## Chapter 4

# Fishing Craft Materials

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### 4.1 Introduction

At present the larger classes of fishing vessels are made of steel, while vessels belonging to the medium and lower category mostly use wood for construction. Newer materials like fibreglass, ferrocement and aluminium are coming up as suitable substitutes for wood as this conventional material has started becoming scarce and costly. As regards service life under critical conditions, the new materials show promise. However, wood and steel permit greater versatility due to their well-known characteristics and working qualities. In this chapter, the materials that are conventionally used for construction of fishing craft and newer materials like Fibreglass Reinforced Plastic (FRP) are discussed.

### 4.2 Wood

India has rich timber resources of around 2000 species. Only a few selected species are suitable for boat construction since the timber for boat building purposes has to satisfy specific requirements. Boat building timbers should be strong, moderately heavy (480-624 $kg.m^{-3}$ at 12% moisture content), elastic and durable against biodeterioration. They should be free from natural defects with straight grains, and should have good retention of shape, strength and stiffness as a beam, good load bearing, shock resistance and nail holding properties. They should also be compatible with metal fastenings, have good working and seasoning properties.

Teak is widely used for fishing boat construction in Gujarat, Maharashtra, Andhra Pradesh and Orissa. The second choice is *aini* (jungle jack) (*Artocarpus hirusta*) particularly in Kerala, Tamil Nadu, Karnataka and Pondicherry. Timber for log raft should have lightness, low absorption of water, rot resistance and good weathering properties in addition to the other properties mentioned. Species best suited are *siris* (*Albizia chinensis*), *semul* (*Bombax ceiba*), Malabar neem (*Melia composita*; *Melia dubia*), *maharukh* (*Ailanthus malabarica*), *murukku* (*Erythrina indica*) and rain tree (*Samanea saman*). Specific requirements for timbers to be used for mechanised boat construction and for planking purpose are that they should have good shape retention, low water absorption and resistance to marine borers. Suitable timbers are teak (*Tectona grandis*), aini (*Artocarpus hirsuta*), *chaplash* (*Artocarpus chaplasha*), *sal* (*Shorea robusta*), *shisham* (*Dalbergia sissoo*), *padauk* (*Pterocarpus dalbergioides*), *laurel* (*Terminalia alata*), and *kindal* (*Terminalia paniculuta*).

Several inherent properties of timber such as its buoyancy, workability, treatability, nail holding power, strength to weight ratio and poor transmittance of heat, sound and electricity make it suitable for boat building. However, dimensional instability and susceptibility to biodeterioration are important handicaps of wood as boat building material. Proper seasoning and storage of timber bring about dimensional stability. Treatment with chemical preservatives gives resistance to biodeterioration and extends the service life of timber. Protection can also be achieved by using physical and/or chemical barriers applied to the surface of the timber. Physical barriers such as metals (e.g. copper and aluminium), concrete and plastic have been used to achieve protection. Fibreglass reinforced plastic sheathing is a proven method of protection for small wooden boats and of late this method is being adopted by mechanised craft also for protection.

### 4.2.1 Wood used for small vessels

The timber should be available in adequate length for construction of dugout canoe. Lightness, rot resistance and resistance to borers are other qualities desired. The most common timber for dugouts is *Mangifera indica* (BOBP, 1980).

Timber for plank-built canoes should have good shape retention and low shrinkage. Low water absorption and resistance to borers are other qualities desired. The most common timber species used for planking are Jeypore teak in Andhra Pradesh, *aini* (*Artocarpus hirusta*) and *venteak* (*Lagerstroemia lanceolata*) in Tamil Nadu. Timbers like *marudu* (*Terminalia tomentosa*) are used for keel and stem and engine bearers. These boats, 8 to 10 metres in length, are of planked construction. They are found in Orissa, Andhra Pradesh and Tamil Nadu. Timber for planking is usually jungle jack. *Venteak* is used for above water, in view of its poor borer resistance and shape retention. *Mangifera indica* (mango tree) and *Dipterocarpus turbinatus* (*gurjan*), if pressure treated, can be used successfully for planking. The amount of wastage in wooden boat construction can be as high as 40% from the log. Construction methods such as strip planking, laminated and double sawn framing and bent framing are used to minimize wastage. Laminated construction would allow the use of cheaper wood of small sizes.

