes directly into the lungs of the workers. They are thus exposed to potential health hazards that may affect their lungs, liver, eyes, skin, etc.

Careless Handling of Dangerous and Highly Inflammable Materials

GRP (Glass Reinforced Plastic) is the only material used in fishing boat construction industry in Sri Lanka. Boat yards involved in manufacturing boats using GRP use highly inflammable materials such as resin, oil based cleansing materials and other chemicals. These are often stocked in large quantities.

A full drum of polyester used as a work bench for the electrical grinder. Look at the wire spaghetti. This is inside the workshop where they are laminating.

Insufficient Waste Disposal Techniques

Boat building using GRP material needs special care not only in actual construction of boats but also in disposition of waste. GRP boat building industry produces a lot of dangerous and inert waste.

Empty resin cans are often left to rust and contaminate the soil; some are re-used for water collection.

Large quantities of cured GRP are piled up in many boat yards. While being not particularly dangerous, it constitutes a problem since cured GRP is virtually not destroyable and could degrade into small particles that could be transferred to food or even inhaled.

Since boatyards are usually located in the backwaters of lagoons and estuaries, it is very convenient for the yards to throw waste into water. Disposal of this toxic waste into water may cause long term repercussions on the aquatic and wild life.

Poor workshop conditions and bad boat building practices will lead to disasters such as this

We want to achieve

IMPROVED STANDARDS

and

SAFER BOATS

for Fishers When Accepting New Boats

- Always check a new boat thoroughly, before you accept it – you have the right and responsibility to do so.
- When checking new boats, seek the help of a competent technician (naval architect, boat builder or fellow expert fisher) for advice.
- Don't be tempted to buy or use cheaper unseaworthy boats – a small saving could end up in disaster.
- If you are unsure of the quality of a boat: do not buy it!
- Quality always pays back in the long run.

for Fishers When Maintaining Boats

- Fishing crafts in all fleets should periodically be checked for fatigue symptoms (like cracks and delamination).
- If you spot a minor failure, report it immediately before it's too late!
- When sending your boat to be repaired, always seek competent and well trained yard operators.
- A repair job by unskilled workers will always remain just a "patchwork" – it will never be as strong as a new boat.
- Investing in boat maintenance means investing in your safety.

for Boatyard Workers

- All boatyard workers should be skilled and well trained.
- While building or repairing a boat, check quality from start to finish.
- Always follow relevant guidelines, technical specifications and instructions on material use.
- Do not forget about your own personal safety.
- Remember: fishers' lives depend on your good work!

Poor Stability

on Multi-day boats (MDB)

When MDB boats go to sea, there is no fish in the holds, the roof and deck is full of supply's and the water tanks are full. These huls are tall and narrow, all the crew has their bunks on deck and the water tank is at the rear, mostly over the water line.

The consequence is a centre of gravity over the waterline and very poor stability.

Why do we need quality control ?

Most workers will be able to put some gelcoat, polyester and fiberglass together, make it harden, and call it a boat.

This is the advantage, but also a major disadvantage with fibre reinforced plastics. You can fairly easy make it look nice on the surface, but it tells you little or nothing about the actual structural quality of the laminate.

The quality of the finished laminate depends on a combination of the quality of the raw materials and how you handle them, the details of putting them nicely together, the environment in which you are working, and the final curing of the laminate.

The consequences of making a bad laminate could be a premature breakdown of the boat, from fatigue and delamination after just a short time in the sea, instead of after at least 20 years, which should be the minimum lifespan expected from an FRP boat.

Another aspect to be aware of is that polyester is not waterproof. The laminate absorbs water from the first day you put the boat in the water, and unlike what most people think, the gelcoat is of no use in preventing it. Gelcoat is made of polyester and absorbs water. After 10-15 years of regular use, a normal laminate will usually have absorbed maximum of what it can take, which is around 1,5-2%. A good laminate will not feel wet, since the water will be like hydrogen and oxygen molecules between the polyester molecules.

We should be aware of that the laminate already will be 30% less stiff than the original laminate, since the water molecules work like a softener.

The most important issue though, is that when the water molecules find voids, contamination or air bubbles, they will condense and turn into water again. Often where there are voids, there is styrene fumes and

uncured polyester. When water, styrene and uncured polyester get together, there will be a chemical reaction called hydrolysation. This reaction is a degradation of the polyester and very often leads into a chain reaction like rust on iron, where after some years, the only thing that will be left, is the "dry" fiberglass and some chemicals.

The better the quality of the laminate is, the longer time it will take for the hydrolysation to start, and the negative effect will be less. In bad cases you will get blisters on the surface after just a couple of years. Blisters often indicate a more serious problem with the laminate.

White,"dried out" spots and white fibers, caused by hydrolysation in the laminate.

