625.82
V666

73009

# BACKGROUND-INFORMATION ON FERRO-CEMENT AS A BOATBUILDING MATERIAL FOR DEVELOPING COUNTRIES

Excerpted from a report on East Pakistan prepared by
Noel D. Vietmeyer, (Professional Associate, National Academy of Sciences) for
TA/OST and NESA/SA (AID)

March 12, 1971

## FERRO-CEMENT (F-C) AS A BOATBUILDING MATERIAL

The very idea of building light, thin-walled boats out of concrete seems at first to be an unusual idea. Most people have an impression of heavy solid rough edged masses of concrete very unlike anything floatable.

In the form represented by what is today called "ferrocement" concrete does, however, become light, delicate, elastic, resilient and above all strong. It can be used to produce a thin, water - tight skin for the hull of boats from 15 - 100 ft in length. In boats of 25 ft. to 45 ft., the thickness generally varies from ½ in. to 3/4 in., depending on number of layers of reinforcing bars and mesh.

Ferro-cement is very highly reinforced concrete in which the reinforcement is in the form of a mesh (such as chicken wire), the aggregate is very fine (such as sand) and the ratio of cement to aggregate is exceptionally high. Ferro-cement in this form has been used in construction since World War II. Many sweeping bridges and soaring arches have been built in Italy and it is being used to construct the sail like domes of the famous Sydney Opera House in Australia.

F-C for boatbuilding has only recently gained momentum, however, it has been predicted that most new fishing vessels constructed in the U.S. will soon be made of this material. In particular low cost, low demand for skilled labor, and rapidity of construction are its major attractions in the U.S. Although fairly new, several countries have produced dozens of vessels (e.g. U.K., New Zealand, Canada, and Australia), and one (Communist China) has produced thousands.

Background Information on Ferro-Cement as a Boatbuilding.

623.82
V666

National Academy of Sciences. NTIS

Background information on Ferro-Cement as a Boatbuilding Material for Developing Countries. Noel D. Vietmeyer. Mar. 1971.

34 p.

Excerpted from a report prepared for TA/OST and NESA/SA(AID).

1. Boat-building. 2. Cement. 3. Engineering materials. I. Vietmeyer, Noel D. II. Title. III. Ferro-Cement as a Boatbuilding Material.

mv db
isn = 17188
loc = P585

62
73224

b'

F-C has been recommended in a recent book as the ideal material for boatbuilding in developing nations and the FAO has recently funded projects for the construction of F-C vessels in Dahomey, Thailand and the U.A.R. This acceptance of the material by the FAO is a high recommendation for the technical experience and capabilities of the design and engineering staff of the FAO's Fishing Vessel Section are unsurpassed.

After exhaustive tests Lloyds Register of Shipping have intimated that they will give 100 A 1 classification to a vessel with a ferro-cement hull. The ultimate tensile strength of this concrete material is 5,340 $lb/in^2$ and because a mesh reinforcement is used, it will have this tensile strength in all directions. The tensile strength of wood is approximately 6,000 $lb/in^2$ along the grain but is negligible across the grain, and is diminished considerably by fastenings and the fact that the grain often "runs out" whereas in concrete hulls the tensile strength is uniform.

A ferro-cement hull is also very flexible. In one part of the testing by Lloyds a sample strip was flexed two million times without fracture.

Concrete-hulled craft may be cast into practically any conceivable form to meet the particular requirements of the user, rather than him having to accept a standard design as in reinforced plastic hulls.

The basic raw materials for the construction are sand, cement, and reinforcing mesh. These items are usually readily available in most countries. It is also important to note that apart from one trained technician, it is quite possible to construct vessels in this concrete using intelligent but unskilled labour. Also this construction requires no expensive molds such as are required in fiberglass boat construction since the mortar is troweled directly on the reinforcing and is supported by it.

Due to the built-in framing and strength inherent in the material, it is possible to obtain 11 percent more space in a concrete material-hulled craft than in a similar sized hull constructed in any other material.

It is quite possible to construct decks and superstructure in the concrete material, using the same form as the hull skin. By doing so one produces a very strong and rigid hull due to it becoming a complete monolithic structure. On smaller vessels this is not advisable due to the weight factor. Concrete is immensely hard and shows great resistance to abrasion. It has distinct advantages over reinforced plastics in this sphere. Because of its greater thickness and the fact that even if the surface suffers abrasion it will not weep as is the case with a glass-reinforced plastic hull due to its internal porosity.

F-C hulls can be repaired in about one-tenth of the time taken for a wooden hul The damaged area is broken away until the surrounding concrete material is undamaged and solid. It should be noted that when a hull is damaged, the damage is completely localized and is confined to the area where the impact took place. Once the broken concrete has been removed any broken mesh reinforcement is replaced and knocked back into its original position and recemented with the normal mortar mix containing a small amount of epoxy bonding agent.

Normally a repair can be effected in one ordinary working day. Whereas it is comparatively simple to repair a concrete hull even in tropical conditions, the same does not apply to glass-reinforced plastic hulls where materials if stored tend to deteriorate and it is not always possible to maintain the correct working temperatures that are all important in effecting a satisfactory repair.

Marine borers have no effect on Ferro-cement and the hulls will not rot. They are fireproof and there are no seams to calk or to leak. The surface will take a good paint coat but painting is for appearance only and is not needed for protection. Barnacles and algae will attach themselves to a concrete hull below the water line in the same manner as a timber or metal hull, but they may be easily removed with a powerful detergent which will have no effect on the hull.

Resistance to shock is excellent, severe impact may cause local damage but seldom if ever has it penetrated a ferro-cement hull. Local damage, usually in the form of fine cracking, has occurred in several boats involved in collisions or running aground. Leakage is easily controlled and readily repaired. The strength of the mortar actually increases with age.

