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# CONCRETE SHIPBUILDING.

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Quite apart from the military aspect, most Australians have realised that this country has not done its part so far in assisting to bring the war to a rapid and satisfactory conclusion. It is true that we tried some time ago to make shells, and that we have all along assisted in augmenting the food supplies of the Allies; but what has been done in these respects has cost us very little effort, and no sacrifice. "Business as usual," that foolish motto, long since discarded by Britain, is still everywhere manifested in our midst. It is high time for a complete change in our attitude toward the war, and unless we can make some notable contribution toward the final victory, our voice will be but a feeble one when peace terms are formulated, in spite of the glorious name of our soldier heroes. An opportunity has now presented itself to us to make a useful contribution to the Allied cause, and as it may be the last opportunity of redeeming our name, and incidentally of doing our plain duty, it behoves us to examine it closely and to consider it carefully, so that we may truly rise to the occasion, and make our strength and energy felt in the great conflict.

The opportunity referred to is that of providing new ships to replace vessels now being destroyed by the submarine campaign of the Central Powers. Time is the essence of the contract, and our public men are to be commended for the proposals which have already been formulated. This paper is written to support their efforts; and, looking at the subject from a somewhat novel point of view, aims at introducing to the notice of the authorities suggestions which are worthy of urgent consideration.

The chief points to be borne in mind are that the ships must be delivered quickly: that they must be constructed in considerable numbers; and that they be sufficiently capacious and speedy to be useful, and reasonably safe from pursuit from under water craft. It will be no use to go on with any scheme that does not provide for quick delivery, nor will it be of any use to build miniature vessels, unless we can build such a large number of them that their total capacity is really considerable.

The ideal vessel for the trade would appear to be a standardised 3000-ton steel ship, fitted with twin screws, the power being supplied from steam engines and coal-burning steam boilers, and capable of a top speed of 11 or 12 knots per hour.

The scarcity of steel plates, and the difficulties in the way of their local production puts steel vessels entirely out of the question here, and it is doubtful whether sufficient material can be assembled to supply even the boilers of the first few craft that might otherwise be constructed.

The composite vessels proposed for construction at Newcastle present a partial solution of the difficulty. The only other serious proposal that has so far received any support is for the construction of a fleet of wooden vessels; but, owing to the scarcity of sheet metal, these craft are to be sheathed abroad.

In spite of the men who have had experience in the building of warships at Cockatoo, and in spite of the work which has been done in the building of miniature craft, all along the eastern coast of the continent in particular, the schemes mentioned above will require a larger amount of skilled labor than now appears available in Australia.

Further, our extremely limited capacity for boiler construction under present conditions makes it impossible for us to build steam vessels.

This paper is written to urge that the required vessels should be built of reinforced concrete; and, in bringing the matter forward, the writer would point out that the project is not nearly so revolutionary as the original proposal for the substitution of iron for wooden ships last century.

Numbers of small craft have been built already of the proposed material in various parts of the world—from motor boats to steam tugs, and from cargo punts and caissons to pontoons.

No large concrete vessels have yet been completed and commissioned, but concrete steel engineering has now become an exact science, and there has been ample experimental work carried out to aid in the solution of the problems that may arise in the construction of the proposed ships.

The construction of large concrete vessels in the past has naturally not appealed to the practical commercial shipbuilder. He would regard such a work as an experiment, which, even if a successful one, might not catch the fancy of conservative ship owners; and the large amount of capital that would be absorbed by the cost of the forms or moulds would greatly augment the first cost of a single concrete ship. At the present moment, however, we are faced with a unique proposition, to wit, the rapid construction of a large fleet of standardised vessels, exact counterparts of each other. All of these could be, and would be, moulded from the original set of forms required, and the ultimate cost of these moulds per ton constructed would become a negligible quantity. As this item has naturally been a serious stumbling block in the way of this class of construction, the consideration of the whole scheme may be approached in the present instance with confidence.

The materials required for the concrete steel construction could all be produced in Australia. The skeleton of the vessels will require steel bars, which Lithgow, Newcastle, and other producing centres should be able to furnish in ample quantity; and steel wire, which we should be able to draw locally if supplies from abroad are unobtainable. So much for the skeleton. The remaining materials required are cement and aggregate. The highest grade of cement is obtainable in great abundance, and the best of materials for making up the aggregate is inexhaustible in positions convenient to the coast.

