



FISHERIES TSUNAMI EMERGENCY PROGRAMME

MALDIVES

Fisheries sector rehabilitation mission

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4th August- 26th September 2005



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Training for boatbuilding with fibreglass reinforced polyester



REPORT

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1. SUMMARY:

The background for this mission was a decision made by FAO and the Ministry of Fisheries, Agriculture and Marine Resources (MOFAMR) to build 89 boats in Fiber Reinforced Polyester (FRP) to replace wooden Bokkuras lost in the Tsunami.

FAO consultant and Naval Architect Øyvind Gulbrandsen with assistance of the boat builders in MOFAMR designed a 4,5m FRP boat based on the Bokkura, with an improved hull for better performance with outboard engine.

The engines supplied with the boats will be 5hp Japanese Yamaha funded by the Chinese government.

A decision was also made to have 69 of the Bokkuras built on the islands of Maroshi, Nalafushi and Kudahuvadoo by local people.

FAO with the assistance of MOFAMR would supply boatbuilding sheds, a complete set of moulds, tools, materials for 23 Bokkuras for each island and also proper training of the local candidates, who mostly had no relation to FRP boatbuilding.

Building of the plug, 4 complete sets of moulds and 20 Bokkuras was set out for tender, and the contract was won by Precision Marine on the island of Thulusdhoo. I visited this boat builder at several occasions, and the quality of their FRP work was very good as far as I could see.

My primary job was to follow up all the FRP related parts of this project, and ensure that the Bokkuras were delivered in time with an acceptable quality.

Due to the limited length of my stay, and the project already well under way, I had to spend some time getting to know all the aspects of the mission, which also had other tasks.

The way things developed, I tried to follow up as many of these projects as possible simultaneously, and produce papers which could be used as help and guidelines for FAO and MOFAMR (Ministry of Fishing) when I left.

The training of the candidates from the remote islands was performed by FET (Faculty of Engineering Technology) on their Boatbuilding School on Alifushi. I supported this training at the site for two periods, supplying with extra information to the Ministry Boat builders who also attended the course. For the practical part of the training, these boat builders were a resource with their experienced skills, and were very useful in training the candidates.

During the building period on the Remote Islands, at least one Boat builder from the ministry will stay on each site. I feel relieved to say that with the joy and eagerness to learn the candidates showed, together with the experienced skills of the Ministry Boat builders, I feel assured that the building of the Bokkuras will succeed with acceptable quality.

The logistics part of the mission was also a challenge. Getting the right amount of materials with acceptable quality to the right time in the middle of the Indian Ocean is not necessarily easy. This part is now taken care of, and hopefully the boat builders will get no problems with the materials and tools.

FRP boatbuilding is relative new in the Maldives, but the boat builders show a genuine interest in doing things right and with high quality. I never had the time or the occasion to survey any of their FRP fishing boats, although I saw a lot of fatigue cracks on the "speed launches" used for everyday transportation. The Ministry Boat builders told me about serious fatigue problems after just a few years in service on the large fishing boats. This is a serious concern, and my report is only addressing general FRP issues and not this in particular.

2. TERMS OF REFERENCE:

Under the general guidance of the Chief TCEO, the technical guidance of the Chief FIIT, under the direct supervision of the FAO Representative in Maldives and Sri Lanka and of the FAO Officer in Charge in Maldives, and in close cooperation with the FAO boat builder and government counterpart officials, national and provincial authorities, the consultant will undertake the following tasks:

1. Supervise the FRP works of the selected local boat yard for the production of the plug, four moulds and first Bokkuras produced. (Ideally the consultant should arrive to Male prior to the beginning of the FRP works in the boatyard).
2. Prepare a manual on FRP boatbuilding and repairs with mainly digital pictures taken during the production process of the plug, the mould and the boats at the selected boat yards.
3. On the basis of the moulds and plug produced, organize a training course in collaboration with the Faculty of Engineering and Technology (FET) in FRP boat building. The training courses will include:
 - a) Selection of the correct FRP materials
 - b) Training in use of tools that will facilitate the repair
 - c) Practical training on boat building
4. Supervise together with the FAO boat builder, FET, and the staff from MFARM and their atoll staff, the works for the construction of the three decentralized Hubs for fiber glass boat construction.
5. Supervise the Training of trainers (TOT) course in Male and the training courses taught by the FET at the decentralized level.
6. Prepare an end of mission report detailing activities conducted; project results, findings, conclusions and recommendations for follow up.
7. Undertake any other task as requested by TCEO or the FAO officer in charge in the country.

3. ACTIVITIES CONDUCTED:

The TOR has several specified tasks and matters in need of support and guidance, but also gives the possibility to supply with other activities.

After approximately 2 weeks of work I had achieved a general overview, and made a priority list of subjects to follow up and how and when to do it.

To my understanding at that point, the most important matter was getting the 89 Bokkuras (4,5m fishing boats) built and delivered as fast as possible according to the strategy made by FAO and MOFAMR.

My main focus was to be as follow:

- 3.1 FRP Practical Training:** Support the Principal / boatbuilding teacher at FET boatbuilding school on Alifushi / Raa atoll, in the training of the boatbuilding students. The students would be both the 3 groups of each 10 students from the remote islands of Maroshi (Shaviyani atoll), Kudahuvadoo (Dhaalu atoll) and Nalafushi (Meemu atoll), and the 6 boat builders from the Ministry.
- 3.2 FRP Theory Lessons:** Supplement the course with written material on chosen FRP subjects.
- 3.3 Bokkura Plug, Mould and Boat Building:** Supervise the FRP works on the building of plug, 4 moulds, and the first Bokkuras at Precision Marine.
- 3.4 FRP Boatbuilding Manual:** Prepare a manual on FRP boatbuilding and repairs, with mainly digital pictures, taken during the production process of the plug, the mould and the boats at Precision marine and / or the Boat Building School at Alifushi.
- 3.5 Boatsheds Remote Islands:** Supplement with my knowledge to help making the temporary boatyards at the atolls as suitable to the purpose as possible.

In addition to this, I would try to conduct as much as practical possible on these matters:

- 3.6 Boatbuilding Standardization:** Support FET to raise their technical standards on FRP boat building. Supply with written material and establish contact with relevant institutions for implementing standards and classification systems in the Maldives.
- 3.7 85foot Fishing Boat:** Assist MOFAMR with planning of an 85foot fishing boat. Look at the internal structures and the FRP lay up
- 3.8 FAD Construction:** Have a look at the FAD construction and see if I can propose an easier and cheaper way of producing an FRP buoy of the same or better quality as the existing one.
- 3.9 FRP Workshop / Seminar:** Make a one or two day seminar / workshop on materials and production methods for the future.

4. PROJECT RESULTS:

4.1 FRP Practical Training: FET already has adapted FRP boatbuilding into their regular boat building classes, but the 4 week “Certificate 1”, Fibreglass Boat Building Course was completely new.

My first task was to help in getting the course accredited. This was sorted out the first week.

Since the training was going on at the FET Boatbuilding School in Alifushi, and this island is situated in the Raa atoll, 5 hours with “Speed Launch” north of Male, the only proper way of handle my part of the training was to stay at the school for at least one week with each group. After my first period I made a report on this trip (Appendix 1)



15foot project boat, built by the students at the Vocational Training Centre in Alifushi. This is a boatbuilding school, run by FET (Faculty of Engineering Technology) in Male. On the picture, the boat is still under construction.

The second period from 15th – 22nd of September was equally successful, and we also made use of the 15foot boat they had laminated in the first course, to go through quality control and further train the students in the fitting of bulkheads. This time, 3 more persons than originally intended, joined from the Ministry. This included another boat builder and two of the staff from the FAD section.

4.2 FRP Theory lessons: For the training, I produced 4 different lessons with written “Hand outs”. Since the boat builders from the ministry were attending the course, the strategy was to supply the lessons with more information than was actually needed for the basic laminating training of the trainees from the remote islands. In this way, the boat builders would get an incentive to develop further knowledge and skills in their work with development of new FRP vessels and their work with supervising and inspection of building them. The subjects were chosen in close cooperation with the teacher at the school and the Ministry boat builders. At the same time it was important that the theory lessons and the training would not get too advanced for the trainees from the remote islands. I feel that this was taken care of.

The lessons were as follows:

1. Personal and environmental safety when working with fibreglass reinforced polyester (Appendix 2)
2. Quality control when working with fibreglass reinforced polyester (Appendix 3).
3. Reinforcement sequence in fibreglass boatbuilding (Appendix 4)
4. Practical FRP repair guidelines (Appendix 5).

4.3 Bokkura Plug, Mould and Boat Building: The contract with the company, who was going to build the Bokkura, Precision Marine, was signed on the 10th of August, and my first trip to inspect the plug building on their yard at Thulusdhoo (45 minutes in “speed launch” from Male) took place on the 17th of August. Since my focus was on the quality of the fibreglass work, I made a general inspection of the facilities and the skills performed by the workforce at the yard.



Model of Mr. Øyvind Gulbrandsen`s design of the Bokkura, made by Ahmed Hassan.

The quality of the work was relieving, and I felt there was no need for me to be placed on the yard to follow up this work. My remaining inspections to this boatyard were on the 29th of August and the 9th of September. Some problems came up later due to changes in design and details.

These matters are described in my intermediate report (Appendix 6), and were sorted out at a later stage while I was in Alifushi. Looking at the matter now, it seems like it would have been smart to station the Ministry boat builder Ahmed Hassan at the boatyard for the whole period of the plug building. He was directly involved in the design together with Mr. Øyvind Gulbrandsen. I also reflected on this in my report from the first trip to the boatbuilding school (Appendix 1).



The picture shows laminating work in a production mould for a 75foot Masdhoni (Fishing boat). The skills and the quality performed by the workers at Precision Marine were good, but the use of personal safety equipment was more or less totally absent.

At the time I left the Maldives the building of the plug and moulds were still being carried out, and the following up was being carried out by the FAO boat builder Mr. Derrick Menezes.

4.4 FRP Boatbuilding Manual: Originally, the intention of making the boatbuilding manual was to make a general document that could be used by boat builders in other countries and boatbuilding situations as well.

The FAO Technical Paper on “Building a Fibreglass Fishing boat” is a fairly large document, containing design elements as well.

After reading the TOR and talking to Mr. Ari Gudmundsson, my interpretation of the task was to produce a more basic, universally understandable, practical document.

As my mission passed on, it became clear to me that I would not be able to take enough pictures of the actual Bokkura building, and I would neither have the time nor resources to develop a complete manual the way I had intended.

Since the boat builders on the remote islands were quite new to boatbuilding and the tools and materials were all supplied in one package, my final decision was to make a manual that would be of practical use for more than just the laminating process.

The manual is attached in Appendix 7, and was produced as a combination of my own pictures and texts and Mr. Gulbrandsen's original drawings of the Bokkura. Since the building of the first Bokkura is not yet completed, and due to detail changes for practical reasons, there will be matters not mentioned.

For the future, it should be easy to use this document as a basis for similar missions, and being a Word document, it can easily be changed and altered.

4.5 Boatsheds Remote Islands: The design and the location of the boat sheds were taken care of by Mr. Derrick Menezes and the boat builders from the ministry. I have not seen a drawing or a picture of the planned shed, but to my understanding, this is a very basic and simple shed without a concrete floor, and it will only be of temporarily value.

At the time I left the Maldives, the building materials for the boat sheds had reached two of the islands. And the materials for the third one were on its way. Local carpenters were hired to set up the boatsheds within ten days from arrival of the materials. Due to the time schedule, distances and practical reasons, I never got directly involved in the development of the boatbuilding facilities on the remote islands.

4.6 Boatbuilding Standardisation: The written lessons, Appendix 2, 3, 4 and 5, were intended as a supplement for FET in raising their technical standards. I also had mail contact with ABYC (American Boat and Yacht Council) to look at the possibilities for using their standards and certification system.

ABYC is just one of several possibilities. The reason why I contacted them is because I am certified as a composite boat builder there, know some key persons, and they also recently signed a contract to implement their standards in China. ABYC were positive about the idea, but I did not have time and capacity to follow this up with the authorities in the Maldives. The positive thing with standards is that they can be carried out immediately without much cost as long as the school and the yard has the standards available. Implementing standards could be seen as an easy way of getting good habits.

When it comes to classification of boats over a certain length or with a certain use, this is another issue which also definitely should be sorted out, but has a different cost frame. Generally, standards are used as part of a classification system.

4.7 85foot Fishing Boat: I realised from the beginning that I would not have much time or capacity to look into the building of the 85foot fishing boat, being as large and complex as it is.

As a reflection to the other work I carried out in the Maldives, I tried to build in related information in my lessons that could be of use for this project. The lessons on “quality control” (Appendix 3) and “reinforcement sequence” (Appendix 4), are actually both designed for the boat builders of the ministry on this behalf.

I have made some comments though, and they are attached in Appendix 8.

In Appendix 9, the FAD report, I also include some information in the end which could be of use when building large vessels in the future.

4.8 FAD Construction: I was specially asked about the FAD by Dr. Faathin Hameed, Deputy Director of the MOFAMR.

Since the buoys were being built in FRP by people from the Ministry, and the production site was at the island of Villingili, just 10 minutes from Male, this was very convenient. I saw this as a task that would not take time from the other projects, just being a supplement that would help making the picture of FRP building in the Maldives complete.



The FAD (Fish Aggregating Device) is of great importance for the fishing fleet in the Maldives. The buoys are made of FRP, and the cost and quality of production is central since several of them are lost every year.

My report on this matter (Appendix 9), gives some suggestions on immediate actions to help saving money on materials, and also making the quality better. It also includes some additional information on building methods that could be useful to implement in the future.

4.9 Boatbuilding Workshop / Seminar: Due to minimal local interest and the need of much work to make a useful seminar, I found it more important to put priority in other work. If something like this should be useful, it has to be planned in forehand, and built up as a combination of theoretical and practical sessions with new materials and methods, and at least some of the “hand outs” should have been translated into Divehi.

5. CONCLUSIONS AND RECOMMENDATIONS:

5.1 FRP Practical Training: With an “Advanced Certificate in Wooden & Fibre Glass Boat Building” class going on simultaneously with the “Certificate 1” class, I found the resources for the teaching not being adequate. The 3-4 week “Certificate 1” classes are being held just occasionally. Seeing how well the Boat builders from the Ministry performed in a practical teaching role, I think it would be a smart idea for FET to make an agreement with the Ministry of Fisheries to use the Boat builders as practical teachers upon demand. It is also quite clear that the school needs upgrading of the facilities and the equipment / tools. This is also mentioned in my report from the school (Appendix 1).

5.2 FRP Theory Lessons: It is quite clear that FET should work for an International upgrade and standardisation for the FRP boatbuilding material being taught at the Boatbuilding School. This should be of great National interest, and should follow the work of the Ministry of Fisheries and the Ministry of Transport in their efforts to implement standardisation in all boatbuilding and classification on larger boats.

5.3 Bokkura Plug, Mould and Boat Building: By the time I write this document, most of the plug and mould building should be finished. In future projects like this, it is important that people being involved in the design process also has to have a clear and direct communication with the actual plug and mould builder during the building period.

Since my mission would end before the first Bokkura was built, I made the Manual as a tool to help in the building. Although the Manual includes a lot of information there will be questions raised since the first Bokkura is not yet completed.

Here is a short list on matters of concern:

5.31: Due to uncertainty and changes of plans on the hull / deck joint, the fender and the materials ordered for it, is not completely planned. These details have to be worked out on the building site by the Ministry Boat builders.

5.32: Wood planes for the fenders are not supplied. This has to be sorted out locally.

5.33: Evacuating dust and debris from the mould / boats during the building period could become a problem. Industrial vacuum cleaner is not supplied. This should be sorted out if it becomes a problem.

5.34: The production date for the resin was not “stamped” on the drums as requested when we ordered them. We were told that the resin was “fresh” and we should not worry, and the supplied papers would tell the production date. At the time of my departure I had not yet seen these papers. Due to Ramadan and general delays, the storage stability of the resin is a potential problem. Due to difficult logistics, all the 18 drums for each island were supplied in one load. The supplier (Guarantee Fiber) says 3-4 months from production date. This could work if the laminating starts as soon as the mould arrives at the islands and continues with a production frequency of at least two boats pr. week.

The drums must be stored as dark and cool (windy) as possible! If the period is extended, the resin will separate; get higher viscosity and shorter gel time. This demands extensive mixing of the resin before use, but it might still be usable for a period without the technical properties of the laminate being critically harmed. This must be monitored by the boat builders, and test laminates should be made for inspection during the period of extended use.

5.35: When half of the Bokkuras are produced, all the materials, equipment and tools should be counted and checked, to see if anything additional has to be supplied. After the building is completed, it would be nice to get a total count to keep as a reference for future similar projects.

5.36: It is important to take pictures during the building period. This is important for the purpose of updating the Bokkura Manual using the lessons learned after completed building.

5.37: Oarlocks has not yet been provided. The ordering of the right size must be followed up as soon as possible.

5.4 FRP Boatbuilding Manual: As a consequence of the time aspect in my mission and the building process, the manual was redesigned as mentioned in chapter 5.3.

5.5 Boatsheds Remote Islands: There should have been drawings and building plans available for the boatsheds.

Materials for the sheds should have been sent separately, and the building site should have been ready in good time before the boat builders are readily trained and the moulds arrive.

If the storage place for the tools and materials is located far from the boatshed, there will be a problem, since daily work will be complicated and there will be no possibilities to close and lock when they leave after work. This has to be checked! I do not have a clear understanding of the future of the sheds, but as far as I understand, these shed will be very temporary. Without concrete floor and with only tarpaulin as walls, they will be very vulnerable to rain and flooding, even if the tarpaulin floor will keep the direct dust separated from the laminating work.

