CONSTRUCTION MATERIALS

The choice of construction materials is often the subject of numerous debates among owners, architects, builders, and brokers. Different mixed solutions and various combinations offered by composite materials have contributed to these heated debates that complicated the ultimate decisions.

Recent statistics show that between the years 1980 and 1995, in global yacht construction for models larger than 78 feet in length, the material most frequently used was fiberglass, followed by aluminum, then steel, and finally wood. It is interesting to note that these statistics change from country to country. In Italy, for example, aluminum is the least used of all materials, the first being fiberglass, then steel, and wood. Whereas in the United States, close to 200 boats were built in aluminum for only 15 in steel. And Dutch builders completed 150 models of which two thirds were built in steel and the rest in aluminum; not a single boat was built from wood or fiberglass. In France, where the construction of large yachts remains limited, fiberglass was the most popular choice with eight models built of this material in 15 years. Without assuming to find an absolute solution to the choice of construction materials, it is nonetheless important to characterize the principal facts and elements to make the choice as objective as possible.

Elements of choice

The elements and criteria that orient the choice of one material over another are sometimes complex and overlapping. It is essential then to precisely identify them before selecting, or ranking their importance.

#1. Operational Constraints.

These define the elements influencing the use and performance of the yacht. The speed, draft, maneuverability, handling under power, pitching and rolling, are all determined by construction. In effect, the choice of materials largely influences the geometry of the hull and the center of gravity.

#2. Livability.

The interior structure of a yacht can vary enormously with the choice of materials used. The volume occupied by different structures can be maximized to limit their interference on the layout of a yacht. Other factors that are influenced are the appearance of the interior surfaces and the efficiency of their protection and maintenance.
The interior of a sandwich hull is quite easy to maintain compared to a wooden or steel hull. Thermal and acoustic isolation on the other hand, which are also important to the comfort of those living aboard, are best on wooden boats. And finally, the necessity of insulating metal hulls for this purpose can be costly and add weight to the model.

#3. Aesthetics.

While it is true that all of the materials mentioned can be finished to obtain the best appearance possible, certain of them can be difficult and costly to work with and maintain. The deformation of metal hull plating is a well known problem, and aluminum is the more sensitive to distortion than steel of equal thickness. In terms of appearance, the quality of a fiberglass hull laid up in a female mold is far ahead of the rest.

#4. Safety.

The biggest concerns in safety are heat resistance and buoyancy reserves. A steel hull offers the best flame resistance, with the exclusion of primers and paints used to coat its surface. Aluminum deforms and begins to melt at relatively low temperatures. As for wood and fiberglass, they are the most sensitive to fire although fire retardant resins have been developed to help in this regard. Buoyancy reserves provide damaged vessels a supplemental security but do not render a vessel unsinkable. In this respect, wooden and sandwich hulls are best.

#5. Price.

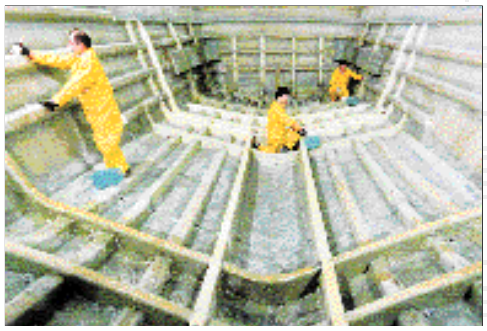
The price of a hull varies with the cost of materials and labor, and the value of capital investment necessary to production. The availability of a material affects its cost, and thus influences the final choice. In fiberglass, where the actual construction material is manufactured and a mold can be used to lay up as many hulls of that model as desired, the price per unit is directly related to the number of units produced. With natural resources like wood, on the other hand, different types may be difficult to find in sufficient quantities for the construction of large vessels and therefore can make construction too costly. Suffice it to say that the materials and construction costs should generally represent 25% of the total finished cost of a vessel.

#6. Operating and maintenance costs.

The major operating costs of a yacht are maintenance, repairs, and fuel. The principal job in maintenance is generally painting the interior and exterior of the hull, decks and superstructure. In this area, steel and aluminum are not as economical as fiberglass because they require much more complex systems of application (aluminum is particularly complicated but it can be left bare in hidden areas). Steel must be protected against corrosion on the interior as well as the exterior. And wood requires an enormous amount of attention to keep it from deteriorating or rotting. The life-span of fiberglass and aluminum is undeniably superior to wood or steel, for identical use and maintenance plans. Steel and aluminum can be easily repaired in any shipyard that has access to welding equipment adapted to the material. Fiberglass repairs simply require qualified technicians to work with the base materials but they can be difficult to find in certain parts of the world. Repairs to a wooden hull can prove to be difficult as they require the skill of a qualified artisan that unfortunately is becoming increasingly rare. And finally, the fuel costs of any vessel depends on the weight of the structure. Steel hull vessels are the heaviest, requiring a much larger hull displacement and surface area below the waterline than any other of the same size. The displacement directly affects its resistance to forward motion which, in turn, affects the engine load and its consumption.

