

# STUDY OF DIFFERENT TYPES OF MATERIALS FOR USE IN PASSENGER VESSELS FOR THE AMAZON REGION

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## ABSTRACT

*Passenger vessels in the Amazon have given a great contribution to the movement of people and to the regional economy. However this type of transport is used by low-income persons and vessels are usually made of wood. However, the use of wood as a building material has proved to be increasingly scarce and expensive. A possible wood substitute is for example steel, but its use leads to increase price of hull construction as steel is more expensive and to increase weight of the hull, that in turn requires higher engine power and loss of loading capacity, which moreover directly contribute to increase cost of transport. This work, studies different materials for shipbuilding in the Amazon region, which seeks to assess different materials to use in building ships for the Amazon with a focus on passenger transport. This work studied different types of materials in order to identify the material that has better physical condition and cost for replacement of wood as a building material for passenger vessels. Five types of materials were studied: wood, steel, aluminium, fibreglass with Kevlar and fibreglass. Different materials were analysed using mathematical models for preliminary design with the objective to understand and compare the fixed and operational costs for the same vessel. Discussion supported by graphs gives indications to identify materials that have higher chances of success in replacing wood as building material for the river passenger ships in the Amazon region. The life cycle approach was used to evaluate the costs (fixed and operating) of a vessel built with different materials throughout its lifetime.*

Keywords: new materials; river ships; Amazon region.

## RESUMEN

*Los buques de pasajeros en la Amazonía han dado una gran contribución al movimiento de personas y a la economía de la región. Sin embargo este tipo de transporte lo usan personas con bajos recursos y las embarcaciones son hechas generalmente de madera. No obstante, el uso de madera como material de construcción ha demostrado ser cada vez más escaso y costoso. Un posible sustituto para la madera es por ejemplo el acero, pero su uso conlleva al incremento del coste de construcción del casco, ya que el acero es más caro, y al aumento del peso del casco, esto a su vez requiere de mayor potencia del motor y pérdida de la capacidad de carga, que además contribuye directamente al incremento de los costes de transporte. Este trabajo estudia diferentes materiales para la construcción de buques en la región amazónica, busca evaluar diferentes materiales para poder identificar el material que tiene mejores condiciones físicas y coste de reemplazo a la madera como material de construcción de buques de pasajeros. Cinco tipos de materiales han sido estudiados: madera, acero, aluminio, fibra de vidrio con Kevlar y fibra de vidrio. Los diferentes materiales han sido estudiados usando modelos matemáticos para el diseño preliminar con el objetivo de entender y comparar los costes fijos y operacionales de la misma embarcación. Una discusión respaldada por gráficos, da indicaciones para identificar materiales que tienen mayores posibilidades de éxito para reemplazar la madera como material de construcción para buques fluviales de pasajeros en la región amazónica. El método del ciclo de vida fue usado para evaluar los costes (fijos y operacionales) de una embarcación construida con diferentes materiales a lo largo de su vida útil.*

Palabras clave: materiales nuevos; buques fluviales; región amazónica.

## 1 – INTRODUCTION

Passenger transport in the Amazon region has mostly based on wooden ships. Wood is used being the most abundant material in the region and since it allows for easy maintenance and replacement of hulls.

However, this type of construction has been suffering questions about their safety and future, once the timber is becoming increasingly scarce and more expensive. With the growing demand for water transportation of passengers in the Amazon region it has become necessary to search for new materials and construction techniques to make the transport of passengers more efficient, safe and sustainable according to the socio-economic profile of the passengers

## 2 – TYPES OF MATERIALS CURRENTLY USED IN SHIPBUILDING IN THE AMAZON REGION

As not all trees give wood usable in shipbuilding, this study only refers to analyse essences whose qualities make them especially recommended. The following list, referring to wood available in the Amazon region and commonly used in Shipbuilding, gives some of the main properties of the different types of wood.

**Piquiá** – Wood of high quality, compact, heavy and not easily decomposed by action of environment. Being a great resource for building the hull of vessels, it is widely used for the large parts of boats. The Piquiá is the preferred wood for the hulls of boats.

**Andiroba** – moderately resistant. Usage: marine stakes, bridges and vessels (keel, deck plating, caverns). It works very well immersed in freshwater environment. Texture ranging from fine to medium, possibly presents itself wavy. It is easy to laminate and with a slight tendency to crack with nails.

**Angelim** – Used in shipbuilding for deck boards, caverns, etc. Hard wood light reddish colour, fibrous aspect, coarse texture. Presents itself as very resistant to fungi and termites.

**Ipê** – highly resistant to fungi and termites. Usage: construction and shipbuilding, sleepers, luxury furniture, flooring, musical instruments, doors, window frames, etc.. Generally uniform, with greenish reflections, surface moderately smooth to the touch, fine to medium texture. The wood is heavy and hard, with high mechanical strength and low volumetric shrinkage. It is resistant to insect attack and rot.