Thermal conductivity is low enough to minimize condensation problems. Ferro-cement absorbs sound and vibration as well as or better than other boat-building materials. It has no odor. Test panels have withstood 3,100° F, (1,700° C) for 1½ hours with no effect on the material and so F-C boat hulls are completely fire proof.

The specific gravity of the concrete is 2.4, that of glass-reinforced plastic is 1.6, and of a wooden hull including fastenings 0.9. In spite of the weight of the material a concrete hull compares favorably in overall weight with both wooden and glass reinforced plastic hulls because a concrete hull requires no heavy internal frames or floors and a panel almost half as thick as timber is equally as strong Hulls in the 50-ft.-size range are often lighter than similar-sized wood, fiber glass, or steel hulls. Weight in the 35- to 45-ft. range is about the same for all types. Below 35 ft. a ferro-cement hull is heavier than a wood or fiber glass one

Perhaps most important of all, the cost of ferro-cement hulls is said to be one-half to three-quarters of the cost of more conventional types. As an example of the simplicity and ease of ferro-cement boat-building the following is very illustrative:

"Stuck for a boat to take on a holiday at the beach, Ferro-cement pioneer Morley Sutherland, put two bags of rapid hardening cement and some half-inch chicken wire netting in his car trunk On arrival at the beach he made a male mould of damp sand and covered this with thin plastic then laid several layers of mesh over it, and wired them together tightly all over. The mesh was then plastered over with a mix of two parts sand to one part cement, made from the cement he had brought and ordinary beach sand. The sand mould was begun at 4 p.m., and the boat plastered by 6.30 p.m. the same day. She was covered with sacks and left to cure overnight, and next day, late in the afternoon, she was immersed in the sea until morning, when she was used for the first time. Although understandably a bit crude, the row-boat added greatly to the fun of the holiday. Too heavy to take away, she was abandoned, but used by locals for quite some time, until blown onto a reef and abandoned."

## FERRO-CEMENT AS A BOAT-BUILDING MATERIAL IN EAST PAKISTAN

Ferro-Cement appears to be as an ideal building material for replacing the vessels in East Pakistan that were destroyed in the cyclone, there is no better candidate. Technically F-C is well advanced, beyond the experimental stage and is completely accepted. Production costs should be considerably less than methods that use wood, fiberglass, plastic, aluminium, steel etc. Any technology used to replace their boats will have to be adaptable to previous designs, and sizes, if it is to be rapidly accepted. Ferro-cement is ideally suited to this.

East Pakistan has a great shortage of the common boat building materials including wood. In order to rapidly replace the fleet which was demolished in the cyclone all steel, fiberglass, aluminium, plastics and much of the wood would have to be imported. Ferro-cement uses a maximum amount of indigenous materials and labor and could be producing in very short time, cheaper and for more durable boats than were previously available The F-C boats would also be strong enough to withstand future cyclones and should have lifetimes in excess of 100 years.

The following is a list of the properties of F-C boatbuilding that make it particularly adaptable to the current situation in East Pakistan

a) Can be used to produce vessels from 15-100 feet in length.

b) Can be used to build craft which conform to any given shape of indigenous boat. Curved shapes are made easily and rapidly.

c) Can be mass produced (it is being done in Communist China).

d) Uses indigenous materials to a very large extent (in this case cement and sand).

e) Is uniquely adapted to use local and unskilled labor.

f) Is less expensive than other modes of boat construction (especially in wood-short areas, such as East Pakistan.) Cost should be between ½ and 2/3 those of wood and a fraction of those of steel, fiberglass, aluminium etc.

g) It could lead to an indigenous boat-building industry in the country, which would not require outside help, and may even lead to exports of boats.

h) Any F-C boat-building program could be producing boats within a very short time period (weeks).

i) Could be used to build boats of any shape or design; for local fishing (inland and marine), deep sea fishing, river transportation as well as for building barges, pontoons, and even terrestrial structures such as cyclone-proof housing, silos (also rodent proof) etc.

j) F-C boat construction allows a surprising margin of tolerance in its practice.

k) There is a wider margin for structural error in the integral F-C hull than in wooden vessels which of necessity are built from separate pieces.

l) F-C will cure well and gain even greater strength in the warm humid atmosphere of East Pakistan. The more humid the climate, the better the cement.

m) There probably will be no need to sink the boats during the dry season as is presently done with the wooden ones.

n) The process is not very demanding on quality in the ingrediants. The beach sand and the cement available in East Pakistan will undoubtedly be satisfactory. The wire mesh would have to be imported however.

o) Does not require a well developed or centralized boatbuilding site.

p) Since the mortar is troweled directly on the reinforcing and is supported by it, complicated formwork is unnecessary.

On the other hand ferro-cement boats once built are remarkable in their properties and are particularly suitable for East Pakistan. The following is a list of properties of such boats:

a) They are stronger than wood, steel or fiberglass and they grow stronger with age . When a heavy engine was being lowered into one new F-C boat it slipped from its slings and fell into the hull. The steel casing of the motor was damaged but there was no damage to the hull whatever. It is reported that seldom if ever has severe impact penetrated a F-C hull.

b) Probably cyclone-proof. They should easily survive future cyclones.

c) Maintenance free (don't even require paint)

d) Resistant to corrosion and rust

e) Resistant to rot

f) Resistant to teredo worm

g) Resistant to other tropical pests

h) Resistant to cracking

i) Resistant to leaking

j) Completely fire resistant an overturned brazier creates no danger and are therefore good houseboats

k) Very easily repaired when damaged (the wire is pushed back and is replastered. Serious jobs only take hours sometimes minutes). If a bag of cement is kept available repairs can be done on the spot.

l) Very seaworthy

m) Do not hole easily and therefore resist a gross inflow of water and may thus save lives.

n) Resist internal explosive forces very well

o) Low noise transference,

p) More interior space as bulkheads and frames can be all but eliminated.

q) Cool in the hot season and warmer in the "cold" because of the very low thermal conductivity of F-C.

r) Immune from leaks that come from shrinking joints as on wooden or steel boats.

s) Long life-span (some small boats built a century age are still afloat and sound today). The boat hulls rebuilt this time should be still in essentially as good condition 50 - 100 years from now.

t) Strong in all directions unlike wood which has grain

u) Require no caulking

v) High resistance to abrasion and shock

w) Possess no odor.