A vessel of concrete steel properly designed should be but little heavier than a wooden vessel of the same strength. Its maintenance cost will be very low. It will resist corrosion, and will offer no attraction to those marine insects that are the ruin of wooden vessels. It will resist decay indefinitely, and in the event of any damage resulting to the hull, may be quickly and satisfactorily repaired at very small expense.

It is hardly necessary to remark that a reinforced concrete vessel can be designed of equal strength to a steel ship. The formulae of the designers in concrete steel have been well tested by experiment and in practice.

Tests made at the Watertown Arsenal in Massachusetts, U.S.A., were the basis of the following tables:—

TABLE 1.

*Modulus of Elasticity of Concrete in pounds per square inch.*

| Proportions. | Age, 3 months. | Age. 6 months. |
|---|---|---|
| 1 : 2 : 4 | 2,160,000 | 2,580,000 |
| 1 : 2½ : 5 | 1,980,000 | 2,220,000 |
| 1 : 3 : 6 | 1,800,000 | 1,860,000 |

TABLE 2.

*Ultimate Crushing Strength of Concrete in pounds per square inch.*

| Proportions. | Age, 3 months. | Age. 6 months. |
|---|---|---|
| 1 : 2 : 4 | 2,900 | 3,700 |
| 1 : 2½ : 5 | 2,670 | 3,400 |
| 1 : 3 : 6 | 2,440 | 3,100 |

As the strength of concrete increases with its age, the accepted ratio of 15, between the modulus of elasticity of concrete and that of its reinforcement, appears to be quite a conservative one.

It will be seen from Table 2 that concrete, which is designed to withstand the compressive stresses in any reinforced structure, is capable of standing up to compression of over 200 tons to the square foot.

Experiments made at the Purdue University, U.S.A., had shewn the co-efficient of expansion of steel to be .0000067. and of Portland cement concrete .0000055. Allowing for temperature differences of 40° for the submerged parts of a vessel of 3000 tons, there would be a difference of about ⅛in. only in the expansion of the concrete and steel in the whole length of the vessel.

The Building Acts Committee of the London County Council recommended that the safe working stresses in concrete should not exceed the following:—

TABLE 3.

*Stresses on Concrete in pounds per square inch.*

| | Proportions by Volume. 1 : 2 : 4 | 1½ : 2 : 4 |
|---|---|---|
| Direct Compressive Stress | 600 | 700 |
| Extreme Flexural Compressive Stress in Beams | 600 | 700 |
| Adhesion of Concrete to Bars hooked at both ends | 100 | 100 |
| Shearing Stress | 60 | 60 |
| Tensile Stress | nil | nil |

With respect to the suitability of concrete steel for the ships' decks and bottoms, it may be pointed out that it has well proved itself in somewhat similar work as an ideal material for the construction of floors for carrying heavy dead and live loads. Similarly, it can be claimed that properly designed and properly constructed concrete steel beams, columns and partitions have been so well tested under widely varying conditions ashore, that their safety and reliability cannot be questioned. There only remains the skin of the vessel to be considered, and the objections that are likely to be offered to the use of concrete steel for this part of the work will be found in the end to be sentimental rather than practical. Given a frame and internal structure designed of adequate strength, the skin of the ship then resolves itself into a series of slabs, which may be constructed of any strength desired, and made capable of withstanding, unshaken, all the shocks and stresses likely to be encountered on the ocean.

We laid it down at the outset that we must have ships in plenty, and must have them quickly. We find that we have at hand all the materials necessary for turning them out quickly, and for building them to be strong and durable. Let them be built in reinforced concrete, especially as this material lends itself, as no other can, to the rapid construction of a large number of standardised vessels.

Attention is being turned at present to the question of reconverting hulks for deep sea work, and doubt has been expressed as to the possibility of obtaining the necessary material to restore the original main beams, decks, bulkheads, etc. The reconstruction of the interior and superstructure of old vessels is easily possible in reinforced concrete, and the use of this material is commended to the notice of the owners of such craft.

Reinforced concrete has been able to hold its own in competition with iron and steel in many fields. But even if this were not so, it is unquestionably superior to timber for constructional work.

The composite vessels proposed for construction are to be built of steel and wood. A steel-framed concrete ship should be superior in strength to a steel-framed wooden ship, and concrete ships may be constructed much more rapidly than wooden ones.