**Maçaranduba** – Resistant to attack by fungi and subterranean termites and stands up well to moisture. For plumbing jobs, decorative objects, tool handles, furniture, farm implements, musical instruments, flooring, turnery, sleepers, construction and shipbuilding, docks for boats. It has a good texture which is fine and uniform, with a medium brightness. The wood is very heavy with a high volumetric shrinkage and mechanical strength of medium to high. It has high durability and natural tendency to crack if nailed or screwed without prior drilling.

**Pau-amarelo** – Wood with a very good resistance to attack by fungi, termites and dry-wood insects. Usage: tool handles, doors, lumber, furniture, sleepers, turnery objects, shipbuilding, flooring, bridges

**Pau-d'arco** – use: sleepers, posts, bridges, immersed works, heavy structures, pillars, framework, roof structures, floorboards, stairs, keels, deck, truck body, tool handles, household items.

**Sucupira** – The timber is moderately difficult to work, shows good performance compared to cutting by saw, but difficult to flattening, has high capacity retention screws and accepts varnish or polish, provided it is first applied to a substance filling the pores of the wood . Has use for sleepers, flooring, joinery and furniture, heavy construction, bridges and marine constructions (above water), stake and maritime constructions (submerged), poles, stakes and small hand tools.

### 3 – ANALYSIS OF NEW MATERIALS FOR SHIPBUILDING IN THE AMAZON REGION

The diversity of materials currently available for use in engineering is extraordinarily large, so there are increasingly specialized materials for specific applications. Composite materials represent a particularly important in the case of non-traditional engineering materials.

The constant technological advances allow reducing processing costs of raw materials thus ensuring a better use of the advantages of non-traditional materials. It is expected that these materials will have a privileged application in advanced markets (military, aerospace and aeronautics), and that they will have an increasing role in replacing traditional materials in more frequent applications of civil engineering and shipbuilding

#### 3.1 – Definition and composition

Composite materials may be defined as mixtures (macroscopic level) of non-soluble constituents with two or more distinct compositions, structures and properties that are combined and in which one of the materials ensures the connection - matrix - and the other resistance - reinforcement. The reinforcement presents itself generally in the form of particles, short fibres or long fibres (with diameter between 0003 and 0.03 mm). In Figure 1 are indicated and exemplified the different natures of the constituents of a composite material.

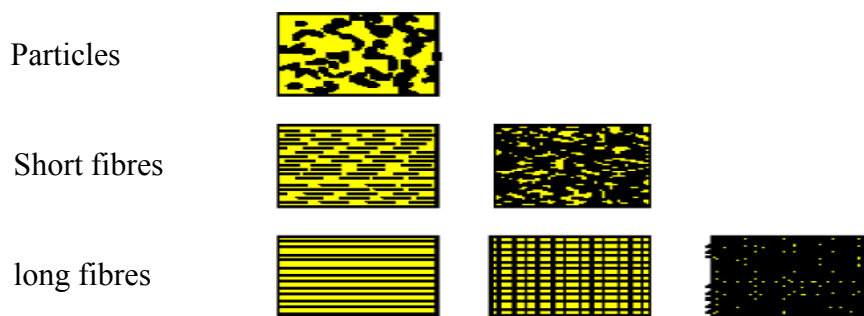


Figure 1 - Schematic representation of the types of reinforcement

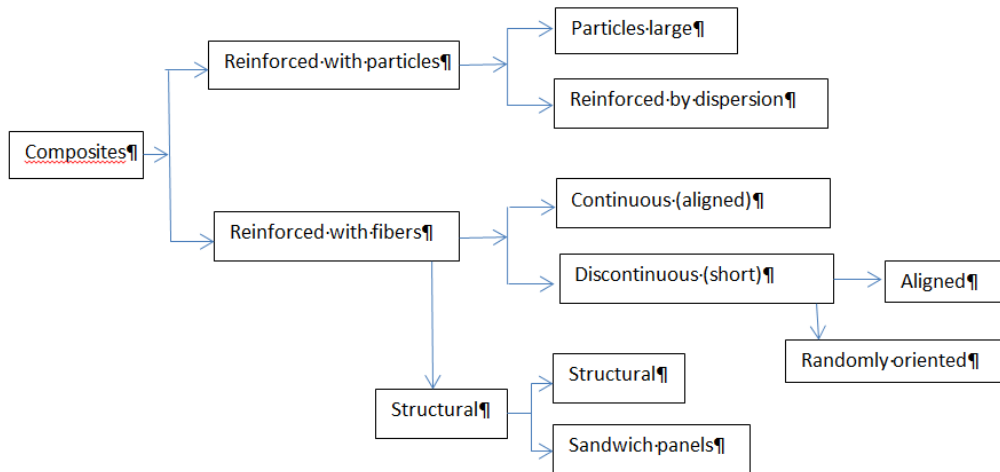


Figure 2 - Classification of composites.

