Fishing Craft Materials

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According to the latest estimates (1999) there are 280491 fishing craft in India. Of these 181284 are traditional craft, 44578 are motorised craft and 53684 are mechanised craft. The larger classes of fishing vessels are made of steel, while vessels belonging to the medium and lower category 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 therefore very 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

Wood

India has rich timber resources of around 2000 species**.** Of which a selected few only 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 biological agencies. 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 (Godavari Teak) and Orissa. The second choice is aini (jungle jack) 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 (*Albizzia chinensis*), semul (*Bombax ceiba*), Malabar neem (*Melia composita*) *M. dubia*, maharukh (*Alianthus 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 (*A. chaplasha*), sal (*Shorea robusta*), shisham (*Dalbergia sissoo*), padauk (*Pterocarpus dalbergioides*), laurel (*Terminalia alata*), and kindal (*T. paniculuta*).

Of the several inherent properties of timber, its buoyancy, workability, treatability, nail holding power, strength to weight ratio and poor transmittance of heat, sound and electricity makes 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 (Copper, lead, aluminium etc.), concrete and plastic have been used to achieve protection. In India, the hull below the water line area of boats is sheathed by aluminium-magnesium alloy sheets. Fibreglass reinforced plastic sheathing also is a proven method of protection.

Wood preservation

Timber in various forms is subjected to biodeterioration. Traditional crafts are mostly affected by wood rotting fungi and mechanised boats by marine wood boring and fouling organisms. Fishermen resort to various types of indigenous preparations, majority of which are found not giving proper protection as established by CIFT's investigations. The various preparations are those of plant and animal origin, such as fish oil (sardine and shark liver), cashew nut shell liquid (CNSL, *Anacardium occidentale*), poon seed oil (*Calophyllum inophyllum*), neem seed oil (*Azadirachta indica*), crude engine oil, coal tar, lime-plaster, animal fat, vegetable tannins etc. which are used either singly or in combination.

Chemical wood preservatives with toxic ingredients, when properly treated can give adequate protection to wooden structures against decaying organisms. Such treatments are generally expected to enhance the life by 3-5 times under marine conditions. Chemical preservatives are either pure chemical compounds or mixtures of compounds, which are toxic to biological agencies. A good preservative should have high toxicity to biological agencies, high permanency, and high penetrability. It should not reduce the strength of treated wood and should be cheaply and easily available.

Timber species vary in their treatability and are graded into five classes based on the degree of resistance offered by the heartwood of the species to the penetration of preservative solutions.

These are:

i. Heartwood easily treatable;
ii. Heartwood treatable, but complete penetration not always obtained;
iii. Heartwood only partially treatable;
iv. Heartwood refractory to treatment, and
v. Heartwood very refractory to treatment

Wood preservatives

Chemical preservatives are of the following four types, each consisting of any one or more of the chemicals mentioned against it.

i. ***Oil type:*** This type comprises various forms of creosote. The most widely used is the coaltar creosote, which is a coal tar distillation product and consists of liquid and solid aromatic hydrocarbons, tar acids and tar bases. Tar acids and tar bases are the toxic compounds and hydrocarbons act as carrier or reservoir for them. Creosote has the advantages of being an indigenous product with high toxicity, relatively high permanence and non-corrosive. Its major disadvantage is that creosoted timber cannot be painted.

ii. ***Organic solvent type:*** Comprise organic or inorganic salts dissolved in suitable organic solvents. Copper napthanate, zinc napthanate, pentachlorophenol, benzene hexachloride etc. come under this group. These are clean to handle, have high permanency and can be painted but some are inflammable.

iii. ***Water-soluble leachable type:*** These are organic or inorganic salts soluble in water. Zinc chloride, sodium fluoride, boric acid, sodium pentachorophenate, benzene hexachloride are examples of this type. These are comparatively inexpensive, easy to transport and oduorless but are subjected to leaching.

iv. ***Water-soluble fixed type*:** Mixtures of various water soluble salts with the addition of a fixative salt, usually sodium or potassium dichromate. Treated timber should be allowed to dry for 3-6 weeks to complete fixation. Copper-chrome-arsenic compound (CCA), copper-chrome- boric compound, acid cupric chromate and chromated zinc chloride come under this type. All woodworking has to be finished before treatment. Timber has to be seasoned to 15% moisture content for non-pressure processes and to 25% moisture content for pressure processes.

Treatment methods

Treatment methods can be mainly grouped into two: non-pressure processes and pressure processes.

1. 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 20-30%. Surface treatment has a limited scope as the penetration will be very less.

