lowed over these figures, and the vessel was designed to stand the stresses corresponding to the following:—

$$\text{Hogging moment } \frac{\text{Displacement} \times \text{length}}{35} = 13{,}500 \text{ foot-tons}$$

$$\text{Sagging moment. } \frac{\text{Displacement} \times \text{length}}{48} = 10{,}000 \text{ foot-tons}$$

$$\text{Shearing force .. } \frac{\text{Displacement}}{9.8} = 240 \text{ tons.}$$

the structural material being arranged so that the tensile stress on the reinforcement, taking account of all local stresses, never exceeded 9 tons per square inch, and the maximum compressive stress on the concrete 750 lbs. per square inch.

Transverse Strength

In calculating transverse strength, the transverse framing was analyzed in order to ascertain the maximum bending moment to be resisted by the floors, frames, and beams under the various systems of loading to be met with in service.

The conditions assumed, for which calculations were made, are as follows:—

(1) Vessel, without pillars, loaded to deep draught in still water. Cargo load in hold and on deck.

(1*a*) Vessel, with two pillars fitted, one at each side of hatch opening, loaded to deep draught in still water as in condition (1).

(2) Vessel, with two pillars fitted, loaded as in (1), and situated on wave crest, with no cargo on floor girder.

(3) Vessel, with two pillars fitted, loaded and situated in wave hollow with full cargo, load centrally placed below hatches and no deck cargo.

(4) Vessel, with two pillars fitted, in light condition, in dry dock, docked on centre keel.

The calculations were investigated on the "principle of least work," taking the reinforced framing as monolithic.

In the moment as calculated there has been taken into account the stresses in the framing where only a partial support is received from the pillaring through the medium of longitudinal girders spanning between the transverse frames. The scantlings of the framing have been proportioned to the more severe conditions met with at the centre of floor girders, bilge, side frame, deck corner and beam.

As a basis for calculation of strength, the following were adopted as working limits for safe stresses on concrete and steel:—

Concrete

Item.	Working Stress, lbs. per sq. inch.	Ultimate Stress, lbs. per sq. inch.
Compression in beams	750	4,000
Compression direct	700	4,000
Shear	70	280
Adhesion	60	240
Adhesion	100	500

Steel

Item.	Working Stress, tons, sq. in.	Elastic Limit, tons, sq. in.	Ultimate Stress, tons.
Tension, spiral bars	9	23½	30-36
Tension, plain bars	7½	15	27-30
Compression	7½	15	27-30
Shear	5½	..	24

Particulars and Description of Hull

Particulars are given of a ferro-concrete, a steel and a wooden ship, each designed for a deadweight carrying capacity of 1,150 tons, as follows:—

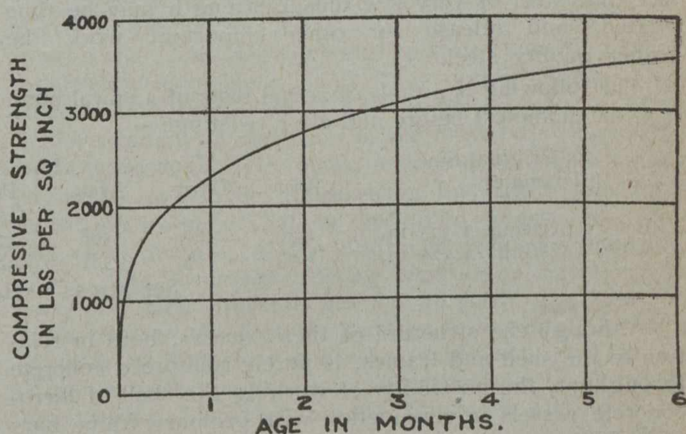
	Reinforced Concrete.	Steel.	Wood.
Length	205 ft. 0 in.	188 ft. 0 in.	205 ft. 0 in.
Breadth	32 " 0 "	30 " 3 "	36 " 0 "
Depth	19 " 6 "	17 " 3 "	18 " 9 "
Draught	15 " 6 "	14 " 6 "	16 " 6 "*
Deadweight	1,150 tons	1,150 tons	1,150 tons
Displacement (load)	2,350 "	1,800 "	2,400 "
I.H.P. (about)	400	400	400

Weights.

	Reinforced Concrete.	Steel.	Wood.
Steel in hull†	190	445	140
Remainder of hull	860	80	960
Machinery and boilers..	80	80	80
Outfit‡	70	45	70
Deadweight	1,150	1,150	1,150
Load displacement...	2,350	1,800	2,400

*Includes 12-in. wood keel.
†Includes hull castings and forgings.
‡Includes anchors, cables, boats, auxiliary machinery, etc.

It will be noticed that the weight of steel in the ferro-concrete ship is about 42½ per cent. of that in the steel ship. This is not by any means such a large reduction



	Cement.	Sand.	Aggregate.
Mixture (by volume) of concrete used.	1.0 :	1.2 :	2.4

Fig. 3—Diagram showing Increase of Strength of Concrete with Age

as some writers on ferro-concrete ship construction have anticipated, nor is it probably the minimum quantity which should be adopted, had we been prepared to incur a certain amount of risk in structural strength. In view, however, of this being our first venture in a new method of construction, we did not feel justified in reducing the strength until we had ascertained from experience how a ship constructed on this principle would act under ordinary conditions of service. One reason was that, should the vessel prove weak, it would be a matter of the utmost difficulty to introduce additional stiffness and strength. A second and even more potent reason was that we were not justified in risking the safety of the ship or the lives of the men who might navigate her, for the purpose of endeavoring in the first ship to reduce the quantity of steel that might be used to the minimum. Actual service will perhaps give an indication where weight may be saved, either in the steel or concrete of the hull; and that such saving will ultimately be effected, even with identical methods of construction, we confidently anticipate. It must not be overlooked that the saving of steel effected, especially under present conditions, is of the greatest importance. If we take, say, 200 vessels similar to the one under discussion, we should have an additional carrying capacity of 230,000 tons added to our mercantile fleet,