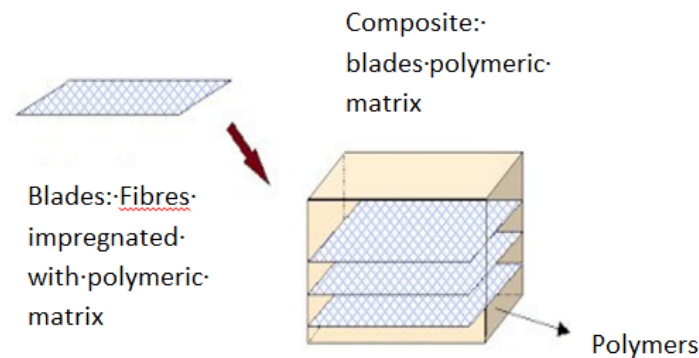


Figure 3 - Schematic structure of composite laminates

The main purpose of producing composites is to combine different materials to produce a single, with superior properties to those of a single component, whereby the combination of the constituent materials is determined from the specific application that is intended for the composite material and the relative importance on several factors such as:

- Resistance to corrosion
- Rigidity
- Weight
- Fatigue
- Thermal expansion
- Electromagnetic Properties
- Thermal conductivity
- Acoustic Behaviour
- Appearance

The high specific resistance and stiffness remains the combination spear composite materials into new areas, and a large damping capacity and low thermal expansion coefficient, characteristics that can be tailored for specific applications. Advanced composites will reduce the problems of fatigue, allowing greater flexibility in design and manufacturing processes. Other advantages of composites are resistance to extreme temperatures, corrosion and wear which may lead to lower costs of the life cycle of the product.

The matrix

The matrix of a composite material should, in addition to maintaining the cohesion of the fibres, ensure the following functions:

- Protecting the fibres of the environment;
- Protecting the fibres of damage during handling;
- Distribute the load of the fibres;
- Redistribute the load resistant fibres by a rupture.

Table 1 - Properties desirable for the matrix materials.

Mechanical-properties	High-resistance-to-traction
	Ductility
	Shear-resistance
	Tenacity
	Impact-Resistance
Thermal-Properties	Resistance-to-temperature-extremes
	Coefficient-of-thermal-expansion-close-to-the-fibre
	Low-thermal-conductivity
Chemical-Properties	Good-adhesion-to-the-fibres
	Resistance-to-degradation-in-chemically-aggressive-environments
	Low-moisture-absorption
other-properties	Low-cost
	Fast-solidification

Materials commonly used as matrix composite materials are polymers (thermoplastics and thermohardening), metals, ceramics and carbon. The polymer matrix composites have emerged in its structural aspect in the mid-twentieth century. This type of materials combined rigid and resistant fibres (glass, carbon and aramid) with an adhesive plastic matrix relatively soft and ductile (which may be polyester or epoxy).

The reinforcement

The reinforcement is a discontinuous component of the composite material and generally more resilient than the matrix and in case take the form of fibres allows the material to have capacity for resistance in the direction of loading.

Fibreglass

The process of manufacture of glass fibre can be summarized as follows: the molten glass is distributed through channels that lead to spinnerettes that remains at about 1250 °C which allows them to leak by gravity yielding yarns with few tenths of mm, these fibres are cooled to exit the spinneret, the first radiation and then by water spraying. The primary fibres suffer a surface finish obtained by coating.

Types of fibreglass

- C glass (Chemical)
- E Glass (Electrical)
- S Glass (Stiffness)

The fibreglass "E" is frequently used in the structural reinforcement of polymer matrix composites.

Table 2 - Advantages and disadvantages of fibreglass

Advantage	Disadvantage
-High traction resistance and compression -High chemical resistance -High resistance to fire -Good acoustic insulation properties, thermal and electrical	-Module reduced elasticity -High density -Sensitivity Abrasion -Sensitivity to elevated temperature -Low resistance to fatigue

### Aramid fibre

The aramid fibres are synthetic and of organic origin, obtained by a wiredrawing aromatic polyamide (benzene). These are generally designated by the trade name Kevlar (DuPont). The tensile strength and modulus of elasticity of longitudinal aramids are much higher than the corresponding properties of other organic fibres.

Table 3 - Advantages and disadvantages of aramid fibre fabric.

Advantage	Disadvantage
-Low specific mass -High traction resistance -High impact resistance -Low electrical conductivity -High chemical resistance to acids and bases except concentrated -High resistance to abrasion -Good fire resistance with the capacity of self-extinction. -Excellent behavior under high temperature of Service	-Low resistance to compression -Degradation under ultraviolet light -Low moisture absorption -Poor adhesion the resins -Relatively high cost

### Carbon fibres

Carbon fibres are produced from organic precursors which are already shaped in filament. They are obtained through the following operations: controlled oxidation stabilization between 200 and 300 °C with simultaneous stretching in the precursor material to induce molecular orientation properly; carbonation in a nitrogen atmosphere at a temperature between 1000 and 1500 °C; graphitization over 1800 °C.