Immersion*:* 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.

Hot and cold process or open tank process*:* The timber is submerged in the preservative solution, which is then heated to 90°C and maintained at the temperature for a suitable period. Then immediately it is cooled until the required absorption is obtained. During heating, the air in the timber expands and is partially expelled, during cooling the residual air in the timber contracts creating partial vacuum, which causes the preservative to be sucked into the timber. This treatment also ensures partial sterilization of timber against microorganisms. In the absence of pressure treatment this is recommended. With CCA type preservatives two separate baths are used to avoid precipitation of chemicals.

Boucherie process*:* Treatment of sapwood of all green timbers is possible. 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 then forced out at the thin end.

2. Pressure Processes

In this type, 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 upto 56 cm of mercury column maintained for sufficient duration followed by introduction of preservative into the cylinder, application of antiseptic pressure (3.52-12.3 kg/sq.cm) 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 vacuum free the timber from dripping preservatives.

Empty cell process : This process aims at maximum penetration of the preservative with minimum net absorption. Two processes, viz. Lowry process and Rueping process are commonly used.

- ***Lowry Process***: The process is same as that of the full-cell process except the initial application of vacuum.
- ***Rueping Process*****:** In this case, an initial air pressure of 1.76 to 5.2 kg/sq.cm is applied and maintained during filling of the preservation. The rest of the steps are like full-cell process. This process is very suitable for treating timber of mixed species.

Role of CIFT in chemical preservation of wood

Since almost all indigenous preservatives were found to be non-toxic, investigations were carried out at CIFT to develop suitable chemical preservatives for wooden fishing boats. A biological assessment of some of the promising chemical preservatives such as pentachlorophenol, coal tar, copper resinate, heavy creosote oil and CCA was carried out. Heavy creosote and CCA alone exhibited reasonable resistance to borers while others failed.

Several attempts were made in the institute on fortification of creosote. Fortification of creosote with arsenous trioxide evolved a product called arsenical creosote having higher toxicity than creosote. Detailed study with reference to leaching, corrosion and anti - borer properties showed better fixation of the preservative into the wood and considerable resistance to boring. Copper creosote was developed by heating copper oxide with creosote and the compound was found to be stable and biologically active. A comparative assessment on the performance of low-temperature creosote (produced by Regional Research Laboratory, Hyderabad), arsenical creosote, copper creosote and tributyl tin oxide (TBTO)- fuel oil mixture showed a higher level of protective value by copper creosote over arsenical creosote. Fortified creosote imparts not only toxicity to wood against biological agents but also retards the formation of cracks and splits on the wood due to weathering.

'Creoscor' developed at CIFT is a high efficiency oil-borne wood preservative which is prepared by heating together heavy creosote oil, copper compound and plant resins. This is used as a second coat over copper creosoted timber. The treatment consists of giving two or three liberal coats of copper creosote or arsenic creosote on all parts of the boat. The hull portion is then coated with creoscor, which not only protects the craft but also provides a smooth surface, which helps to reduce the frictional resistance to motion of the craft in water. The new treatment procedure evolved by CIFT need to be done only once in a year only whereas most of the indigenous preservatives have to be applied at least twice a year. The new treatment costs only 28 % of the traditional treatment practice.

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. 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.

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 *Lagerstromia lanceolata* (Venteak), *Adina cordifolia* (Haldu) *Terminalia tomentosa* (Maruthu), *Antiaris toxicaria* (Arayanjili) *Mangifera indica* (Mango), etc., X-ray radiographs are also used to assess the nature and extent of damage.

The Central Institute of Fisheries Technology, Cochin has been trying to use rubber wood (*Hevea brasiliensis*) for boat making since 1997. Studies were conducted on the natural durability of the wood under marine, soil and atmospheric conditions. The encouraging results obtained through the laboratory and field trials paved the way for the construction of two prototype canoes - one for marine fishing and the other for backwater fishing. The canoes are being operated by fishermen from October 2002. The cost of rubber wood is only about one – fourth that of the conventionally used timber, jungle jack (*Artocarpus hirsuta)* used for traditional craft construction

Steel

The use of iron in ship construction began in England in the latter part of the 18 th century, however the major use was not until 1818, when a river barge called 'Vulcan' was built. Steel is the principal material used in hull construction in large fishing or merchant vessels over 50 m length. A steel hull has a relatively thin outside shell and the minimum thickness is just 2 - 3 mm. In tropical environments where corrosion is a major problem the lower limit of the length of fishing vessels are often 15 m or more. Steel hulls may be prefabricated in section, which adds to its many advantages.