5.6 Boatbuilding Standardisation: I mentioned this also in chapter 4.6, and there is no doubt that this matter should be of great concern since FAO is supporting MOFAMR in different boatbuilding activities and FRP quality control. There should be put resources into the work of finding the right standards and Classification Societies to suit the special needs of a small but demanding Marine Nation like the Maldives

5.7 85foot Fishing Boat: The matters mentioned in chapter 5.6, is very much forced to a conclusion by the progress of this project. My suggestions are mentioned in Appendix 8. Although, due to limitations in building time and cost, changes and alterations are difficult to conduct.

5.8 FAD Construction: My recommendations are described quite closely in the FAD report, Appendix 9.

5.9 Boatbuilding Workshop / Seminar: Boatbuilding is a natural resource on the Maldives, and a matter for future development and expansion as all Marine activities are in this nation.

To be able to develop the already existing knowledge and skills, and to keep up the ability to compete with imported boats, it is essential for the boat builders of the Maldives to be updated on international matters.

With the fast developing technology on composites (reinforced plastics) in the world today, it is essential to obtain a high level of competence and quality as a balance to the low cost production in neighbouring countries.

In my view, geography and economic development will make it difficult for the Maldives to become a large producer of boats and ships for export.

It is clear though, that the boatbuilding knowledge is deeply anchored, and a lot of the young boat builders has a strong wish to expand their competence and become engineers or Naval Architects.

The domestic market will always be strong due to the nation's geography; and the dependability on the boat for transport makes the demand for high quality a natural issue for the Maldivians. This natural demand for quality will ensure that there will be a continuous domestic market for engineers and naval architects.

For a small nation, heavily dependent on tourism and fisheries, a future as an exporter of Marine knowledge and competence should be a positive alternative.

Having seminars and workshops on related issues or sending boat builders, engineers, naval architects to international seminars / workshops, is an important part of developing this national knowledge.

One should keep in mind that making and holding these seminars should not solely be left to private companies who sell materials and products.

List of Attachments:

Appendix 1: Report from 9 days trip to the Boatbuilding School.

Appendix 2: Personal and environmental safety when working with fibreglass reinforced polyester.

Appendix 3: Quality control when working with fibreglass reinforced polyester.

Appendix 4: Reinforcement sequence in fibreglass boatbuilding.

Appendix 5: Practical FRP repair guidelines.

Appendix 6: Intermediate report on Bokkura building.

Appendix 7: Bokkura Boatbuilding manual

Appendix 8: 85ft FRP Fishing Boat

Appendix 9: FAD Report

REPORT FROM 9 DAY TRIP TO THE BOATBUILDING SCHOOL ON ALIFUSHI

Thomas Anmarkrud

28th of august 2005

The intention of the trip was to supervise the training of the Candidates from the Remote Islands, and give special lessons on chosen subjects.

Also joining us were 6 Boat builders from the Ministry of Fishing. They were there to gain additional experience to their FRP knowledge from the lessons I provided. They also showed to be a valuable resource in helping out the trainees in the practical training.

The boatbuilding school itself has nice facilities. The only problem I could see were potential problem with contamination of fresh gelcoat and laminates, since an advanced course (1,5 years wood and FRP) is being held simultaneously.

The Principal is Mohammed Yosuf, and the second teacher is Umar Zahir.

Although the school is nice, there are some major restrictions when it comes to performing a fully professional education program on FRP boatbuilding.

It clearly shows that up to quite recently, the school has mainly dealt with wooden boatbuilding.

To be able to give the candidates a clear understanding of how things are supposed to be when it comes to efficiency, materials handling and health and safety aspects out in the boatyards, there would have to be made some investments both in buildings and equipment.

Some of these changes might be made by rearranging some of the existing buildings, but making the shed permanent and insulated is probably a must.

These requirements are recommended for any professional FRP boatbuilding plant.

The FRP work should be kept separately from other activities because of the volatile fumes and the aggressive dust.

It should be kept in mind that FRP work is more vulnerable to temperature and humidity than wooden boatbuilding, and one should always try to keep the environment at a stable temperature with the right humidity (40 – 80 %) and as free of dust and volatile fumes as possible.

The resins should be stored at temperatures below 25° C, and the reinforcements in separate rooms with low humidity, since the fibres accumulates humidity from the air.

When it comes to fire and explosion, the dangerous liquids like peroxide should be kept separate from the resin.

There should be extractors and/or fans to get rid of the dust and fumes in the working area, and the school should definitely have a good compressor of fair capacity, to enable the teaching of gelcoat spraying and so related activities.

In my paper on “Quality Control when working with Fibre Reinforced Plastics”, I mention several useful instruments which also should be available at the school, as well as there should be no economical restrictions when it comes to personal safety equipment.

All these matters mentioned here are not critical for the actual training of the people building the Bokkuras, but they are very important when it comes to building up a professional attitude and skills for future FRP boatbuilding in the Maldives.

For the practical part of the training, the school has built a mould for a v-bottom 15foot “Bokkura”, with a coaming/deck. The moulds are made by former students and are not of very good quality, but serve the purpose.

Because of the short “time window” for building the Bokkuras, we asked the FET to do the practical part of the curriculum in the first three weeks, because the actual FRP building was the most important part.

After finishing the building of the Bokkuras on the Remote Islands, the Candidates would then return to the school to finish the theoretical part with boat design and lofting.

The Ministry and FET decided to compress the whole four week course into three weeks, so the candidates will not have to come back to the Boatbuilding School.

They will have a written exam, and the teachers will provide an evaluation of each Candidates practical skill.

The FET school board will get these papers and provide the certificates to the approved candidates.



Some of the candidates and boat builders in front of the school

The boat builders will return to Male after the training of the first group of candidates.

This will weaken the training of the second group, because from what I saw of their practical skills, they were a valuable asset to the training.

Since there is an advanced course going on at the same time, and there are only two teachers available, they will not have enough capacity for a decent practical training for the candidates.

I recommend that at least two of the boat builders from the Ministry will stay with the second group.

For the first 1/3 of the day, there were theoretical lessons in the classroom.

On the next 2/3, the candidates were divided into two groups for practical training, one with the hull and one with the deck.

Within the three weeks, all of the candidates will have gone through all the aspects of preparing a mould, putting on the gelcoat, laying up the laminate and releasing a complete 15foot boat from the mould.

The progress of the work was good, and I feel reassured that together with the supervision of the boat builders from the Ministry, the candidates should be able to build Bokkuras of acceptable quality on the remote islands within the time window.



The candidates in work, laminating a 15 foot, "Bokkura size" boat. They are showing good skills, and are using proper gloves and respirators.

I went through the different subjects with Mohammed Yosuf and the boat builders, and we decided I would do lessons in the following subjects:

- 1- "Personal and environmental safety when working with fibre reinforced plastics".
- 2- "Quality control when working with fibre reinforced plastics".
- 3- "Reinforcement sequence in fibreglass boatbuilding.

The written handouts for these lessons are attached to the report.

On the last day there also was a request for a lesson in the repairing of fibreglass boats. I will make a lesson for this and provide FAO and the ministry with this paper later. There will also be an update of the other lessons with additional information and drawings.

The candidates from Maroshi invited me to an overnight trip to see their island. This was very interesting and enjoyable, both professionally and social, and I feel quite confident that these people will benefit from the boatbuilding activity and hopefully be able to develop some sort of business from this opportunity.

Hopefully I will return to Alifushi on the 15th of September to follow the second group of candidates for a week and do the four theory lessons with them.

As a note, I will just mentioned that since I started writing the report, we have had a meeting with the Ministry, who has agreed to let two of their boat builders stay on Alifushi to assist with the training of the second group of candidates.

Thomas Anmarkrud

PERSONAL AND ENVIRONMENTAL SAFETY WHEN WORKING WITH FIBRE REINFORCED PLASTICS.

Personal:

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.



Eye protection/goggles, ear protection, and a dust mask with ventilator

2. Respirator Safety:

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 fibreglass 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 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 none ventilation, such as inside a boat, you should always use a respirator with an external source of fresh air, ore you will be in severe danger of developing what we might call a chemical lung inflammation.

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.



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. Comfortable and easier to talk with.

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. Hand and finger 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 regarded, which leads us to the next point:

6. Skin Safety:

It is not what you see which is the most dangerous; it's what you not see.

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.

Here we are also talking about long term effects, and not a problem you will face the same day or the day after.



This is proper use of long sleeved gloves for spillage, and respirator against volatile fumes like styrene.

7. 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 is 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.

Environmental/workshop conditions:

1. Air Control, dust and fumes:

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 where several operations are being executed at the same time.

In a boatbuilding plant, the most ideal action is to perform, as much as practical possible of, the sanding and grinding in a separate room.

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

2. Fire Hazard Control:

Everyone in the workplace must do their part to eliminate fire hazards.

If you are using spray equipment, leakage of catalyst can be a significant source for fire. Also in hand laminating, spillage of catalyser is possible and dangerous.

You should always be alert to the possibility of an early “kick off” in the bucket due to the use of too much catalyser, or maybe you used too much time on some laminating details. The exotherm will quickly build up if there is too much resin in the bucket, and if you don’t put water on top of it and take it to a safe place, you might have a fire coming up.

Always be aware of abnormal exotherm build up when disposing saturated wet fibreglass in a waste container. Don’t put wet rags with solvent in the same containers.

If you are not using a pre accelerated resin, also be aware that mixing accelerator and catalyst (promoter and initiator) together, immediately will lead to an explosion.



The man to the left is spraying gelcoat and has a facemask with external air supply. The man to the right is wearing no respirator although the air is heavily loaded with styrene. Gelcoat overspray will also contaminate the fiberglass on the cutting board.

3. Waste Material Reduction and 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 diversifying hazardous and non-hazardous waste.

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

4. 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 here is to keep the catalyser in a separate room from the polyester and gelcoat, due to the potential fire hazard.

5. Documentation:

When you buy any chemical from a supplier, you should ask for, and they should supply, a technical data sheet, which provides you with all the technical information you need to be able to handle the chemical in a safe way.

All technical data sheets should be collected in a holder and kept on a safe place, available to all personnel who potentially can be exposed to these chemicals.

This Document was made by Thomas Anmarkrud, August 2005.

QUALITY CONTROL WHEN WORKING WITH FIBRE REINFORCED PLASTICS:

Why do we need quality control?

Most workers will be able to put some gelcoat, polyester and fibreglass 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.

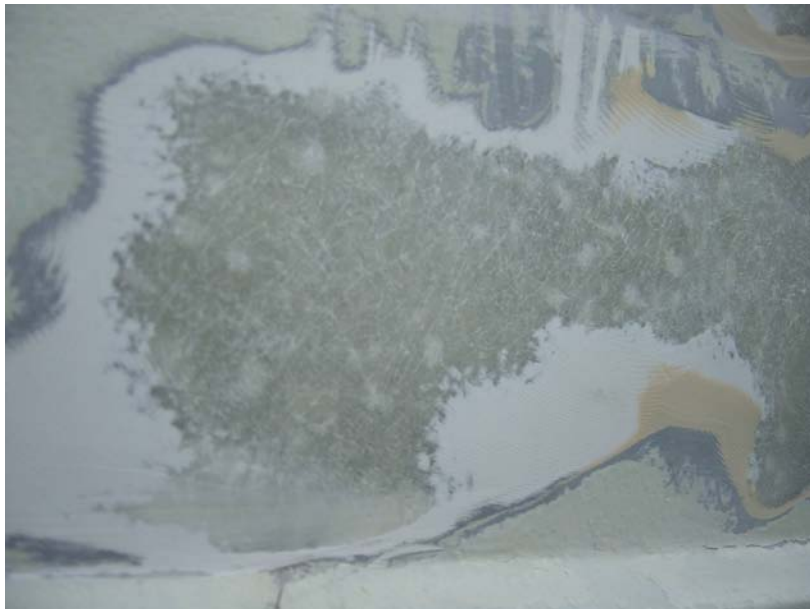
Another aspect to be aware of is that polyester is not waterproof. The laminate absorbs water from the first day you put the boat in the water, and despite what most people think, the gel coat is of no use in preventing it. Gelcoat is made of polyester and absorbs water.

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 hydrolysis. 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” fibreglass and some chemicals.

The better the quality of the laminate is, the longer time it will take for the osmosis (hydrolysis) 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 osmosis (hydrolysis) in the laminate.

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

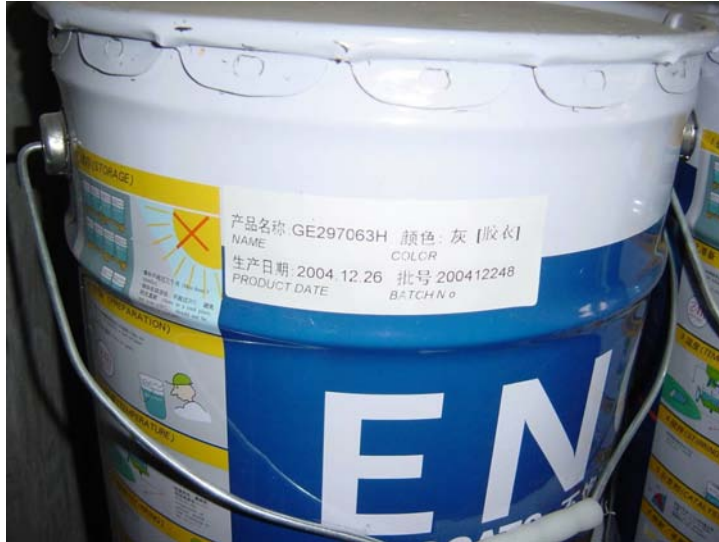
Bear in mind though, that in many cases, the laminate could be badly hydrolysed as you see here, with white fibres and white shadowed areas in depth, without any formation of blisters.

The laminate has then already lost at least 30% of its original

Material handling:

There are some major considerations you have to follow when handling the 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 on the cost of the supplier! In the first line, you are the one who gets the blame from the boat owner if the boat breaks down due to poor raw materials.



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

2. Require 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 things like viscosity and strength. The data sheet is also the key to details like proper mixing and the right temperature when laminating.
3. Keep the fibreglass dry and clean.
4. Proper mixing of gelcoat 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.

How to make your own quality control when laminating:

If you have followed all the necessary steps above, it is now time for doing the actual work. I will not get too much into detail of all the steps; just mention some major points of concern:

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 ligaturing 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 aligating. The potential possibility of contamination of the surface makes it smart to start the lamination within 24hours.
 3. Always apply a coat of wet resin/polyester, before you put on fibreglass.
 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 get 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 have 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:
 $5,57 \times \text{sec} - (452/\text{sec}) = \dots \text{mPa}$
 Example: 72 seconds
 $5,57 \times 72 - (452/72) = 394,76 \text{mPa}$

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

1. 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!

2. Curing Measurer, Barcol. Barber Colman, Impressor.

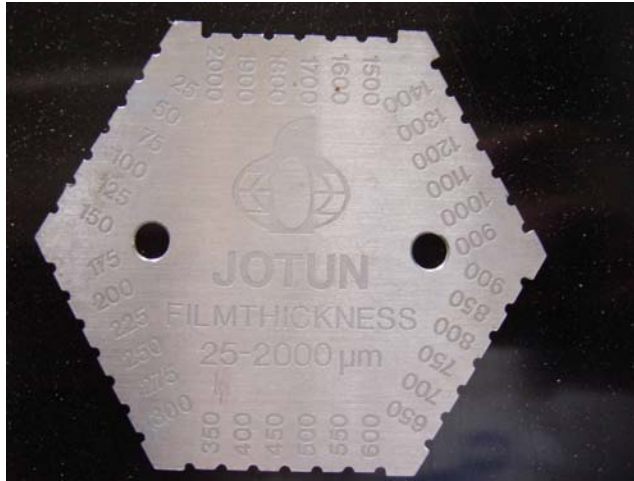


The Barcol measurer is a must for any serious FRP boat builder. With this equipment you can perform tests to see if your laminate is of adequate quality. The instrument pushes a needle in to the laminate to check the hardness. There has to be made at least 10-20 tests, and the average should be more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

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 fibreglass which has not been completely saturated with resin, which is often an issue with the 800g woven rowing.



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.



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. This is a version used by a boat manufacturer in the Maldives.

LIST OF INSTRUMENTS / EQUIPMENT FOR DOING QUALITY CONTROL WHEN WORKING WITH FIBERGLAS REINFORCED PLASTICS.

The cost estimate is rough, and the specific brands mentioned here are just examples

1. DIN 4 cup for measuring the viscosity of resins. Estimated price: 10\$
2. Moisture meter, "Tramex Skipper", for measuring relative moisture content in fibreglass and polyester laminates. Estimated price: 700\$
3. Barcol meter. Impressor to measure the stage of curing in a polyester laminate. Estimated price: 650\$
4. Ultra sound, laminate thickness measurer, Cygnus SE. Used to measure laminate thickness without needing to have access to the other side. The instrument is also very useful to detect air voids and delaminations. Estimated price: 2300\$
5. Wet film thickness gauge. For measuring the thickness of wet gelcoat when applying it. Estimated price: Should be given away for free from gelcoat supplier. 1-5\$
6. Infra Red surface temperature measurer. For measuring the temperature of the mould and the materials prior to laminating, and the development of the curing stages and exotherm while laminating. Can be purchased in a number of varieties and prices. Estimated price: 150-300\$
7. Hygrometer. For measuring the relative moisture content in the air. Very useful and important for keeping control of the working conditions. Also here there are a number of varieties to get. You can buy simple electronic ones of sufficient quality for approximately 20\$

This brings the total cost of these tools up to approximately 3985 \$

This document was made by Thomas Anmarkrud, Sept. 2005.

REINFORCEMENT SEQUENCE IN FIBREGLASS BOATBUILDING.

The lay up sequence is determined by the nature of the fibreglass materials.

Traditionally, boats have been built with Polyester resin, reinforced with fibreglass Chopped Strand Mat (CSM) and Woven Roving.

Generally this has worked well when the boats have been built with thick single skins, and large safety factors.