Table 4 - Advantages and disadvantages of carbon fibre

Advantage	Disadvantage
-High traction resistance -High modulus of longitudinal elasticity -Low specific mass -High electrical conductivity -High dimensional stability -Low coefficient of thermal expansion -Good behaviour at elevated temperatures -Chemical inertness, except in strongly oxidizing environments -Good damping characteristics structural	-Reduced impact resistance -High thermal conductivity -Fragile Fracture -Low deformation before fracture -Low resistance to compression -High Cost

There are other fibres that can be used to strengthen composite materials, such as fibres of:

- Boron;
- Polyester;
- Polyethylene;

- Quartz;
- Natural fibre from Amazon: examples - jute, sisal, sugar cane, bamboo.

### Specific features and applications

During the last 20 years or so, there has been a large development of composite applications. The main motivation of this great development was the possibility to produce composites with high mechanical properties and low densities that could replace commonly used materials such as steel and wood. The combination of high performance polymers with ceramic or polymeric fibres of high tensile modulus and mechanical resistance, allows the production of new composites with a group of specific properties superior to steel, aluminium and others. These composites generally have higher values for both the modulus/weight ratio and the resistance/weight ratio. These are even higher than those of ceramic materials, polymers and metal.

The composite laminates made of high resistance fibres, surrounded by a matrix, have particular importance due to numerous applications in Aeronautical Engineering, Mechanical Engineering and Naval.

The efficiency of the composite material and its numerous advantages, for example, its high reasons rigidity / weight ratio and resistance / weight ratio, excellent corrosion resistance, low thermal expansion, good fatigue behaviour, portability, low power consumption in the process manufacturing and the structure itself, have spread its use arising from this fact, the need to efficiently analyse their complex behaviour. The use of composite materials creates engineering to more carefully examine the changes suffered by these materials over time of use, since the service life required in such cases is usually large.

### **3.2 – Materials for composite structure vessels**

Composites FRP (fibreglass Reinforced Polymer) using glass fibres, Kevlar and carbon fibres have excellent structural performance can be optimized with the use of manufacturing processes increasingly sophisticated especially when used sandwich constructions is eliminated where adding caves and stringers, allowing the fabrication to be very light and stiff. The cost of materials for construction in PRF is competitive when compared to aluminium and steel; however the largest economy occurs at the speed of construction, easy repeatability and low initial investment.

High performance boats and at the same time requires them a large radius of action and the ability to face severe service conditions, causes the material chosen for construction has high specific resistance (strength / density), eliminating heavy metals such as steel. The composite materials also have excellent stiffness and resistance, and good fatigue resistance and impact. FRP materials have been used increasingly not only on recreational craft, but also on service vessels and for the military. However, contrary to common sense, composite materials, using the same fibres as Kevlar, may have a better cost-effectiveness than the metals.

Boat building in PRF has the advantage of not requiring industrial tools, such as welding machines, cutting treadmills and overhead cranes. With a minimum of training, one can prepare a laminator, while for aluminium, it requires highly specialized in welding. Composite materials have characteristics of high productivity, especially for the manufacture of a large number of vessels, which is difficult to obtain in aluminium and other metals without a significant increase in production cost. Thus PRF enables a more rational and a variety of mechanical properties, combined with ease of construction, which most metals do not possess.

## Materials PRF

The mechanical properties of the composite material depend not only on what kind of material (fibre and resin) but also manufacturing techniques which in turn, allow the control of fibre content and final properties of the laminate. Temperature and pressure module also has a profound influence on the mechanical properties of the laminate. Figure 4 shows a graph of tension versus deformation for various laminates with 40% fibre content, compared with aluminium and steel.

Tension and deformation traction resistance comparison of laminates with 40% of Fibre weight.

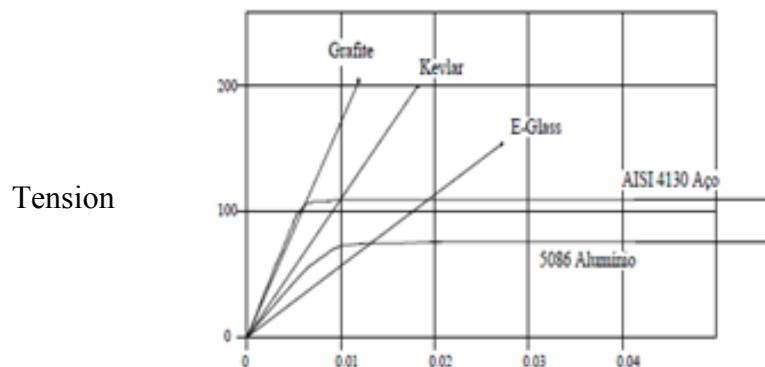


Figure 4 - Tension rupture for various materials

## Resins

The most common type of resin used in marine structures in PRF is the polyester. The latter has the lowest cost but also the lowest performance. The resin isophthalic has better resistance to osmotic and epoxy resins are preferred for structures that require high resistance, tenacity and rigidity.

