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CONCRETE BOATS AND SHIPS
RALPH A. BURTON
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CONCRETE BOATS AND SHIPS

INTRODUCTION

When anyone mentions concrete boats, there is an inherent prejudice in the mind of the listener who has not inspected one of the more modern of such vessels. Experience with ordinary concrete construction leads one to visualize a bulky and fragile craft whose only justification would be material shortages or the demand of high speed production during a wartime emergency. Since none of my prejudices were removed by material I read before my visit to Windboats Ltd., I do not expect that this report will remove yours. It is my hope, however, that the impression will bo conveyed that concrete is indeed an attractive material for boat hulls in many special applications, and that its ultimate use may be even more general than presently foreseen by the constructors. It is my belief that confidence will be increased as more persons see and use concrete boats or ships.

Concrete as a construction material for boats was adopted by the Windboats Shipyard when the present owner's nephew, a civil engineer by training, recommended that they build such a boat as an experiment. Following considerable development, both in concrete mix and in constructional methods, the company made several launches which could be hired for use by vacationers. Such launches are subject to considerable abuse in the hands of amateur pilots and normally need major repairs at the end of a holiday season. Much to the surprise of the manufacturers the concrete launches were found to be intact, and capable of being left in the water until the next season came round. Further development led to the construction of more ambitious sizes of boat, and the firm now manufactures a trawler of 47-ft length and $13\frac{1}{2}$-ft beam. Such boats are ordered primarily for use off the coast of Africa, the Solomon Islands, and other such places where wooden boats have very short life, and where metal boats require more maintenance than the owners wish to give them.

The boat yard in England has built over 160 different boats, and presently turns out a fresh hull every five days. Interest in the boats has developed over the past year and licensees are being set up throughout the world. Mr. T.M. Hagenbach, owner of the boat yard, expects that, ultimately, his yard will only be concerned with research and development of pilot models for new applications. Presumably the experience so obtained would be transmitted to the licensees, and the main construction efforts would be carried out by these. He cites advantages of the technique in that very little plant investment is required, and that only a reasonable level of skill is required of the construction crew. He said that garage mechanics or others who had a basic facility for use of their hands could be trained to manufacture concrete boats in only a few weeks.

Hagenbach points out that many kinds of concrete boat have been attempted in the past. Indeed, he notes that a ferro-cement boat was built by a man named Lambot in France over 120 years ago. The boat, only 3.6 m long and 1.35 m across the beam, is in a museum in Brignoles, France. The shell is approximately 35 mm thick (much thicker than a comparable boat would be under present design techniques) and is said to be in good condition still. Similarly, Prof. T.L. Nerzi of Rome (who is said to be a recognized expert on shell roofs) has used the technique in the construction of a dozen boats, principally to demonstrate that the material is suitable for the purpose. As noted above, work at the present shipyard began in 1959 when Mr. Paul Hagenbach pursuaded his uncle to embark on ferro-cement construction.

Mr. T.M. Hagenbach observes that the evaluation of concrete boats has been confused by the fact that amateurs can build a passable hull from ordinary cement. Presumably all one would have to do is set up a hardware-cloth shell to serve as lathing, and then force the concrete mix through from the inside. The next task would be to smooth the material on the outside by a technique ordinarily used by plasterers. This will produce a boat, but it will have to be water-proofed, and it will not be shock-resistant enough to be acceptable for day-to-day commercial use. A major effort of Windboats has been to develop the concrete mix so that it is impervious to water (and consequently prevents a problem of rusting of the metal reinforcement), and does not need to be painted in order to function properly. The group has reportedly solved the crazing problem and that of development of crack-stars around an impact point. As will be explained further, what Windboats have to offer are a number of techniques by which problems have been solved at many different levels of boat construction. Hagenbach notes that the majority of their knowledge (some 75% by his estimate) is in the form of things not to do.

