PRACTICAL ACTION
Technology challenging poverty

BASIC FIBREGLASS BOAT BUILDING

technical brief

This technical brief attempts to set out the basic construction techniques as well as the material, equipment, infrastructure, skills and labour requirements necessary to build fibreglass fishing crafts suitable for use in Sri Lanka's coastal fisheries industry.

Introduction

As a material for boat building, fibreglass has gained in popularity over wood and metal in both developed and developing countries, mainly because of the relative simplicity of construction, the ability to produce many identical hulls from a single mould, and the ease of maintenance of the boats themselves. Fibreglass boats are completely watertight, rot-proof and resistant to borers.

Disadvantages of fibreglass stem from the health risks associated with inhalation of fibre dust during construction, and the fact that the boats are slow to degrade and disposal at the end of their life is difficult.

Fibreglass is a term used to describe Fibre Reinforced Plastic (FRP), a material consisting of glass fibre impregnated with resin. Typically, a hardwearing surface is created with the use of a gel coat, strengthened by layers of fibreglass mat impregnated with resin. The required strength is achieved either by using several layers of mat or by using a thicker gauge of mat.

Credit: Practical Action

Materials and equipment

The key to producing high quality boats is a good mould - a mirror image of the finished hull, which is also a fibreglass construction cast from either a plug, which is wooden replica of a hull, or the hull of an existing boat. In Sri Lanka, it is almost always an existing hull that is used to create the mould. Once the mould is created, it can be used to build hundreds of boats, which will have precisely the same shape as the original boat or plug used to create the mould. Therefore, it is very important that a good boat with the perfect hull shape is selected for this purpose. The better the plug, the better the mould and all the boats that come out of it. For larger vessels the plug and mould building is repeated for the deck and interior moulds.

Practical Action, The Schumacher Centre, Bourton on Dunsmore, Rugby, Warwickshire, CV23 9QZ, UK
T +44 (0)1926 634400 | **F** +44 (0)1926 634401 | **E** infoserv@practicalaction.org.uk | **W** www.practicalaction.org

Glass fibre
Glass is processed into filaments then woven or chopped and supplied in rolls of matting. The thickness of the cloth or mat varies with the weight of the glass in grams per square metre. Type E glass should be used for tropical marine use. Reinforcement materials are supplied in rolls sealed in polythene bags inside cardboard boxes. On delivery the material should be checked for contamination by dirt, oil or water. If spoiled, it is unusable. After checking, the rolls, they should be re-sealed to prevent contamination by high humidity. If damp, the bonding between the resin and mat are weakened.

Chopped strand mat (CSM)
The continuous filament is held together with a binder to form a continuous sheet of chopped strand mat of variable thickness. This material is specified by weight: 225, 300, 450 and 600 g/m^2. One side of the material is slightly smoother than the other. It is the rougher side which should be placed down when laminating.

Woven roving (WR)
Standard specifications for WR are 600 g/m^2 and 800 g/m^2. WR has a high tensile strength and also gives a higher glass per unit volume ratio than CSM, which means less resin is needed, and therefore is cheaper to use. Approximate resin to glass ratio for CSM is 2.5:1 by weight (30% glass) and for WR is 1.25:1 (45% glass).

WR is rarely used in vessels of less than 6 m. CSM laminates are normally adequate for smaller boats. Laminates for larger hull are best made of alternate layers of CSM and WR with extra CSM near the outside.

Surface tissue / satin mat
This is very thin and can be compared to a very fine, smooth CSM. It is used to support a thick gel coat or to produce a smooth finish on the innermost layer of a laminate.

Core mat
This is a course mat that is specified by thickness rather than weight. 2 – 5 mm core mat is available. It is used only for specific areas which require extra strengthening.

Resins
All resins should be stored in a cool, shaded and ventilated place. The usual shelf life for resin is given as 6–12 months, but it can be used as long as it is liquid. Pre-accelerated resins have a shorter shelf life than pure resin.