The gelcoat over each of these spots will most of the times form a blister filled with bad smelling chemicals.

Bear in mind though, that in many cases, the laminate could be badly hydrolysed as you see here, with white fibres and white shadowed areas in depth, without any formation of blisters.

The laminate has then already lost at least 30% of its original stiffness and strength.

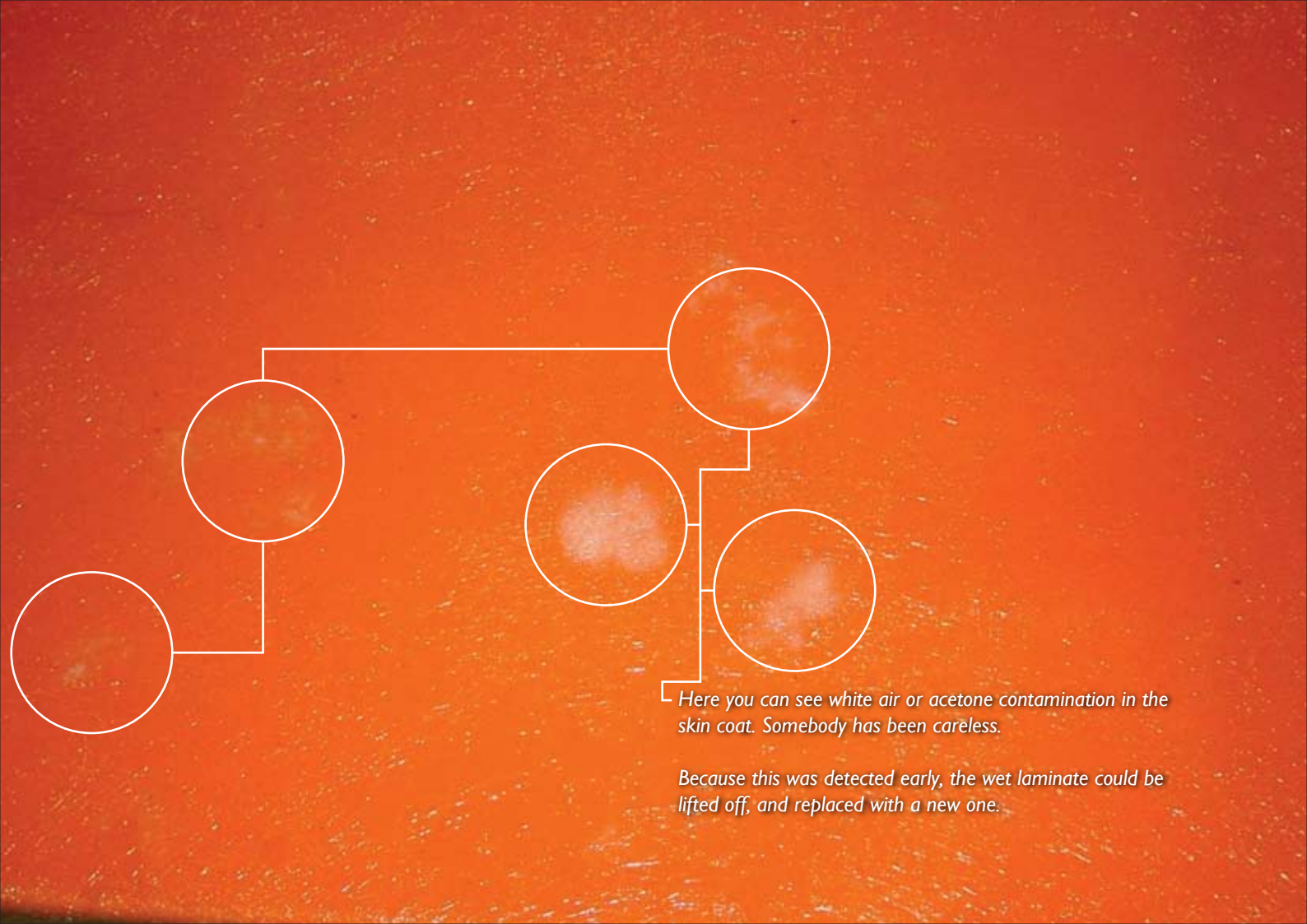
How to make your own quality control when laminating

1. The gelcoat is usually the first step, and besides mixing in the right amount of catalyst, which is mentioned in the data sheet, it is important that the applied thickness is right. To measure this, you can use a simple "wet film gauge" which your gelcoat supplier should be able to supply you with. This applies whether you are rolling, brushing or spraying. Be aware that if one layer is less than 0.2-0.3mm and left to cure, you will easily get aligatoring when applying the next layer. Ideal total thickness of gelcoat is 0.4 – 0.7 mm.