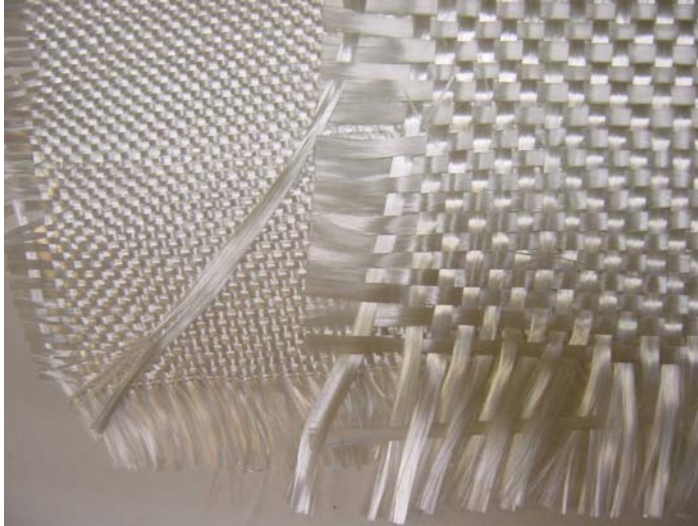
In the 1980`s and 90`s, the boat manufacturers realised there was a growing problem with degradation of polyester, or what is more commonly known as osmosis. Today this is recognised as a chemical process called hydrolysatation, triggered by water absorption, which can and will affect older boats in varying ways, depending on the quality of the boat.

One thing which has been detected is that heavy woven roving seems to get affected more than other reinforcements, which can lead to severe delamination. This is mainly because the heavy fibre bundles are difficult to saturate, but also because they bend and twist and easily make room for voids and air bubbles.

The nature of the woven roving also makes it resin rich on the surface, and because polyester is a brittle resin, this makes it vulnerable for micro cracking and delamination.

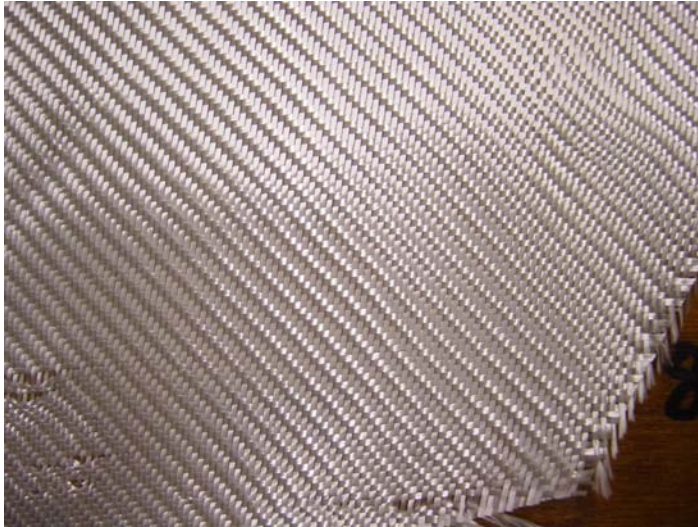


Chopped Strand Mat (CSM), consist of randomly oriented strands of fiberglass chopped to approximately 2” or 5cm length. This is held together with a styrene soluble binder.



Heavy; traditional 800g woven roving, the 600g in the back ground. They both look fairly much the same, and will face the same problems in modern boatbuilding.

For this reason, and other reasons, which I will explain later, it is not advisable to stack heavy woven roving in the middle of a polyester laminate. It is better to locate it closer to the surface, where a delamination is less critical and easier to detect.



This is a lighter, 290g/390g twill weave fibreglass fabric. It drapes very easy over more complex shapes. It is mainly used with epoxy, but can also be used as an alternative to the heavy rovings with polyester. In many cases, the strength and the texture of this weave, does a good job close to the surface of the laminate.



In the last 10 years the use of “knitted” reinforcements (stitched fabrics) has taken over most of the use of the woven roving, in large parts of the boatbuilding industry. Stitched fabrics consist of bundles of directional fibers laid on top of each other and stitched together. In this way, the glass bundles get closer to each other, and they are not bent. This means more compact laminate with fewer voids. On the picture you see an 800g “triaxial” reinforcement.

As the customers wants faster, lighter and more fuel efficient boats, the laminates has to be fine tuned to give as much strength and stiffness as required for daily use, and also have sufficient safety factor for the more extreme situations.

In this work there has been a lot of testing, both in laboratories and in real life situations. Reinforcements and resins has been put together in many sequences, tested over the limit and cut open for inspection. Also by studying damaged and grounded boats prior to repair, useful information has been gained.

We will not get into all the aspects of different resins and more exotic fibres now, but give some guidelines for the best use of fibreglass reinforcement in polyester resin.

If we are talking about shear forces, which you mainly get in the centre of a laminate, a well made, homogenous CSM laminate is what best takes care of these forces.

This is explained by the fact that the fibres are randomly oriented, and the mat layers are compacted and worked into each other with the metal roller.

Since polyester as a resin is very brittle, and has an elongation to break of approximately 0,9-1,5%, it is not the best resin to “glue” two woven rovings or stitched fabrics together with.

When you are using woven roving or stitched fabrics with polyester, there must always be a CSM mat in between the layers. Woven rowing needs a thicker CSM than stitched fabrics.



On this 1100g quadraxial mat, there is a 100g CSM mat already stitched to one side.

Just make sure you always put the right side down.

This is a fairly heavy mat and should not be used in sharp corners.

Be aware that since epoxy does not work with CSM, this stitched fabric can only be used with polyester and vinylester.

Both woven roving and stitched fabrics have their strength in tension and compression, and not in shear.

In a loaded laminate panel, there are compression forces on the side from where the panel is loaded, and tensile forces in the fibres on the back side (Figure 1).

In the middle there are shear forces, but this is also the place which is most neutral and needs the least strength.

This means that when the strength of the woven roving or the stitched fabrics is wanted, these reinforcements should be placed on the outside and the inside of the laminate.

One thing which is often overseen by naval architects in modern advanced design is the importance of local stiffness. Laminates are often designed by scantlings for strength, and suffers prematurely failure and delamination due to flexing and fatigue. Stiffness is mainly built by thickness, but also by orientation of fibres on the surface of a laminate.

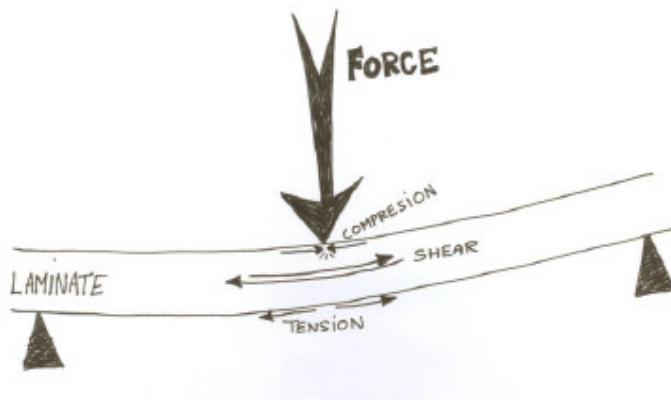
If all this is taken into consideration, you can build up a strong and stiff laminate like a small sandwich (“quasi sandwich”), with the bulk in the middle built up with CSM, and then on each side, traditional woven roving, or stitched fabrics with an orientation of the fibres optimised to take up the expected forces from this particular place in the boat.

Also remember that when starting up with a new laminate on a fresh prepared surface, the control of voids, air and adhesion, is much better if you start with a lighter weight of reinforcement. Like a 450g or less.

When laminating on details like frames, use 450g or less if time allows you, and avoid traditionally heavy woven roving, except for maybe one layer close to the laminate surface. If CSM is used, the sequence is of little importance. If woven or knitted is used, start with the largest fabric first to ensure as much adhesion to the surface as possible free of voids.

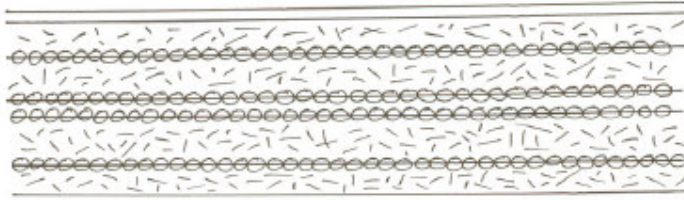
4-450g DB (Double Bias) stitched fabrics are perfect for laminating in frames because they drape well. Unidirectional fibreglass is of good help for stiffness on the top along the frames, stringers and other stiffeners.

Figure 1



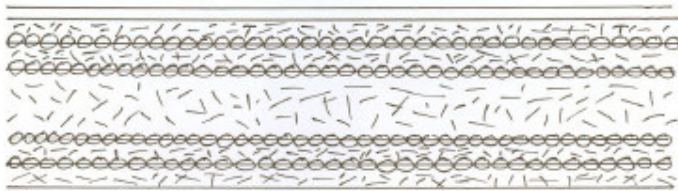
This sketch shows the principal of the different forces acting on a laminate under pressure. In a case like this, the shear forces are actually largest close to the two points holding up the laminate here, and fatigue failure will first appear inside the laminate at these places.

Figure 2



This is a bad example of laminate sequencing.

Between the two layers in center, there is no CSM, and the layers of woven roving or stitched fabrics are placed more or less evenly throughout the laminate.



This is a good example of laminate sequencing.

The CSM is placed as a core in the laminate, and the more sophisticated reinforcement is placed closer to the surface where their potentially better performance is of better use and less harm.



CSM laminate



Woven roving or stitched fabric.



Gelcoat

This document was made by Thomas Anmarkrud. 2005-08-29.

PRACTICAL STRUCTURAL FRP REPAIR GUIDELINES

In general, repair to FRP boats can be easier than repairs to other materials. However, proper preparation and working environment is critical.

When damage occurs, you first have to determine if it is just a cosmetic surface problem or a more structural damage.

In this paper we will not discuss the matter of getting a proper finish, but only concentrate on the issue of getting the boat back to a sound and homogenous structure, as close to the original strength and stiffness as possible, and better if it is needed.

We will use a real repair with pictures as an example, and supply with some drawings to ease the understanding and help as a guideline.



This picture shows a typical fatigue fracture inside the transom on a boat with outboard engine.

In this case there has been made an effort to repair the crack, but putty and gelcoat can not mend a structural damage.

Ideally, the boat should be repaired indoors, to protect the work from rain and sun, and secure a stable temperature. If this is not possible, a tent should be made.

All hardware and equipment which prevents access must be removed.

Before you start grinding, you have to protect yourself with a dust mask, eye and ear protection. You should also make an attempt to collect the dust at the source, by using a dust extractor or a vacuum cleaner attached to the shield on the grinder.

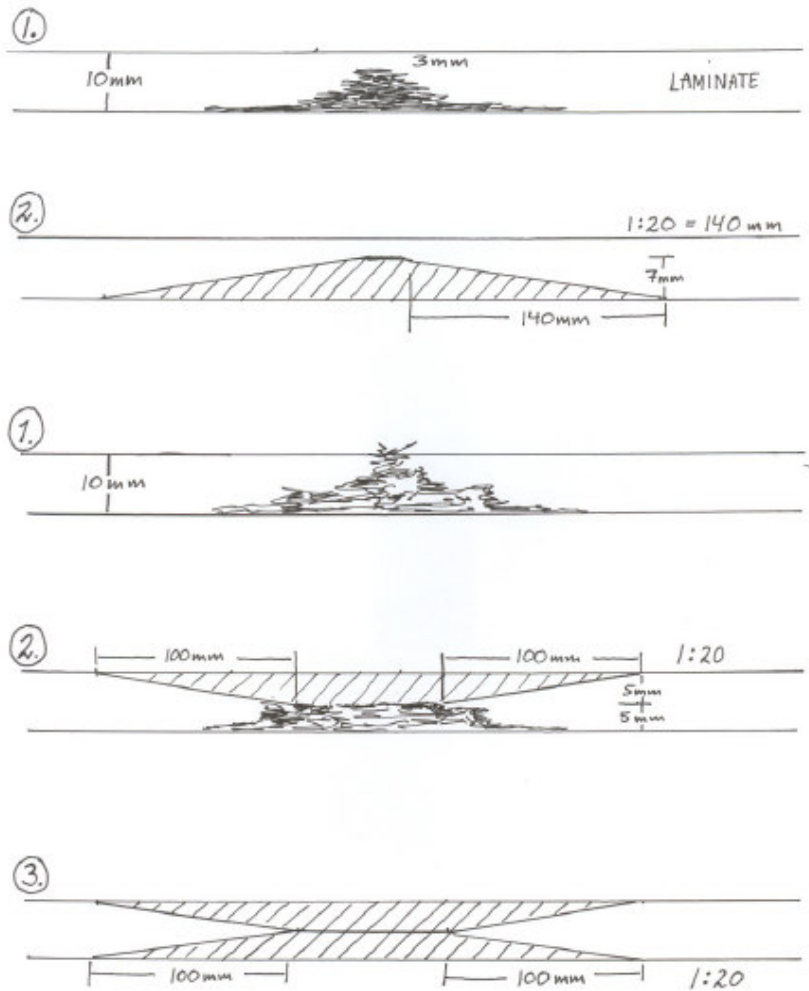


Initial to grinding, all surface contamination like oil and silicone should be washed off and removed with a suitable solvent or likewise.

The use of 40 grit sandpaper is a good choice.

Grinding uncovers deep delaminations.

We have to grind as far and as deep as demanded, to get rid of all delaminated fiberglass.



This is a schematic drawing on the principle of laminate repair.

The first two pictures show damage which is not penetrating the whole laminate, and the next series is of a two sided repair.

A lot of books state that 1:12 is sufficient for fiberglass repairs. This could be sufficient in unloaded areas with thick laminates.

With thinner laminates and loaded areas, the scarf should be at least 1:20.

In many cases, a scarf of 1:40 or more must be used to ensure a proper area of adhesion and absorption of forces in a loaded area.



When all the grinding is done, the area to be laminated is much bigger than the initial survey would suspect. The other side of the engine well had just tiny cracks in the gelcoat, but grinding revealed that the delamination was just as deep on both sides.

At this stage of the repair a decision has to be taken on what kind of materials you want to use for laminating, if it has not already been done.

The following text is meant as a guide in making this choice.

PRIMARY BONDING

Primary bonding is when two surfaces are connected directly to each other, forming a chemically homogenous laminate with no weakened bond line.

When a polyester laminate is fresh (green) you can start to laminate directly on top of it without doing other preparations than sanding off bumps and fibres which could cause defects/air pockets in the laminate.

A “green laminate” means that the surface still has active molecules on the surface that will bind chemically to a new laminate.

Laminating on a green laminate gives a primary bond.

How long the laminate surface will be active, depends on a combination of the technical properties of the resin and the temperature during curing.

Generally the open time for polyester is 24-48 hours.

Ideally in a building situation we will struggle to achieve primary bonding. But the nature of building large FRP boats, and the time consumed, makes it more difficult to operate within the time window. The least we should try to achieve is that the main hull laminate is build with primary bonding.

When we are laminating in the frames, stringers and bulkheads, we are definitely talking about secondary bonding in most cases.

SECONDARY BONDING

We should keep in mind that all repair work relies on secondary bonding, which means that stronger or additional replacement material is needed to achieve the original strength.

When laminating over a cured laminate, the cross linking reaction does not occur to a significant degree across the bond line, so the polymer networks are discontinuous and the bond relies on the adhesive strength of the resin.

What resin to use?

In general, isophthalic polyester, vinylester, or epoxy resins are preferred for FRP repairs and alterations. General purpose (GP) polyester resins are less desirable.

When considering strength, cost and ease of processing, isophthalic polyester and vinyl ester resins are recommended for most repair works.

For more critical structural repairs, we must keep in mind that epoxy laminates are generally stronger (but not stiffer!). Epoxy resins are highly adhesive and have longer shelf life than polyester and vinyl esters, which makes them ideal for emergency repair kits. They also have no solvents, which give almost no shrink when curing (less tension) and no “surface contamination” of the original laminate.

Epoxy does not hydrolyze, and this together with the good adhesion, the low shrink and the high ratio of elongation to break, makes them more liable to perform as good as a primary bonded laminate. However they are intolerant of bad mix ratios and can not be speeded up or slowed down by altering the amount of hardener. We also must keep in mind that the surface is definitely not active with styrene, therefore, any further rework to an epoxy boat or an epoxy repair will have to be made with epoxy.

A proper and clean preparation of the bonding surface is very important for a good adhesion.

What reinforcement to use?

If practicable, the original reinforcement shall be used in the repair, especially if the part is heavily loaded and operating near its design limits. We should bear in mind though, that the continuation of the fibres in the laminate is lost, and the strength is solely relying on the adhesion of the new laminate. The initial stiffness will be there almost 100% if you build up the laminate to the original thickness, but the strength and fatigue properties will be weakened.

Therefore, the dimension of the fibre bundles is critical for the performance of the repair, because large bundles and heavy mats/fabrics makes the appearance of air, and resin rich pockets more probable in the borderline between the old and the new laminate.

Lighter weight reinforcement will give a better contact with the surface, and the importance of this should be weighed up against the importance of using the original reinforcement.

All these matters taken into consideration, the design of the repair laminate is important, and if additional reinforcement is required to maintain the global strength, one should be careful to avoid excessive laminate build-up, with the danger of developing stress concentrations.



In this case, the choice was epoxy, but vinylester might also have performed well. We must bear in mind that this is a single sided repair, and the original polyester laminate has already shown weakness from fatigue. The reinforcement is a mix of 290g woven twill and 450g Double Bias fibreglass, chosen because of their drape ability and good performance with epoxy.

Surface preparation:

It is important not to clean a freshly sanded porous fibre laminate with acetone or solvent prior to lamination, unless you have contaminated it with oil or grease.

If you have to clean it, do so, but make a light grinding with clean sandpaper after the washing, and give the solvent sufficient time to “air out”.

