Trends in the Design Manufacture of Transportation Barges for Inland Water Ways

Cmde Retd N Kumar, *Non-member*

S R Suresh, *Non-member*

For a healthy and responsive transportation system, safety, security, conservation of energy and environmental quality are mandatory. This paper has discussed about the most efficient use of transport resources to attain substantial economic benefits without negative environmental impacts. A comparative study of the different modes of transport has been discussed which points towards Inland Water Transportation through Barges, as an efficient mode. The commonly used Barges have been elaborated with pictures for easy understanding and appreciation. The newly improved design of Barge results improved maneuverability, attainment of better speed, serving less accessible canals and rivers, carrying more pay-load by increasing Barge strength, reduction of construction costs by adopting innovative design, new materials and construction methods. This is termed as Inter-Barge concept, where Barge hulls are built faster and easier with less material and simple production. Moreover, FRP and weathering steel are suggested as new material of construction for their improved mechanical properties. Hence, the paper concludes that (i) use of Barges for transportation in Inland Waterways would be the invariable choice from the point of view of cargo capacities capable of being handled, relative energy efficiency and safety and (ii) adoption of new technology into their design and manufacture would lead to better cost effectiveness.

Keywords : Barge; FRP; Inter-Barge Concept; Hulls; Screw propelles Ro Ro technology

INTRODUCTION

Transportation has substantially shaped the growth and development of the nation. To sustain and enhance economic vitality and growth along with commercial productivity, the nation needs a healthy and responsive transportation system. It should therefore be ensured that the nation's transportation system supports safety, security, conservation of energy and environmental quality. The strength of this transportation system lies in its diversity, with each mode having its own system-specific advantages as follows

- Motor carriers having the ability to provide door-to-door service;
- Water carriers capable of handling bulk commodities safely at very low cost; and
- Rails for transporting a broad range of commodities over long distances.

The public good is best served by the most efficient use of transport resources, regardless of mode.

Efficiency and competitiveness of different transportation systems is essential to both economic growth and productivity and essential for modern society. There are substantial economic benefits to be realized from them, as also significant negative environmental impacts, including preemption of land, disruption of topography, use of energy and other resources, noise and air pollution. More and more public concern is focusing on these negative impacts.

Cmde Retd N Kumar and S R Suresh are with the Hindustan Shipyard Ltd, Visakhapatnam.

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PRINCIPAL CHARACTERISTICS OF TRANSPORTATION BARGES

Cargo Capacity

In terms of capacity, a 1 500 t Barge capable to carry 15 number of 100 t jumbo hopper rail cars or 60 number of 25 t trailer trucks as shown in Figure 1. When a standard Barge is 59.43 m long, 15 rail cars would be 251.46 m long and 60 trucks would be over a 0.8046 km long. A typical size Barge tow consists of 15 Barges that has a capacity of 22 500 t and is approximately 0.4023 km in length. The equivalent capacity of the other modes would be 225 rail cars measuring 0.8046 km and 1.2069 km long and 900 number of 25 t trailer trucks stretching 58 km — assuming 45.72 m gap between two trucks. To transport this 22 500 t over 1.6093 km, it will take 167.32 l of diesel fuel by water, 422 l by rail and 1448.67 l by truck.

Relative Energy Efficiency

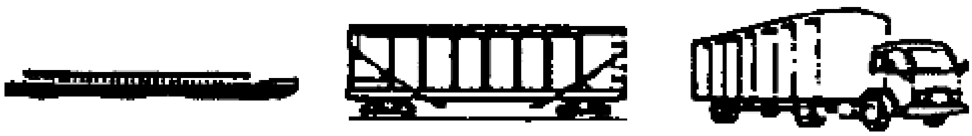
Most studies have concluded that water transportation is more economical in its use of energy/t-mile transported than either rail or truck, consuming significantly less fuel to do the same job. The energy cost/t-mile for truck is at least four times greater than rail, and five times greater than water transport.