IMPRESSIONS OF BOATS OBSERVED IN THE WINDBOATS YARD

The Windboats Yard is located in Wroxham on the Norfolk Broads, England, a popular area for water sport enthusiasts. The Yard itself is not inordinately large, but, as has been noted, is capable of producing one relatively large boat per week. The actual construction of the hulls is done in secrecy in large hangar-like buildings, and the outfitting is done by conventional carpenters and shipwrights. On entering the boat yard, I passed the hull of a large trawler (47 ft long, 13½ ft beam) of pleasing form. It was outfitted with engines and propeller and was essentially ready for sea once its wooden deckhouse is set on it. The decks of the boat are of concrete and are made integral with the hull. There are no structural beams throughout the interior since the concrete shell itself is strong enough even for a boat of this size. There are some flooring members on which the engine is set, and the packing gland for the propeller shaft is cast into the concrete hull. Fish tanks, mounting plates for the winches, and the bulwarks are part of the concrete unit, so very little finishing is required. Presumably the deckhouse (which simply serves as weather protection for the pilot) could also be made of concrete if this were desirable. For such a hull completely outfitted as described, the materials cost is only £540 ($1296) and construction requires 2752 man hours. On this basis the cost will vary from nation to nation (time and overhead for labor in Spain, for example, may be as low as 75¢ an hour). Delivered in England, with winches and a Kelvin engine (which reputedly costs £4000), the boat can be sailed away for £17,500. This would run about $42,000, which is not cheap but is in line with what a similar boat would cost when made of conventional materials. Hagenbach says the hull can actually be made 15 to 30% cheaper than by conventional materials, and that the boat would run 3 to 5% cheaper than conventional ones. The 47-ft trawler is going to South Yemen, and there the ease of maintenance is as great a consideration as is the cost itself.

Inside the shipyard, one finds a houseboat outfitted to be floated in the Mediterranean and hired out for British vacationers. It has complete galley, commodious rooms with blue deep-pile nylon carpeting, and is air conditioned. More spectacular is a personnel transport for the Solomon Islands, a most business-like and efficient looking cutter with a hull form somewhat like that of a PT boat. Also there are additional trawlers and a tug in various stages of completion. (One may go down into the holds of these and examine them to see if water is seeping through, and reassure himself that it is not.)

The firm has also built (1) a 35-ft pilot boat for the Persian Gulf, (2) a smaller 30-ft trawler for shell fishing in Somalia, (3) a 47-ft seiner hull for South Yemen, (4) a luxury 26-ft four-berth cruiser for sheltered water cruising (here more care was given to the finish than in the fishing boats. After painting, the general appearance in no way betrays the concrete skin), (5) a series of 33-ft houseboats with fiberglass cabins and all necessary luxuries, (6) a 16-ton auxiliary sloop with sails, designed for use in the West Indies.

They have built police patrol boats for Nigeria, pontoons, buoys, floats, and tanks for water as well as oil. They have even constructed a prefabricated swimming pool which is carried as a shell and dropped into a hole which has already been dug for it. The firm has not yet foreseen any upper limit in the size of a ship which could be made by their techniques, and they are simply waiting for an order to start building something bigger.

DAMAGE RESISTANCE OF CONCRETE BOATS

When one turns into the parking lot of the boat yard, he finds the smokey remains of a burned-out hull. For some reason not attributable to the concrete, an explosion inside the boat blew the cabin top 50 ft into the air and sent the mast 200 yds away. The interior of the boat was completely gutted by fire and all wooden construction was consumed. The explosion caused only minor cracks at the transom corners on the port and starboard sides. The hull was purchased for salvage and floated back to the boat yard. It is now used to demonstrate the fire-proof nature of the concrete construction itself. It is also used in another very convincing demonstration which is better carried out physically than discussed. The observer is given a 4-lb sledge hammer and told to hit the hull and break the concrete. The hammer simply bounces back with a deep ringing sound on contact with the hull. Repeated blows can flake off a thin layer of the external material down to the first layer of iron mesh. But the principal thing is the concrete does not behave as brittley as one might expect. Interest in determining more quantitatively how the concrete resists fire has led to panels being subjected to temperatures as high as 1700°C without showing ill effects.

Another example of damage resistance was provided when a cabin cruiser was struck from the side by a two-ton yacht moving toward it at five knots. Damage was limited to an area 2 ft long and 2 ft wide. At the point of impact the hull was deflected from the true by 1 5/8 in. Surface damage consisted of a crack 1/8 in. deep and some slight flaking. Damage was repaired with the aid of a hydraulic jack, which pushed the hull back into shape, whereupon the cracks were filled and the hull was judged to be as good as new. The whole job took 30 min. It was estimated that if a timber hull was subjected to similar impact, it would require the replacement of at least four planks.

On another occasion a 34-ft concrete-hulled cabin cruiser was struck amidships by a 3½-ton sloop traveling at 10 knots. The concrete cabin cruiser was able to proceed under her own power for repairs which took 21 man hours to complete. Damage consisted of deflection of the hull from true over an area 7 ft long and 3 ft wide. At the point of impact the hull was pushed in 3½ in. It was repaired by hammering the reinforcement back into position and cutting away the damaged surface. It was then filled, sanded and brought back to as-new appearance. In the view of the marine surveyor a similar craft with a timber hull would have been sunk.