## MAJOR PROBLEMS WITH FERRO-CEMENT BOATS IN THE EAST PAKISTAN CASE

Relative to the number of advantages the list of possible disadvantages is very short.

a) Weight. Ferro-cement boats over 35 feet in length are lighter than equivalent wooden boats. Wooden boats of these lengths however require considerable supports and a thick hull which adds markedly to the weight. In smaller craft (in the 20 foot range as in East-Pakistan) it is the ferro-cement construction that tends to be heavier when kept to ½" thickness. However, not too much should be made of this point as: in many developing countries the indigenous wood construction is already very heavy; light weight ferro-cement hulls with thicknesses down to 1/8 inch have recently been constructed in the U.S.; the effect of additional weight is greatly lessened in the water.

b) Ferro-cement is a little less homey for a houseboat as its surface is rougher than wood. It can be finished off with a thin skin of plywood or other surface however.

c) The major difficulty during construction is to get complete penetration of the mortar through the layers of mesh. The wooden-mold method promoted widely by the Samson company in particular suffers from inadequate penetration as the inner surface is covered with wood. The new shot crete method in which the mortar is blasted into the reinforcing can overcome this but the most technoligically possible approach for East Pakistan is to use the pipe mold method. In this case the reinforcing is supported around the ends of a few pipes. The inner surface of the reinforcing is then open and mortor can be forced in from both sides ensuring adequate penetration.

d) Minor flaking of the outer cement surface appears to occur to some extent especially when the outer cement layer projects beyond the reinforcing surface more than 1/8 inch. In the East Pakistan situation flaking would seem to be of very little significance.

e) F-C is strongest on curved structures. Some craft in East Pakistan may have flat sides and bottoms and in this case extra supports may have to be added.

## SOURCES FOR FERRO-CEMENT BOAT BUILDING EXPERTISE

I have been able to identify the following people as having exceptional expertise in ferro-cement boat building:

1. Prof. James Romualdi
   Dept. of Civil Engineering
   Carnegie-Mellon Institute
   Pittsburgh, Penn. 15213 Tel.: 412-621 2615

Prof. Romualdi is very knowledgeable about the correct engineering of ferro-cement and is familiar with improvements in techniques that are not yet generally known.

2. Mr. John Gardner
   Technical Editor
   "National Fisherman"
   Elm Street
   Camden, Maine 04843

   Home:
   12½ Bruggemann Place
   Mystic
   Conn. 06355
   Tel.: 203-536 2631

Mr. Gardner has written extensively on F-C and appears to be able to identify strengths and weaknesses of the various proprietary systems and methods. He has taken part in international FAO fishing fleet conferences.

3. Mr. Jack R. Whitener
   Vice President and Publisher
   The Ferro-Cement Times
   Director; North America Ferro-Cement Marine Association Inc.
   1959 Old Middlefield Road
   Mount View, California 94040 (415) 964-0394
   Author of a new and definative book on the subject and is considered to be one of the foremost authorities on the techniques and practical aspects of F-C marine applications.

4. Martin Iorns (see a) below)

5. W. Morley Sutherland, Consultant to FAO (see c) below)

6. Dr. Pier Luigi Nervi (see e) below)

7. John Fyson (see f) below)

8. T.M. Hagerback (see i) below)

9. John Samson (see b) below)

10. Richard H. Muenzer, President
North American Ferro-Cement Association Inc.
P.O. Box 786
Mountain View
California 94040

11. Robert P. van Spyk
Assistant Professor of Geography
California State College, Hayward
Hayward, Calif. 94542

Phone: (415) 538 8000 EXT. 635

Professor van Spyk and his colleagues have developed a proposed training program for giving underdeveloped nations the capability to build their own F-C craft. This team has gathered considerable information on pertinent economic, social, and cultural factors as well as on evaluations of the design and construction alternatives available.

12. Professor Surendra P. Shah
Dept. of Materials Engineering
College of Engineering
University of Illinois at Chicago Circle
Box 4348
Chicago, Ill. 60680

Has considerable experience with the engineering of F-C structures. Has written what may become the key papers on the subject. He is from India.

13. Professor Brady Williams
Department of Engineering
University of California
Berkeley
Cal. 94720

Developer of new techniques for combining layers of fiberglass with layers of ferro-cement.

14. Prof. L. Lachance
Dept. of Civil Engineering
Laval University
Quebec City
Quebec
Canada

and P. Fugere
Piette, Audy, Lepinay, Bertrand and Lemieux
Consulting Engineers
Quebec City
Quebec, Canada

Developers of ferro-shotcrete where the mortar is made in a nozzle as it is being forced into the reinforcing.

15. Prof. Sami Abboud Klink
Department of Civil Engineering
American University
Beirut
Lebanon

Developer of Fycrete a fiberglass impregnated cement. A very similar product is being used commercially in the U.S.S.R. for boat-building.

16. American Concrete Institute
P.O. Box 4754
Redford Station
Detroit
Michigan, 48219

17. Portland Cement Association
Old Orchard Road
Skokie
Illinois, 60076

18. Cement and Concrete Association of Australia
147-151 Walker Street
North Sydney
NSW
Australia

19. Mr. R.G. Lefebvre
F.A.O. Project No FH/INT/2
BP 506
Cotonou
Dahomey
West Africa

Mr. Lefebvre, a Canadian, is developing indigenous capability to produce ferro-cement fishing craft among Dahomeyan fishermen who now use very primitive methods.