While inland water transport requires 12 l of fuel / 1000 t-miles of freight, rail freight requires 16 l or 33 % more that Barges and truck freight requires 31.67 l or 164 % more than Barges.

The Eastman study shows that the distance through which 3.8 l fuel can move with 1 t is 95 km by truck, 325 km by train and 827.18 km by water as shown in Figure 1.

Safety

The inland water transportation environment, with its slow transit speeds, is relatively mild. The shock and vibration



Cargo capacities	1500 t Barge 52.500 bushels 1723.68 l	100 t jumbo hopper rail car 3.500 bushels 115 l	25 t trailer truck 875 bushels 28.5 l
Relative energy efficiency	216.42 km/t/l of fuel (822.4 km/t/gallon of fuel)	85.05 km/t/l of fuel (323.2 km/t/gallon of fuel)	24.84 km/t/l of fuel (94.4 km/t/gallon of fuel)

Figure 1 Eastern study

levels, which are dampened out by the cushioning effect of the waterway itself, are not normally considered as a problem. The commodities on which our lives and livelihood depend upon are transported by one mode or another and shallow-draft water transportation offers definite advantages as follows

- Significantly safer.
- Not intermixed in traffic.
- Less susceptible to accidents, preventing loss of cargo.
- Barge transportation has few crossing junctures.
- Is relatively remote from population centres.
- Less congestion.
- Reduced air/noise pollution.
- Barge spills occur much less often than spills from either tank trucks or tank cars.
- Barges, require far fewer units to move an equivalent amount of cargo.
- Design features, such as, double-hulls, bolted flanges, automatic shutdowns, and various spill containment devices help reduce the likelihood of a spill.
- Barges can be protected in tows which is unavailable for rail and truck.
- Relative human exposure index higher for truck and rail than that for water.
- Water transport is the safest and most regulated form of transportation.
- It maintain operational safeguards as well as strict federally-mandated inspection standards.

INFERENCE OF COMPARATIVE STUDY

The schematic diagram of Cargo transport is shown in Figure 2. From the comparative study, it can be concluded water transportation is the most economical and safe mode, subjected to proper choice of Barges.

TYPES OF BARGES

Principally, Barges are of two types.

Dumb Barges

Dumb Barges are usually pushed with a pusher tug. Slots on the stern of the Barge mate with the bow of the tug. Barges are often rafted up in pairs. The tug Barge combination is made to act as a single unit by tensioning cables at either side of the stern of the Barge to the tug.

To aid maneuverability, an auxiliary engine is often fitted to power bow or stern thrusters and to operate the anchor. It can be operated by an operator at the bow in radio contact

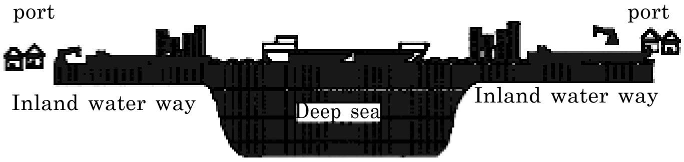


Figure 2 Basic concept of cargo transport using the Barge-Carrier system

with the tug with a controller unit.

The standard Barges can be configured into various tow configurations for transit. The typical configuration is a 15 Barge tow with one towboat. To accommodate the containers in the Barges, wooden dunnage blocks need to be installed underneath the bottom layer of containers. Illustration of a Dump Barge is shown in Figure 3.

Powered Barges

Inland waterway Barges have a low air draught and a very low freeboard when loaded. Both the bridge and masts are often collapsible so as to pass under low bridges.

Both Dumb and Powered Barges

- able to carry general cargo and are built specifically for an identified type of cargo, such as, chemicals or cement;
- have dimensions which exactly fit the cargo like intermodal containers;
- are operated by companies / owners with the family living on board; and
- have very well appointed living accommodation.

Various types of Barges in common use are enlisted and depicted below through representive illustrations by Figure 4 to Figure 9.