### 4.2.2 Wood preservation

In field conditions, wood is susceptible to decay and deterioration by a variety of organisms like bacteria, fungi and marine woodborers belonging to different crustacean and molluscan groups. Some animals bore into the wood for shelter while some use wood as food. Marine fungi and bacteria play a relatively minor role in the total destruction of submerged water front structures and craft. Their decay results in the softening of wood surface, which brings about easier settlement of marine borers. The natural durability of wood in the aquatic conditions varies from species to species. However, their life in water can be increased through the application of preservatives (Kumar, 1985). Initially, traditional fishermen used plant and animal based preservatives for increasing the service life of wooden boats. These indigenous preservatives included crude fish oils (sardine oil and shark liver oil), groundnut oil, cashew nut shell oil, poon seed oil (*Calophyllum sp.),* neem oil (*Azadirachta sp.*), castor oil, coal tar, plant resins and extracts like chandrus (a solidified plant resin) and *dammar-batu* (oleo-resinous substance obtained from trees of family Dipterocarpaceae, imported from Malaya). The preservatives were applied either alone or in combinations. But the action of these preservatives was limited as they can only provide a hydrophobic surface without any prophylactic activity. This superficial protection provided, was only for a short duration and the maintenance is costly and labour intensive. Chemical wood preservatives are broadly divided into oil borne preservatives, water borne preservatives and solvent type preservatives. Water soluble preservatives such as chromated copper arsenate (CCA), copper chrome borate (CCB), ammoniacal copper zinc arsenate (ACZA) and ammoniacal copper quat (ACQ) were developed during early 1950s. Among these preservatives, CCA proved to be very efficient in protecting the wood against marine borers (Findlay, 1985). A product called arsenical creosote having higher toxicity than creosote was evolved by fortification of creosote with arsenous trioxide (Kumar, 1985). Copper creosote was developed by heating copper oxide with creosote and the compound was found to be stable giving resistance to boring. *Creoscor* developed at the Central Institute of Fisheries Technology (CIFT) is a high efficiency oil-borne wood preservative prepared by heating together heavy creosote oil, copper compound and plant resins. This is used as a second coat over timber treated with copper creosote. The more recently developed 'dual preservative treatment' technique using a water borne preservative (CCA) followed by an oil borne preservative (creosote) under pressure with an intermittent drying period was recommended for areas of extreme borer hazards. It also helps to minimise surface cracks and splits on the wood (Edwin and Thomas, 2000; Edwin and Pillai, 2004). India's seas being an area of heavy borer activity, studies were carried out to evaluate the efficacy of dual treatment over CCA or creosote alone. The dual treated panels were found to be free from borer attack over an extended period.

The preservative treatment methods can be mainly grouped into two: non-pressure processes and pressure processes.

### *Non-pressure processes*

**Surface application:** This is done by brushing or spraying the preservatives on the timber. For oil type preservatives, moisture content in timber shall not be more than 14% and with aqueous solutions moisture content can go up to 20-30%. Surface treatment has a limited scope as the penetration will be very less.

**Immersion:** Immersion treatment consists of either dipping or soaking. Dipping is for short duration. Soaking is the immersion of wood in the solution for sufficiently long period until required absorption is obtained.

**Boucherie process:** Treatment of sapwood of all green timbers is possible by this process. The pole is held in an inclined position at 45° angle and to the butt end of it a rubber hose connected to preservative solution is placed at a higher level. Due to hydrostatic pressure, the preservative displaces the sap in the timber which is forced out through the thin end.