## Reinforcing Fibres

Glass fibres of type “E” fibres are most commonly used in boat building because its balance of mechanical properties and cost. Fibreglass of the type “S” are used when more resistance is required. Aramid fibres, better known as Kevlar or Twaron fibres are among the most specific resistance because its low density. The aramid fibres are widely used in areas of high impact due to its high toughness. Carbon fibres have higher rigidity and higher tensile strength than the materials mentioned above. When carbon fibres are used exclusively, the construction tends to be penalized in terms of cost therefore, carbon fibres are only used in high performance applications.

## Core Materials

The faces of the sandwich panel are compared to beam flanges and resist compressive and tensile stresses, while the core material acts as supports cutting efforts. The most common material used as the core, are PVC foams. This type of construction provides a reduction in weight of the structure and at the same time, an increase of rigidity. The weight difference between the different types of construction is presented in Figure 5.

Approximate weight of hull 40ft, built with different laminations.



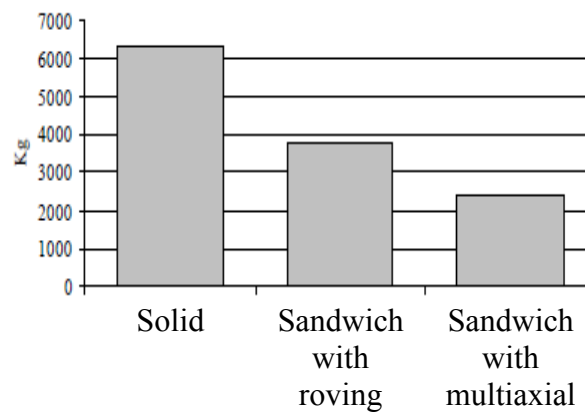


Figure 5 - Comparison of rolled

Further development of sandwich core materials on the market today was directed to increase the impact resistance and shearing. For vessels that suffer from impacts and dynamic loads, with ability to undergo large plastic deformations, allowing a higher capacity to absorb energy at impact. The core materials have a further advantage is that the thermal and sound insulation while working on the rigidity of the structure.

#### 4 – COST EVALUATION OF VARIOUS MATERIALS FOR PASSENGER VESSEL

This topic seeks to compare the cost of building and operating a single vessel built with different materials in order to verify the type of material that has the lowest total cost over the lifetime of the vessel and the capacity gains when using materials more lightweight. This analysis was to study if a route of 1600 km and vessel intended for the carriage of passengers and cargo.

To compare the cost of a vessel built with different materials. The project used as a basis of a wooden ship designed to transport cargo and passengers, with the following main features:

- Capacity (t) : 200.00
- Total displacement (t) : 309.18
- Length (m) : 31.42
- Beam (m) : 7.12
- Draught (m) : 2.26
- Depth (m) : 2.74
- Lightweight (t) : 79.38
- Weight of wood without motor (t) : 71.79
- Passenger capacity : 295
- Block coefficient : 0.61
- Speed (Knots) : 12.00

The general arrangement of the vessel is shown in the following figure.

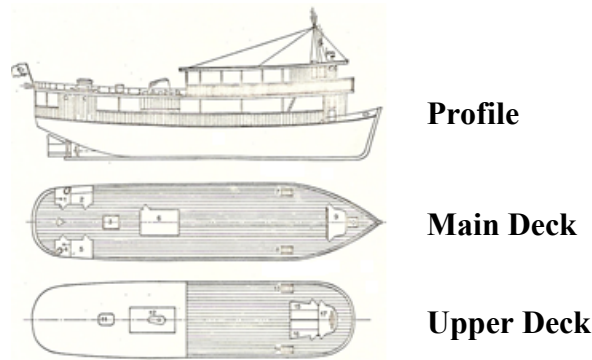


Figure 6 - Layout of the vessel chosen for analysis

#### 4.1 – Analysis cost of materials

Presented below is a comparison between the costs of five types of constructive materials in US\$/kg, which were: wood, steel, aluminium, fibreglass with the kevlar and fibreglass. It is observed that materials having lower cost per kg are wood and steel. The materials: aluminium, fibreglass and Kevlar with fibreglass have very high costs when compared with wood and steel, but they become competitive when an analysis of the reduction of weight by the vessel when using the total cost of materials over the life of the vessel.

