say twelve diameters in the small rods and eighteen diameters in the rods over 1 inch diameter, relies mostly upon the hooked ends and appears to be a satisfactory solution, as it reduces weight without sacrificing strength. Welding is certainly the most economical as regards weight, but if done in the shop makes the rods difficult to handle and keep in shape, and if in place may result in a local weakening of the rod at the weld. A mechanical connection such as a turnbuckle, to unite screwed ends of the rods, is sometimes adopted for special purposes. The cost of welding and mechanical connection is usually considered prohibitive. In each of the above cases the loss due to the weakness of all rivetted seams or butts in a steel ship is avoided.

In order to resist the diagonal tensile stresses induced in a beam by the action of the shearing force, stirrups are frequently introduced extending between the tension and compression members. They may be considered as the web members of a truss system, the triangulation of which will vary as they are placed vertically or diagonally.

In ordinary building work, considerable dependence is placed upon the "adhesion" of concrete to steel, as it is called, but perhaps it would be better to speak rather of the "grip," as indicating that the bond between the steel and the concrete is derived chiefly from the contraction of the concrete in hardening in air. Therefore precaution is taken to give a mechanical bond by hooking or bending the ends of all reinforcement. It will be found advantageous to employ concrete richer in cement than that ordinarily used for buildings, and made with ballast or other coarse material (sometimes called aggregate) restricted in size. There is also another element in question, as to what reduction in stress, if any, should be allowed in concrete which is always kept in water and that which is alternately wet and dry, while it is necessary in addition to ascertain what effect salt water has on the strength of concrete as used in a vessel, although data go to show that salt water has no effect on a dense concrete: this is a subject that can well be experimented with in regard to concrete shipbuilding.

In a steel ship, say, up to 1,000 tons, it is usual to allow a stress of 8 tons per square inch on the steel, but in view of the uncertainty of the behavior of the concrete work at sea, it will no doubt be found advisable to allow only one-fifth of the ultimate tensile resistance for the reinforcement.

Weight of Hull

The weight of reinforced concrete hulls is the most serious problem in the adoption of this type of vessel, the concrete being 143 lbs. per cubic foot, plus the reinforcement.

The bare hull with fittings of a coasting vessel of, say, 300 tons deadweight, will weigh 130 per cent. more than that of a steel vessel, while the increase in total displacement is about 40 per cent. (see table below). Put in another way, if a concrete coaster was built of the dimensions and coefficient of fineness of a 420-ton deadweight steel vessel, it would only carry 300 tons deadweight on the same draught.

The linear increase (length, breadth, and depth) would be 12 per cent. to 14 per cent. greater for a concrete vessel than for a steel vessel.

The table below gives a comparison of a 300-ton deadweight auxiliary coaster in concrete, wood, and steel.

The practice of stating that a concrete hull is from 50 per cent. to 70 per cent. heavier than a steel vessel of the same dimensions does not give a fair comparison, because the concrete hull would carry much less cargo. The method of comparing the weights of vessels of similar deadweight has therefore been adopted.

It will be seen that the total steel is only 27 per cent., the reinforcement alone accounting for 25 per cent. of that of a steel vessel of the same deadweight capacity.

Comparison of a 300-ton D.W. Vessel in Concrete, Wood and Steel.

	Reinforced Concrete.	Wood.	Steel.
Length	125 ft. 0 in.	108 ft. 0 in.	105 ft. 0 in.
Breadth	25 ft. 0 in.	23 ft. 9 in.	21 ft. 0 in.
Depth	11 ft. 9 in.	10 ft. 7 in.	11 ft. 4 in.
Draught, bottom of keel aft	10 ft. 3 in. (no keel)	10 ft. 3 in. (keel)	10 ft. 3 in. (no keel)
Deadweight cargo, tons	300	300	300
Cubic capacity of holds and hatchways, ft.^{3}	17,320	12,350	12,500
Displacement, tons	640	495	455
Time to construct, months	4	8	6
Weight of steel, tons	28½	15	110
Weight of bare hull, tons	290	140	120

Disadvantages

The principal disadvantages are: —

(a) Greater weight and consequently greater displacement for the same deadweight.

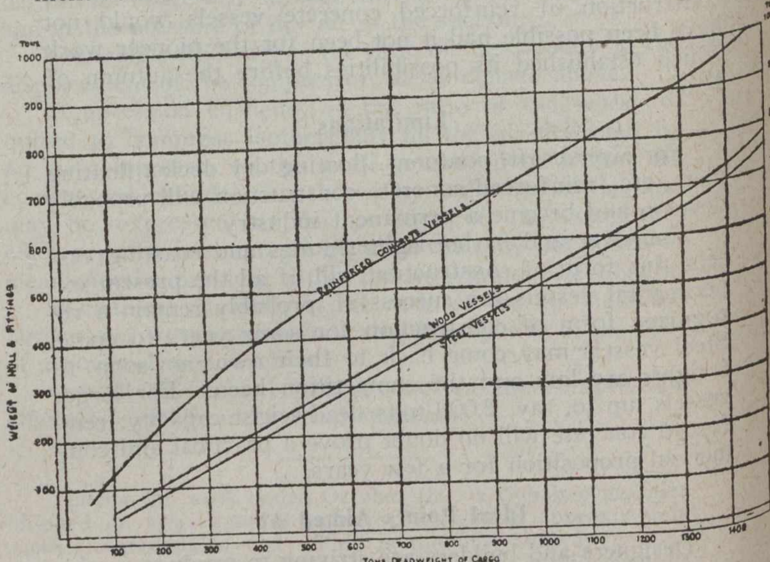

Fig. 1—Curve of Comparison of Dead Weights

(b) Increase of net tonnage and consequent increase in port and harbor dues.

(c) Increased cost of building and launching ways.

(d) Longer time to repair if bottom repairs are necessary.

Advantages

(1) Much less steel than is necessary for a steel vessel, and no waste due to scrap.

(2) No loss of strength due to rivet-holes and jointing as in a steel vessel.

(3) Cheaper and quicker construction.

(4) Very little skilled labor, no platers, anglesmiths, or riveters required.

(5) Longer life and reduced depreciation.

(6) Reduced upkeep and repair bill.

(7) Freedom from dry rot as in wooden vessels and freedom from corrosion as in steel vessels.

(8) Smoother surface and less skin friction.

With regard to depreciation: so far as can be at present ascertained, the concrete should last for several hundred years. Depreciation, however, may take place in the steel bars due to corrosion and fatigue of the metal. The former will only occur if the concrete is permeable to water and air; this can be avoided by a careful selection of the materials used and by strict