(i) Barge with tanks for carrying cement products
(ii) Barge for carrying vehicles having bow doors
(iii) Barge for carrying containers
(iv) Barge for carrying spoli or bulk cargoes
(v) Tanker Barge
(vi) Pallet-carrying Barge

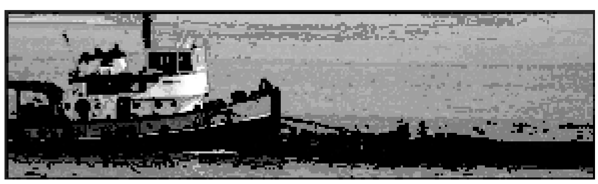


Figure 3 Illustration of a Dumb Barge

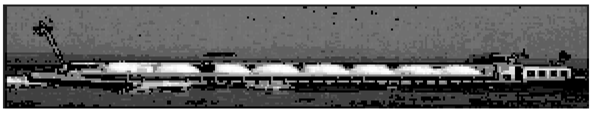


Figure 4 Barge with tanks for carrying cement products

Figure 5 Barge for carrying vehicles having bow doors

Figure 6 Barge for carrying containers

Figure 7 Barge for carrying spoli or bulk cargoes

Figure 8 Tanker Barge

Figure 9 Pallet-carrying Barge

BARGE DESIGN AND BUILD TECHNOLOGY

Design and technology is constantly being developed by shipping farms to

- improve maneuverability;
- attain better speed;
- serve less accessible canals and rivers;
- carry more pay-load by increasing Barge strength;
- reduce construction costs by adopting;
  - innovative design;
  - new choice of material; and
  - new construction methods.

Optimization function should aim to achieve the following

- fuel efficient ship;
- cost effective inland water transport; and
- production effective ship.

Some methods currently under study towards achievement of the earlier objectives are presented here.

Towards Better Fuel Efficiency by Reduction of Weight

Contemporary hulls are made of steel and not differ too much from those of few decades ago which consists of durable construction, with a life span of 50 years. Use of high tensile steel would lead to only negligible weight reduction. This reduction of weight by application of new materials, like Al, composites etc is feasible for smaller vessels only.

The most promising alternate in this field is the application of Sandwich Plate System (SPS).

This system replaces traditional steel plate with stiffeners and comprises of two plates with welded perimeter bars where in between an elastomer is injected to form a solid unit. However, Classification Societies' Rules need to be adapted accordingly for acceptance of the new trend. A typical cross section of an indicative construction for a light weight Barge is presented Figure 10.

New light weight construction materials and innovative structural design, therefore, help in optimizing shallow draught propulsion systems and hull forms.

Towards Better Propulsion Efficiency

Main propulsions on IWW vessels are Screw propellers. Some promising types of Screw propeller are

- Propellers in nozzles (FPP, CPP, rudder-propeller, slotted nozzles)
- CRP and Tandem propellers;
- Pod (diesel-electric) propulsors; and
- Combination of horizontal mechanical and pod propulsors.

Illustration of some typical Screw propellers are shown in Figure 11.

Towards Improvements in Propulsion Plants

Nowadays, diesel engines dominate IWW. New generation of diesel engines are lighter but require higher gear ratios.

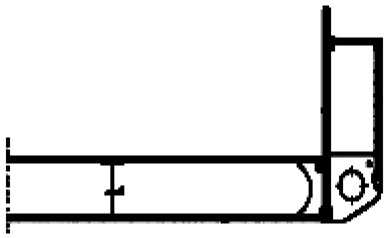


Figure 10 Typical frame cross section of *I*-core *R* panel Barge

(a) (b) (c)

Figure 11 (a) RR Ulstein CPP (b) Schottel twin propeller and (c) VETH FPP in nozzle

Environmental considerations will guide and force future engine development. A break-through in this direction is expected in the next 20 years. In the meantime, emission problems with diesel engines could become more pronounced. In this context, a few other types of engine are currently under study as below.

- Gas turbines of characterized by high power to weight ratio, reliability, controllable exhaust gases, but relatively efficient for high powers only, costly, high gear-ratios are necessary
- Fuel cells which is in experimental phase. However, R&D focused on road vehicles, where goal is to the achieve zero emission.