The steel hull structure consists of rolled plates and profiles. Plates appear in different sizes and different thicknesses. The thinner plates (3 -6 mm) are mostly 5 - 8 m long and 1.2 - 2 m wide. Thicker plates up to 30 mm and more are up to 12 m long 2.5 m - 3 m wide. The thicknesses are mostly sub - divided by half millimeters (3, 3.5, 4, 4.5). For greater thickness over 20 mm however the difference is one millimeter.

Types of construction

Steel hulls are constructed either in the longitudinal type or transverse type or longitudinal to transverse type according to one of the three systems. **Longitudinal** construction is characterised by members stiffening the plating in the fore and aft direction. This type of construction is used in very large merchant vessels and sometimes on smaller boats. It gives a reduction in hull weight compared to other types of construction. In **transverse** type of construction the main stiffening of the shell and deck plating is arranged in transverse planes at a distance of about 500 - 650 mm. The appropriate transverse elements are floors, frames and deck beams connected to each other by brackets. These types of construction are used most frequently in small and medium - sized vessels and steel fishing vessels are practically built in conformity with the transverse system. The mixed or **transverse - longitudinal** system is used on ships with a length of over about 100 m up to some 250 m. It combines the advantage of basic systems but due to technological reasons is not used in smaller vessels.

The ship building industry requires special type of steel for use. Carbon steel (mild steel) is the base material for ships hull, harbour structures, port piles, buoys etc. The conventional mild steel has a yield strength of 15 tonnes / psi. Steel with small alloying additions can increase the yield strength to 22 t / psi. Corrosion of steel is a major problem in the ship building industry. Average rate of corrosion of steel and iron under immersed conditions in seawater is 0.006 ipy (inches penetration per year). Seawater corrosion of steel can only be controlled by external factors rather than by the composition of steel since none of the common alloying elements has any commercially significant influence on corrosion

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 somewhat 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. FRP is probably the most suitable material for boat building among different materials available. Reinforced plastic with the use of 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 this is ideally suited for construction in mass numbers. FRP boats require greater initial investment but minimum expenditure on maintenance thereafter.

FRP can be used as a sheathing material for boat hulls and also as basic construction material of boat hulls.

Materials required

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, also from other 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. So it has to be reinforced with fibreglass.

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

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.

FRP as boat building material

FRP boat building is not the assembling of performed components as in wood or steel but a new structural material with resin and fibreglass is made on the spot at the time of fabrication. FRP boats require special design and construction details as otherwise if built on the same line of wood or steel they tend to float excessively and may not provide a stable platform for fishing. This undue lightness is made use of by increased speed, increased fish hold capacity and lesser engine horsepower.

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.

FRP sheathing for wooden hulls

The hull to be sheathed is dried and made free from grease, oil etc. 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 voides or air bubbles. Thus the first layer is made and when it is still tacky, the second layer is made in the same manner as in the previous case. Sufficient numbers of layers are made 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 hours prior to launching.

The advantages of FRP are (1) low maintenance and repair costs; (2) light (3) durable (4) unaffected by seawater (5) will not split or crack (6) non-corrosive (7) do not absorb water like wood (8) not attacked by marine borers (9) stronger than wooden hulls of same weight (10) can be fabricated to any desired shape and have (11) greater resistance to impact. Its disadvantage is that it is not free from marine fouling.

Properties

The specific gravity is approximately 1.6. The specific gravity of wooden hull including fastenings will be 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. It is very strong but is also flexible.

Aluminium

Fishing vessels using aluminium as a construction material have proven to be good proposition. This is because marine-aluminium alloys combine high corrosion resistance and low maintenance with high strength to weight ratio. Aluminium alloy 5086 has 1270 kg/cm^2 strength to weight ratio compared to 493 kg / cm ^{2} for steel and 1060 kg/cm^2 for the highest quality mahogany. The good corrosion resistance is due to the presence of a thin, compact inert and protective hard surface film of aluminium oxide about 2/10 of a million of an inch thick bonded to Al.

This oxide film thickens with time and when scratched a new protective film is built up. Pure Al containing 99.5% or more and minimal amount of silicon and iron has the highest corrosion resistance of all Al alloys. As this is too soft for application Al is alloyed with Mg, Mn and Si for marine application. Generally speaking, the higher the Mg content in marine Al 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 Al. 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.

Properties

Mechanical

The ultimate tensile strength of marine Al range from 31,000 - 48,000 psi. the elastic modulus for Al is about 1/3 that of steel. Al has greater impact resistance than steel. The table shows the weight of Al structures as a percent equivalent steel structure.