The reason for this is that the solvent is absorbed by the porous surface and “contaminates” the laminate, potentially acting by diluting the resin and preventing a proper adhesion.

A light styrene wipe prior to laminating, when using polyester, is the only acceptable procedure. This will activate the surface slightly, and will improve the adhesion when performed properly. Too much styrene will weaken the bond line.

On repairs under the waterline, fresh styrene from the new polyester laminate is also liable to trigger hydrolysis at an earlier stage than the original laminate, and cause a premature failure in the borderline between the old and the new laminate

An important issue in repairs is to check the content of humidity in the laminate with a moisture meter.

If the laminate is humid, the bonding will fail eventually, and the new laminate will separate from the old one prematurely.

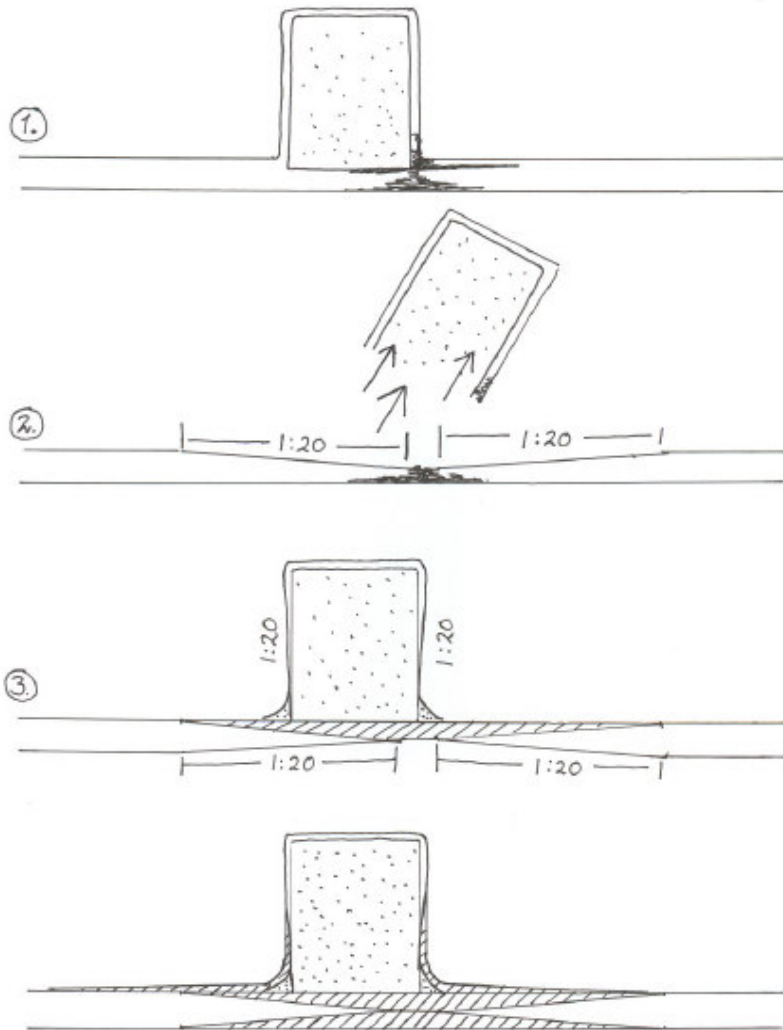
When it comes to the actual laminating, we have to follow all the same procedures as we do when we are making a new boat, and the quality control has to be just as good.



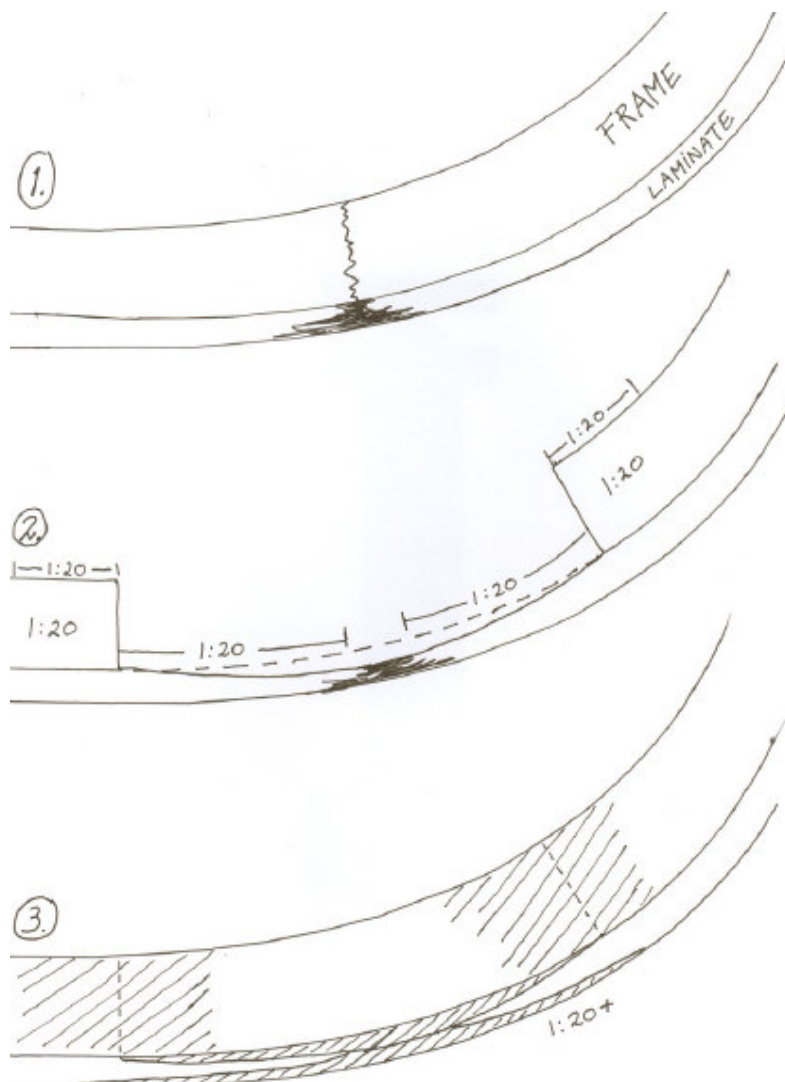
At this stage, the laminate build up is finished. The surface is grinded flat to a nice “finish”, and the use of any form of putty is to be avoided on all structural repairs. Putty has a short “elongation to break” ratio, and will break up and crack much faster than a laminate.



The final picture shows a finished product. Gelcoat has been put on, water sanded, buffed and polished to a decent gloss. There is no problem with using polyester gelcoat on top of epoxy as long as the epoxy is properly cured before you apply it. In this case we have also put on a 5mm aluminum plate to spread the pressure from the bolts.



1. A fracture in the outer skin has penetrated the whole laminate, and caused a delamination in the framework.
2. To perform an acceptable repair, the frame has to be cut and removed, and a regular repair has to be made to the hull laminate first.
3. The frame has to be grinded to a scarf wherever it meets other laminate, before being bonded down with putty/glue and finished with a radius filet.
4. All lamination work on the frame is best done with easily drapable fabrics or CSM lighter than 450g/m^2



1. This is more or less the same repair as the previous series, but viewed from the side.
2. The frame is cut and taken away to get access to the laminate. In this case, there is no scarf in the core of the frame, like on a wooden boat, since the frame is foam or air, and is not structural.
3. The place you cut and how you cut the frame, vary for different damages, and have to be estimated carefully in each case. Some times with structural foam, you also have to make a scarf as with a wooden frame. "Stepping" the scarf is also an alternative in some cases. The use of additional extra length reinforcement must also be considered, such as unidirectional fibres along the top of the frame.

This document was made by Thomas Anmarkrud. 2005-09-16

PROGRESS ON BOKKURA BOATBUILDING. Thomas Anmarkrud

Alifushi 27/8 2005

On the 24th of August I send a letter to Mr. Øyvind Gulbrandsen about the progress of the building of the plug and mould for the Bokkuras.

On the 26th of August I received a reply on my questions, with the last changes on the drawings for the Bokkura.

It is easy to understand Mr. Gulbrandsen`s concern with the shoebox joint, since I am also used to the flange as a stiffener and a handle for lifting.

On my first visit to Precision Marine, Mr. Omar Maniku argued that it is easy to lift by holding on the inside or on the wooden fender, that access to the nuts is easy, and showed me on a similar construction.

He argued so good for his views, and being fresh on the scene, not yet seen the revised drawings, I felt a little trapped. Especially since the TCEO now is pushing quite hard to make us build the Bokkuras within the time window.

Actually, from what Mr. Gulbrandsen is explaining, and from the drawings, it looks like Precision Marine did not have the revised edition either. I did not look closely at Mr. Maniku`s drawings at that time, and was more concerned about getting a general view on their skills in fiberglass boatbuilding and quality control.

The problem now is that we visited Precision Marine on the 17th of August. At that time they were well away with the plug building, and by now they should be finished.

I will hopefully be able to discuss this with Derrick, Yon and Winston as soon as possible getting back to Male.



This picture is showing the Plug on our first visit to Precision Marine.

There also was another point of concern, when I shoved Ahmed Hassan, boat builder from the Ministry, the pictures of the plug building; he said that the boat will be 30mm narrower since they have taken off the thickness of the battens and the fancy ply from the drawings.

I could not give an answer to that, but we should definitely go to Precision Marine tomorrow to sort out the details. On the other hand, a few millimeters here and there is not critical, and we are running out of time

Maybe it would have been better to have had Ahmed Hassan to join Precision Marine at the whole plug building, but that is too late now.

I do agree, which I have mentioned earlier, that it is good to skip the woven roving in the Bokkura, and I completely trust Mr. Gulbrandsen`s calculations on the floatation.

I mentioned Polystyrene to Derrick when we were at Precision Marine, and he said it was difficult / impossible to get hold of. They do not use it here in construction of buildings. Due to problems with the internet and my computer on Alifushi, I am not able to open the revised drawings.

Male, 30/8

I could not finish my report without a new inspection at Precision Marine, and some more discussions with the Yard Owner / boat builder Mr. Omar Maniku, and Derrick, Yon and Winston at FAO.

Because of the time window we are working within, we just have to meet on the halfway in some of the issues, and I also feel that we are better off following local practices in some cases, as long as they are well funded.

Yesterday we visited Precision Marine to have a look at the Bokkura plug.
Because of the revised drawings with the bilge keels, they had not put on the gelcoat for the last finish and polishing of the plug.
They had just started the work on the bilge keels.



The plug almost finished. Bilge keels are ready to be added. Then the gelcoat will go on, and only the finishing and polishing will be left.

We went through a lot of the details for the construction, and especially discussed the hull-deck joint, since this was such a concern for Mr. Gulbrandsen. The joint, as proposed from Precision Marine is not what we traditionally call a shoe-box joint. They are actually making the mould of the hull and the deck in the way they build a split mould for a big boat.

First they laminate the hull and the mould separately. Then the edges are cleaned and the area where they are laminated together is scarfed and sanded. The two parts are put together with fixed references, bolted, and then they are solidly laminated together.

There will be an additional 3-4mm x 50mm strip of wood laminated in this area, and the wooden 2" x 2" fender will be bolted through.

To me, this looks like a solid and stiff joint, and there will be no potential stress as you often get in a shoe-box joint.

The revised drawings show good access to the bolts on the inside.

Mr. Omar Maniku of Precision Marine says that this is a well tested detail. He says that they tried with the flanges years ago, but they struggled with fatigue problems in the corners and ended up with the way they are doing it now with good longevity.

I have no problems following Mr. Maniku's argues. Another benefit with this is the cheap cost, availability and ease of manufacturing of the wooden fender.



The picture on the left shows details from a similar mould as intended for the Bokkura, with the fixing points and the bolt holes clearly shown.

On the picture below, it shows how the two moulds are put together and bolted. This will be done when the products are already laminated in, and the hull and deck is ready to be joined.



Another change from the revised drawings is the center thwart, which we will let go all the way across in full depth to handle the transverse stiffness and strength when it comes to fatigue.

For the stiffening of the transom and to prepare it for the outboard, they will use 3mm x 50mm wood strips with plenty of drilled holes in it, laminated in a special pattern. These strips will go all the way from the top and almost down to the drain plug.

For the assembling of the Bokkuras I will prepare a small manual in addition to the drawing, to go with the boat builders to the remote islands.

Male, 1/9

BUILDING A BOKKURA WITH FIBERGLASS REINFORCED POLYESTER

BY THOMAS ANMARKRUD



CONTENTS:

1. WHAT IS FIBERGLAS REINFORCED POLYESTER (FRP)
2. MATERIAL GUIDE
3. TOOLS TO BE USED
4. PUTTING THE MATERIALS TOGETHER TO MAKE A LAMINATE
5. MAKING THE PLUG
6. MAKING THE MOULD
7. BUILDING THE BOAT
8. REPAIRS
9. HEALTH AND SAFETY ISSUES

1. WHAT IS FIBERGLAS REINFORCED PLASTICS?

Fiberglas Reinforced Plastics is a composite of several materials put together and hardened to form a solid laminate.

If put together right, it can be both strong, stiff, with good fatigue resistance properties and have good resistance to the influence of water.

If put together wrong, it might still look good on the surface, but the lack of quality could make it degrade and collapse in maybe ½ the expected lifetime or even less.

We can compare how the Fiberglas is glued together with the resin, to how the wood fibers in a tree are being held together with the natural glue Lignin.

The fibers, both in a tree and in a Fiberglas reinforced plastic laminate, is giving the strength to the structure, and the lignin and the resin is holding it together, creating stiffness, and transferring the loads between the fibers.

In this basic manual, we will concentrate on the reinforcement made of tiny hairs of Fiberglas bundled together, and the resin we are using as glue, is General Purpose Orthoptalic Polyester, hereafter referred to as Polyester.

When these materials are put together, they form a laminate called Fiberglas Reinforced Polyester, FRP.



2. BASIC MATERIAL GUIDE FOR BOKKURA:

- **Fiberglas:**

CSM (Chopped Strand Mat):



Randomly oriented fibres from 25 – 50mm (1 – 2 inches), held together with a styrene soluble PVA binder. Comes in two “weights”, 300g/m² and 450g/m².

The 300g/m² is mainly to be used as a “skin coat” or “first layer” instead of a surface tissue.

- **Polyester**



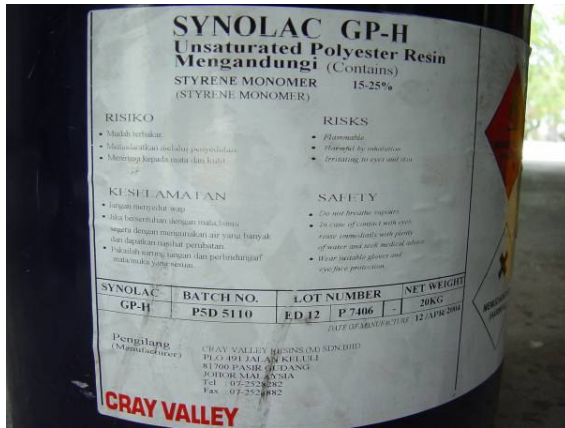
The polyester is a GP (General Purpose) Ortho-Polyester from SHCP in Singapore.

With 1% MEKP catalyst, it has a gel time of 8-15 minutes at 30°C.

Storing stability in the dark, below 25°C, is 6 months. With the high storing temperatures we have in the Maldives, we are talking about 3-4 months stability from production date.

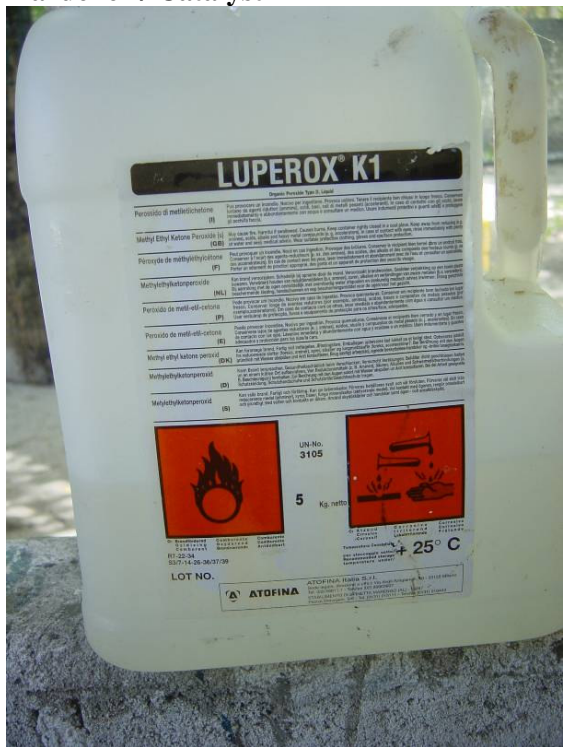
The date is not written on these drums. Check with technical papers from Guarantee Fibreglass that should come with the drums.

- **Gelcoat**



The gelcoat is "non pigmented" Synolac GP-H from Cray Valley. Date of production is written on the container, and storing stability is the same as for the polyester resin. Pigment, less than 10%, is to be mixed in with thoroughly with a "blender" on the power drill prior to use. Use no more than 2% hardener.