20. Mr. Wilder Moffatt
9 Common Street
Hingham, Mass.

21. Mr. Jim Mc Culloch
Box 5647
Tampa, Fla. 33605

22. Mr. Russell Bartell
85 Glendale Drive
Miami Springs, Fla.

23. John Vasta
Litton Systems
P.O.Box 92911
Los Angeles, Cal. 90009
Tel.213-322 9220
ext. 1426

24. Captain John Enterprises
Route 3
Delaware, Ohio

25. Dr. R.B. Heckler
Loew Chemical Corp.
Box 615
Miami. Fla. 33133

26. J.R. Benford
Yacht Quay
Box 456-8
Friday Harbor
Washington 98250

(Author of a book on ferro-cement boat-building)

27. Dr. John C. Gebhardt
2024 West Street
Suite B
Annapolis Md. 21401

(Naval Architect)

## BOATBUILDING COMPANIES WHICH HAVE SPECIALIZED IN FERRO-CEMENT

a) Fibersteel Corporation (Mr. Martin Iorns, President)
P.O. Box 661
West Sacramento 95691

This company has been in ferro-cement for some 10 years. Mr. Iorns is reputed to be the most knowledgeable person in North-America about the technique in its practice. He has now developed a method for rapid construction using a male and female mold system.

b) Samson Marine Design Enterprise Ltd. (John Samson, President)
P.O. Box 98
Ladner
B.C.
Canada

Specialise in designs, plans, training programs, books etc.

c) Ferro-Cement Ltd. (W. Morley Sutherland, Manager)
P.O. Box 2393
Auckland
New Zealand

Sutherland is author of "The best manual for the amateur builder yet published and the only one I can unconditionally recommend" (This, and following quotes are all from John Gardner writing in the National Fisherman)
This company has built boats for South East Asian conditions under contract from Hong Kong, and is reputed to have built the widest range of F-C boats yet built anywhere in the world.

d) Ferro-Cement Marine Construction Ltd.
800 Bank of Canton Building
8 Des Voeux Road C.,
Hong Kong

Now building 55 foot fishing vessels out of Hong Kong. Their vessels are some of the largest commercially built ferro-cement fishing vessels in the world.

e) Nervi and Bartoli
Lungotevere Arnaldo Da
Brescia 9
00196 Rome, Italy

"In a press release from Rome early this year, the FAO announced that two ferro-cement fishing boats for use on Lake Nasser in the United Arab Republic had been ordered, to be built in Rome by the architectural and engineering form of Nervi & Bartoli. As is generally well known, the senior member of this firm, the world famous architect, Dr. Pier Luigi Nervi, originated ferro-cement as differentiated from reinforced concrete; and designed the first vessels built of this material immediately following World War II."
That the FAO has retained the services of the firm of Nervi & Bartoli is further indication of the quality of their experimental program

which it is announced, will include testing for the best types of steel mesh for use in ferro-cement boat construction.

f) F.A.O.

As mentioned above, the F.A.O. has 2 boats being built for the U.A.R. "The larger of these two boats is 32'8" x 10', will weigh 3½ tons and will be equippe with a 16 h.p. diesel engine. The smaller is 24'6" x 8', to weigh 2 tons with an 8 h.p. motor. These boats are designed for the arid climate of the upper U.A.R., are open and cabinless and will be used to demonstrate fishing techniques, as well as serving as prototypes for a feet of similar fishing craft to be built on the lake shores by native labor. Assisting in the project is the FAO boatbuilder R.G. Lefebvre of Canada who will be in charge of a similar boatbuilding project in Dahomey financed by Canada under the Freedom From Hunger Campaign.
Another ferro-cement vessel in successful operation in the Far East is a 52' trawler fishing out of Thailand. This vessel, intended as the prototype for future low-cost fishing fleets, was designed by John Fyson, N.A., of the Food and Agriculture Organization of the U.N., assisted by Thong Nagradok of the Royal Thai Fisheries Dept. According to an estimate made by Fyson, the cost was only about two thirds the cost of a comparable craft constructed of conventional materials. The vessel is powered by a 6-cylinder Caterpillar D333C marine diesel rated at 190 h.p. which was donated, together with the driver gear, to the FAO and the Thai Government by the Caterpillar Tractor Co. of Peoria, Ill."

Fyson's address is: Mr. John J. Fyson
Boatbuilder FH/THA/9
c/o F.A.O.
Maliwan Mansion
Phra Atit Road,
Bangkok 2, Thailand

g) Communist China has more ferro-cement boats (thousands) than the rest of the world combined. They obtained the basic ideas from the New Zealanders mentioned above and at a plant at Wusih not far west of Shanghai they have a highly efficient production line producing sampans by the hundreds.

h) Featherstone Marine Corp.
Tampa, Florida

Have built the first American luxury yacht made of ferro-cement, an order exceeding one million dollars.

i) Windboats Ltd.
Wroxham
Norfolk
England (Manager T.M. Hagenbach)

This company has been building successful F-C boats for over a decade.

j) Windboats Ltd. collaborates with

Jones Buckie Shipyard Ltd.
Buckie
Banffshire
Scotland

who have facilities for building up to 85 foot F-C boats.

k) The Luzon Stevedoring Co.,
Port Area,
Manila
Philippines

This South East Asian company has been quick to see the merits of a related technique that of pre-stressed concrete. They use pre-stressed barges for interisland commerce and the barges have proved resilient enough to withstand a collision with a freighter.

l) Forster Shipbuilding Co.
Ferry Berth 231
Terminal Island
San Pedro 90731

m) Gutent & Zimmerman
Construction Div., Inc.
Box 1688
Stockton 95201

n) Harbor Boat Building Co.
258 Cannery St.
Terminal Island
San Pedro 90731

o) Harbor Boatworks
Harbor Dr. at 26th
San Diego 92112

These last four are all listed as F-C boatbuilders in the Fishery Leaflet 618 of the U.S. Dept. of Interior, Nov. 1968

cont.

p) The Naval Ship Research and Development Center
Annapolis, Md.