Super structure and Deckhouse	38 %
Hatch covers	37 - 50 %
Life boats, Davits	33 %
Leads, gratings, engine room floors	45 %
Hull	41 - 50 %

The fatigue endurance limit (500,000,000 cycles) of Al alloys range from 16,000 to 23,000 psi for various types of marine Al.

Physical

Al is non-sparking and non-magnetic. The co-efficient of thermal expansion of Al is about twice that of steel. Al has high heat reflectivity- 90 % as compared to 50 % for steel thus Al will emit only 10 % of the heat from the sun while steel emits 50 %. Insulation and refrigeration requirements are smaller in fish holds. Al is much more hygienic than steel Al has more thermal conductivity, 3 to 5 times more than steel depending on materials in consideration and therefore uniform distribution of temperature takes place faster in aluminium fish holds.

Fabrication

Methods for fabricating Al varies 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 are used.

- Metal Inert Gas (MIG) and
- Tungsten Inert Gas (TIG)

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 Al 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 sufficient thick coat of Zn chromate is used. The following points should be taken into consideration during the fabrication of Al.

- Care should be taken to avoid metal to metal contact to avoid electrolytic corrosion
- All exposed timber surfaces in contact with Al must be painted with Al based or bituminous paint.
- Aluminium to steel joints should have tapes or gaskets of insulating material such as neoprene, tufnol, etc.
- Al 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

Advantages of Aluminium

Use of aluminium for fishing craft construction offers the following advantages

- Improved stability
- Reduced displacement and therefore improved maneuverability
- Increased cargo carrying capacity
- Increased speed and increasing operating range
- Decreased engine size
- Decreased fuel consumption
- Reduced maintenance therefore less idle time

Ferrocement

Ferro-cement is the name given by Dr. P.L. Nervi, of Italy and it can be defined as a material consisting essentially of a number of layers of wire mesh impregnated with in mortar made of fine sand and Portland cement. According to Nervi (1956) it did not behave like ordinary reinforced concrete but "exhibited all the mechanical properties of a new material”. The main difference between ferro-cement 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, (v.) crack inhibition due to high proportion of small diameter wires in mesh.

Materials Required

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

Sand*:* Substantially quartzitic with grain size not exceeding 2 mm fitting the following:

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
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 materials in solution, however additives can be used to get the desired ratio.

Construction

No mandatory standard is followed. However, there are different methods of construction.

- The pipe-frame method - the construction of a reinforcement armature of rods and mesh over mesh covered span frames.
- The welded armature method - use of a mould to form a hull using timber at determined spacing - an armature being laid inside and outside the hull
- The use of female mould (wooden plug method) as in FRP construction
- Use of high tensile wires laid up as a grid at determined spacing.

The web frames, which support the armature, the framing the keel stem and stern reinforcement structure is 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.

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, environment at the time of mixing (wind, humidity, temperature), curing (temperature, duration, type) compressive stress not less than $420 kg/cm^2$. Mixing time of mortar should be controlled. Particular care should be taken to ensure full penetration 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 (0.125") 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^oC 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.

Properties of Ferrocement

The following parameters should be considered in the construction of a ferro cement vessel

Steel content is the weight of steel per unit volume of ferrocement element, ie. complete ferrocement section including rods, mesh and mortar.

Minimum $380 kg/m^3$ - Maximum $650 kg/m^3$

Steel cross section: Steel area divided by the total area in a cross section of the element and expressed as percentage. Measures the same property as steel content but is unidirectional.

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 ferro cement element containing it and is measured in cm^2/cm^3 (m^2/m^3)

1.8 - 3.0 cm^2/cm^3

Advantages

In the light of experience gained in building over 150 ferrocement hulls T.M. Hagenbach (M.D. Seacrete Limited, Norfolk, England) cites the following merits:

- 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.
- 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 as no temperature control is necessary. Local manufacturing can be done without sophisticated facilities.
- The raw materials necessary for ferrocment construction are easily available in most countries. There is actually a dearth of good quality boat building timber. FRP raw materials are relatively expensive and requires storage facilities.
- 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 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 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, FRP is1.6 and that of wood with fastenings is 0.9
- Over 40 ft., when skin thickness of other materials has to be increased the ferrocement boat compares favourably with other vessels – wood, FRP and steel, because 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
- No risk of fish contamination and acts as a good insulator. Its thermal conductivity is 68.88/btu/sq.ft. /deg F/h.