Current trends in the construction of reinforced concrete ships

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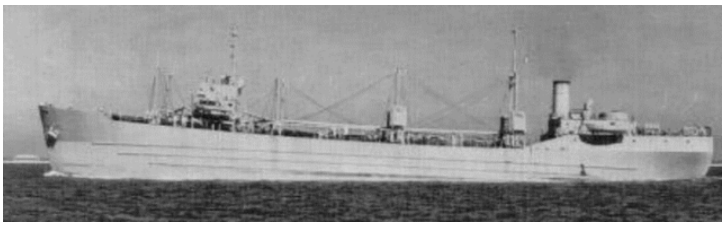
Nowadays, rolled steel is used as the main construction material in shipbuilding. However, in 1849, French inventor Jean-Louis Lambo came up with the idea of creating a rowing boat, the frame of which consisted of reinforcing mesh with cement mortar applied on top. The Frenchman presented his invention at the International Maritime Exhibition in 1885, which became a real sensation of those times.

Already during the First World War, when the warring countries needed a huge number of ships while experiencing an acute shortage of high-quality steel, they returned to the use of such technology. By 1919 more than 1 thousand reinforced concrete ships had been built, most of them in Italy, Germany, Norway, France, Denmark, Sweden, USA, and China.

P.1 The concrete tug Paul Kossel from 1920 at the Bremerhaven Maritime Museum.



Concrete shipbuilding returned during World War II. In the USA, 24 self-propelled "Liberty" type transport ships and many non-self-propelled reinforced concrete ships were built.

P.2 Ironclad Liberty, built in 1943.

Concrete is much more accessible and cheaper than steel. Therefore, in hard times this method of construction had considerable popularity. In addition, during the interwar period, the technology of reinforced concrete ship construction was significantly improved. The new ships were stronger and lighter than their predecessors and were built in record time – in just one month. They were usually used for transportation of various cargoes, including ammunition. They were also used as huge floating pontoons, to create cul-de-sacs in various harbors, to make crossings, and for other purposes.

Reinforced concrete ships surpassed steel ships in all parameters (even in protection from combat impact), except for cargo capacity, which, due to the greater mass of the reinforced concrete hull of the ship, was about 30% less than that of similar steel ships, and due to the lack of corrosion of concrete in the water, the economic efficiency of the self-propelled reinforced concrete ship was the same as that of a similar steel ship.

As for non-self-propelled reinforced concrete ships, the operating costs of one of them were more than three times lower than those of a similar steel ship, which was also 13% smaller in displacement.

Reinforced concrete ships are still being built today, usually as mooring vessels: floating berths, oil storage and drilling platforms, floating hotels, and warehouses. The costs of operating their hulls are considerably lower than those of similar steel vessels, and vessels built in the early 20th century retain their strength properties in technically serviceable condition to this day.

As the practice of Kherson State Plant "Pallada" (Ukraine), one of the two enterprises building composite reinforced concrete floating docks in the post-Soviet space has shown, reinforced concrete shipbuilding is due to the following advantages of composite floating structures as compared to all-metal ones:

- Hull maintenance costs are reduced by 6-10 times. Shipbuilding concrete does not deteriorate over time under the influence of corrosion in seawater like steel and does not reduce its strength properties.
- Reinforced concrete floating structures under normal operation can serve up to 70 years, which is 1.5 – 2 times longer than steel ones and which significantly reduces the size of amortization charges.
- The cost of composite docks construction is 15-20% lower than similar all-metal docks with less capital investments for the organization of production, which gives sufficient economic effect connected both with construction and operation.

If we compare ship hull manufacturing technologies, in conventional ship construction, metalworking takes more than 60% of the labor intensity of construction: complex surfaces are assembled from "small" sheets, there are a lot of assembly operations, a lot of misalignments, fitting, and welding. This percentage is much higher compared to the composite concrete ship construction technology, which involves first installing large-block equipment and then erecting a composite concrete hull around the pre-installed and tested ship equipment. In turn, creating composite reinforcement of any shape is easier than producing steel reinforcement, making it easier and more economical to build complex ship hull structures.

However, maritime transportation is a rather conservative industry, so the solutions for the technology of reinforced concrete ship construction have not changed much over the last 50 years, while the technologies of ship construction from other materials have been constantly improving.

But modern consideration of the issue allows us to start applying the latest shipbuilding technologies associated with the replacement of the main structural material of shipbuilding - rolled steel - with concrete reinforced with composite reinforcement of new forms (the so-called composite concrete).

By replacing the steel reinforcement with a less massive composite, a 30% reduction in vessel weight is achieved, thereby increasing the carrying capacity by the same value.

The cost of metals is currently very high, and the cost of polymers, on the contrary, is significantly lower, which achieves the effect of reducing the cost of construction by several times. The use of composites also implies the reduction of energy costs during the construction and operation of a concrete vessel, and at the same time, an unprecedented reduction of harmful emissions is achieved.

Simplified construction technology, no need for traditional shipbuilding facilities and shipyards, greater durability, and lower construction costs are the advantages of composite concrete shipbuilding that private and national shipbuilding companies should pay attention to.

By applying modern software to ensure the optimization of concrete composite ship structures, it is possible to achieve higher than previous values of strength, and thermal conductivity (to ensure structural fire protection of the ship), and reduce costs.

Modern technology of printing with concrete 3-D printer, which is used by advanced builders in shipyards, can be applied without limitations in this area of shipbuilding.

It is proposed to build new shipyards with such printers, having the dimensions of the dock itself built into it as the main part of it.

Concrete shipbuilding remains a promising direction, for example, the use of glass microspheres in the concrete mixture as an inert material instead of sand, the use of composite materials either with mineral binder for reinforcing concrete or without binder at all, which provides the required heat resistance of composite concrete, as well as the possibility of its recognition as a non-combustible material, the use of modified glass-ceramic granules based on widely used types of alumina-containing raw materials and technogenic waste.

At present, there are technologies of high-strength self-compacting concrete of low strength with porous lightweight aggregate - stalite, produced in the USA from unique natural raw materials. It provides the necessary strength of lightweight concrete and, most importantly, meets the requirements of modern construction technologies (use of concrete pumps).

As reinforcement, it is possible to use composite pipes with different cross-sections and other 3D shapes made of carbon fiber-reinforced plastic and other composite materials.

These perspective technologies allow to building of composite concrete vessels of any displacement on the unequipped shore at minimum power consumption (for example, for the construction of even several hulls of such vessels of any displacement only one 100kW diesel generator is needed at the same time).

The materials used and the technologies employed provide unprecedented environmental protection and ecological preservation:

- reduction of harmful emissions into the atmosphere by dozens of times;
- utilization of industrial waste (large-tonnage man-made raw materials);

Composites are "slowly but surely" occupying the niches where metals and their alloys were used before.

The global composites market is about 11.5 million tons per year, which is five times smaller than the aluminum market and 30 times smaller than the plastic market. Composites are more than 150 times smaller than the steel market, but in the period 2010-2020 the greatest penetration of composites was observed in wind energy (15% growth) and shipbuilding (7% growth), which indicates the promising use of these materials.