Lay-up or laminating resins
The laminating resin (a translucent liquid of pale colour) provides the medium within which the fibreglass mat is bedded. “Marine General Purpose” resin, which has been previously approved by a Classification Society such as Bureau Veritas or Lloyds Register of Shipping, should be used. The resin is usually supplied in 200-litre drums, but can also be bought in smaller quantities from retail suppliers.

Gel coat resin
The gel coat resin is a more viscous liquid. When cured, the gel coat forms the shiny, smooth, weather resistant outer surface of the hull.

Credit: Practical Action

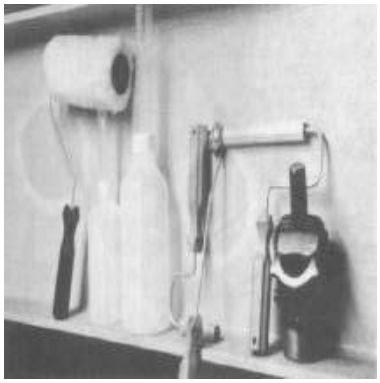
technical brief

Resin putty
This material is used as filler, or for bedding deck fittings or filling internal corners on joints which require bonding. Since it is composed
mostly of a filler powder, which is water absorbent, it should not be used on underwater surfaces unless based on an epoxy resin.

Poly Vinyl Acetate (PVA)
PVA (a clear odourless liquid) is a releasing agent. A coating of PVA is used to prevent the mould from sticking to the plug or finished hull.

Catalysts and accelerators
To cure (harden), resin requires a catalyst and an accelerator. Resin can be ordered with or without the accelerator pre-mixed. Pre-accelerated resin is recommended because the supplier is able to make a more thorough mix; and it is one less step for the user.

If accelerator is purchased separately, a purple liquid (Cobalt Naphthanate) is usually used with Methyl Ethyl Ketone Peroxide (MEKP) catalyst. When using un-accelerated resin, the accelerator should be thoroughly mixed in first. Accelerator and catalyst must never be mixed directly together as this could cause an explosion.



Credit Practical Action South Asia

Tools
The following tools are usually used for working Fibreglass:

- Paintbrushes of 1 inch and 2 inch width with unpainted handles (handles can be waxed for easier cleaning)
- Mohair rollers in various sizes for applying resin
- Washer-type laminating rollers

Credit Practical Action South Asia

technical brief

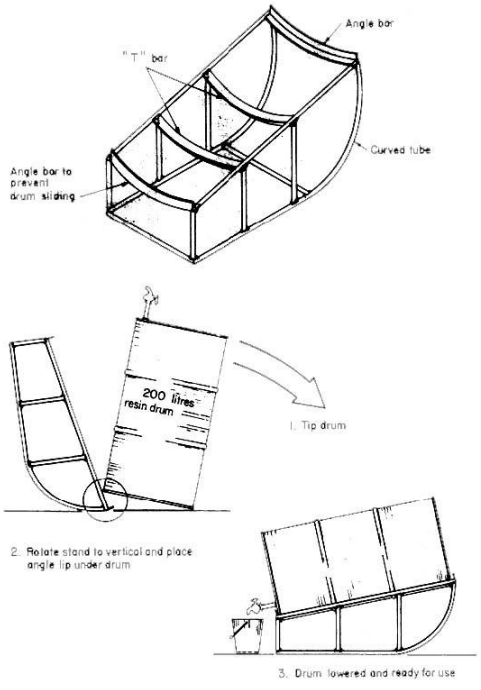
- Plastic buckets (5 L) and bowls (1 L)
- A graduated pipette (for accelerator and resin)
- Weighing scales to 20 kg
- Barometer (if the ambient humidity exceeds 65%, greater care must be taken during curing)
- Hacksaw 18/24 point blades
- Rasp 250 mm half round
- Files 250 mm flat, half round and round
- Knife and standard blades
- Hole saws 25 mm – 100 mm
- Rubber mallet 1 – 2 kg for mould release
- Wet and dry abrasive paper 100 – 1 000 grit
- Wooden sanding blocks
- Pad saw handles to accept hacksaw blades
- Spirit levels 250 mm and 750 mm
- Plumb bob
- Chalk line
- Squeegees metal, rubber and plastic for resin and putty spreading
- Masking tape (12– 50)mm. Scissors tailoring quality for reinforcement cutting
- Measuring tape - 5 m
- Plain wooden sticks for mixing
- Cotton rags
- Small pieces of wood for scraping off excess resin from brushes