However the improvements in propulsion and transmission efficiencies would prove more advantageous and also result in enhanced maneuverability, thereby proving more significant than the choice of the Propulsion Plant.

Towards Carrying More Pay-load and Improved Barge Strength

Inter-Barge concept represents state-of-the-art Barge design with efficient Ro Ro technology which shows how the inter-Barge solution might be adopted to accommodate the requirements for cost and speed of handling the cargo.

Choice of Alternate Material for Construction

Quality engineering, construction and advanced materials ensure the Barge owners regarding trouble free ownership for many decades.

FRP Construction

The minimum material strengths and properties of FRP are as follows

Tension	2320 kg/cm^2 (33 000 psi)
Compression	2320 kg/cm^2 (33 000 psi)
Shear	316.4 kg/cm^2 (4 500 psi)
Bending	2320 kg/cm^2 (33 000 psi)
Young's modulus	196859.6 kg/cm^2 (2 800 000 psi)

The minimum thickness of the FRP composite elements in general are as follows, unless otherwise specified:

- Square tube members (closed type shape) shall be 0.635 cm.
- Wide-flange beams, channel sections, and angles (open type shapes) shall be a minimum thickness of 0.635 cm.
- Standard plate shall be a minimum thickness of 0.635 cm.

Fasteners in general use are 316 stainless steel bolts and nuts for a long lasting rust resistant construction.

MANUFACTURE OF FRP BARGE HULL

The Barge construction system incorporates a factory built FRP or fibre reinforced polymer, bridge truss element into Barge design. The strength of these bridge truss elements when compared to steel is very close. The difference is in the weight and the cost. While a bit higher in price when compared to a galvanized steel frame truss they will never rust or corrode so they will provide a longer service life to the Barge. Figure 12 demonstrates the structure of the Barge.

The Barge construction has reduced steel weight through the use of curved steel plates enabling better cargo carrying capacity and economy for transporters compared to conventional Barges of same size. The inter-Barge new construction concept enables building ship/Barge hulls easier and faster with less use of steel, fewer and easier operations during production, and thinner shell plating due to the concept of increased ability to resist water pressure. Moreover, inter -Barge alternative adopts the basic idea of the structural concept to take advantage of the imminent strength capacity of a plate after the bending resistance limit is exceeded. A plate clamped at the ends is many times stronger when the acting forces are absorbed in the plate — as membrane tensions instead of stresses as in bending.

Benefits derived from this new construction concept are as follows

- By giving the plate a curvature, the above state will be obtained and the stress level in the plate decreases compared to a flat panel. This again will allow the plate thickness to be reduced without a reduction of the strength of the plate, as shown in Figure 13.
- The second benefit that comes from using this concept is that, the number of strengthening members in the construction can be greatly reduced. In contrast, a Flat panel, as illustrated in Figure 14(a) and 14(b) has to be supported by closely spaced supports due to the low bending resistance of the plate, whereas, a curved plate in tension will need no support between the clamping which will reduce the weight and simplify the production of the structure. A curved panel configuration is shown by Figure 14(b).

These FRP bridge truss elements are fabricated primarily

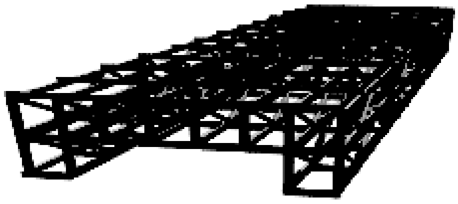


Figure 12 Truss structure of FRP hull

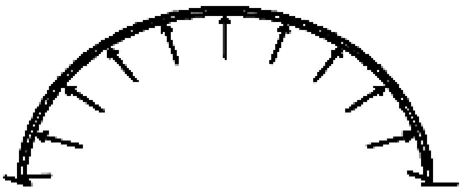
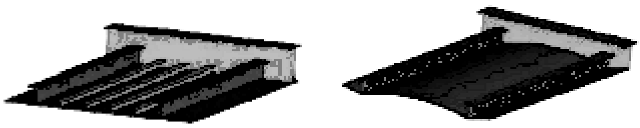


Figure 13 Curved plate with water pressure at the inner wall. Plate acts like a membrane



(a) (b)

Figure 14(a) Flat panel and (b) curved panel

from high-strength E-glass and isophthalic fire retardant polyester resin (Series 1525). Weathering and ultraviolet light protection is provided by addition of a veil to the laminate construction.