### *Pressure processes*

In this process, treatment is done by forcing the preservative into the wood by pressure and vacuum applied in a closed cylinder. In this process, penetration of preservative in even resistant species is to a much greater depth compared to non-pressure processes. There are two main types of pressure processes.

**Full-cell or Bethel process:** This process is put to use when the highest volumetric absorption of preservative is desired. Timber charge is introduced into the cylinder, made air tight and applied vacuum maintained for sufficient duration followed by introduction of preservative into the cylinder, application of antiseptic pressure (3.52-12.3 $kg.cm^{-2}$) for sufficient time, withdrawal of preservative and a final application of vacuum. Specified retention of preservative can be had by a proper selection of concentration of toxic chemicals, duration of pressure and vacuum periods. Final application of vacuum frees the timber from dripping preservatives.

**Empty cell process:** This process aims at maximum penetration of the preservative with minimum net absorption. Two processes, *viz.* (i) Lowry process and (ii) Rueping process are commonly used. The Lowry process is the same as that of the full-cell process except the initial application of vacuum. In the Rueping process, an initial air pressure of 1.76 to 5.2 $kg.cm^{-2}$ is applied and maintained during filling of the preservative. The rest of the steps are like full-cell process. This process is very suitable for treating timber of mixed species.

### *Evaluation of preservative effectiveness*

Resistance of preservatives to borer attack is commonly evaluated by visual observation of the number of surface borer holes on timber panels exposed to sea. It however, does not totally assess the extent of internal damage. Determination of the strength loss of field-exposed panels is a new method, which takes into account all forms of biodeterioration including fungal attack. The percentage residual strength allows a quantitative assessment of the deterioration. Studies have already been conducted on species like *Lagerstroemia lanceolata* (*venteak*), *Adina cordifolia* (*haldu*) *Terminalia tomentosa* (*maruthu*), *Antiaris toxicaria* (*arayanjili*) and *Mangifera indica* (mango). X-ray radiography is also used to assess the nature and extent of damage.

### 4.2.3 Rubber wood

A combination treatment with water borne preservatives followed by oil borne preservatives was successful in warding off biodeterioration in rubber wood (*Hevea brasiliensis*), making it a cheaper alternate material for boat construction. Canoes constructed using treated rubber wood have been deployed for coastal and backwater fishing (Fig. 4.1) (Edwin and

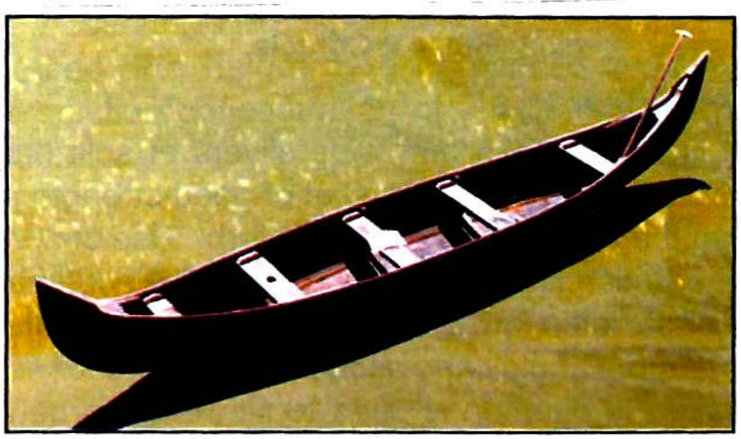

**Fig. 4.1 Canoe made of chemically treated rubber wood**

Meenakumari, 2005). The cost of rubber wood is only about one-fourth of the conventionally used timber, jungle jack (*Artocarpus hirsuta)* used for traditional craft construction.

### 4.2.4 Bamboo

In peninsular India, basket boats called coracles made of bamboo have been in use for long. Coracle is a saucer shaped country craft, generally made of split bamboo frame with a covering of hide. It is a versatile craft used for operations of fishing nets besides navigation and transport of fish and other material. Coracle of Krishnarajasagar is made by wrapping HDPE over the bamboo frame with the help of coal tar as an external covering in place of hide.