Mr. C. Weber, the President of the Cement Gun Company of Chicago, who claims to have made the building of concrete ships one of his life's problems, writes in "Marine Engineering" for January:—

"Not only for the construction of smaller . . . vessels is concrete an entirely suitable material, but also for large ocean going ships will its use be perfectly safe and extremely advantageous. . . .

"I have invented and developed a series of entirely new methods of construction, which allow the building of large and small concrete vessels of remarkable elasticity, and of comparatively light weight. In addition to this, the cost of construction is greatly reduced—no forms being used—as all concrete is handled, applied and finished by machinery, especially designed for this purpose, the risk of poor workmanship is almost entirely eliminated.

"The ship's hull consists of a strong framework of steel, which is so designed that the combined strength and advantages of steel and concrete are fully recognised. This truss frame is erected and rivetted in the ordinary manner. In the completed ship the steel frame is entirely encased in concrete, and thereby protected against rusting. By this encasing, the steel members are also stiffened, and the 'buckling' stresses are greatly reduced. For this reason the steel members of the frame are of simple design, and relatively light weight.

"After the steel framework is completed, the same is covered with a 'multiple unit' wall construction (of the inventor's design) of varying thickness. . . . All ship shells, bulkheads and decks are formed in a similar manner without the presence of any construction or connection joints, so that the completed ship is one seamless, monolithic structure. . . .

"The concrete . . . is applied in even and uniform layers by means of a powerful stream of compressed air with a special machine. . . . After the last coat has sufficiently hardened, the outer surfaces are rubbed down to an even, smooth finish with rotary, compressed air-driven grinders, and the entire ship may be painted as usual."

The writer of the above is admittedly an interested party, but his remarks are worthy of attention. The cement gun is now a proved tool. It is so called from the fact that the material is ejected from its nozzle by means of compressed air, and is thus, as it were, "shot" on to the work, with a muzzle velocity corresponding to a pressure of 35 lbs. per square inch. The machine mixes the materials in a dry state, and they are only hydrated just as they are projected from the nozzle. As a result of this method, the initial set cannot take place until the concrete is deposited in place.

Tests made in New York of concrete deposited by compressed air, and reported in "Engineering News," shewed that this class of work was much superior to hand work.

The testing engineers reported that the compressive strength was from 20 per cent. to 720 per cent. better than that of hand work; and the adhesion was, on the average, 27 per cent. better. The surface permeability was greatly reduced, as was also the capacity for absorption, by the compressed air method.

If a departure from orthodox methods of construction is to result in an increase in the safe working values usually assigned to concrete, the aspect of the problem of concrete shipbuilding is somewhat changed, and its difficulties reduced. Considerable light is thrown upon the subject by Mr. Duff A. Abrams, of the University of Illinois, who conducted a long and exhaustive series of careful experiments into the strength of the bond between concrete and steel, and who took pains to enquire into such incidental problems as arose during the experiments.

Concrete cylinders, mixed 1:2:4, were allowed to set under applied pressures of up to 100 lbs. per square inch, and were compared in the experiments to cylinders that had been allowed to set in the usual way under atmospheric pressure only.

The experimenter was able to report that the effect of the applied pressure was to increase the compressive strength of the concrete by 73 per cent., the initial modulus of elasticity by 37 per cent., and the bond resistance by a maximum of 92 per cent.

One half of the increased strength was secured at pressures up to 20 lbs. per square inch. As no tests were made between pressures of 20 lb. and 100 lbs. per sq. inch, it seems likely that the maximum strengths reported could have been obtained at a pressure not exceeding 50 lbs. per square inch; especially as the strength of the concrete would be reduced by the water which was forced out of it at the higher pressure. In different cases the pressure was applied until the ages of 1, 7 and 77 days were reached, but it was found that it was not necessary to continue the applied loading after the initial set of the concrete had taken place. The specimens were all tested at an age of 80 days.

These results are a confirmation of the reported tests of the application of concrete by means of compressed air. It is natural to expect that concrete deposited with the considerable force that is a feature of this method should furnish results somewhat similar to those obtained by concrete setting under pressure.

The secret of the high values resulting from both these methods doubtless lies in the fact that voids in the structure are absent, and the particles of the concrete lie in intimate contact with one another and with the reinforcing material. The advantage of tamping or ramming of the mass is evidently due also to the partial elimination of voids. It does not matter what method is employed, provided the best results can be obtained in the construction of concrete ships. It is interesting to note here that Mr. F. Huntingdon Clark, of the United States Shipping Board, is experimenting with the building of concrete ships, on the Weber system.