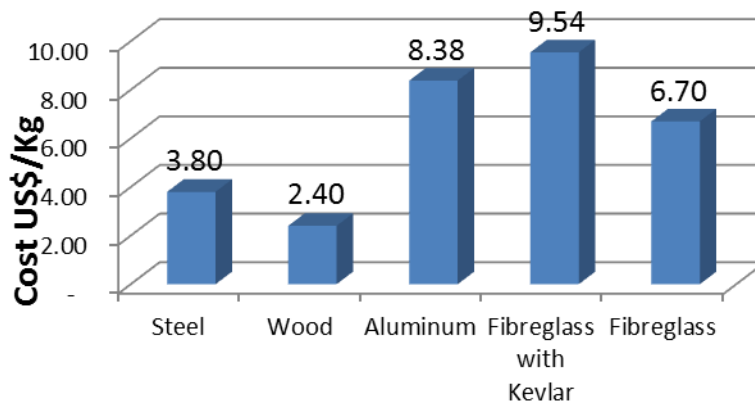


Figure 7 - Graph of the construction cost in US\$/kg by material

When analysing the capacity gain for the same vessel, it appears that the fibreglass with Kevlar is the material that has better capacity gain for providing a lighter weight for the vessel, followed by fibreglass and aluminium, having steel as a reference. The steel is the material that delivers the highest weight to the craft and further loss of capacity.

This data is very important, because despite being more expensive, lightweight materials have capacity gains with weight reduction by the vessel, which leads directly to increased cargo carrying capacity of the ship or simply the reduction of engine power by require less energy to propel the boat in design speed. This economy when examined over the lifetime of the vessel is very favourable to lighter materials by gains in capacity and fuel efficiency over the years.

The cost of materials for construction in PRF (fibreglass with Kevlar and fibreglass) is competitive when compared to aluminium and steel, however the largest economy occurs at the speed of construction, easy repeatability and low initial investment. Figure 8 the percentage weight for each material is compared with steel (100%) in the same vessel.

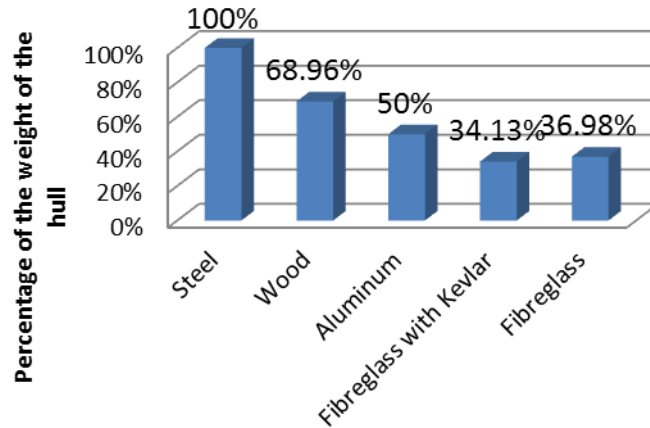


Figure 8 - Graph with the percentage reduction in weight by type of material for the same vessel.

When comparing the cost of the same hull built with different materials, it is found that aluminium is the material that has the highest overall cost, followed steel. The cheapest is still wood. It is observed that in spite of employing more weight for the same hull steel, the steel is still cheaper than aluminium which has a higher cost because of the high value per kg. Despite the cost per kg of the fibreglass with Kevlar be the highest of all, it generates less weight hull, making it a material that, although more expensive per kg, having cost competitive due to reduced overall weight of the hull.

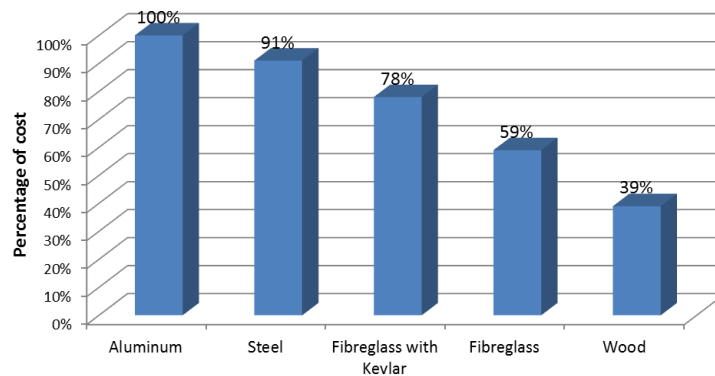


Figure 9 - Graph with the percentage reduction of cost by type of material for the same vessel.

Weight reduction by the vessel compared with steel, can be observed in Figure 10, which there reductions greater than or equal to 50%. As in the case of aluminum fibreglass with klevar and fibreglass.