- **Hardener / Catalyst**



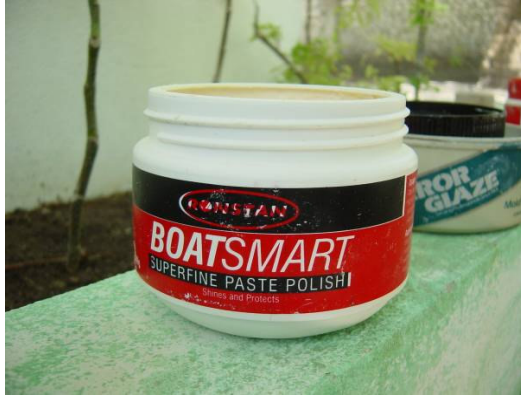
The hardener, also called catalyst, is used to make the polyester cure. It is extremely corrosive, and special care must be taken in handling and storage. Use eye protection and gloves as personal protection. Extensive spillage on floor can cause reaction with several materials, and heat build up can cause fire. To be stored separate from polyester. If accelerator is used to make a fast cure "fixing putty", make sure you mix it thoroughly with the paste before you add hardener. Mixing accelerator and hardener together will cause an explosion. With temperatures up to 37°C, the gel time has been adjusted with the use of 0,75% hardener. The cure has been tested with a Barcol meter with readings of 45-50, which is acceptable, although it is advisable to stick to the manufacturer's advice of 1% hardener and shorter gel time. Mix smaller

- **Wax**



A high quality paste release wax. To be spread out in moderate amount on the surface of the mould, and then polished to a high gloss with a clean cloth. A mould is "broken in", with 5-10 layers of wax, and maybe PVA as a mould release for the 5 first products. For a good quality mould, it is sufficient with a polishing after each boat is released from the mould, and no PVA. This gives the best finish result

- **Buffing compound**



The paste comes in two different grades, coarse and fine or superfine.

To be used when repairing and building up a new high gloss finish, either in a mould or outside a hull.

Surface is first water sanded with grits from 240 all the way up to 1200.

Then the coarse paste is used, and after thoroughly washing off any remains, the surface is buffed with the fine grade paste and then polished with wax. If it is a mould repair, the repaired spot has to be broken in as new.

- **Acetone**

A solvent, used to clean brushes, rollers and other tools from polyester prior to curing. Avoid getting acetone directly on your skin since it takes away the natural grease you have on the surface to keep it flexible and healthy.

If used extensively over long periods it is stored in your blood and can cause negative effects. So do not wash your hands in it. Use gloves!

- **Styrene**

Is a “natural” ingredient in polyester. It is also a solvent, and can be used to give polyester and gelcoat lower viscosity. Use no more than 5%, since it is also an important part of the curing process, and extensive use can unbalance the curing process and weaken the quality of the finished laminate.

When repairing old laminates, a light styrene wipe prior to laminating can give a better bond between the old and the new polyester laminate.

Styrene is also good for cleaning moulds.

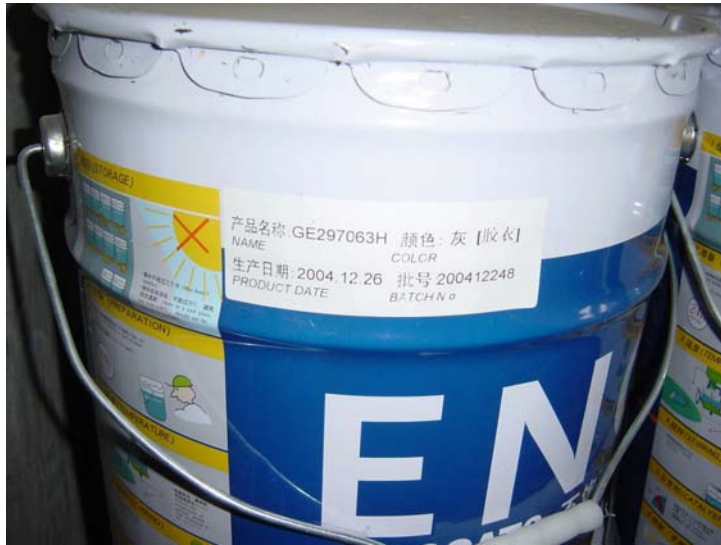
- **PU Foam.**

Pourable polyurethane foam (PU) is used in thwarts and other hollow cavities for floatation. The foam is liquid, delivered in can A and B, and is to be mixed 50:50 to give a proper expansion and cure. The ratio of expansion has to be tested before use, but could typically be that 1,6kg of liquid expands to approx. 1cubic foot of foam.

Material handling:

There are some major considerations you have to follow when handling the materials:

7. 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 on the cost of the supplier! In the first line, you are the one who gets the blame from the boat owner if the boat breaks down due to poor raw materials.



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

8. Require 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 things like viscosity and strength. The data sheet is also the key to details like proper mixing and the right temperature when laminating.
9. Keep the fibreglass dry and clean.
This is of great importance, but difficult in a hot and humid climate. Try to keep the fibreglass in a dry and ventilated room. If there is much dust or contamination in the air or if there is a possibility of rain, cover the reinforcement with plastic
10. Polyester and gelcoat should, if possible, be stored under 25° C. The shelf life is being reduced drastically as soon as the temperature rises.
11. Proper mixing of gelcoat and resins in the drum or container before you use them, to avoid settling of additives in the bottom. According to the book, a resin is supposed to be mixed 10 minutes every day to avoid additives to separate and settle in the bottom of the drum or as you see some times in the gelcoat container, on the top.



If a proper mixer on the drill can not be used, rolling the drum is the second best alternative. There might be a risk though, that if the bottom part is already of higher viscosity, rolling for 10 minutes might not be enough to blend this in with the lighter resin. If the resin is tapped out of the drum afterwards, the first resin coming out might be of high viscosity.

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

. 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:

$$5,57 \times \text{sec} - (452/\text{sec}) = \dots \text{mPa}$$

Example: 72 seconds

$$5,57 \times 72 - (452/72) = \underline{394,76 \text{mPa}}$$

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

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



Even a simple workshop working with fiber reinforced plastics, should have a temperature gauge and a gauge showing the relative air humidity in the workshop. The version showed here is sufficient and inexpensive.

If the temperature is much above 30°C, like 37°C, the gel time will be shortened, and if the temperature is getting considerably lower, the risk of insufficient curing is extensive.

Lower temperatures and high air humidity has also showed a greater risk for “aligatoring” (wrinkling) of the gelcoat.

If air humidity gets above 80%, the binder of the fiberglass will absorb moisture and the reinforcement gets “wet”.

3. TOOLS TO BE USED



This picture shows some of the tools you are supplied with when building the Bokkuras.

The brushes are best for applying gelcoat, but can also be used for polyester resin in tight corners and on small details.

You will get the 4" resin rollers you can see here with the blue handles, and bigger 6" rollers.



You will be supplied with 3 different sizes of compacting rollers. Numbers 1, 3 and 5 from the left on the picture.

Number 2 is meant for corners, but is not really good. Number 5 is better for bigger laminating jobs.

The rollers must be used firmly and not too hard, and is not to be used after gelling of the resin has started, since this will only create air and not get rid of it.

There will be a rubber mallet for careful hitting of the mould when releasing from the mould, and a 1kg hammer for hitting the wooden wedges to be used around the edge of the mould.

Dry sandpaper is supplied on rolls. 60 grit to be used on the laminate, and 80 and 120 to be used for finish work and on the wooden fenders.

Wet sandpaper is delivered in these grits: 240, 400, 600, 800, 1000 and 1200, and is intended for finish work on mould and gelcoat.

Screwdrivers are for mounting the stainless steel cleats and the drain plug.

The Stanley type knife with extra blades is for cutting dry reinforcement or "soft" laminate from the edges.

Reinforcement can also be cut by the supplied scissors or ripped gently by hand.

The wood chisel is handy for cutting bumps and cured strains of fibreglass.

Two sizes of masking tape are supplied for a variety of tasks. It can be used when applying two different colours in the mould, ore for repair operations.

The tape is also handy for securing the covering plastic when used for protection against dust or rain.

The combination wrenches is for the bolts and nuts on the fender, cleat, eye bolts and u-bolt.

Holesaw to be used with the electric drill should fit the drain plug.

The drill is also supplied with a full set of twist drill bits, and a 12mm flat wood drill for countersinking the 6mm bolts in the fenders.

A mechanical weighing scale is to be used for measuring the amount of gelcoat and polyester.

A variety of syringes is for measuring the correct ml of hardener, and a 1 litre transparent measuring container can be used for several purposes.

The funnel is mainly for use to get the polyester safely into smaller containers unless the buckets are used directly.

For the spreading of putty, there are two scrapers with handles, and a wider, “softer” one of metal.

A disc grinder like the smaller (5”) one on the picture is mainly intended for sanding laminate prior to assembling and secondary bonding.

It is supplied with a rubber backing disc for 100mm 40 grit sanding paper. There are also carborundum cutting and grinding discs in the set. These can be used for cutting or grinding of cured laminate, and cutting of stainless steel bolts.



The wood saw can also be used for cutting foam, and the hacksaw for both cured laminate and bolts.

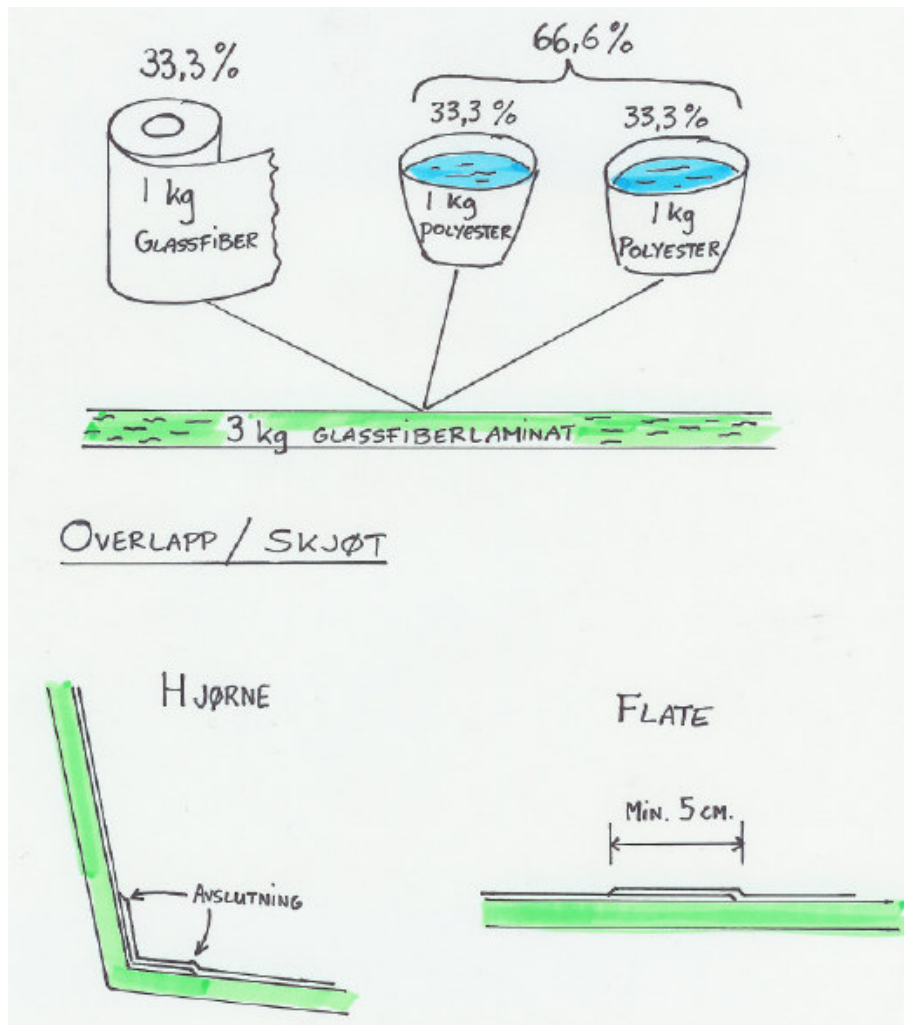
4. PUTTING THE MATERIALS TOGETHER TO MAKE A LAMINATE

5. The gelcoat is the first step after preparing the mould with either just polished wax or mould release agent.
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 aligating when applying the next layer. Ideal total thickness of gelcoat is 0,4 - 0,7mm.
Generally, a generous layer of gelcoat applied by brush, is around 0,25 to 0,3mm.
6. Laminating should not start sooner than approximately 1,5 hours after gelcoating, due to probability of aligating. The potential possibility of contamination of the surface makes it smart to start the lamination within 24hours.
Make sure your gelcoat is properly cured, and rather wait 3-4 hours than starting to soon.
If the fresh gelcoat is left overnight in your “open” shed, you should consider covering the mould with light plastic, depending on the weather and the general conditions.
7. The first layer, the “skin coat”, is a 300g mat. Make sure there are no bumps or contamination on the cured gelcoat prior to starting the lamination. It is vital to carefully work out all air in the first layer, and to let it cure for 4-6 hours, maybe overnight, before continuing the lamination with the next layers



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.

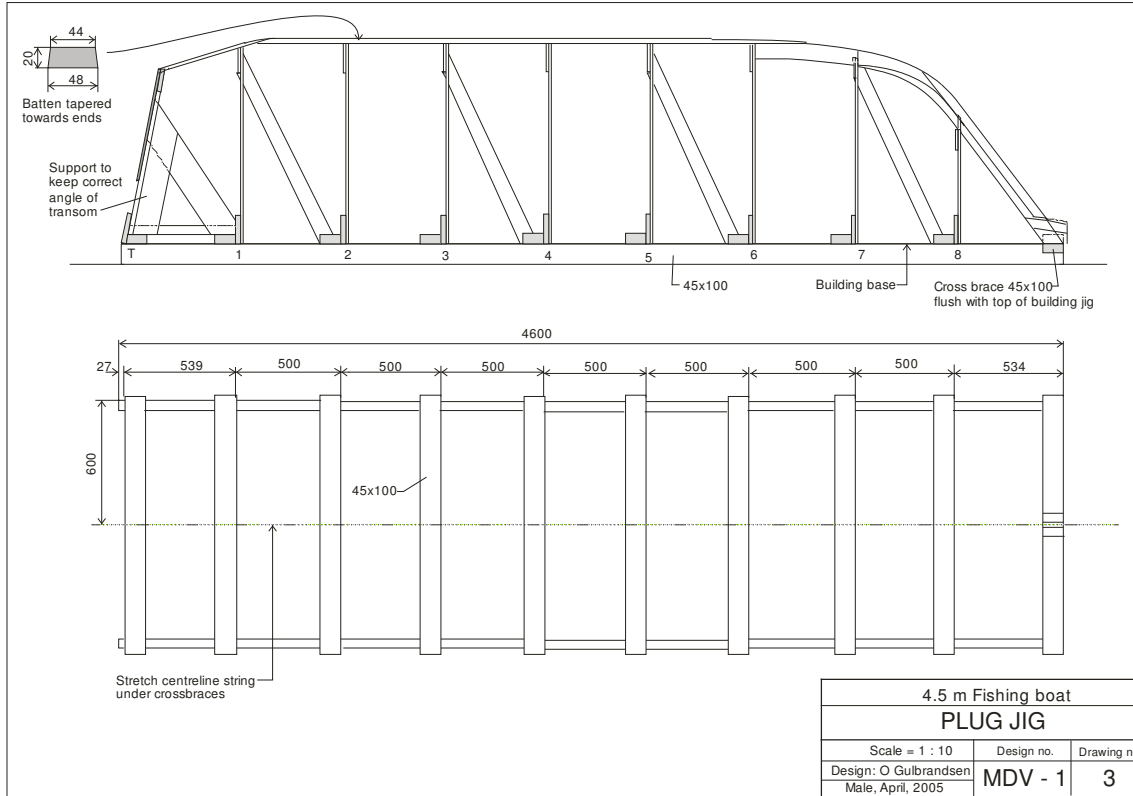
8. Follow the initial steps mentioned in the materials guide chapter and make sure you are using the correct amount of hardener for a proper cure.
Always apply a coat of wet resin/polyester, before you put on the fibreglass, and use the metal roller to work out the air bubbles and compact the different layers together. The text on the next figure is in Norwegian, but the context should be understandable in any language. It explains the right amount of glass fibre and polyester to use in a CSM laminate, and the staggering / overlap of the different layers.