In "The Shipbuilder" for February, an article on "The use of Reinforced Concrete for Shipbuilding" is concluded as follows:—

"The difficulties experienced in obtaining supplies of steel for shipbuilding purposes under war conditions have been referred to, and this has led to the suggestion in some quarters that the Government may have to consider the use of reinforced concrete in the construction of small merchant vessels. Whether this will be so remains to be seen, but the war and the attendant difficulty of obtaining shipbuilding steel appears to have given a fillip to reinforced concrete shipbuilding in the Scandinavian countries."

The "Motor Ship" for April 22nd reports that: "An extensive ferro-concrete shipbuilding industry has recently sprung up in Scandinavian countries, the biggest yard being the Fougner's Staalbeton Skibsbygnings Co., at Moss, Norway, which has raised its capital from £22,220 to £72,220. Formed in 1916 as a special yard for ferro-concrete vessels up to 5000 tons, 16 lighters of 100 tons to 300 tons in size were completed during the year, and at present a motor ship of 3000 tons is being built for the Sydvaranger Mine Co., for carrying iron ore across the North Sea. This interesting first sea-going ferro-concrete motor ship is to be delivered in July next, and it will be propelled by two Polar-Diesel engines of 300 h.p. each. A second ferro-concrete shipyard has been started by a Swedish concrete company in Malmoe, which has already delivered three lighters; while a third yard for concrete vessels has been formed in Masnedsund, Denmark, and further ferro-concrete shipyards are being formed in Drammen, Bergen and Frederiksstad."

The Premier of South Australia recently received a cable to the effect that one 3000 tons vessel had now been launched in Norway. The South Australian Government is to assist a private firm with the construction of a large sea-going concrete vessel.

In 1906 a concrete steel barge, 52ft. 6in. long x 24ft. 3½in. wide x 9ft. 10in. deep, with a carrying capacity of 150 tons, was constructed in Italy for the carriage of coal, and had given continued satisfaction.

Concrete barges have been employed on the Panama Canal work. A barge of this type, 80ft. long x 24ft. beam x 7ft. depth has been in use for some years on the Welland Ship Canal, and has often been severely tried through having rubble dropped on it from a height of 12 feet. "Concrete" states that the hull is divided into eight compartments by one longitudinal and four cross bulkheads. There are 2ft. x 2ft. 6in. openings through the cross bulkheads. The deck, bottom, sides and bulkheads are 2½in. thick, reinforced in both directions by ¼in. round rods on 2in. centres. Beams 6in. square on bulkhead lines, reinforced with heavier steel as required, and braced by reinforced concrete posts, care for the principal stresses. The concrete is a 1:4 mix, using small gravel.

Fig. 1 shews particulars of a reinforced concrete vessel constructed for the Manchester Ship Canal Company for sludge pumping purposes. It is 100 feet long by 28 feet wide, with a draught of 5ft. 6in. laden, and is fitted with coal bunkers, boiler and pumping machinery. The shell is 3in. thick, except under the boiler, where it is 4in. thick.

Fig. 2 shews details of one of a fleet of concrete barges designed for service at San Francisco.

The "Motor Ship" for March 22nd describes an ocean-going motor cruiser, the "Wanderer," lately built in America for a world tour. This vessel measures 41 feet overall, and has a beam of 8 feet. "The framing of the boat is of angle steel, and a 10in. steel H-beam forms the keel. Galvanised expanded steel was attached to the framing to hold the concrete, which tapers from 1½in. thick at the keel to ⅞in. at the gunwale. At each side, at the waterline, . . . is a sponson which increases the beam to 11ft., and gives the vessel great buoyancy in a seaway, making her practically unsinkable." She is the first self-propelled ocean-going concrete vessel, and is evidently constructed on a system similar to that proposed by Weber. France is also giving attention to this class of construction, and a company has just been formed there to build sea-going concrete lighters of reinforced concrete. A powerful company has just been formed in San Francisco for the building of concrete ships. The first vessel will be of 4500 tons capacity, and will be reinforced with steel rods welded together.

The satisfactory service of the small concrete craft already referred to is evidence of the suitability of concrete steel for marine purposes, and of the resistance which this class of construction offers to the corrosive action of sea water; although the latter quality has also been amply established by the experience of those who, like our Harbour Trust, have made use of reinforced concrete for the construction of pontoons, wharves and sea walls.