Have built a number of ferro-cement swiftboats for riverine duty in Vietnam

q) Mc Connell Dowell Ltd.
89 College Hill
Auckland
New Zealand

Civil engineers and contractors, especially knowledgeable about concrete barges.

r) Fletcher Holdings Ltd.
Private Bag
Auckland
New Zealand

s) Ce Fer Designs Ltd.
898 River Richmond, B.C.
Canada

t) Hartleys Boat Plans Ltd.
P.O. Box 30094
Takapuna North
Auckland
New Zealand

PEOPLE KNOWLEDGEABLE ABOUT FISHING VESSELS AND THEIR DESIGNS

a) Mr. M.R. Greenwood
U.S. Department of Commerce, NOAA
National Marine Fisheries Service,
Acting Chief, Division of Resource Technology
2559 Main Interior Building
18th & E St., N.W.
Washington, D.C. 20235

b) Mr. Loyal G. Bouchard
U.S. Department of Commerce, NOAA
National Marine Fisheries Service,
Staff Assistant, Division of Resource Technology
2559 Main Interior Building
18th & E St., N.W.
Washington, D.C. 20235 Phone: 343-2646

c) Mr. O. Gulbrandsen
Fishing Vessels Section
Fishing Vesselsand Engineering Branch
Fishery Industries Division
FAO of the UN
Via delle Terme di Caracalla
00100 Rome
Italy

The FAO has done important work on fishing craft of the world for more than 20 years. They have done a great deal of work with fishing boats in India. They are familiar with steps necessary to

negotiate the transition from traditional but primitive native craft to more efficient craft.

d) Dr. Lindsay Lord N.A.
Amerscoggin Road
Falmouth Foreside
Maine 04105

Designed composite wood-plastic fishing boats for East African fisheries which were packaged in a "knocked-down" state here, shipped by steamers, and assembled at the destination where they were used by unskilled labor.

EXPERTISE ON EAST PAKISTAN FISHERIES

a) Basil Greenhill CMG.
Director, The National Maritime Museum
Greenwich
London, SE 10
England

Long time resident in East Pakistan, author of "The Boats of East Pakistan". World renowned expert on small vessel designs.

b) John W. Parsons
Biological Laboratory
U.S. Fish and Wildlife Service
Ann Arbor
Michigan

Spent several years as resident USAID fisheries specialist in East Pakistan. Very conversant with the problems, sociology, technology and needs of fisheries in the area.

c) Dr. Norman L. Brown
Office of the Foreign Secretary
National Academy of Sciences
2101 Constitution Ave., N.W.
Washington, D.C. 20418, Phone: 961-1524

Spent time in East Pakistan as consultant to USAID on the potential for fish protein concentrate production in the delta area.

## BUILDING A FERRO-CEMENT BOAT

When plans for the boat have been completed, the first step in ferro-cement construction is to build the pipe and rod framework that outlines the form of the hull. Vertical frames spaced at 2- or 3-ft. intervals, or as needed, along the length of the boat are fabricated from ½- to 1-in. -diameter pipe or tubing. Standard ½-in. concrete reinforcing bars also can be used.

The deck can be formed from ferro-cement or wood. To fasten a wood deck to the hull, bolts can be welded to the reinforcement and left projecting through the mortar; or holes can be drilled through the mortar with a carbide-tipped drill for mounting bolts.

Location of fittings should be planned along with hull design so that bolts can be anchored in the hull reinforcement at the proper location before mortar is placed. Dowels or plugs can be embedded in the mortar to provide for fastening wood or timbers, or they can be used for blanking out openings in the hull.

Sand should be sharp, clean, and well graded, with 100 percent passing a No. 8 sieve and 10 to 15 percent passing a No. 100 sieve. Actual mix proportions and workability requirements have to be determined by trial in each case based on the materials available.

A power-driven mortar mixer or small concrete mixer should be used. Hand mixing should be avoided. The mortar should be thoroughly mixed keeping in mind that only the minimum water needed for workability should be used.

Mortar is placed on the inside of the hull and forced through the mesh reinforcement. It is then troweled to a smooth finish on the outside. Where possible, the entire hull should be plastered in one continuous operation to avoid formation of cold joints between hardened and fresh mortar.

A small pencil vibrator can be used to consolidate concrete in areas where a number of rods intersect or where multiple layers of mesh overlap.

Exposure to hot, dry winds, during plastering should be avoided as this tends to dry out the mortar and prevents hydration of the cement. A temporary enclosure may be needed to protect the hull during plastering and curing.

After the mortar has been forced through the mesh to the outside of the hull, it si smoothed first with a wood float. After a brief waiting period, the surface can be steel troweled to a smooth, hard finish

Projecting ends of wire should be cut off or bent below the surface of the mortar. The surface should then be repaired.

To complete the finish of the hull, ridges and rough spots can be smoothed out by rubbing with a carborundum stone a few days after the mortar is placed.

Previous Page Blank

Proper curing is essential to fully develop the desired properties of the cement mortar. Curing ensures complete hydration of the cement and prevents surface cracking. Basically, good curing requires that the cement mortar be kept continuously moist for at least 7 days and preferably up to 28 days. Burlap can be draped over the hull and kept continuously wet. Soaking the hull periodically with a garden hose is acceptable. Lawn sprinklers, placed inside and outside of the hull and automatically turned on and off at suitable intervals by a timer, have provided good curing. A drain in the bottom of the hull is needed to prevent its filling with water. It may be helpful to enclose the hull in plastic sheeting to keep the surrounding atmosphere continuously moist.

Experience has shown that ungalvanized steel properly embedded in cement mortar does not corrode even in a marine atmosphere. Nervi's original boats were built with ungalvanized steel. Therefore, it is not necessary to use galvanized reinforcement to avoid rusting as some have suggested.