For all but the smallest and simplest boats, the following electrical tools are also used

- Electric drill -13 mm chuck industrial quality
- High speed twist drills 3 – 18 mm
- Jigsaw industrial quality with metal-cutting blades
- Angle grinder hand held with 100 mm disc
- Grinder discs (carborundum for cutting and grinding)
- Grinder discs disposable aluminium oxide 40 grit

Material requirement for an 18.5-foot flat bottom boat

Material Quantity (kg)
Mirror Glaze Wax 0.150
Wax Polish 0.200
Gel coat Resin 23.000
Moulding Resin 155.000
CSM (Chopped Strand Mat) 55.000
Catalyst 1.850
Accelerator 0.050
Acetone 7.000
Pigment Paste 2.900
Brushes, Plastic Buckets etc
Timber & Plywood
Hardware
Total Cost of Material (GRP) Rs. 49,000
Total Cost of other Material/items Rs. 3,664
Average sale price of boat Rs. 94,500



Credit: Practical Action South Asia

Preparation of material

Mixing resin or gel coat
Resin is stored in drums in a cool, shaded place, preferably in a separate resin room. The drum in use will be laid horizontally off

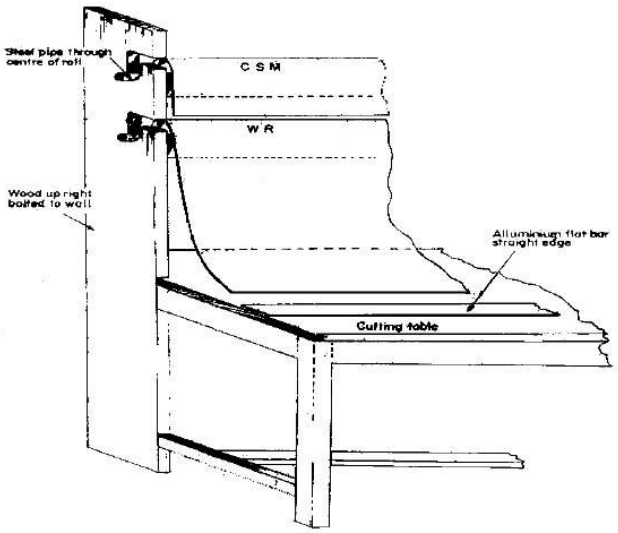
the ground on a steel cradle (see figure) with a removable brass tap screwed into the drum lid. There should be a drip tray beneath the tap. Between the tap and the tray will be enough room to place a 5–10 L plastic bucket, which can be filled with resin for use by a laminator. Every two days, the drum should be rotated by 180o and the tap removed and cleaned with acetone, to prevent blockage. Outside the resin room should be a two separate store cupboards for catalyst and for accelerator.

Accelerator can be added during the preparation stage and mix well with a clean, disposable wooden stick. The amount of accelerator added will be determined based on the weather conditions (humidity). Catalyst is only added at the very last moment before laminating begins, when everything else is ready. Both these additives are supplied in 20 or 5 L plastic drums (not in steel containers because resin reacts with rust) and are used to refill 1 L plastic bottles fitted with a graduated pourer for final mixing.

In the case of gel coat, a colour pigment will have been added to uncoloured gel coat according to supplier's mixing ratios. Standard white pre-pigmented resin is widely available as it is the most popular hull and superstructure colour.