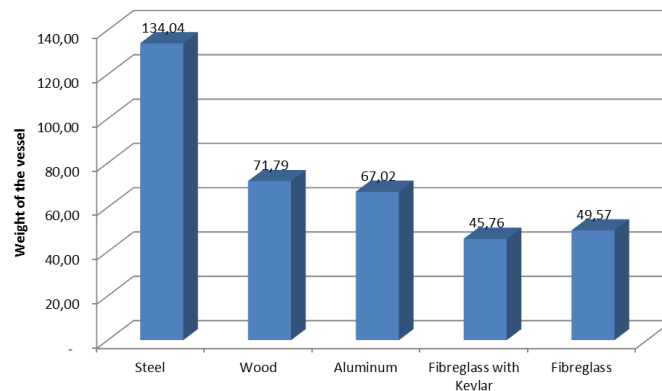


Figure 10 - Graph comparing the net weight of the vessel constructed with five different types of materials.

## 5 – EVALUATION OF COST FOR A LIFE CYCLE OF A VESSEL BUILT WITH DIFFERENT MATERIALS

The life cycle cost was studied over time the life of vessel with five different types of hull.

Hulls made with different kinds of materials also have different lifetimes and this must be considered. Thus, the following was considered useful lives for each type of material.

- Wood: 20 years
- Steel: 20 years
- Aluminium: 25 years
- Fibreglass with Kevlar and Fibreglass: 30 years

For the composite vessel (fibreglass with Kevlar and fibreglass) was assumed to be between 30-35 years in service, while the calculation 25 can be fairly optimistic for an aluminium vessel of the same size, since fatigue becomes a serious problem after that age.

From the point of view of manufacture, wood and fibreglass are the most economical to build boats. The following is presented in Figure 11 graph showing construction costs for the project studied.

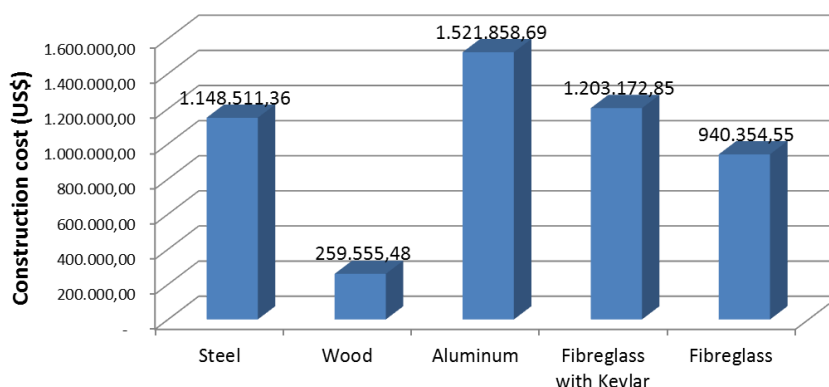


Figure 11 - Graph with the construction cost of the vessel constructed with five different types of materials.

However, the vessel will continue to create costs to the owners for operation and maintenance during use.

In this approach were taken into account for the assessment of the cost for a cycle of life, the same service, in terms of capacity, distance and speed in order to enable comparison.

This means that the motor power can be reduced for lightweight boats, as well as fuel consumption.

For all types of materials, a preliminary design was developed. The cost of the life cycle was developed as a systematic process of analysis to evaluate various designs made with different materials, with the goal of choosing the cheapest project at the end of the useful life of the vessel.

The holding of a evaluation the life Cycle Cost includes all costs of purchase and operation by the end of its useful life. Therefore, the costs of all items need to be considered. Current trends show that, in general, the complexity of systems and products are increasing as time to market must be reduced. At the same time, technology in nearly all industries is changing rapidly. The reason for the increase in costs combined with inflation makes it essential to optimize the design.

Optimizing this case does not mean a minimized acquisition cost in the short-term. The final objective is to focus on overall cost as a long term strategy. The costs related to an acquisition are often not transparent at first glance, which is illustrated by the "iceberg effect" in figure below.

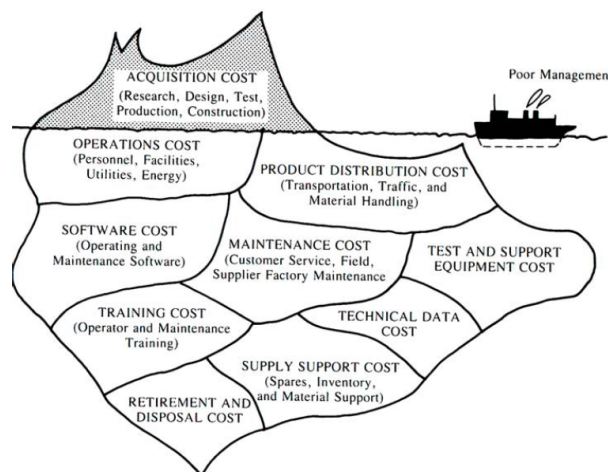


Figure 12 - What is visible and not visible in the total cost

A comparison of all the items of fixed costs and operating is shown in Figure 13, an overview where the cost is divided in two phases of the life cycle.