## NEW DEVELOPMENTS IN FERRO-CEMENT TECHNOLOGY

There have been a number of variants on the Nervi-Ferro-cement process (as described above) that have been developed in recent months. In each case they require more skill and technique than the Nervi method and thus have not been explored fully in this study.

The following is an outline of these with leading references from which further information can be gained.

a) Fycrete: Uses specially treated glass fibers mixed with concrete instead of steel rods. Reputed to possess an effective tensile strength six times stronger than reinforced concrete. Using the glass - reinforcing the elimination of the steel rod in reinforced concrete would mean a savings of from 40 to 60 per cent in construction costs. Dr. Sami Abboud Klink, a 41 year-old professor of civil engineering, believes that his use of specially treated glass fibers mixed with concrete on the construction is the answer to current use of steel rods.
Fycrete's reported superiority relative to reinforced concrete is in low cost, short preparation time, resistance to micro-cracking, elimination of expansion and thus the need for expansion joints.
It is reported that two factories in Kiev (U.S.S.R.) have began production of such "glass-cement" boats.

Developer is: Professor Sami Abboud Klink
Department of Civil Engineering
American University
Beirut
Lebanon

b) Ferro-Shotcrete: "The technique of shotcreting permits, in general, a better penetration of a low slump concrete mix through the various layers of reinforcement. For the construction of the hull, the dry-mix process has been used in order to shoot the concrete onto the wooden form. In this technique, the sand and cement are first thoroughly mixed, then blown through a hose by means of compressed air. Water is introduced under pressure inside the nozzle at the end of the hose, and the concrete is shot onto the form and reinforcement. The relatively dry mix projected with force by the air jet gives a concrete of high ultimate strength and impermeability.

Developers:

Prof. L. Lachance
Dept. of Civil Engineering
Laval University
Quebec City, Quebec
Canada

Mr. P. Fugere
Piette, Audy, Lepinay, Bertrand and Lemieux
Consulting Engineers
71, Saint Pierre
Quebec City, Quebec
Canada

c) Expanded Metal technique: Expanded metal can be used as a substitute for chicken wire and it is cheaper and thicker so that fewer layers ( and therefore less labor) are required to achieve a given thickness.

d) Aluminium Reinforcing: Aluminium has the tremendous advantage of lightness but corrodes in contact with wet cement. The development of suitable coatings may see this method become practical though there still remains problems of differences in the coefficients of expansion between concrete and aluminium.

e) Wirand: Short lengths of fine wire are mixed directly with the concrete in the mixer. These slivers become embedded and closely spaced in the concrete, laying in random directions. Remarkably resistent to cracking and can resist very high tensile stresses. Can be cast into thin sections and into any shape desired. Can be molded with styrofoam molds.

Developer:

Prof. James Romualdi
Department of Civil Engineering
Carnegie-Mellon University
Pittsburgh, Penn

f) Pre-stressed concrete: The steel reinforcing is put under tension before the concrete is enmeshed with it. This method is superior to F-C for flat bottomed or straight sided boats such as barges. Hundreds of pre-stressed concrete barges and pontoons have been built worldwide; (ever has been recommended for airplane and submarine construction).

g) Self-stressing cement: This material expands as it cures and thus creates stress on the reinforcing. Not yet tried for boat-building.

Developer:

Chemically Prestressed Concrete Corp.
14656 Oxnard St.
Van Nuys
California

A new non shrinking cement called "Chem Comp" developed by the same company is reputed to have potential here but some problems remain as it is a fairly wet mix and does not adhere to the reinforcing well during plastering.

h) Combination F-C and fiberglass: This method uses fiberglass webbing in the outer layers of the ferro-cement. Still in the experimental stage.

Developer:

Prof. Brady Williams
Dept. of Engineering
University of California
Berkeley
California, 94720

i) A source of strong fibers that is available in South East Asia is bamboo. As a speculation, bamboo may be able to be used as a fiber-filler in ferro-cement structures.

## EAST PAKISTAN SHIP-BUILDING COMPANIES

Khulna Shipyard
East Pakistan Industrial Development Corp.
Khulna

Narayanganj Dock and Engineering Works
Narayanganj

Pak Bay Shipyards
Narayanganj

## REFERENCES

Nervi, P.L., Structures, McGraw-Hill Book Co., Inc., New York, 1956 118 pp

ACI Committee 506, "Recommended Practice for Shotcreting", ACI Standard 506-66, 1966, 26 pp.

Hagenbach, T.M., "Ferro-Cement Boats", Proceedings of the Conference on Fishing Vessel Construction Materials, Montreal, Oct. 1968.

Lorman, W.R., "Engineering Properties of Shotcrete", ACI Publication SP-14A, 1968, 53 pp.

Romualdi, J.P., and Mandel, J.A. "Tensile Strength of Concrete Affected by Uniformly Distributed and Closely Spaced Short Lengths of Wire Reinforcement", ACI Journal, Proceedings V. 61, No. 6, June 1964, pp. 657-671.

ACI Committee 506, SHOTCRETING, ACI Publication SP-14, 1966, 223 pp.

ACI Manual of Concrete Practice, Part 1, "Materials and Properties of Concrete", ACI Publication, 1968.