Preparing the mat

The task of storing and cutting the mat may be allocated to one labourer who then becomes skilled at this task. For preparation, a cutting table is needed (see picture) with a vertical rack for the rolls of different types of reinforcement from which appropriate lengths can be drawn and cut and then re-rolled and labelled with a felt tip pen to indicate to the laminators what it is for.



Credit: Practical Action South Asia

It is good practise to use a plywood template for each section of mat needed. Lengths up to 10 m can be prepared on a shorter cutting table by folding the reinforcement. The table edge should have graduations at 10 cm intervals to ensure precise measurement. A sharp knife is needed for cutting and since glass reinforcement blunts steel blades very quickly, they should be sharpened often. A straight edge is needed to cut the glass to length. An aluminium strip is best as it is light to handle and does not contaminate the cloth.

For cutting curves, a felt tip pen or chalked line can be drawn for guidance and the cut made freehand whilst allowing a 10 cm margin. Industrial quality scissors may also be of use.

The building process

Preparing the plug

To begin, place the plug (or existing hull being used to create to mould) upside down on a level floor, and make sure the plug is absolutely level using a spirit level or transparent flexible tube filled with water. At the deck edge, which is in this case near the floor, attach a plywood flange so that later during the moulding process, gelled Fibreglass can be trimmed back to leave a solid laminate with a clean cut edge. If the plug is wooden, cover the plug with a Fibreglass skin. This layer can then be filled where necessary with resin putty to remove the shallow indentations, which will show up once the fibreglass skin is consolidated.

Remove any irregularities by grinding or by hand sanding. Repeat this process of hand finishing until the plug is smooth enough to receive a layer of hard tooling gel coat. This especially formulated gel coat is the beginning of the coating, which will eventually give the polished surface from which the mould will be lifted. The plug and mould gel coat should be black in colour, to contrast with the finished hull. There is no shortcut at this stage. The more time that is spent hand sanding the plug with wet and dry sandpaper, the better the plug will be. After applying the gel coat, further filling with resin putty and sanding may be necessary for a good finish. In some cases the gel coat layer on the plug is omitted and only cataloy paste is used to fill imperfections.

Credit Practical Action South Asia

Finally, polish with rubbing paste and then with 5–7 coats of non-silicone wax to give a brilliant sheen, before applying a coat of PVA release agent, which is the last step before the mould itself is begun. Five workers would take at least a week for the final preparation of a plug for a 10 m hull.

Making the mould

If the shape of the hull is such that the mould has acute release angles, a split mould, rather than a one-piece mould, is necessary. The two or more pieces of the mould will be bolted together at a flange. To create the flange, a pattern of it has to be made on the plug on each side of the joint line. It is possible to use the first mould flange as the pattern for the second half. This will provide a very accurate joint and will allow boltholes to be through drilled in situ before release.

Credit Practical Action South Asia

To build the mould, first, a uniform layer of gel coat should be applied to the plug, using paint brushes with unpainted wooden handles or a high-pressure spray gun. The resin is prepared by adding 1% catalyst to pre-accelerated resin. In tropical countries this mixture will set hard in 20-40 minutes, so only the amount required for the immediate job at hand should be prepared.

For best results, panels of surfacing mat should then be laid down to create a smooth skin. Once the panels are ready the resin should be prepared as above. If a brush is being used to impregnate the fibreglass mat, short jabbing motions of the brush should be used. Once the resin has been applied, it can be spread using a washer-type or treaded roller, which helps to spread the resin out

evenly and prevent air bubbles from getting trapped between the mat and the resin. Leave for 8-24 hours until set and cooled. Next, apply a layer of CSM. The panels of CSM should be cut to overlap each other by 3-4 inches. Te resin should then be prepared and applied and rolled as above. A layer of core mat may also be added sandwiched between layers of CSM.

This layered approach is to be repeated until the required thickness is achieved. Ideally the thickness of the mould should be at least twice that of the hulls to be made using the mould.