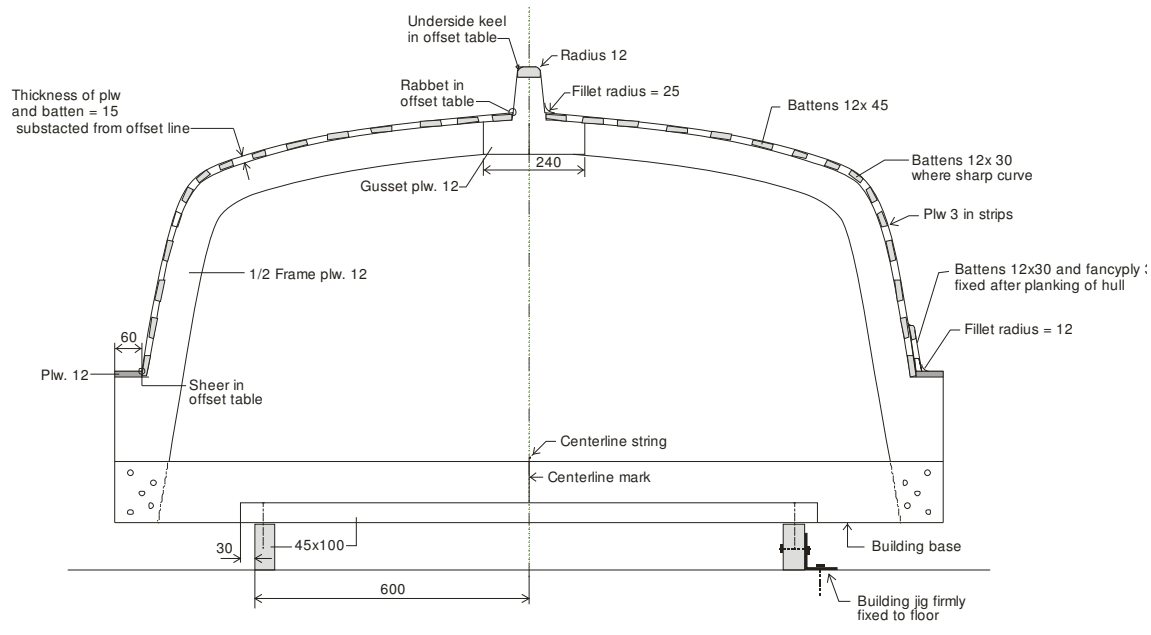
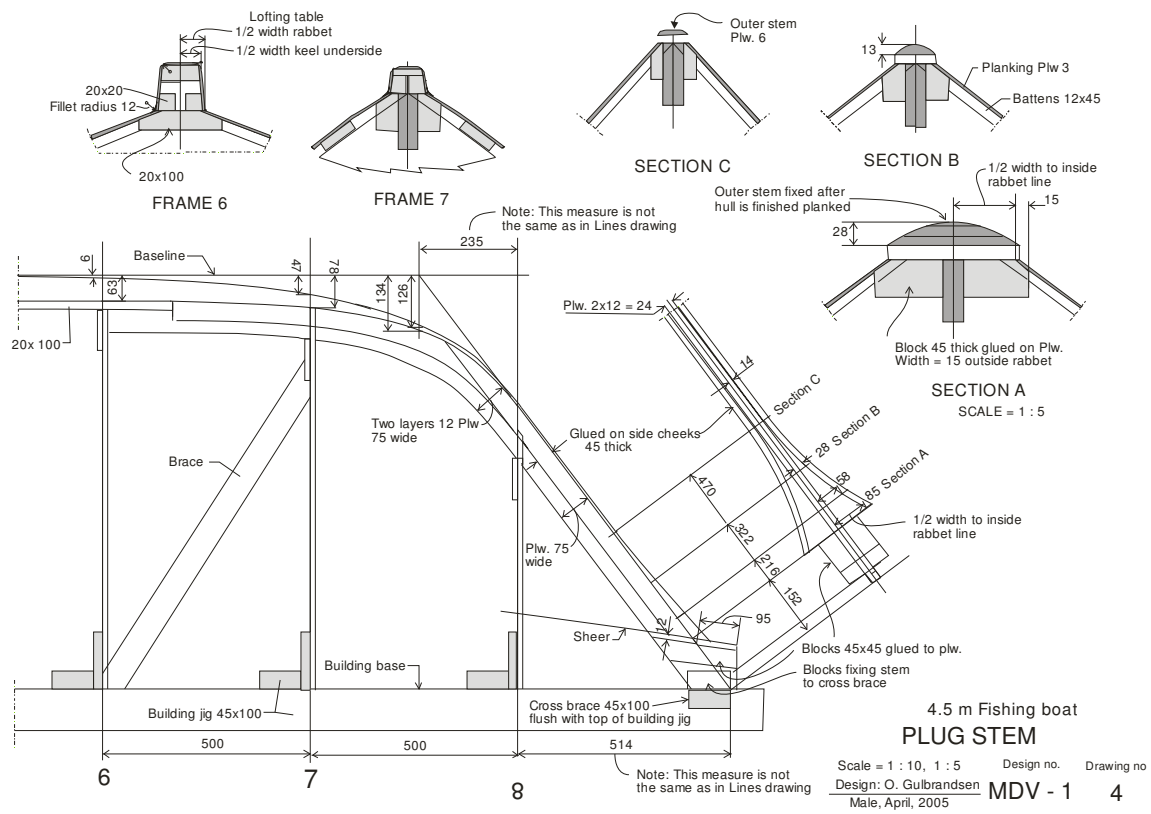


9. Your eyes are your best instrument for quality control. They will tell you if your laminate turns white because of too wet fibreglass, if there is any air or contamination in it, if the exotherm builds up too quickly and changes the colour of the laminate and gets aerated/foamy, or if you use too 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

10. In the Bokkura we are only using CSM, so the main concern when laminating is that you try to laminate the different layers with not too long intervals. The topic of primary and secondary bonding, and the preparation of the surface to be laminated, is mentioned in the "Repair" chapter.

5. MAKING THE PLUG







Here the wooden part is finished and the first layer of fiberglass is put on to ensure the stability of the plug.
After this, the surface is built up with several layers of putty, and sanded to even out any imperfections in the lines



Almost ready for the gelcoat, only the bilge keels left to be fitted on and blended in.
They are using different colors of putty to easier recognize where the imperfections are.



To achieve a high gloss and proper finish, gelcoat has to be applied over the putty.
On this picture, the only remaining work on the plug is water sanding the gelcoat before buffing and polishing.

6. MAKING THE MOULD

It is important that the plug is worked to a proper finish with a perfect gloss before you start building the mould.

The mould is a mirror of your plug, and every blemish will show.

Your moulds lifespan is very dependent on this finish, because if the first thing you have to do after pulling the mould off the plug, is to start improving or repairing the surface of the mould, you have already lost valuable time.

The longer you can keep the surface of the mould unbroken, only polishing or using buffing compound, the more products you can pull off the mould.

Prepare the surface of the plug with a 5-10 layers of wax to a perfect finish. If you are feeling insecure and / or the gelcoat on the plug has not been given sufficient time for a proper pre cure (2-3 weeks), it would be smart to use anti release agent.

Make sure you are using a real tooling gelcoat, and not just regular gelcoat with black color. Tooling gelcoat is generally harder than regular gelcoat, to be able to build up a higher gloss. It also has less shrink.

Build up a decent thick layer by applying at least 3 coats of gelcoat with a proper cure in between.

The molds for the Bokkuras has a layer of tissue mat incorporated.

Tooling gelcoat is not UV stabilized and should be protected against direct sunlight when stored.

The procedures for building up the laminate is more or less the same as for building up the laminate in a boat, but there are also available special tooling resins that are formulated to better withstand the repeated heat from exotherm and the strain from releasing from the mould.

If using more common GP polyester, make sure you do not laminate more than 3 layers a day to allow the styrene to evacuate and avoid heat build up and excessive shrink.

For this size of boat, a 10mm laminate should be sufficient.

Before releasing from the mould, stiffeners of plywood or steel must be laminated to the mould to ensure that the shape of the plug is kept original.

The stiffeners are often made into a wagon or a cradle for the ease of handling.

The ideal procedure for a new mould is to make a tent, heat up to maybe 40°C and pre-cure the mould for a couple of days. In a tropical climate this should be an easy task.

This should get rid of most of the active styrene on the tooling surface, and help preventing the fresh mould to stick to the gelcoat on the first product.

“Braking in” the mould by using extra hardener in a “hot” gelcoat and just a couple of layers of laminate in the first two “throw away” products, could also be a “cheap” investment instead of getting your first boat stuck in the mould.

Using PVA mould release is an easy precaution but gives a poor surface finish and more work with building up a proper finish on the boat.

This picture shows an example of a modern production mould / tool, with pivoted cradle for easy access to both sides.



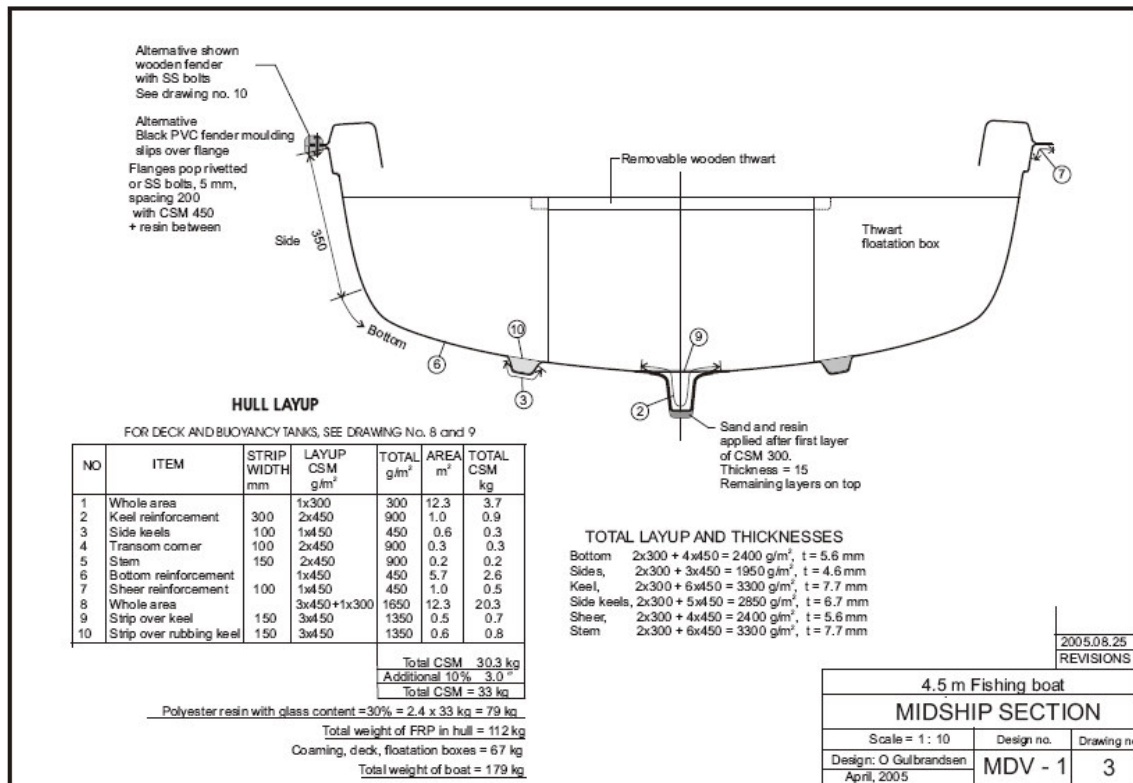
Efficient boatbuilding with a combination of hand lay-up and spray chop laminating.



7. BUILDING THE BOAT

This is a detail drawing of the Bokkura, and it also tells how many layers of reinforcement to use in each place.

There will not be a removable thwart as shown on the drawing, but a storage box with an opening hatch on one of the sides.



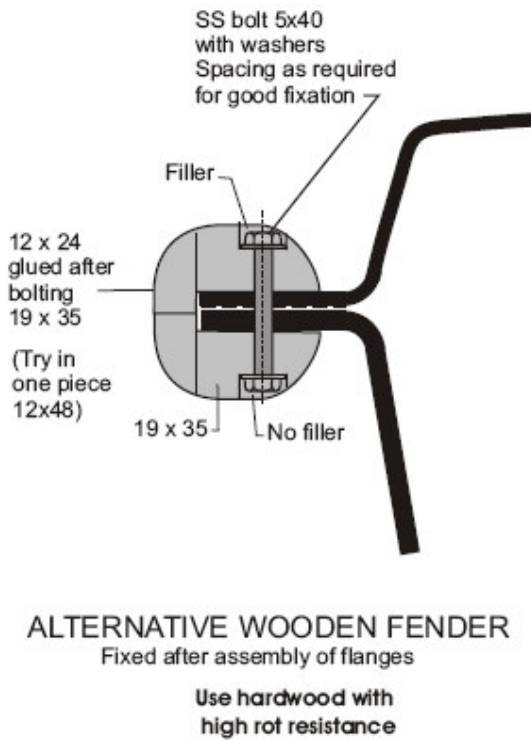
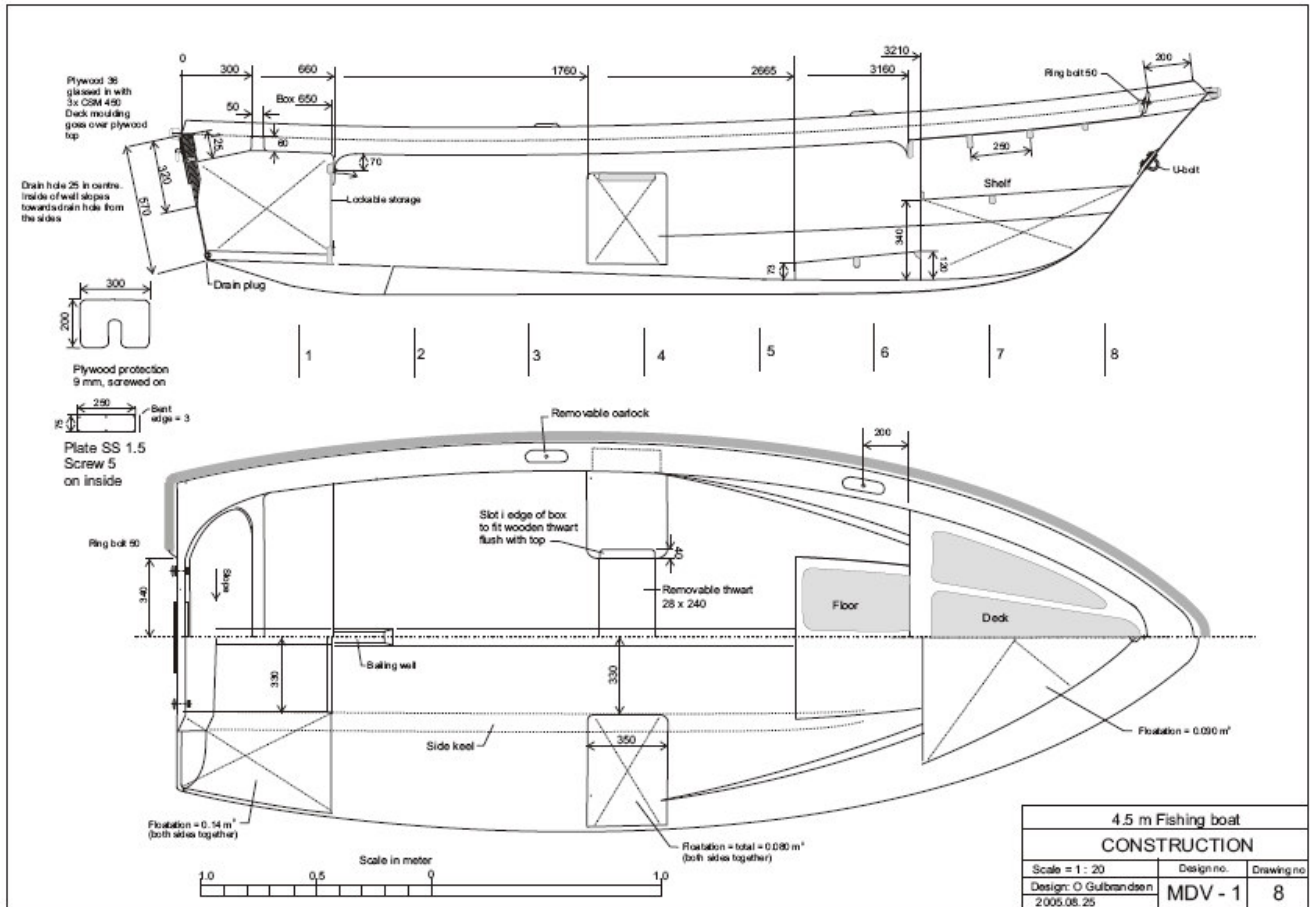
COAMING, DECK AND FLOATATION BOXES

	ITEM	LAYUP CSM	g/m ²	AREA m ²	WEIGHT kg
1	Coaming	300 + 3x450	1650	3.07	5.06
2	Deck aft, engine well	"	"	1.09	1.80
3	Deck forward	"	"	0.95	1.57
4	Floatation boxes aft	"	"	1.00	1.65
5	Thwart boxes	"	"	1.20	1.98
6	Floatation forward	"	"	0.74	1.22
7	Floor forward	"	"	0.46	0.76
8	Strip in flange, assembly	450	450	0.40	0.18
CSM					14.22 kg
Waste 10%					1.42
CSM total					15.6 kg
Polyester, 30% glass content: 2.40x15.6					37.4 kg
Total Deck and floatation: FRP materials					53 kg
Wood fender and thwart					14
TOTAL					67 kg

The transom is strengthened by two pieces of 18mm plywood bonded together on top of each other.

The sides must be tapered at least 45° before laminated over with 3 layers of 450g mat.

Make sure that any drain holes for the engine well are properly sealed to prevent water from entering the plywood.



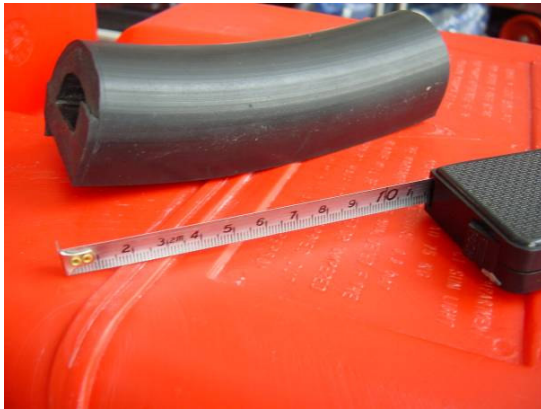
To fix the deck to the hull, the two flanges are first grinded nice and flat to a porous finish with the disc grinder.

One or two layers of 450g CSM is placed on the flange and the two parts are clamped together and cured.

A better way of fixing the two halves together, would be by bonding them with "Sikaflex Construction or likewise. You have not been supplied with enough Sikaflex for that purpose, and should use it only to seal off hardware, bolts and screws while mounting them.

Due to changes in plans, the supplied bolts are 6mm x 60mm, but by cutting off the length, there should be no problem using them.

The design of the wooden fender will be slightly different, with fewer pieces, and the details will be supplied by the ministry boat builders.



The D “rubber” fender which is actually PVC, and needs to be heated up to bend around the front. It needs to be fixed to the flange at each end with some kind of arrangement



The stainless steel cleat is fixed in the bow with a piece of 18mm plywood reinforcement under the deck, and tapered SS 6mm through bolts. Seal the bolts with Sikaflex.



The 8mm stainless steel U-bolt is mounted in the bow according to the drawing on the previous page.



The drain plug is mounted in the transom with two supplied 1/2” nr. 8 taper head pozi SS screws, sealed with Sikaflex.

8. REPAIRS

PRACTICAL STRUCTURAL FRP REPAIR GUIDELINES

In general, repair to FRP boats can be easier than repairs to other materials. However, proper preparation and working environment is critical.

When damage occurs, you first have to determine if it is just a cosmetic surface problem or a more structural damage.