2. Laminating should not start sooner than approximately 1.5 hours after gelcoating, due to probability of aligatoring. The potential possibility of contamination of the surface makes it smart to start the lamination within 24 hours.

3. Always apply a coat of wet resin/polyester, before you put on fiberglass.

4. Your eyes are your best instrument for quality control. They will tell you if your laminate turns white because of too wet fibreglass, if there is any air or contamination in it, if the exotherm builds up to quickly and changes the colour of the laminate and gets aerated/foamy, or if you use too much polyester and get wet puddles. If any of these things happen while you are laminating, and you don't do anything to improve it, your boat will already have a minor or major weakness. You might be the only one who has the possibility to detect this, because when the next layer of laminate goes on, it will all be covered.



Here you can see white air or acetone contamination in the skin coat. Somebody has been careless.

Because this was detected early, the wet laminate could be lifted off, and replaced with a new one.

Examples of instruments
to use when checking materials or laminates

1. VISCOSITY MEASURER, DIN 4

This cup is filled with resin. The time is measured for the resin to drain out of the hole in the bottom.

The time/seconds is put into a formula to find the viscosity.
Formula:
5,57 x sec-(452/sec)=…..mPa
Example: 72 seconds
5,57x 72 –(452/72)=394,76mPa

The given viscosity for your resin, you will find in the Data Sheet.

2. MOISTURE METER, Tramex Skipper and Protimeter Surveymaster

With the Tramex you will be able to detect different degrees of moisture in fairly thick single skin laminates and sandwich constructions. Always bear in mind that they will detect metals as well (tanks on the inside), or metal in antifouling paint. Good for checking moisture in dry fiberglass.

The Protimeter is a combination instrument both for wood and FRP laminates.
This instrument is better for wood, but not as good as the Tramex on FRP laminates. Check moisture when doing repairs!

3. CURING MEASURER, Barcol. Barber Colman, Impressor

The Barcol measurer is a must for any serious FRP boat builder. With this equipment you can perform tests to see if your laminate is of adequate quality. The instrument pushes a needle in to the laminate to check the hardness. At least 10-20 tests have to be made, and the average should be more than 35 on a good polyester laminate. A boat should not be demoulded before the Barcol is over 25.

4. ULTRA SOUND LAMINATE THICKNESS MEASURER Cygnus SE

With this instrument you can measure the thickness of a cured laminate without access to the backside.

If there are delaminations or flaws in the laminate, the sound will stop in the "air pocket" and you will not get a full thickness measurement.

This instrument will also detect heavy bundles of fiberglass which have not been completely saturated with resin, which is often an issue with the 800g woven rowing.

5. WET FILM THICKNESS GAUGE, showing the thickness in 1/1000mm

This shows the gauge in practical use.

The thickness will show where the wet gelcoat touches the surface of the gauge.

6. TEMPERATURE & RELATIVE AIR HUMIDITY GAUGE

Every workshop working with fiber reinforced plastics should have a temperature gauge and a gauge showing the relative air humidity in the workshop.
There are several varieties.

Material handling

Here are some guidelines for you to follow when handling laminating and boat repair materials:

1. Always check that you really get what you ordered from the supplier. Never trust that you get what you ordered. Check lot number and date of production and/or expiry as soon as you receive the drums. If the product is old or of another quality than ordered, send it back. You are to blame from the boat owner if the boat breaks down due to poor raw materials. Request technical data sheets on the actual product, from the supplier. This paper should give all the physical and technical properties acquired by the boat designer, since resins can vary widely in properties. The data sheet is also the key to details like proper mixing and the right temperature when laminating.

This is a good way of treating the fiberglass, even if it's in a shelter and not indoors and the floor should have been concrete or at least covered with something. The cutting surface for the glass is plastic and not wood, which is good.

2. Keep the fiberglass dry and clean.

3. All polyester related materials should be stored dark and as cool as possible, and the hardener should be stored separately.

4. Proper mixing of gel coat and resins in the drum or container before you use them, to avoid settling of additives in the bottom.

5. Check that the viscosity of the resin is according to the data sheet.

6. Ideally, when doing the lamination, all the raw materials, the mould and the environment, should have the same temperature.

The manufacturing date on this drum of polyester is 19-09-05. In this heat, the manufacturer guarantees the stability of the content in 3-4 months. This one is 5 months old and the curing properties are changing. The quality of the laminate could be affected unless you add accelerator. In this yard they used a wooden stick to mix the polyester in the drum when it was half full. The barrel should be rolled for 10 minutes when it is new as well as later, to keep additives and chemicals from separating and settling on the bottom or floating to the top.

Always check and write down the Lot Number and the Production Date when you receive storage sensitive products. This information will always be written on the container.