After the fibreglass laminate has been completed, and has cured beyond the gel stage, bond the stiffening to the outside before release from the plug. This may include a stand to raise it off the floor. The reinforcement stiffening can be of wood, foam or rolled newspaper, which are placed against the outer surface of the mould and covered with a layer of fibreglass to form a box section. This will strengthen the mould and help prevent distortion. More details on stiffening are given below. Leave the whole assembly for up to 3 weeks to become fully cured before releasing the mould.

To release the mould from the plug, gently hammer small wooden wedges between the mould and plug. A few blows to the flat areas with a rubber mallet can also help. Once the plug has been removed, inspect the mould for flaws and damage and make any repairs necessary before sanding with water sandpaper of increasingly finer grades, and polishing with 5–7 coats of wax to finish.

Plugs and moulds for deck and interior can be made using sheets of hardboard, or plywood covered with Formica, as a plug, to provide large flat areas of decks and bulkheads with a uniform surface. Tight corners are generally made from resin putty and sanded to shape.

Making a new hull

After the mould has been cleaned, waxed and polished, the first step in laying up a new hull is the application of gel coat with paint rollers or paint brushes, or by spraying.
A single heavy coating of 0.6 mm thickness or 2 medium coatings of 0.5 mm each is required on all surfaces. Paint brushes can be used to cover restricted corners. Have a follow-up bucket of resin ready for use as soon as the first is emptied, to achieve a good bond between the two separately mixed batches.

As soon as the gel coating is finished, start washing hands and tools in acetone, followed by soap and water. Brushes and rollers must be dry before re-use. After the gel coat has cured (in 6 – 12 hrs), check for flaws. It is important that it is not left longer than 48 hours, before being overlaid. Any rough areas on the gel coat may need to be lightly sanded and cleaned. Any areas that have become too dry because of overcure can be lightly washed with styrene to regain some stickiness.

Credit: Practical Action South Asia

The mat now needs to be laid in either a fore and aft (forward and back) direction or transversely (across). The fore and aft option is recommended as it is faster. A sequence should be worked out so that the binder is dissolving in CSM laid in one part of the mould, while previously laid CSM with now dissolved binder is being consolidated in another part. While a layer is curing in one side of the mould, the other side can be worked on. This allows application of resin and reinforcement, consolidating and curing to take place in rotation. Always apply resin before mat. Usually, one layer of satin mat and then CSM is laid up for 1 or 2 layers next to the gel coat. Subsequent layers should be applied as soon as the resin hardens. These subsequent layers may be strengthened by the inclusion of a cloth or WR layer which can be laid in the mould at the same time as CSM and which are consolidated together. This saves time and achieves a better bond since both layers of reinforcement are using the same batch

of resin. WR is applied after its associated mat layer has been lightly rolled into the resin. If there are large dry patches, more resin can be applied before the WR is laid on as better impregnation is achieved if the resin is drawn up rather than forced down through the reinforcement. Being of a woven nature, WR is less prone to disintegration than wet CSM during rolling out, it can be consolidated using rollers, but a "squeegee" is probably the best, quickest and simplest tool to use. It is important that the opposite side of the hull should be moulded in sequence with the first side. Light sanding and cleaning may sometimes be required between layers to remove any protruding pieces of resin and glass, which may prevent a smooth bond with the next layer.

Keels and areas requiring extra stiffening

A keel is formed by laminating additional material along the centreline of the hull extending forward to the stemhead and aft to the transom boundary, to form a structural backbone. This backbone can be maintained at the midwidth throughout the length or be reduced in weight towards the ends. Around the joint line a scarphed laminate should be made with succeeding layers 25 mm shorter than the preceding layer. The laminate is completed when the mould halves are bolted together.

Topsides are increased in thickness to form a strong sheer in powered vessels and further increased in areas that will take mast rigging or equipment loads. The boundary of the transom should be increased to support and stiffen the sides, bottom and transom laminates. A typical boundary lay-up is formed by overlapping the side and bottom with the transom reinforcements, but as with the backbone the increase can also be achieved by the addition of strips of material laid around the boundary.