**Fig. 4.2 Coracle**

The craft is made of 25 mm wide slivers of split bamboo, closely woven into stiff matting forming a basket of good strength and resilience. In the ovate form the wider end forms the stern. Use of coracle has been reported from the British Isles, Vietnam and Tibet. A boat made of bamboo (3.65 m $L_{OA}$) constructed on experimental basis at Indian Institute of Technology, Kharagpur could carry a load of about one tonne (Sahoo et al., 1988). Jute soaked in bitumen is used to fill the gaps between bamboo pieces from the outside. The cost of construction of a bamboo boat was comparatively lower than a wooden boat of the same carrying capacity.

In most of the traditional methods of construction, bamboo is used in the untreated form. Bamboo in general is not durable and is prone to the attack of biological organisms. Graveyard tests on some important Indian species have shown that the average life of untreated bamboo is less than two years. When used under cover and out of ground contact, bamboo may last longer up to about 5 years. Biodeterioration is caused by fungi, insect borers and termites on land. Bamboo can easily be treated with chemicals to make them hydrophobic. Some methods, such as the sap displacement technique, can be used which make it easier to treat bamboo than wood. It has been a well-known practice to protect the bamboo rods with paint, tar, cement and asphalt emulsion against water absorption. Unfortunately such techniques are either too expensive or ineffective due to difficulty of application.

Preservative treatment can be given to bamboo in green and dry condition (Gnanaharan, 2000). Steeping is a treatment method in which freshly cut culms are immediately placed upright in containers of concentrated solutions of water borne preservatives (5-10 %) for 7-14 days. The butt end, up to 25 cm is kept immersed in the preservative solution. In the sap displacement method round, half, quarter and 1/8 split fresh bamboo are immersed vertically up to 25 cm in 10 % aqueous solution of water borne wood preservative such as boric acid-borax, copper–chrome-arsenic and copper-chrome-boron (CCB). A maximum preservative retention above 10 $kg.m^{-3}$ can be achieved through this process. In the diffusion process freshly felled culms or bamboos with high moisture content (above 50 %) are kept submerged in solution of water borne preservative for a period to attain the required preservative loading. Diffusion with copper sulphate solution (20 %) is done for 96 hours followed by dipping in sodium dichromate solution (20 %) for 96 h and then storing for one month. In the Boucherie process, the preservative is pushed through the bamboo by gravity from a container placed at a height by air pressure of 1.0 to 1.4 $kg.cm^{-2}$. A preservative solution concentration of 2-6 % is used (Gnanaharan and Mohanan, 2002).

Dry bamboo can be treated by submerging in an oil type or solvent type preservative solution for a period depending on the condition of the bamboo to be treated. Soaking treatments with organic solvent type preservatives such as penta chloro phenol, copper naphthanate and zinc naphthanate are better than water-soluble preservatives. A pressure of 3.5 $kg.cm^{-2}$ for one hour is sufficient to achieve retention of more than 8 $kg.m^{-3}$ in split bamboo. With proper chemical preservative treatment bamboo can be used for construction of small fishing craft. This can help in augmenting the scarcity of conventional wood used for boat construction, particularly in the North East Hill regions.