Construction
... the materials

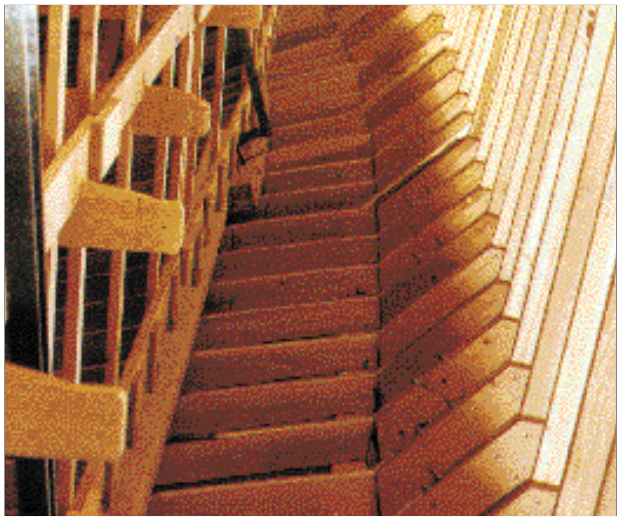
Wood construction demands enormous preparatory work.



Stratification of a fiberglass vessel is done by hand.

Inside an aluminum structure.

The materials



#1. Mechanical and Physical properties.

These properties are essential to the design and engineering of a yacht. In order to compare them objectively, it is preferable to use specific mechanical properties as they are called, in other words, the mechanical properties to density ratio.

#2. FRP (Fiber Reinforced Plastics).

This material is a composite of resin and different types of fibers and reinforcements. The resin can be polyester, vinylester, or epoxy for most composites. The reinforcement can be chopped strand mat, woven roving, or unidirectional roving of either E, R, or S glass fibers, aramide (Kevlar), or carbon/ graphite. For our comparison, we will use the characteristics and properties of polyester resins reinforced with E glass; the components most widely used in the boat building industry.

For a long time this material was considered indestructible, until the early 1970's when evidence of osmosis blistering appeared in the gel coat at the bottom of the hull on several FRP yachts. It is still rather easy to manufacture and maintain, and provides sound construction thanks to the development of a sandwich construction.

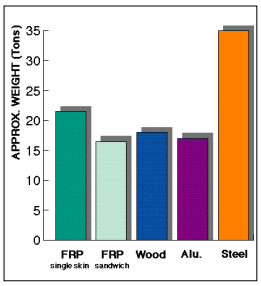
Construction requires a large investment in infrastructure.

This sandwich technique is one that is characterized by increasing the thickness of the panels with a low density core and "sandwiching" them between the two layers of fiberglass laminates. Returning to our example, a 15 mm single skin panel can be replaced by a sandwich of the same weight, for a total thickness of 60 mm, which is about 27 times stronger than a single skin laminate. This increase in the rigidity of the panel allows builders to eliminate stiffeners (economizing the additional weight) and at the same time benefit from improved thermal and acoustic insulation. One of the critical points of FRP construction is the secondary bonding and attaching stiffeners and bulkheads onto the hull or deck laminates in order to minimize the risk of delamination.

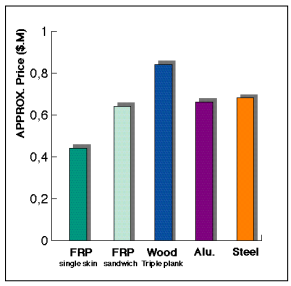
Its weak points are its susceptibility to fire and the risk of composite degradation due to resin and fiber hydrolysis.

#3. Aluminum.

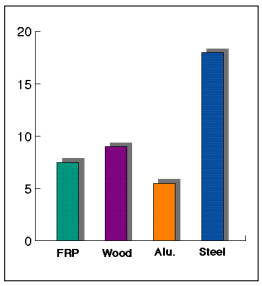
This metal offers a number of advantages and is available as sheet metal in various alloys, thicknesses, or extrusion forms. The most common marine alloys are known as 5000 or 6000 series which are alloys that have a low copper content and are particularly adapted to marine use. The mechanical properties of these alloys can be substantially augmented by thermal treatments designed to indicate the strength of the metal. Aluminum is a relatively easy metal to work with and the cost of inert-gas welding has become competitive. But the concept and construction of an aluminum alloy hull requires a basic unders-



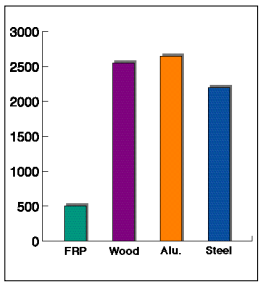
Estimated weight of a 30 meter hull.



Estimated price of a 30 meter hull.



Resistance.



Elasticity modulus.

tanding of the effects of corrosion. It is imperative to follow certain guidelines when selecting other metals in construction in order to eliminate the risk of galvanic corrosion. Zincs anodes must be secured to the hull and checked regularly to insure that they were properly installed and are working correctly.
In addition, all electrical wiring on an aluminum yacht must be efficiently insulated and protected for the same reason. Electrical tinkering or "do-it-yourself" installations, especially on aluminum boats, can have dramatic consequences.

#4. Steel.

The principal advantages of steel construction are the availability and implementation of this material. It is the least expensive of all for initial construction but over time can be costly to maintain because of oxidation. The degree of wastage to the structure can be determined with regular surveying, but after twenty or thirty years of service, a steel hull may require the replacement of damaged plates. Certain preventive measures can be taken to limit the effects of corrosion. The specific weight can make steel a bad choice for certain types and sizes of vessels.

#5. Wood.

A wooden hull can be built and repaired using simple tools. The resistance to weight ratio is the best of all materials and its thermal and acoustic insulation is excellent. But unfortunately, the resistance of wood to wet and dry rot varies with the type of wood and is prone to attack by Toredos and other marine borers. For many years, wooden boat hulls have been built using a method known as West System developed in Michigan by the Gougeon Brothers. It involves encapsulating the wood in low viscosity epoxy resin that impregnates the wood and increases its rigidity, strength, and durability.

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