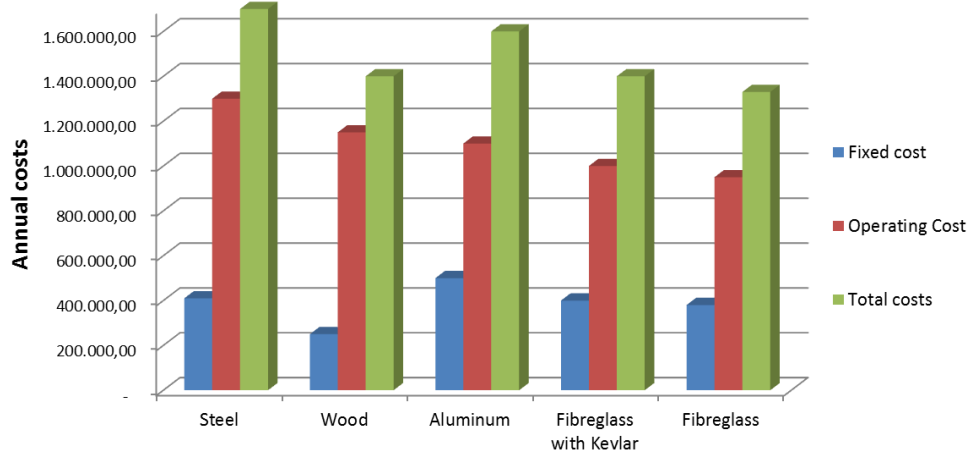


Figure 13 - Graph comparing the annual costs for a vessel built with different materials operating on the same route

Analysing only the acquisition cost of the vessel, the wooden vessel was the cheapest, followed by fibreglass and fibreglass boat with Kevlar and steel. However when analysing the operational cost, it appears that the vessel is steel which has a higher cost because of their greater weight, greater engine power and the resulting higher fuel consumption, where this cost item is the one with the higher rates of participation in the total annual cost.

The inclusion analysis of the operating costs over the lifetime of the vessel, gives advantage to the costs of vessels constructed of lightweight materials. Due to the price of raw material is raised to the ship constructed of aluminium and composites (fibreglass with Kevlar and fibreglass), these alternatives are more expensive in production. However, they gain competitiveness when they are analysed for the complete life cycle, which takes into account operating costs. The steel version requires more powerful machines because of its greater weight, which increases fuel consumption and maintenance costs. The main advantages of composite version (fibreglass with Kevlar and fibreglass), is low weight and reduced cost of maintenance of the hull structure.

The calculation indicates that a version of material fibreglass is the most economical option. The accumulated costs of steel version are superior to the version made after 4 years (2 years of operation). In the same perspective, the cost of aluminium version surpasses the composite version after 12 years (10 years of operation).

As shown in Figure 13, vessels of lightweight materials have higher fixed cost, however at the end of the useful life of each, where operating costs are analysed, lightweight materials turn out to be more economical since they need less motor power and consequently lower fuel consumption.

The distribution of power consumption for the five vessels shows the higher energy consumption for steel version, as expected. Most of the energy consumed during the life of all versions, is the fuel consumption.

As the price of fuel is around US\$ 1.00 per litre cost-benefit evaluation becomes quite favorable for the vessel built in composite material (fibreglass and fibreglass with Kevlar). Wood appears with small reduced cost, but it has other characteristics of obsolescence and replacement needs due to security issues.

Calculating the life cycle cost, the benefits of cost reduction in one year of operation, was US\$ 242,000.00 in favour of composite materials compared to steel and US\$ 156,000.00 for Aluminium. When one analyses these costs for a period of 25 years there is a difference of 6 million U.S. dollars of economy for vessels constructed of composite materials compared with steel, and 4 million dollars compared with the aluminium vessels for the proposed situation (same size vessels and operational characteristics of the route).

## **6 – CONCLUSIONS**

The use of composite materials has been successful in reducing weight criteria in naval applications where strength and rigidity are also required. In high-speed craft, lightweight composite materials offer a competitive cost level due to lower life cycle cost, which is basically obtained during operation, and lower fuel consumption.

Maintenance costs also have a positive influence, since they appear repeatedly, and are favourable for composite structures. In high-speed vessels are readily apparent benefits as in the case of significant reduction of fuel consumption which is an important criterion for making the decision.

In large slow ships benefits may be achievable with weight reduction in the superstructure, with significant gains in stability.

A combination of the use of composite steel and may therefore be favourable to ships large and slow. It is concluded that from this study that composite materials can come to replace wood in the construction of boats in the Amazon with good adequacy of cost to local economic reality as well as adds significant gains in relation the safe transport.

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