### 4.2.5 Marine plywood

The artisanal fishing sector in India to a great extent was dependent on highly durable varieties of wood species for boat building. The decline in the availability of durable wood varieties forced the fishermen to opt for newer materials. During the past two decades, marine plywood has become a well-established boat building material mainly due to its commercial feasibility, high economical viability and relatively low damage in aquatic conditions. Marine plywood is prepared by gluing together a number of thin veneers of wood using a waterproof adhesive such as epoxy or phenol resourcinol. According to the veneer quality and quantity the characteristics of the plywood produced also varies. Best quality marine grade plywood should have at least 5 layers of veneers. The marine plywood is having high strength-to-weight ratio. The adjacent veneers are kept in such a way that the grain direction is in right angles to each other. The most common preservative treatment for plywood used in boat construction is chromated copper arsenate (CCA) at 6.4 $kg.m^{-3}$ retention. Other preservatives employed for marine application are ammoniacal copper zinc arsenate (ACZA) and ammoniacal copper quat (ACQ). After preservative treatment, the panels are re-dried to a moisture content of 18%. The kiln drying method is preferred so as to minimize the development of bends and cracks. Many uses of plywood in boats involve laminating fiberglass over a plywood boat component. The re-drying of the treated plywood is essential to ensure good performance when laminating with fiberglass. The fibreglass coating protects the underlying plywood from abrasion and wear while landing and launching of boats. Marine plywood can ensure protection in severe conditions if it is made of durable or treated veneers.

In the south-west coast of India, the commercial application of plywood boats started in mid-80s. There are about 5800 plywood boats in operation along the coast of Kerala (SIFFS, 1998).

### 4.2.6 Fibreglass Reinforced Plastic

Fibreglass Reinforced Plastic (FRP) refers to any plastic material (polyester resin) whose physical properties have been upgraded by the addition of some auxiliary material (fibreglass). Reinforced plastic is analogous to reinforced concrete in which the low tensile strength of concrete is upgraded with steel rods. FRP is a proven hull material meeting satisfactory service in commercial and pleasure crafts. Fibreglass and thermo setting resins give a material, which is light, durable, tough and suitable for fabrication to any desired shape. In fishing boats where production can be made from a single mould, FRP is ideally suited for construction in large numbers. FRP boats require greater initial investment but minimum expenditure on maintenance thereafter. FRP can also be used as a sheathing material for boat hulls.

The specific gravity of FRP is approximately 1.6. The specific gravity of wooden hull including fastenings is between 0.8 and 0.9. So FRP is twice as heavy as wood but it is so much stronger that even if the plastic is only half as thick as the timber it will be equally strong as wood. This means that it will have the same weight, but would be stronger than wood. The advantages of FRP include (i) low maintenance and repair costs; (ii) durability (iii) resistance to corrosion, (iv) resistance to water absorption, (v) resistance to marine borers (vi) amenability to moulding and (vii) good impact resistance.

Materials used for FRP include the following:

*Fibreglass:* Glass strands of approximately 50 mm length held together in random mat by adhesive resinous binders are used. Fibreglass chopped strand mats are produced from continuous glass filament fibre, unidirectional rovings, woven rovings and woven cloth. In the case of chopped strand mat, the filaments provide fairly consistent multidirectional strength and are easier to fit into deep curves and difficult corners. Glass fibre has low weight, high strength and is chemically compatible and corrosion resistant.

*Resin:* The most widely used resin is the unsaturated polyester resin. It has good compressive strength properties but have low rigidity, tensile and impact strength which necessitates reinforcement with fibreglass.

*Catalyst:* The resin is activated by the addition of a catalyst. The resin remains in a fluid or plastic state for long periods and the introduction of a catalyst is required for thermo-setting. Most commonly used are methyl ethyl ketone peroxide and cyclohexamine peroxide.

*Accelerator:* An accelerator is used to increase speed of the chemical reaction of resin and catalyst. Cobalt naphthanate and cobalt acetate are commonly used accelerators. The accelerator and catalyst cause the resin to set hard in a predetermined time, *viz.*, the liquid polyester resin is converted to a rigid solid state.

Hulls are laid up inside a mould. The process by which the glass mat is laid up into a mould and impregnated with polyester resin so as to form a laminate is generally termed 'wet lay up'. Laminates are produced in moulds of the form and shape required by laying plies of glass fibre impregnated by resin and application of succeeding layers. The inside of the mould is first treated with a separating agent such as wax to ensure that the laminate will not stick to the mould.