MANUFACTURE OF FRP BARGE OUTER SHELL

The composite outer shell cladding system is made from high quality pultrusion sheet pile material which is 40.64 cm to 45.72 cm in width and is in interlocking form, that provide a continuous shell structure and external cross bracing provide added strength to the structure. The structure of an outer shell is shown in Figure 15. The same material is commonly used to hold back tons of fill along a shoreline. In its most common use, this material is used to hold in tons of fill rock and dirt on one side and a body of water on the other. The strength of this material is 2109.09 kg/cm^2 in compressive strength, flexural strength and tensile strength. This is far in excess of any other material of this weight and cost.

The weight, strength and cost are comparable. This material with a final UV stable urethane coating is used to improve on the rather dark and utilitarian appearance of the sheet pile material.

MANUFACTURE OF FRP BARGE DECK

The deck is made from a similar pultrusion material that is designed to fit tongue and grove together to form a strong deck platform to construct upon. The Barge is then completely filled with 0.907 kg urethane foam so that no moisture reaches the inner structure. The inner surface of the sheet pile is also coated with a heavy urethane coating to prevent water from seeping into the structure from the bolt holes.

MANUFACTURE OF FRP BARGE BULKHEADS

Corrugated FRP sheets moulded to the required size and shape, to provide the required strength, prove to serve the intended purpose of steel bulkheads at lesser cost and weight which is termed as bulkheads. Figure 16 depicts a typical corrugated FRP bulkhead construction with reinforced edges.

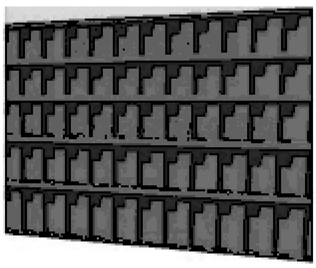


Figure 15 Outer shell/decks

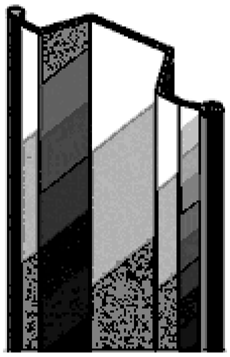


Figure 16 Bulkheads

CONSTRUCTION WITH WEATHERING STEELS

Use of Weathering steels for shell plating of Barges is under active study. Weathering steels, such as, ASTM A588, A242, A606-4 and Cor-Ten exhibit,

- Minimum yield strength characteristic of 50,000 psi. (3515.35 kg/cm^2).
- Same long term life / strength expectancy as thicker mild steel, with use of lighter gauge.
- Cost reduction through the ability to design lighter sections into structures, thereby.
- Superior corrosion resistance over regular carbon steel.
- Slow corrosion rates, due to development of protective oxide film on metal's surface.
- Reduction in maintenance costs, arising due to non requirement of painting.
- End results of a lighter hull, giving more usable weight carrying ability.

Since, their development, weathering steels are now being used in shipbuilding.

CONCLUSION

When decisions are being made concerning a choice of modes, consideration should be given to the mode that does not contribute to unnecessary increases in fuel use, exhaust emissions, accidents, spill incidents and congestion. Each form of transportation, as a major energy user, needs to be evaluated both, as to the scarceness and future availability of the energy resources that it uses and to its impact on the environment. Use of Barges for transportation in Inland Waterways would be the invariable choice from the point of view of cargo capacities capable of being handled, relative energy efficiency, safety. Adoption of new technology into their design and manufacture would lead to better cost effectiveness.

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