Ferro-shotcrete: a promising material Ocean Industry Nov. 1970 p 60

Ferro Cement Boats Concrete Information Bulletin C 39 Cement and Concrete Association of Australia

The Boats of East Pakistan B. Greenhill, Society for Nautical Research, National Maritime Museum, Greenwich, London SE 10, England

The Ferro-Cement Times (a quarterly publication) 1959 Old Middlefield Road
Mountain View, Calif 94040

Ferro-Cement Boat Construction by Jack R Whitener
Cornell Maritime Press, Inc.
P.O. Box 109
Cambridge, Maryland 21613

James, reported in Fishing Boats of the World, Vol. 3 p 314
Fishing News International

Transactions of the Fish Protein Concentrate Seminar Dacca Pakistan
Nov. 7-8 1967 (USAID) Edited by John W. Parsons

The Navships Translation No 1148 of "Ship Hulls Made of Reinforced Concrete"
Bezukladov Amel'yanowich Verbitskiy and
Bogoyavlenskiy, Shipbuilding Publishing House.
Leningrad 1968

How to Build a Ferro-Cement Boat John Samson and Geoff Wellens
Samson Marine Design Enterprises Ltd
Vancouver, Canada, 3rd Ed. 1968

Concrete Boatbuilding its technique and its future
G.W. Jackson and N.M. Sutherland
John de Graff Inc.
Tuckahoe, New York 1969

Proceedings, Conference on Fishing Vessel Construction Materials
Montreal, Canada Oct 1-3, 1968
Canadian Fisheries Reports No. 12,
June 1969, Dept. of Fisheries and Forestry
Ottawa, Canada

Mechanical Properties of Ferro-Cement, A.E. Naaman and S.P. Shah, Research
Report R70-68, Dept. of Civil Engineering, Mass.Inst.
of Technology

Some Micromechanical Properties of Fiber Reinforced Concrete, S.P. Shah and
B.V.Rangan, Mimeographed Report from Prof. Shah,
Dept. of Materials Engineering, University of Illinoi
at Chicago Circle

Ferro-cement as a material for Offshore Structures, S.P. Shah and W.H. Key.
Paper # 1465

Offshore Technology Conference, April 1971

Construction of a Ferro-Shotcrete Motor-Sailer, L. Lachance and P. Fugère, L'Ingenieur, Montreal Mar 1970

Ferro-Cement as a New Engineering Material, S.P. Shah, Report R-70-11, Presented at the annual convention of the Canadian Capital Section of the American Concrete Institute, Ottawa, Dec.1970

# A BIBLIOGRAPHY ON CONCRETE SHIPS AND BOATS,
Including References on Ferro-Cement,
compiled by the American Concrete Institute
Revised by M. K. Hurd, Oct. 15, 1968


## 1908

"Reinforced Concrete in Shipbuilding," Scientific American, Mar. 21, 1908.

## 1910

"Concrete Battleship," Cement Age, V. 10, p. 56, 1910.

"Reinforced Concrete Barges at Panama," Engineering Record, 1910; Cement Age, V. 11, Sept. 1910, p. 145.

## 1916

"Concrete Barges Stand Test," Engineering News, Nov. 16, 1916, V. 76, p. 927.

MacDonald, A., "Lightweight Aggregate Alters Ship Design," Concrete, Oct. 1916, p. 131, Nov. 1917, p. 162, Oct. 1918, p. 113.

## 1917

Boon, A. A., Der Bau Von Schiffen aus Eisenbeton, Berlin, 1917.

## 1918

Boon, A. A., "Concrete Vessels in Holland," Concrete and Constructional Engineering, V. 13, No. 2, 1918, p. 83.

"Britain's Concrete Ship Program," Canadian Engineer, V. 35, 1918, p. 119.

Freeman, J. E., "Developments in Concrete Barges and Ships," Proceedings, American Concrete Institute, V. 14, 1918, pp. 422-427. (xerox copy) $1.10

"Government Designs and Builds 3500-ton Concrete Ship," Engineering News-Record, V. 81, July 4, 1918, p. 17.

Livingston, L. L., "Design and Construction of a Concrete Barge," Proceedings ACI, V. 14, 1918, p. 433. (xerox copy) $ .80

Monks, A. C., "Yard for Building Concrete Ships at Wilmington, N. C.," Proceedings ACI, V. 14, 1918, pp. 428-432. (xerox copy) $ .50

Pollock, W., "Reinforced Concrete Vessels," Transactions, Institution of Naval Architects, V. 9, 1918, p. 138.

Report of the Joint Committee of the American Concrete Institute and the Portland Cement Association on Concrete Ships and Barges, Proceedings ACI, V. 14, 1918, p. 505. (xerox copy) $1.20

Searle, A. B., "Shipbuilding in Norway," Concrete and Constructional Engineering, V. 13, No. 2, 1918, p. 35.

Wig, R. J. and Hollister, S. C., "Problems Arising in the Design and Construction of a Concrete Barge," Proceedings ACI, V. 14, 1918, p. 441. (xerox copy) $2.40

## 1919

Bush, A. L., "Lay-Out and Equipment of Government Concrete Ship Yards," Proceedings ACI, V. 15, 1919, pp. 216-230. (xerox copy) $1.50

"Concrete Ships in America," International Marine Engineering, V. 24, Jan. 1919, p. 62.

Glaetti, J., Jr., "Problems in the Design of Reinforced Concrete Ships," Proceedings ACI, V. 15, 1919, p. 231. (xerox copy) $1.00

Hollister, S. C., "Construction of Concrete Barges for Use on New York State Barge Canal," Proceedings ACI, V. 15, 1919, p. 289. (xerox copy) $2.10

Report of Committee on Ships, Proceedings ACI, V. 15, 1919, p. 312. (xerox copy) $ .20

Slater, W. A., "Structural Laboratory Investigations in Reinforced Concrete Made by Concrete Ship Section, Emergency Fleet Corporation," Proceedings ACI, V. 15, 1919, p. 24. (xerox copy) $3.60

Wig, R. J., "Method of Construction of Concrete Ships," Proceedings ACI, V. 15, 1919, p. 241. (xerox copy) $4.80

## 1920

"Problems of Reinforced Concrete Shipbuilding," Zement-Verarbeitung, Heft 13, 1920, Zementverlag, Charlottenburg, Germany.

Searle, A. V., "Reinforced Concrete Ships, Barges, and Pontoons," Concrete and Constructional Engineering (London), 1920, V. 14, p. 73, 137 and V. 15, p. 420.