### 4.2.7 FRP sheathed wood

In FRP-wood composites, wood is acting as a core material over which the fibreglass resin is coated. As a construction material wood offers many advantages like good strength to weight ratio, workability, load bearing capacity, tensile strength and elastic strength. However, the wood is susceptible to decay and deterioration by different biodeteriorating agents like microorganisms, fungi and woodborers if it is not protected by the laminate or resin. The wood used in FRP-wood composites can be treated using chemical preservatives to enhance resistance to deterioration. The studies conducted at CIFT showed that the Modulus of Rupture (MOR) of the samples sheathed with one layer of FRP showed a 34% increase when compared to unsheathed panels. Similarly, there was an increase of 57% and 75% in Modulus of Rupture (MOR) in two layers and three-layer reinforcement, respectively.

Wood of the rubber tree (*Hevea brasiliensis*) is an under-utilised agricultural byproduct, which can be upgraded through preservative treatment for the construction of fishing canoes. The planks of rubber wood were first made into scantlings according to the design. Then the scantlings were treated with preservative by immersing in CCA solution for about 10 days in a cement tank. The scantlings were then air seasoned and after drying they are assembled to form the canoe. The hull to be sheathed is dried and made free from grease and oil. The bolt holes and other holes are seamed using special seaming compound. The surface is made rough by sandering. One coat of active resin is applied and when the resin coat is still tacky, the glass fibre mat is laid upon it, the activated resin is applied over the mat and impregnated properly eliminating any voids or air bubbles. When the first layer is still tacky, the second layer is laid in the same manner as in the previous case. Sufficient number of layers are laid and the surface is allowed to dry and cured for 10-15 days. After curing the surface is etched and a suitable anti-fouling paint is applied a few hours prior to launching. The canoes have been successfully deployed operating fishing gears in the backwaters and coastal waters (Fig. 4.3) (Edwin et al., 2005). Cost of sheathing a wooden canoe of 6.4 m $L_{OA}$ is about Rs. 8000 (Table 4.1).

**Fig. 4.3 FRP sheathed canoe**

**Table 4.1 FRP raw material requirement for sheathing a 6.4 m $L_{OA}$ wooden canoe**

| Description | Quantity required | Unit cost (Rs.) | Total cost (Rs.) |
|---|---|---|---|
| Chopped strand mat (300 g.m$^{-2}$) | 13 kg | 130/kg | 1690 |
| Surface mat | 10 m$^2$ | 40/m$^2$ | 400 |
| Polyester resin | 40 kg | 102/kg | 4080 |
| Catalyst | 260 g | 170/kg | 44 |
| Accelerator | 260 g | 470/kg | 122 |
| Pigment | 1 kg | 300/kg | 300 |
| Labour | 2 man-days | 300/man-day | 600 |
| Miscellaneous | | | 750 |
| Grand total | | | 7986 |

### 4.2.8 Aluminium

Aluminum alloys have a number of qualities that makes it suitable as a boat building material. It is lightweight with good dent resistance, has high strength to weight ratio, high corrosion resistance and low maintenance costs. The good corrosion resistance is due to the presence of a thin, compact inert and protective hard surface film of aluminium oxide. This oxide film thickens with time and when scratched a new protective film is built up. Pure aluminium containing 99.5% or more and minimal amount of silicon and iron has the high corrosion resistance. As this is too soft for application, aluminium is alloyed with Mg, Mn and Si for marine application. Generally speaking, the higher the Mg content in marine aluminium higher the strength and the upper limit of Mg content is 5.5 % both from a corrosion point of view and from the workability point of view. In spite of its resistance, pitting corrosion occurs in aluminium. Another type of corrosion occurring is the galvanic corrosion. This depends on the conductivity of the liquid and the relative position of the metal in the galvanic series. The tensile strength of marine aluminium range from 31000 to 48000 psi and the elastic modulus for aluminium is about 1/3 of steel. Aluminium has greater impact resistance than steel (Simpson, 1964).