In this paper we will not discuss the matter of getting a proper finish, but only concentrate on the issue of getting the boat back to a sound and homogenous structure, as close to the original strength and stiffness as possible, and better if it is needed.

We will use a real repair with pictures as an example, and supply with some drawings to ease the understanding and help as a guideline.



This picture shows a typical fatigue fracture inside the transom on a boat with outboard engine.

In this case there has been made an effort to repair the crack, but putty and gelcoat can not mend a structural damage.

Ideally, the boat should be repaired indoors, to protect the work from rain and sun, and secure a stable temperature. If this is not possible, a tent should be made.

All hardware and equipment which prevents access must be removed.

Before you start grinding, you have to protect yourself with a dust mask, eye and ear protection. You should also make an attempt to collect the dust at the source, by using a dust extractor or a vacuum cleaner attached to the shield on the grinder.

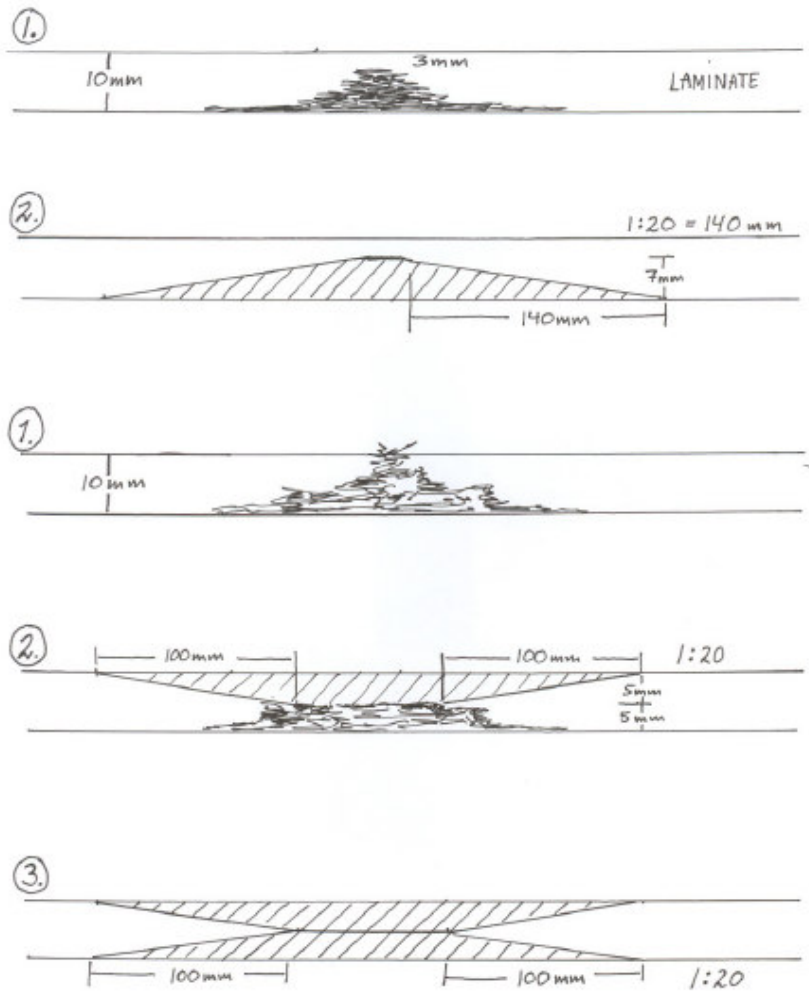


Initial to grinding, all surface contamination like oil and silicone should be washed off and removed with a suitable solvent or likewise.

The use of 40 grit sandpaper is a good choice.

Grinding uncovers deep delaminations.

We have to grind as far and as deep as demanded, to get rid of all delaminated fiberglass.



This is a schematic drawing on the principle of laminate repair.

The first two pictures show damage which is not penetrating the whole laminate, and the next series is of a two sided repair.

A lot of books state that 1:12 is sufficient for fiberglass repairs. This could be sufficient in unloaded areas with thick laminates.

With thinner laminates and loaded areas, the scarf should be at least 1:20.

In many cases, a scarf of 1:40 or more must be used to ensure a proper area of adhesion and absorption of forces in a loaded area.



When all the grinding is done, the area to be laminated is much bigger than the initial survey would suspect. The other side of the engine well had just tiny cracks in the gelcoat, but grinding revealed that the delamination was just as deep on both sides.

At this stage of the repair a decision has to be taken on what kind of materials you want to use for laminating, if it has not already been done.

The following text is meant as a guide in making this choice.

PRIMARY BONDING

Primary bonding is when two surfaces are connected directly to each other, forming a chemically homogenous laminate with no weakened bond line.

When a polyester laminate is fresh (green) you can start to laminate directly on top of it without doing other preparations than sanding off bumps and fibres which could cause defects/air pockets in the laminate.

A “green laminate” means that the surface still has active molecules on the surface that will bind chemically to a new laminate.

Laminating on a green laminate gives a primary bond.

How long the laminate surface will be active, depends on a combination of the technical properties of the resin and the temperature during curing.

Generally the open time for polyester is 24-48 hours.

Ideally in a building situation we will struggle to achieve primary bonding. But the nature of building large FRP boats, and the time consumed, makes it more difficult to operate within the time window. The least we should try to achieve is that the main hull laminate is build with primary bonding.

When we are laminating in the frames, stringers and bulkheads, we are definitely talking about secondary bonding in most cases.

SECONDARY BONDING

We should keep in mind that all repair work relies on secondary bonding, which means that stronger or additional replacement material is needed to achieve the original strength.

When laminating over a cured laminate, the cross linking reaction does not occur to a significant degree across the bond line, so the polymer networks are discontinuous and the bond relies on the adhesive strength of the resin.

What resin to use?

In general, isophthalic polyester, vinylester, or epoxy resins are preferred for FRP repairs and alterations. General purpose (GP) polyester resins are less desirable.

When considering strength, cost and ease of processing, isophthalic polyester and vinyl ester resins are recommended for most repair works.

For more critical structural repairs, we must keep in mind that epoxy laminates are generally stronger (but not stiffer!). Epoxy resins are highly adhesive and have longer shelf life than polyester and vinyl esters, which makes them ideal for emergency repair kits. They also have no solvents, which give almost no shrink when curing (less tension) and no “surface contamination” of the original laminate.

Epoxy does not hydrolyze, and this together with the good adhesion, the low shrink and the high ratio of elongation to break, makes them more liable to perform as good as a primary bonded laminate. However they are intolerant of bad mix ratios and can not be speeded up or slowed down by altering the amount of hardener. We also must keep in mind that the surface is definitely not active with styrene, therefore, any further rework to an epoxy boat or an epoxy repair will have to be made with epoxy.

A proper and clean preparation of the bonding surface is very important for a good adhesion.

What reinforcement to use?

If practicable, the original reinforcement shall be used in the repair, especially if the part is heavily loaded and operating near its design limits. We should bear in mind though, that the continuation of the fibres in the laminate is lost, and the strength is solely relying on the adhesion of the new laminate. The initial stiffness will be there almost 100% if you build up the laminate to the original thickness, but the strength and fatigue properties will be weakened.

Therefore, the dimension of the fibre bundles is critical for the performance of the repair, because large bundles and heavy mats/fabrics makes the appearance of air, and resin rich pockets more probable in the borderline between the old and the new laminate.

Lighter weight reinforcement will give a better contact with the surface, and the importance of this should be weighed up against the importance of using the original reinforcement.

All these matters taken into consideration, the design of the repair laminate is important, and if additional reinforcement is required to maintain the global strength, one should be careful to avoid excessive laminate build-up, with the danger of developing stress concentrations.



In this case, the choice was epoxy, but vinylester might also have performed well. We must bear in mind that this is a single sided repair, and the original polyester laminate has already shown weakness from fatigue. The reinforcement is a mix of 290g woven twill and 450g Double Bias fibreglass, chosen because of their drape ability and good performance with epoxy.

Surface preparation:

It is important not to clean a freshly sanded porous fibre laminate with acetone or solvent prior to lamination, unless you have contaminated it with oil or grease.

If you have to clean it, do so, but make a light grinding with clean sandpaper after the washing, and give the solvent sufficient time to “air out”.

The reason for this is that the solvent is absorbed by the porous surface and “contaminates” the laminate, potentially acting by diluting the resin and preventing a proper adhesion.

A light styrene wipe prior to laminating, when using polyester, is the only acceptable procedure. This will activate the surface slightly, and will improve the adhesion when performed properly. Too much styrene will weaken the bond line.

On repairs under the waterline, fresh styrene from the new polyester laminate is also liable to trigger hydrolysis at an earlier stage than the original laminate, and cause a premature failure in the borderline between the old and the new laminate

An important issue in repairs is to check the content of humidity in the laminate with a moisture meter.

If the laminate is humid, the bonding will fail eventually, and the new laminate will separate from the old one prematurely.

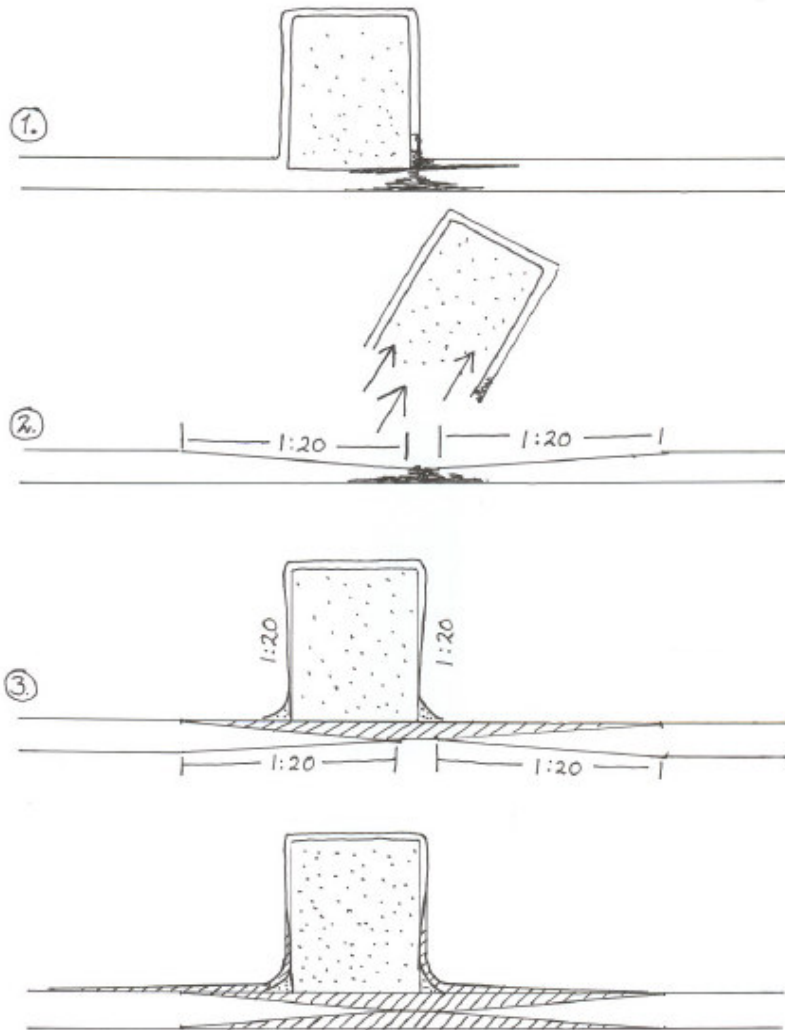
When it comes to the actual laminating, we have to follow all the same procedures as we do when we are making a new boat, and the quality control has to be just as good.



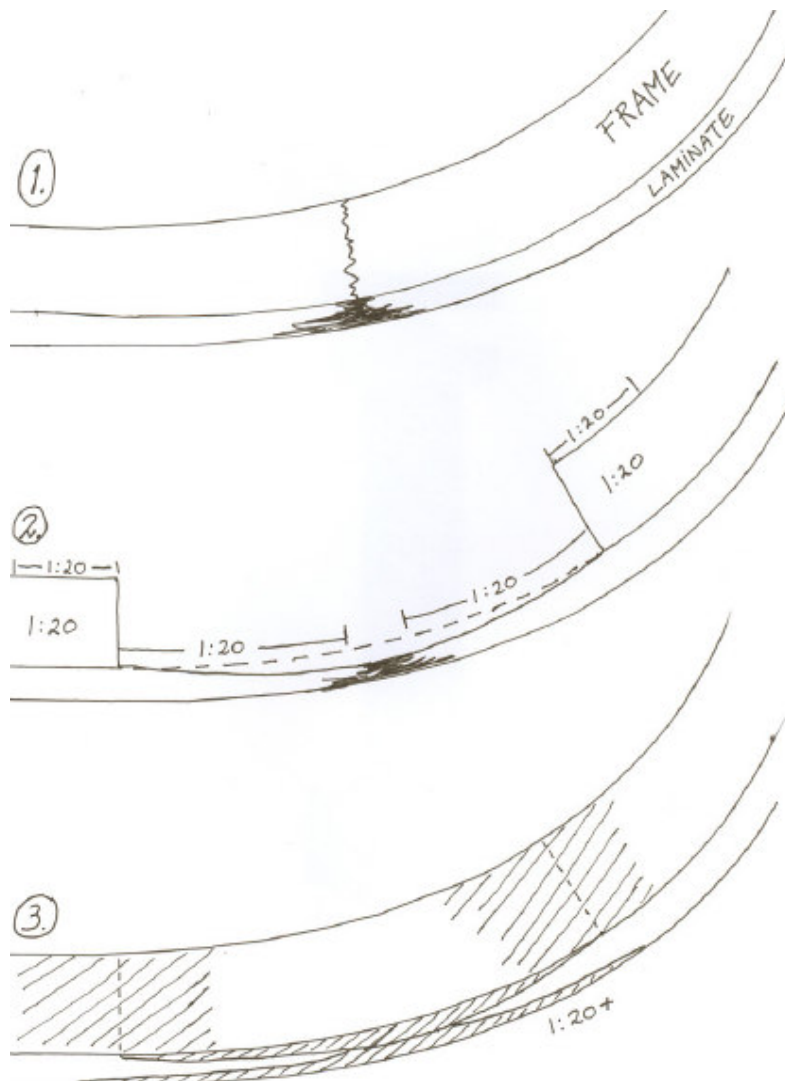
At this stage, the laminate build up is finished. The surface is grinded flat to a nice “finish”, and the use of any form of putty is to be avoided on all structural repairs. Putty has a short “elongation to break” ratio, and will break up and crack much faster than a laminate.



The final picture shows a finished product. Gelcoat has been put on, water sanded, buffed and polished to a decent gloss. There is no problem with using polyester gelcoat on top of epoxy as long as the epoxy is properly cured before you apply it. In this case we have also put on a 5mm aluminum plate to spread the pressure from the bolts.



5. A fracture in the outer skin has penetrated the whole laminate, and caused a delamination in the framework.
6. To perform an acceptable repair, the frame has to be cut and removed, and a regular repair has to be made to the hull laminate first.
7. The frame has to be grinded to a scarf wherever it meets other laminate, before being bonded down with putty/glue and finished with a radius fillet.
8. All lamination work on the frame is best done with easily drapable fabrics or CSM lighter than 450g/m^2



4. This is more or less the same repair as the previous series, but viewed from the side.
5. The frame is cut and taken away to get access to the laminate. In this case, there is no scarf in the core of the frame, like on a wooden boat, since the frame is foam or air, and is not structural.
6. The place you cut and how you cut the frame, vary for different damages, and have to be estimated carefully in each case. Some times with structural foam, you also have to make a scarf as with a wooden frame. "Stepping" the scarf is also an alternative in some cases. The use of additional extra length reinforcement must also be considered, such as unidirectional fibres along the top of the frame.

9. HEALTH AND SAFETY

PERSONAL AND ENVIRONMENTAL SAFETY WHEN WORKING WITH FIBRE REINFORCED PLASTICS.

Personal:

6. 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.



This face mask is supplied for each Bokkura boat builder.

There are two different filters available, one for volatile fumes and one for dust. Make sure you are using the right filter for the right occasion. Goggles for eye protection are also supplied for each person.

7. Respirator Safety:

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 fibreglass 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 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 none ventilation, such as inside a boat, you should always use a respirator with an external source of fresh air, ore you will be in severe danger of developing what we might call a chemical lung inflammation.

8. 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.



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. Comfortable and easier to talk with.

9. 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.

10. Hand and finger Safety:

Always remember that if you damage or lose 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 required, which leads us to the next point:

6. Skin Safety:

It is not what you see which is the most dangerous; it's what you not see.

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.

Here we are also talking about long term effects, and not a problem you will face the same day or the day after.



This is proper use of long sleeved gloves for spillage, and respirator against volatile fumes like styrene.

The Bokkura builders are supplied with a generous amount of industrial gloves that should withstand the harsh environment.

7. 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 is 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.

Environmental/workshop conditions:

4. Air Control, dust and fumes:

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 where several operations are being executed at the same time.

In a boatbuilding plant, the most ideal action is to perform, as much as practical possible of, the sanding and grinding in a separate room.

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

5. Fire Hazard Control:

Everyone in the workplace must do their part to eliminate fire hazards.

If you are using spray equipment, leakage of catalyst can be a significant source for fire. Also in hand laminating, spillage of catalyser is possible and dangerous.

You should always be alert to the possibility of an early “kick off” in the bucket due to the use of too much catalyser, or maybe you used too much time on some laminating details. The exotherm will quickly build up if there is too much resin in the bucket, and if you don’t put water on top of it and take it to a safe place, you might have a fire coming up.

Always be aware of abnormal exotherm build up when disposing saturated wet fibreglass in a waste container. Don’t put wet rags with solvent in the same containers.

If you are not using a pre accelerated resin, also be aware that mixing accelerator and catalyst (promoter and initiator) together, immediately will lead to an explosion.