Framing and stiffening sections

The stiffener former is placed in position on the gelled laminate and the reinforcement is built up layer by layer as a continuous process. Frames are usually a solid or hollow core former covered with several layers of fibreglass mat forming a closed box or semicircular section when combined with the hull laminate. These are known as "hat" and "half round".

Hollow cores are plastic, cardboard or a single layer of Fibreglass from a hat shape mould, which can be cut to allow a fit to hull curves. Frames can be tapered off in shape and weight at the upper and lower ends.

The strength and stiffness of the section can be varied by adjusting the section depth and retaining a constant lay-up or by increasing the lay-up where the stiffener depth cannot be increased. The last layer of hull laminate can be timed to cover the framing to give a more finished appearance.

Bulkheads

In addition to separating compartments, bulkheads are essential in providing the rigidity necessary for maintaining the shape of the flexible fibreglass hull. A collision bulkhead should be installed forward and machinery space bulkheads should be watertight. Wood or exterior-grade plywood is usually used for bulkheads and should be fitted while the hull is still in the mould. The plywood should have a roughened border to improve adhesion of the resin when the bulkhead is bonded into the hull. In small boats the thickness of the plywood is normally adequate for stiffness. All openings in bulkheads should be filled to avoid stress fractures.

Use of other material

Material incompatibility is one problem that may lead to de-lamination and the seepage of water. Polyester resins are not good adhesives so the resin must have a physical grip on the adjacent material.

technical brief

Wood
Wood should be roughened, dry, dust free, unpainted and given as big a contact area as possible. Resin thinned with 10% styrene or 5% acetone will allow a keying coat to better penetrate a wood surface. Any wood that has been treated with preservative should not be used, but if unavoidable then a joint using screws or bolts should be substituted. Oily hardwoods such as teak should be degreased with acetone and the moisture content of all woods checked before use. De-bonding of Fibreglass angles securing structural members, such as bulkheads and frames, is a common problem. De-lamination through resin contamination or movement caused by wood shrinkage will make the joint useless. Epoxy resin has better adhesive qualities.

Metal
Some metals accelerate gelling time; others slow it down. Copper should be avoided. Brass or bronze fittings should be coated with epoxy resin before being overlaid with any structural resin. Aluminium and steel are best etch primed before coating. All metals should be de-greased before use, even finger marks or sweat from a hand can make the bond ineffective. Roughened surfaces provide better keying. It is best to avoid metal to wet resin joints, because if the metal corrodes, it may cause delamination and leaks.

Other materials
Glass, polythene, formica, aluminium and the like will not bond and can be used to mould flat panels of Fibreglass. Cardboard, hardboard, cement, and canvas all have rough porous surfaces and will give some degree of bonding.

Using tools on fibreglass mouldings
Metalworking rather than woodworking tools should be used. Fibreglass can be drilled, filed, sawn and polished but not hammered or bent and not easily punched or sheared. The basic shape cannot be altered and the resin component shows a tendency to fracture and chip.

Drilling
Holes can be drilled easily with ordinary twist drills. Wherever possible drill from the smooth face towards the rough side as this prevents chipping the resin-rich gel coat. Masking tape or a punched mark will help prevent scratch marks from skidding drills if a hole has to be drilled from the gel coat side. For large holes use a tank cutter or hole saw or drill perforations around the circumference of a large hole with a drill bit wide enough to accept a jigsaw blade, then saw it out.

Sawing
A hacksaw, pad saw or jigsaw should be used for sawing and trimming. Always saw on the face opposite the gel coat to avoid chipping. Heavy-duty electric jigsaws with metal cutting blades or diamond wheel compressed air cutters are the most effective.

Filing
Fibreglass files easily. An open pattern file is less liable to clog particularly when the resin is not fully hard. On edges, the cutting stroke should be in the direction away from the gel coat once again to avoid chipping.