Methods for fabricating aluminium vary little from steel and are usually more economical because of lighter handling and faster operating speeds. Cutting of the plates is normally done with light hand power tools. Joining is by high speed welding. Two welding processes *viz*., (i) Metal Inert Gas (MIG) and (ii) Tungsten Inert Gas (TIG) are used for fabrication. TIG welding is normally used for sheets below 1/8" thickness and therefore the MIG process is most common in the ship building industry. When welding marine aluminium the heat partially reduces the strength of aluminium but the strength loss is usually only 10%. Small boats are usually constructed upside down over jigs with relatively lightweight of the material facilitating turn over process for outfitting and completion. Larger vessels are built upright and jigs can be used to fabricate the fitting and welding of the hull plate. Alternatively, construction in sub-assemblies can be carried out and completed sections can be transported to the construction site for tacking and welding.

Painting is not essential except for antifouling paint. When painting is required the alloy surface is etch primed and painted with zinc chromate or chromate-phosphate chemical conversion coatings as a base coat. Paints containing lead, copper and mercury should not be used. Antifouling paints containing Hg in any form should not be used. Cu based antifouling paints can be used provided a sufficiently thick coat of zinc chromate is used. During the fabrication of aluminium, care should be taken to avoid metal to metal contact to avoid electrolytic corrosion and all exposed timber surfaces in contact with aluminium must be painted with aluminium based or bituminous paint. Aluminium to steel joints should have tapes or gaskets of insulating material such as neoprene. Aluminium hulls must be protected from stray electric currents in water. Attention must be given to the specification and installation of electric circuits to avoid stray currents.

Use of aluminium for fishing craft construction offers a number of advantages that includes improved stability, reduced displacement and therefore improved maneuverability, increased cargo carrying capacity, increased speed and operating range, decreased engine size, decreased fuel consumption, reduced maintenance and therefore less idle time. An aluminium fishing craft (5.20m $L_{OA}$, 1.10 m breadth and 0.55 m depth) built at CIFT for inland fishing operations is shown in Fig. 4.4.

**Fig. 4.4 Aluminium craft (5.2 m $L_{OA}$) for inland fishing**

### 4.2.9 Ferrocement

Ferrocement consists of a number of layers of wire mesh impregnated within mortar made of fine sand and Portland cement. The main difference between ferrocement and other forms of reinforced concrete is in the use of a fine grained aggregate and fine meshed reinforcement in a thin shell structure. The fine ingredients give (i) increased flexural and shear strength (ii) resistance to corrosion due to restriction of crack widths below critical values above which moisture could enter the shell structure, (iii) increased specific surface (iv) improved tensile bonding capacity and (v) crack inhibition due to high proportion of small diameter wires in the mesh. The materials required for ferrocement boat construction are given below:

*Cement:* Type II Portland or Type V rapid hardening cement (ASTM 50-70 T or BS 12) containing not more than 10% tricalcium aluminate, of fresh fine quality without lumps.

*Sand:* Substantially quartzitic with grain size not exceeding 2 mm conforming to ASTM sieve size 7 (100% passing), ASTM sieve size 15 (80-90% passing), ASTM sieve size 60 (75% passing), ASTM sieve size 100 (5-20% passing) and ASTM sieve size 150 (0% passing). If quartizitic sand cannot be obtained suitable alternative sand is used.

*Water:* The water used should be clean and free from harmful salts or foreign materials which may impair the strength and resistance of the mortar.

*Reinforcements:* Reinforcements consist of frame rods, galvanized welded mesh reinforcements (e.g. 13x13 mm; 19 gauge), staples and lacing wire. All reinforcement should be free from contamination, grease and mill-scale.