In another case a boat was lifted up by a wave and deposited down on the upper end of a pile which produced a considerable impression in the hull and opened it to leakage. Pumps were able to keep the boat from sinking while a repair man was brought in. He went over the side and forced in concrete mix in the presence of sea water until the leak was controlled, thus enabling the boat to proceed back to the shipyard under her own power.

In an accident off the shore of France, a hull experienced a number of hair-line cracks which permitted water to seep through at a rate that taxed the ability of the pumps on board. Concrete mix was simply rubbed into the cracks, and this filled them sufficiently to permit the boat to proceed back to the shipyard for more permanent repairs.

Concrete hulls have been frozen through a winter in as much as 18 in. of ice, without injury.

MATERIALS CHARACTERISTICS OF "SEACRETE," A CONCRETE MIX DEVELOPED FOR SHIP CONSTRUCTION

Seacrete is the trade name of a particular form of concrete with steel wire reinforcement developed by the Windboats Company. Details of the mix are proprietary, but properties may be listed as follows:

a. Density

151 lb/ft^3 (mahogany is 36 lb/ft^3; reinforced plastic is 100 lb/ft^3).

b. Ultimate Stress Tensile

(i) Tensile bending stress on panels 48 x 12 x 7/8 in. loaded at center point:

Stress to crack	1900 lb/in^2
At yielding	3000 lb/in
At ultimate	5340 lb/in^2

(ii) Tensile Stress:

Stress to crack	1300 lb/in^2
Stress to break	1690 lb/in^2

c. Ultimate Stress, Compression

Compression tests on sample cubes 6 x 6 x 6 in.

Maturing time (days)	7	14	28
Failing load (tons)	116	135.5	196.5
Ultimate stress (lb/in^2)	7217.3	8742.2	12225

d. Young's Modules

Modulus of elasticity: 1.3×10^6 lb/in^2.

e. Bending Fatigue Tests

Four sample strips 21.65 in. long, 5 in. wide and 0.65 in. thick were tested. The distance of the loading point from one support was 8.5 in. The results were as follows:

Sample	Nominal Stress Levels lb/in^2	Cycles	Remarks
A	+625 -544	2×10^6	Cracked
B	+700 -600	2×10^6	No fracture
C	+1100 -0	100,000	Cracked
D	+1185 -0	100,000	Cracked

f. Thermal Conductivity

Low: 1/6th that of steel.

g. Resistance to Chemical Agents

(i) Organic acids, e.g., sulphuric, nitric, sulphurous, hydrochloric and hydrofloric. Poor. Special surface treatment necessary.

(ii) Acetic acid, carbonic acid in water, lactic acid, tannic acid, sulphates, mil or juices: Fair. Special surface treatment desirable.

(iii) Chlorides, ammonia, wood pulp, alcohol, salt water or crude oil: High. No surface treatment necessary.

h. Resistance to Mechanical Agents, e.g., ice, shock, impact, explosion: High (see comments on damage resistance).

i. Resistance to Fire: Test panels have withstood 1700°C for 1½ hours with no effect on the material. Very high.

j. Resistance to Marine Borers: Complete. They have no effect.

k. Ageing Properties: Concrete boats are said to be still in use after 42 years service and tests are said to show these to be as strong as when made. Seacrete hulled craft in Windboats' Charter Fleets are in excellent condition after seven years service.

l. Sound Absorbance. Good.

m. Vibration Absorbance. Good.

n. Odor. Nil.

o. Surface Finish: Smooth.

p. Features:

(i) No maintenance is required.

(ii) Damage, if it does occur, is usually very localized and is easily repairable.

(iii) Good thermal insulation minimizes condensation.

(iv) Seacrete hulls may be painted to enhance appearance and the surface will take paint well.

The test data as set out above are attributed to a report prepared by Lloyds Register of Shipping, who are said to give Classification 100 A.1. to a vessel with a Seacrete hull, provided that in all respects, e.g., superstructure, engine installation, electrics, etc., the construction complies with their rules.

Seacrete is said to be approved by Lloyds Register of Shipping, Bureau Veritas, the United Kingdom White Fish Authority, and the Food and Agricultural Organization of the World Health Organization in Rome. Seacrete is described as a specialized form of ferro-cement and involves a developed mix, recommended additives, a specially developed reinforcement manufactured to suit the process, and a technique of manufacture.

CONSTRUCTION TECHNIQUES

Although information on construction techniques is somewhat limited due to the necessity of maintaining secrecy for proprietary reasons, it is understood that the hull is laid up on a frame of metal tubing which supports layers of several different sizes of steel mesh. Apparently all methods of concrete construction are used in different portions of the craft. Guns may be used to spray the concrete; also ordinary trowelling as well as casting techniques are applied in certain areas. Many special tools have been developed by the shipyard for these purposes.