Hammering
Hammered fastenings or blows with a metal hammer will shatter the laminate.

Sanding
“Wet and dry” (black colour) sandpaper is the only suitable kind, and it must be used with plenty of water. A small amount of liquid soap added to the water will reduce friction. For power sanding, a very open grade of disc will clog least. Resin bonded discs must be used. Facemasks should be worn and dust removed before applying the next layer.

technical brief

Cleaning
Files, drills, saw blades and discs can be cleaned with acetone when clogged. If left overnight the resin will harden and render the tool useless.

Trimming
The easiest stage to trim is just after the resin has set, when the moulding is rubbery and can be cut with a sharp knife. A large moulding must be trimmed in stages as each layer sets. The rubbery "gel" stage lasts only about thirty minutes depending on the type of resin used. Do not trim too soon as the laminate will not have set enough and will be disturbed.

Sealing edges
All Fibreglass working will leave a rough, shattered edge where water can penetrate and eventually cause de-lamination. All such edges must be sealed either with resin painted on or bonded over when assembling. Holes for deck and underwater fittings should be treated carefully in the same manner. If possible work from the gel coat face and support the inside with a wooden pad. Seal the hole edges thoroughly.

Care of moulds
The mould must be kept in excellent condition for re-use. Between mouldings it should be checked for damage and receive a coat of wax. Every five to ten cycles, the mould should be thoroughly checked and any repairs carried out to wear on flange boltholes, or damage caused by hammering during release. Wax can build up in some areas to form a thick layer, which gives a dull gel coat, this should be washed or polished off. The inside surfaces should be kept as smooth and polished as possible. If unused for a long period, the mould must be stored under cover. Exposure to the sun and wind will dull the shiny gel coat surface. Small moulds can be turned over or covered with a dustsheet.

General precautions

Fire hazard
Catalyst and accelerator, when mixed directly, form an explosive mixture. They are also highly flammable. Smoking in working areas must be totally forbidden. Great care must be taken to mix the correct amount of catalyst to the resin to avoid a "Hot mix" which could produce so much heat that it self-ignites. Any bucket of resin producing smoke should be immediately taken outside the moulding shop and filled with water. Any spillage should also be diluted with water.

Health hazard
All these materials are toxic if swallowed. Special care should be taken with catalyst, as it will cause burns to skin and possibly blindness if in contact with the eye. Fire extinguishers of the correct type, patent eyewash and a First Aid Kit should be readily available. Facemasks must be worn when laminating in confined areas and when grinding or sanding cured laminates.

Further reading

- *Fishing boat construction: Building a fibreglass fishing boat.* Ned Coackley. FAO
- *Fisheries Technical Paper 321*, FAO, 1991
- *Fisheries* a selection of Technical Briefs Practical Action
- *Livelihood from Fishing* A Le Sann Practical Action Publishing 1998
- *Country Boats of Bangladesh* E Janssen et al Practical Action Publishing 1989
- *Sailing Against the Wind* E Janssen Practical Action Publishing 1992

For more information about *Boat building* contact:
The Project Manager – Fisheries or the Resource Desk.

Practical Action South Asia
No 5, Lionel Edirisinghe Mw, Colombo 5, Sri Lanka
T +94 (11) 2829412
F +94 (11) 2856188
E practicalaction@practicalaction.org.lk
W www.practicalaction.org

Practical Action
The Schumacher Centre
Bourton-on-Dunsmore
Rugby, Warwickshire, CV23 9QZ
United Kingdom
Tel: +44 (0)1926 634400
Fax: +44 (0)1926 634401
E-mail: inforserv@practicalaction.org.uk
Website: http://practicalaction.org/practicalanswers/

Practical Action is a development charity with a difference. We know the simplest ideas can have the most profound, life-changing effect on poor people across the world. For over 40 years, we have been working closely with some of the world's poorest people - using simple technology to fight poverty and transform their lives for the better. We currently work in 15 countries in Africa, South Asia and Latin America.

technical brief