The man to the left is spraying gelcoat and has a facemask with external air supply. The man to the right is wearing no respirator although the air is heavily loaded with styrene. Gelcoat overspray will also contaminate the fiberglass on the cutting board.

6. Waste Material Reduction and 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 diversifying hazardous and non-hazardous waste.

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

4. 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 here is to keep the catalyser in a separate room from the polyester and gelcoat, due to the potential fire hazard.

5. Documentation:

When you buy any chemical from a supplier, you should ask for, and they should supply, a technical data sheet, which provides you with all the technical information you need to be able to handle the chemical in a safe way.

All technical data sheets should be collected in a holder and kept on a safe place, available to all personnel who potentially can be exposed to these chemicals.

Appendix 8

FRP 85foot Pole & Line “Masdhoni”:

I was asked by The Ministry of Fisheries, as an FRP expert, to give a comment on structural matters concerning their 85ft FRP fishing boat design.

When it comes to this vessel, it is not part of my missions, but I will mention it in this report since it is important and I was asked.

I have just spent a little time looking into the special matters which concerns my profession, e.g. the laminating sequence and use of materials.

Attached to my report, are some views on “Reinforcement Sequence in Fiberglass Boatbuilding”, which I made in Alifushi and had as a lesson for the remote island candidates and the boat builders from the ministry.

These are matters of concern when building the 85foot fishing boats, and this view on stacking sequence is not according to the drawings.

Also attached is a lesson I made on “Quality Control when working with Fiber Reinforced Plastics”, which outline my view on the need for proper quality control when building, and the need to use resins of better quality than the GP ortho polyester when building large structures like this.

Another major concern of mine is the extensive use of PU foam for insulation of the fish, bait and landing tanks.

The nature of PU foam is so that as soon as it gets in contact with water, it will soak and turn into a soggy mess within a few months.

These tanks will hold a big load of water for long periods of time, and both the technique of producing / laminating the tanks when it comes to secondary bonding, and the nature of polyester, absorbing water, determines that it is not a matter of if, but when, the PU foam is going to get soaked by water.

As far as I can see, these bulkheads also have a certain structural value. The structural value of PU foam is close to zero, and when soaked it is worse.

Of course the insulation value has to be taken into consideration, but one should definitely consider the possibility of using more structural foam like PVC or others, which in addition does not soak water when exposed.

By prefabricating sandwich panels outside the boat, you will save time in production and weight on materials (thinner FRP laminates), which might add up for the more expensive structural and “waterproof” foam

There will be a problem of using the structural foam as insulation against the hull, since you can not get it poured or sprayed as far as I know.

You could always make the tanks as angled panels, but that has to be sorted out.

Another concern of mine is that forward of frame 25, you don't have a direct continuation of the longitudinal stiffener / bulkhead. This leads to a potential stress point in the corners between these two longitudinal stiffeners and the bulkhead / frame 25.

Especially since the weight / load of the boat with the tanks is much heavier behind frame 25, and the waves will lift the boat in the front.

Thomas Anmarkrud / Male, 1/9 2005

Appendix 9

FAD REPORT

This is not an in depth report, but some reflections after a visit at the FAD workshop on Villingili and some talks about the topic with FAD staff and boat builders from the Ministry. I have also read some background papers on the development of the FAD.

First of all, the workshop is really not a workshop, but just an open shed with earth floor. If we are talking quality and controlled conditions when working with fiberglass reinforced polyester, this is not the way to do it.

Because the laminate in the buoys are over dimensioned, the lack of quality control is not critical, but if you want to fine tune the laminate and save money on materials, there has to be taken some major steps when it comes to working conditions.

Ideally, FRP work should be performed in an isolated house with concrete floor, air condition, controlled air humidity and proper ventilation.



Not good workshop conditions for quality FRP work.
No walls and earth floor.



”Aligating” or wrinkles, is a typical sign of changing conditions and high air humidity.

Talking to different people, I was given different figures when talking about the laminate sequence and build up. The papers from the ministry, was not up to date.

According to the foreman at Villingili, they are applying 2 coats of gelcoat, for a total of 10kg gelcoat on each buoy.

The laminate is built up with 2 layers of R600 woven roving, and the FAD staff said 3 layers of 600g CSM. By the looks of the laminate, which I measured mechanically to 10mm at the top, there must be more than 3. On the other hand, the laminate looks extremely “wet”, and each layer might measure to more than the normal 1,2mm.

It was said that a 225kg barrel of polyester resin is used for 3 buoys.

For the same 3 buoys, 1 1/2 roll of CSM 600g is used. Each roll is 30kg, for a total of 45kg.

Finally 1/2 roll (20kg) of R600 is used for 3 buoys, and for each buoy they use 50kg of Pourable polyurethane foam.

3 men use 3 days to complete the fibreglass part of each buoy, as far as I understood.

There were none updated figures on cost, but with these numbers there should be no problem to calculate an average.



The laminate in the cut out is 10mm.

The R600 woven roving is visible near the middle, and in a normal laminate with a glass percentage of around 30-33%, the thickness of the 600g CSM laminate is corresponding to approximately 8 layers.



This picture shows the interior with the plywood stiffeners laminated in place, and the reinforced center with 1/2" plywood and 7 additional layers of 600g CSM.

The appearance of the laminate is very "wet", and I will guess that the fibre content is closer to 20% than 30%.

This could be positive if we are talking about hydrolysis, but the whole structure will be more brittle, and it is actually a waste of polyester and money.

In my point of view, the laminate is an "over kill", and more than stiff and strong enough.

With the plywood stiffeners, and a compact and good fill of foam, a CSM laminate of 5mm should do the job in the sides and top.

As far as I understand, mechanical forces and slamming is not what brakes down the buoys, and CSM alone should do the job around the flange area.

The bottom area could do with a couple of layers of R600 because of the attachment, and depending on the size and weight of the top structure for the solar panel, the top flange area might also do with a couple of layers 30-40cm from centre.

These layers should be placed on the inside and the outside of the laminate, and not in the middle. They should also be cut at different places, so that the inside R600 is cut 5-10cm closer to the top and bottom than the outside one. This is done to avoid a "stress point" if the two layers are stopped at the same place.

The layers used to laminate the plywood stiffeners comes in addition to the 5mm laminate.

This laminate should be tested on one or two buoys first, to check for fatigue.

With this laminate schedule and a controlled use of polyester for a 30-33% fibre ratio, it should be possible to save some money on materials.



This practice of joining the two halves is not good and it is very likely that water will enter at weak points between the two halves, penetrate and mix with the “not waterproof” polyurethane foam, and prematurely sink the buoy. A better practise would be to grind the two flanges flat together for a snug fit, apply a generous amount of “Sikaflex construction” or likewise (not silicone!), and clamp the two halves together to cure. Make sure you also seal the boltholes when the fender is mounted. Use the same sealing compound for all through bolts.

I have also considered the use of more modern laminating methods, like vacuum infusion or RTM-light.

According to the amount of Fad’s produced every year, 20-30, I think the initial cost of equipment, moulds and training of personnel, might be too high at this stage.

On the other hand, the size and shape of the FAD is perfect for infusion, and for future purposes of learning the methods, this might be the right opportunity for a start.

The advantage with vacuum infusion / RTM-light is that you get a cleaner working environment with almost no styrene in the air (“closed moulding”), the quality of the product is very consistent, with fewer voids and higher resin to glass ratio.

There are several methods on the market, but the two I have mentioned here, are the ones that has shown best cost effectiveness in the marine FRP manufacturing.

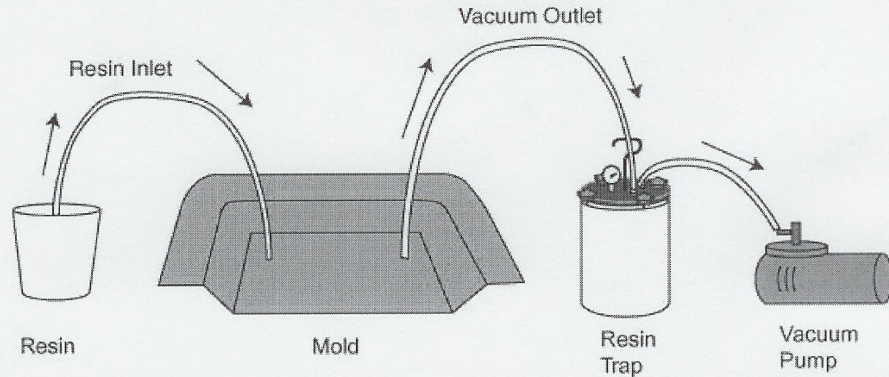
With vacuum infusion, you can use more or less the same mould as with hand laminating. Just check that it has no through fractures in the laminate and gelcoat which will cause a vacuum leakage.

Depending on the size of the existing flange, the ideal set up would also be to extend the flange of the mould with 10-15cm (for a total of 20cm), to get a better working area for the spiral tubing, sealant tape and vacuum bag. The vacuum bag is a disposable transparent nylon bag. This method has shown best cost effectiveness on boats from 30feet and upwards, and especially for larger boats, like the Masdhonis you are building, this is absolutely the future.

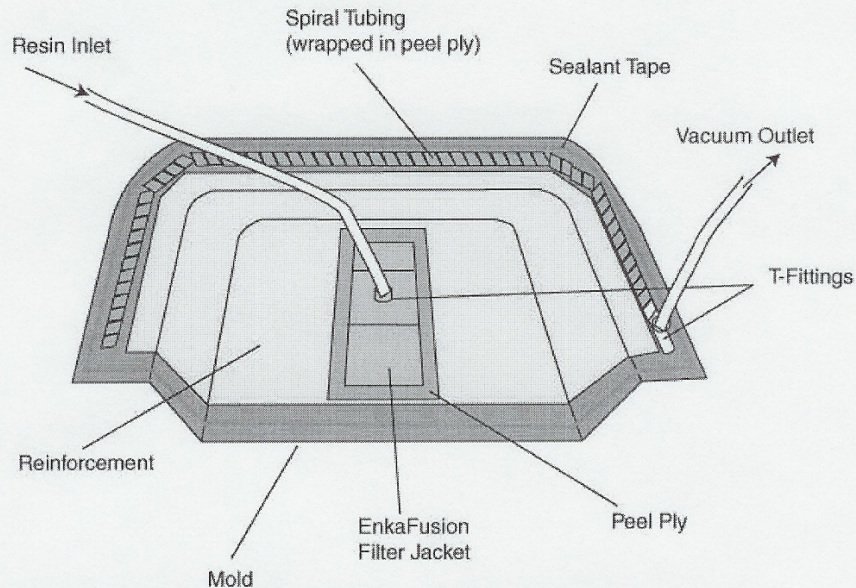
VIP Set-up and Equipment

When preparing to experiment with infusion, it is important to understand some general concepts about how materials are used and arranged. Keep in mind that every project is unique and this guide is not intended to provide the only available options. We will discuss some variations later.

First, the general sequence of events that comprises vacuum infusion is illustrated in the following diagram.



For the purpose of this brochure, we will be focusing on one general set-up idea with the notion that resin will be infused into a center point in the laminate. From there, resin will be pulled outward via vacuum pressure. The final arrangement of materials should look something like this.



Note: For the purposes of this diagram, the vacuum bag itself is not shown

Page 2 of 14

Vacuum infusion is the most basic way of infusing resin into a dry reinforcement fibre stack to produce a laminate. This method has the lowest initial cost.

For smaller parts like your FAD buoys, the RTM-light method has shown great potential cost effectiveness after a run-in period.

It might be a bit confusing with the different names of the methods, and I have only mentioned two of them. Although both the methods are about resin infusion, the one with the vacuum bag is called “Resin Infusion”. RTM-light stands for “Resin Transfer Moulding”.

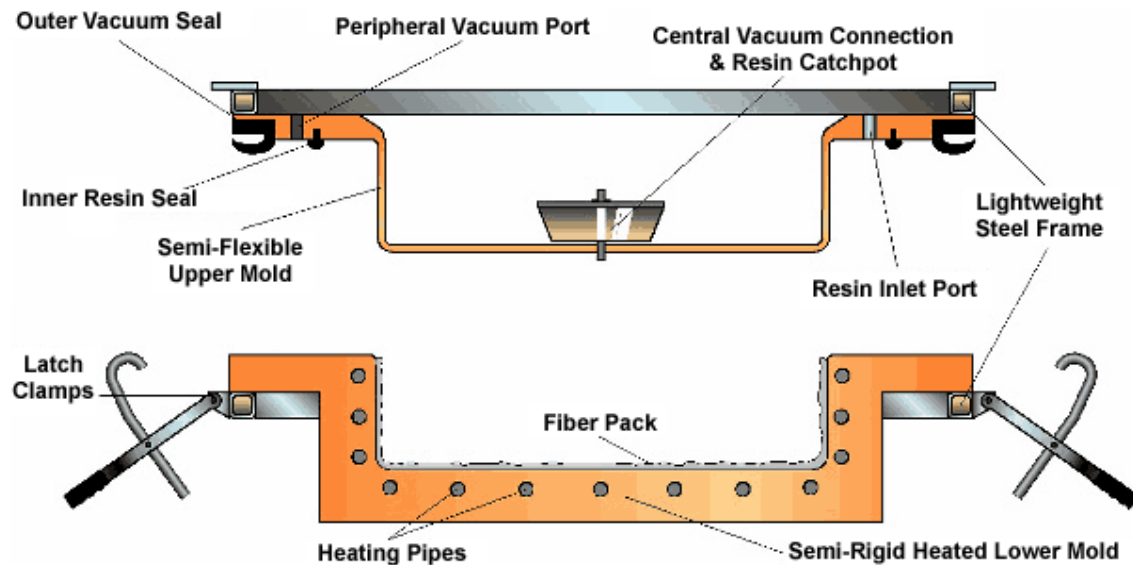
The figure below shows the principle of the system. It might look complicated, but also with this method you can get away with extending the flanges of your existing mould. The heating pipes shown in the figure is not needed, but is a way of controlling temperature and/or speeding up the curing process.

In RTM-light you are using a semi-flexible upper mould Instead of a vacuum bag, to achieve a “closed cavity” of reinforcement where resin can be infused.

The advantage with the inner mould is that it is reusable, gives a nicer inside finish, and it is also possible to put some additional pressure on the resin to speed up the infusion sequence.

With a vacuum bag it is all about vacuum infusion, and no pressure on the resin.

The inner mould can be made by fine tuning the laminate thickness of an existing product, finish off the inside with a nicely polished gelcoat finish, apply release agent, and laminate an upper mould with transparent gelcoat, and approximately 3mm fibre and resin.



The latch clamps does not have to be permanent like here.

I provided the next figure just to give you an idea on what is going on when you pull the vacuum and let in the pre-catalysed resin.

The resin flows through the reinforcement, and part of the trick with infusion is to predict the flow and make sure you do not get any dry spots when the infusion is fulfilled and the resin is curing.

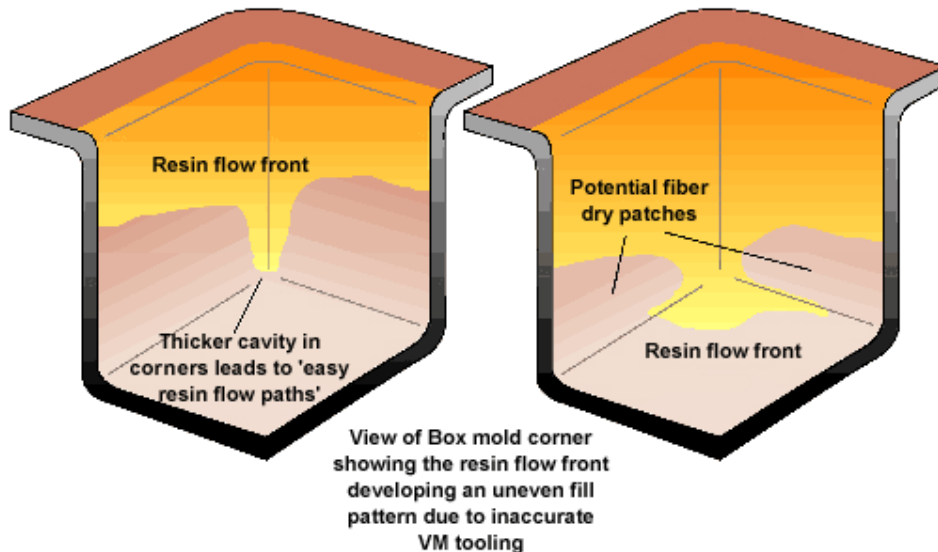
You must also be aware that both CSM is no good for infusion, and woven roving is also a bad choice. Instead of CSM we are using CFM (Continuous Filament Mat), which also is a comparably cheap reinforcement with continuous fibres instead of chopped, and no binder.

CFM ensures a better resin flow, and is good for building up the bulk and stiffness of the laminate.

Instead of woven roving, stitched fabrics are mainly used for strength.

Beside these reinforcements, there is a “jungle” of specialized materials being “pushed” by different manufacturers and suppliers, so be aware when in your initial steps into infusion.

Make sure you are getting the right materials and tools for your special need, and do not sell your soul to a supplier!



For both methods it is possible to have stiffeners inserted in the mould and infused in “one shot” together with the laminate.

Infusion is also perfect for structural cores to make a light and stiff sandwich construction.

Actually, the use of grooved core as a help for resin flow, is in itself an excellent method for making the process better.

This information was just to give an idea of the potential possibilities in FRP manufacturing. The “closed mould” methods are expanding rapidly both in Europe and the United States, especially because of the environmental issue which I know is also becoming a matter of concern on the Maldives. With the pre cut reinforcement packages and the special materials being developed today, the consistent quality of the product and the speed of production is improving all the time.

In Sri Lanka, the English infusion equipment supplier Plastech, together with some other companies is supplying a complete setup with a boat mould and equipment as part of a private Tsunami aid project.

This document was made by Thomas Anmarkrud. 24 - 09 2005.