Some interest by British military agencies has led to studies as to how one might be able to build such craft (say pontoons, or barges) in the field. It was found that with the support of one transport aircraft bringing in concrete, with an adequate supply of water and with shading from the direct rays of the sun, a complete manufacturing operation can be set up with a reasonable number of men, in almost any part of the world. For example, a pontoon bridge could be built in the jungle with the pontoons made directly from concrete.

The thickness of the shell of a boat may vary from as little as 5/8 in. to as much as 1 ft. This latter thickness was used in the bow portions of a tug boat, where severe impacts would be expected. Because it is not practical to make Seacrete much thinner than ½ in., this material is a little heavy for small pleasure boats. At lengths greater than 30 ft., concrete begins to show an advantage over other methods of construction in that the stiffness of the hull obviates the necessity for the interior framing required by more conventional construction techniques. There appears to be no problem in joining thick to thin cross sections (as one would encounter in metal casting), and the requirements of shape have been found so far to have no particular limitation. In design, one is not restricted to shapes which hold compound curvatures to a minimum.

The following listing is given by the Windboat Company to prospective licensees, and in many ways shows roughly what the design and research effort have generated.

1. Plant and equipment necessary for ferro-cement boat construction.

2. Facilities to send operatives for training to the Windboat factories at Wroxham, Norfolk, England.

3. A senior technical man available to initiate local production or give advice.

4. Complete checking of the suitability of the sand and water and the cement a constructor has proposed to use.

5. Guidance as to how best to set up a hull if series production is contemplated or if a "one off" is being built.

6. Details in regard to spacer rods and the manner of fixing.

7. Particulars of the best method of stretching the mesh reinforcement to ensure tight, fair and sound evenly spaced mesh framework, with details of tools developed to facilitate fastening the layers of mesh together.

8. Details of the Seacrete mix and additives, and a guide as to variations that must be made to suit changing conditions of temperature and humidity.

9. Details as to how the mix should be applied.

10. Special tools to overcome the problem of voids in the skin of the hull.

11. In the case of large vessels, the stages in which a hull should be made, the man hours that should be involved, and how to make joints.

12. Details in regard to the building in of integral floors and engine bearers, watertight bulkheads, fish holds, hatch coamings and bulwarks.

13. The means by which arrangements can be made to facilitate the removal of the stern tube, how to insert steel rings into the framework to produce holes for fittings, etc., how to strengthen and build up decks to take winches, etc.

14. When and how the hull should be treated to get the desired finish.

15. The manner in which standard test cubes should be taken and the strength that should be achieved.

16. Particulars in regard to curing and means by which this can best be carried out.

17. Details of faults that can appear in a newly manufactured hull, the cause of these and how to cure and obviate them.

18. Procedures for undertaking repairs.

19. A design department with a Naval architect at its head, who will approve new designs, advise on the reinforcement to be used to suit the particular design and give guidance notes on any particular vessel.

20. Availability of plans and general arrangement drawings of a variety of craft that have been very successfully built by Windboats Ltd.

21. Lloyds test data for Seacrete.

22. A complete interchange of information between one licensee and another. Any improvement in technique discovered by one licensee, will be promulgated to all other licensees.

23. Three patents have been applied for and, if granted, the licensee has free use of them.

24. Data on the design and construction of other products and the benefit of research into gunniting, vacuum process, and vibration.

This listing indicates to me that this effort has been carried out with serious intent, and that the company has indeed developed the technology significantly.

CONCLUSION

1. Inspection of the boats being constructed and review of operating experiences lead one to conclude that concrete is indeed a feasible and attractive material for many kinds of boat hulls.

2. Damage survival histories indicate that concrete may contribute to the safety of operation of some classes of boat.

3. Ease of repair and maintenance as well as freedom from rot, rust and marine borer damage are in themselves justification for increased interest in concrete hulls.

4. Appearance of the boats already built confirmed that the designer had not been forced to compromise shape or layout in order to accommodate the material.

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13. ABSTRACT

A visit to the British concern Windboats is reported. This firm has made over 160 concrete boats of various sizes, and has developed the mixes as well as constructional methods over a period of 10 years.

Comments are included with regard to impressions of the boats themselves and special features of the manufacturing method. These boats presently span the size range from small pleasure craft to a 47-ft-long shrimp trawler. They offer the special advantages of simple maintenance, freedom from insect attack in the tropics, and freedom from rusting. Other advantages of the construction material are also outlined.

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