Common methods of construction, followed for ferrocement boats include (i) pipe-frame method – the construction of a reinforcement armature of rods and mesh over mesh covered span frames, (ii) welded armature method - a mould is used to form a hull using timber at determined spacing and an armature is laid inside and outside the hull, (iii) wooden plug method - a female mould is used as in the FRP construction and (iv) high tensile wires are laid up as a grid at determined spacing.

The web frames which support the armature, the framing, the keel, stem and stern reinforcement structure are to be well braced so as to fully support the armature without distortion under the weight. Rods have to be wire tied to the framing and the overlapping rods are to have an overlap length of at least 30 times the rod diameter. Mesh is to be stretched taut in the plane of the ferrocement element and ties applied at crossings of rod reinforcement in such a way that the mesh is not tightened in between the reinforcing rods. This should be applied at distances not more than 15 cm and according to vessel size (Anon, 1974).

Properties of mortar depends upon the water-cement ratio by weight (0.38-0.4:1), sand : cement ratio by weight (2:1), grading, shape, source, purity and chemical composition of sand, quality, age and type of cement and the quality of water and type and amount of admixtures. The quality of mortar depends on the type of mixer, mixing time, type and amount of vibration or compaction and environment at the time of mixing (wind, humidity and temperature). Particular care should be taken to ensure full penetration of mortar at angles and thicker sections. Hull should be protected from direct sunlight and wind, both during application and during curing. Mortar over reinforcement should not exceed 3 mm thickness nor be less than the wire diameter in the mesh layer nearest to the surface. Ambient humidity of 85% is necessary for cement hydration and early development of compressive strength. The period of curing ranges from 14 to 28 days. Steam curing at higher temperature decreases the curing period. Temperature should be raised to 75°C in at least four hours and to be held at that temperature for at least 12 hours and then be allowed to drop to air temperature over a 4 hour period. Smoothing of the hull should be carried out before first set. After curing, stoning or sand blasting, a sealant is applied., e.g. water based epoxy lacquer.

Steel content is the weight of steel per unit volume of ferrocement element, including rods, mesh and mortar. The minimum recommended steel content is 380 $kg.m^{-3}$ while the maximum is 650 $kg.m^{-3}$. The steel content expressed as percentage steel area in the cross section of the ferrocement element is in the range of 2.0-6.5%. Specific surface measures the dispersion and fineness of the meshes and their ability to control cracking. The total surface area of the mesh divided by the volume of the ferrocement element containing it is in the range of 1.8-3.0.

The ability to build hull, decks, bulkheads, floors and engine bearers, fish tanks and bulwarks in one piece resulting in a monolithic structure of immense strength which actually increases in strength with age is an important advantage of ferrocement. Ferrocement craft can be built without highly skilled labour. No expensive plant is needed as in the case of steel construction and to a lesser extent with timber construction. It is not necessary to use a mould for ferrocement construction as in the case of building with FRP. The raw materials necessary for ferrocment construction are easily available in most countries. Ferrocement hull costs 20-25% less than a similar hull in timber or steel. Overall saving may not be more than 4-7%. Unlike steel it is immune to rust and corrosion and will not rot like timber. It is resistant to marine borers. Ferrocement has proven aging qualities. No painting is required except to enhance appearance. Because mesh reinforcement is used it will have the tensile strength in all directions. The tensile strength in wood is reduced due to numerous fastenings whereas ferrocement do not have any fastenings. Compressive strength without reinforcement is 4200 psi after 7 days and 12,225 psi after 28 days and continues to increase with age. The specific gravity of ferrocement is 2.6 compared to FRP (1.6) and that of wood with fastenings (0.9). In vessel of over 12 m $L_{OA}$, when skin thickness of other materials has to be increased the ferrocement boat compares favourably with wooden, FRP and steel vessels, as no heavy internal frames are required. Damaged area can be chipped away until surrounding area is fine. Ferrocement mix applied both in interior and exterior outer area is left little pruned and finally ground off. In addition, ferrocement has good heat insulation properties (Fyson, 1973).

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