PERSONAL, ENVIRONMENTAL AND WORKSHOP SAFETY GUIDELINES

1. Eye Safety

In all industrial environments, you have to protect yourself against objects or chemicals that can get into your eyes.

When working with fibre reinforced plastics, there are hazards both from chemicals, which can be anything from an eye irritant to a severely corrosive liquid, to airborne particular matter.

An example of a severely corrosive liquid is the Catalyser (Mek Peroxide), and a typical dangerous airborne particle, is what you get when using a grinder. In both cases you should **use goggles/eye protection,** when exposing yourself.

2. Respirator Safety Against Dust and Fumes

This woman is working inside the boat. Styrene fumes are heavier than air and will stay in the boat. The most dangerous situations occur when they work like this inside the keel area in larger boats. Without ventilation, the worker will potentially be inflicted by chemical lung inflammation almost immediately.

One of the most obvious and important organs to protect in a boatbuilding plant, is your lungs.
Most boatyards have mechanical ventilation to keep the levels of volatile/hazardous fumes, and dust, under an acceptable level. Even if they have fans/extractors, you should always **protect yourself with a suitable respirator** when being exposed directly to hazards such as Styrene fumes and fiberglass dust.

DUST: You might not feel it as a problem within the first years, but as the years pass by, the dust which gets collected in your lungs can cause breathing problems and lung collapse.

The most effective way of stopping dust when sanding, is at the source.

You can either use an extraction fan/dust collector with a large hose diameter, or you can use a vacuum cleaner connected to a hose attachment on the grinder itself.
It is hard to get rid of all the dust at the source, but a

combination of these mechanisms can be very useful to make a good working environment if you are working in a room were several operations are being executed at the same time. In a boatbuilding plant, it would be ideal to carry out the sanding and grinding in separate rooms.

FUMES: The styrene fumes from polyester can cause nerve problems/brain damage, the isocyanides in curing polyurethane is poisonous, and the amines in curing epoxy can cause cancer.

When working with volatile fumes in a closed area with poor or no ventilation, such as inside a boat, you should always **use a respirator with an external source of fresh air,** or you will be in severe danger of developing what we might call a chemical lung inflammation.

There should always be some sort of air ventilation and extraction for fumes in an area were you work with painting, gel coat or laminating. This is to minimise the area of the boatbuilding plant where you have to wear respirator.

Battery powered facemask. The battery pack is carried in the belt. Air is forced through the filters and pushed up in to your mask. The mask provides protection for both eyes and lungs. It is comfortable and easy to talk with, but even a simple facemask with gas filter is acceptable.

3. Hearing Safety

When being exposed to elevated sound levels for shorter or longer periods, it can lead to a permanent hearing loss. In all cases where you are using a power tool, such as a grinder, or likewise if you are working in a room with noisy machinery, you should **wear ear protection.**

If you are wearing ear protection, you should always be aware that you will not hear if somebody talks or shouts at you, so pay extra attention to look around to ensure your co-workers safety and to communicate with them.

Caution
High noise levels

4. Trip and fall Safety

You should always be aware that **uncured fibre and resin is very slippery.** Spillage on the floor, steps and "climbing constructions" can lead to severe falling accidents.

When working on larger boats where the need to access without damaging a wet laminate is important, you have to **take care when building and using the steps and ladders.**

Watch your step!! It is easy to fall when walking on narrow planks and stepping on fiberglass.

5. Skin Safety

Always remember that if you damage or loose your fingers, you will most probably have lost your best and safest source of income.

- Try to **use a suitable guard for the grinding disc or the power saw.**
- **Use gloves** when needed.

Solvents like styrene and acetone will get absorbed by your skin and find the way into your blood vessels if you are sloppy and don't protect yourself. This can happen both by direct spillage on your hands/skin, and when using spray equipment and the air is heavily polluted with solvents.

Use gloves while working

6. Fire Hazard Safety

Never smoke or use open fire in a boatbuilding plant/boatyard!

Be careful when using electric appliances and power tools. Poor wires and loose contacts could cause explosions or start fires. Air powered tools are the safest.

In this instant it is also the time to mention that the combination of cigarette smoke and volatile fumes, makes the negative health effect much worse to your body.

7. Waste Material Reduction & Disposal

Always have a plan and good routines for getting rid of the waste, both related to fire hazard and to potential pollution of the environment.

Check with your local authorities on how to handle the hazardous waste. In most places there is much money to save by separating hazardous and non-hazardous waste.

You should also always have in mind that all raw materials like gel coat, polyester and fiberglass which goes in the waste is a waste of money!

8. Raw Material Storage

All raw materials should be stored in separate rooms; both to retain their quality prior to use, but also for safety reasons.

The most important thing is to **keep the catalyser in a separate room from the polyester and gel coat,** due to the potential fire hazard.