## 1921

"Notes on Construction of Concrete Ships at San Diego," Concrete, V. 19, July 1921, pp. 18-22.

Report of Special Committee on Ships and Barges, Proceedings ACI, V. 17, 1921, p. 285. (xerox copy) $ .70

## 1922

Fougner, N. K., Sea-Going and Other Concrete Ships, Frowd, Hodder. and Stoughton (London), 1922.

Harper, W. R., "Concrete Ships Constructed by U. S. Shipping Board," Proceedings ACI, V. 18, 1922, p. 83. (xerox copy) $3.20

## 1923

"New Concrete Barge," Concrete and Constructional Engineering (London), V. 18, Sept. 1923, p. 622.

1924

"Concrete Water Barge Resists Sea Water," Concrete, V. 24, June 1924, p. 246.

1925

Stevens, A. D., "Successful Experiment in Concrete," Concrete Products, V. 2, April 1925, p. 60. Coating 3/4 in. thick on expanded metal lath used to repair wooden ship riddled by teredo.

1931

Lange, H., "Concrete Barges," Beton und Eisen, V. 30, May 20, 1931, p. 182. Construction barges 32 x 20 x 8 ft and 20 x 16 x 5 ft of reinforced concrete, Rio de Janeiro.

1940

"Revived Interest in Ships of Concrete Recalls World-War Experience," Concrete, V. 48, May 1940, pp. 5-6.

1942

"Building Concrete Ships in Prefabricated Forms," Engineering News-Record, V. 129, Dec. 31, 1942, pp. 902-906.

"Concrete I is Launched--the First Since 1920," Concrete, V. 50, Dec. 1942, p. 34.

Kauf, L., "The Possibilities of the Concrete Boat," Concrete, V. 50, May 1942, pp. 2-4.

1943

"Concrete Steel Barges," Concrete and Construction Engineering (London), V. 38, Nov. 1943, pp. 354-355.

"Construction of Concrete Barges in the United States," Concrete and Constructional Engineering (London) V. 38, Aug. 1943, pp. 256-260.

Korni, M. A., "Reinforced Concrete Boats," The Indian Concrete Journal (Bombay), V. 17, Jan. 1943, pp. 3-6.

"Ocean-Going Concrete Vessels," Engineering News-Record, V. 130, June 17, 1943, pp. 878-883.

"Paint and Waterproofing Applied to Concrete Ships," JPP 39-133, Proceedings ACI, V. 39, June 1943, pp. 593-594. (xerox copy) $ .20

Yorkevitch, M. V., "An Experimental Concrete Tanker," Concrete and Constructional Engineering (London), V. 38, June 1943, p. 200.

## 1944

"A Concrete Ship of Circular Section is Tried Out in San Francisco Bay," The Indian Concrete Journal (Bombay), V. 26, May 1944, p. 165.

"First Self-Propelled Concrete Ships Built for War Service," The Indian Concrete Journal (Bombay), V. 18, Nov. 1944, p. 208.

"Lightweight Concrete-Steel Barges Armoured Against Hard Service," Constructional Methods and Equipment (London), V. 26, Apr. 1944, pp. 72-73.

McLaughlin, Robert E., "Powered Concrete Ships of World War II," Engineering News-Record; V. 133, Oct. 19, 1944, pp. 472-476

"Sea-Going Barges Built of Concrete," Constructional Methods and Equipment (London), V. 26, Apr. 1944, pp. 72-73.

"Stronger Concrete Ships," The Indian Concrete Journal (Bombay), V. 18, Sept. 1944, p. 165.

## 1945

"Precast Concrete Cargo Barges," The Indian Concrete Journal (Bombay), V. 18, Nov. 1945, pp. 205-206.

"Precast Reinforced Concrete Cargo Barges," Concrete and Constructional Engineering (London), V. 40, Oct. 1945, pp. 206-11.

Tuthill, Lewis H., "Concrete Operations in the Concrete Ship Program," Proceedings ACI, V. 41, Jan. 1945, pp. 137-180. (xerox copy) $4.40

## 1949

Finsterwalder, Ulrich, "Betonschiffe in Schalenbauweise," VDI Zeitschrift, V. 91, No. 7, 1949, pp. 157-163.

MacLeay, Francis R., "Thin Wall Concrete Ship Construction," Proceedings ACI, V. 46, Nov. 1949, pp. 193-204. (reprint) $ .35.

## 1954

Willson, George, "Concrete Ship Resists Sea Water 34 Years," Concrete, Jan. 1954, pp. 5-8, 53. Expanded shale lightweight aggregate concrete used in 7500-ton tanker built in 1919.

## 1956

"Small 'Ferro-Cement' Ships for Inland Water Transport," The Indian Concrete Journal (Bombay), V. 30, Nov. 1956, pp. 358-59 and 376.

Nervi, P. L., "Ferro-Cement: Its Characteristics and potentialities," Cement And Concrete Association* (London) Library Translation No. 60, 1956.

* 52 Grosvenor Gardens, London, SW 1.

1959

Collen, Lyal D. G., and Kirwan, R. W., "Some Notes on the Characteristics of Ferro-Cement," Civil Engineering and Public Works Review (London), V. 54, No. 632, Feb. 1959, pp. 195-196.

1960

Lossier, H., "Actual Examples of Sea-Going Ship Construction in Reinforced and Prestressed Concrete" (in French), Le Génie Civil (Paris), V. 137, No. 8, Apr. 15, 1960, pp. 170-173.

"New Splash for Concrete," Concrete Construction, Nov. 1960, p. 236.

1961

"Reinforced Cement Mortar Construction," Concrete and Constructional Engineering (London), Dec. 1961, pp. 429-433.

1962

Maynard, J. A., "Ferro-Cemento Boat Construction," Sea Spray* (New Zealand), July 1962, pp. 27-29, 39.

1963

"Concrete Boats" (editorial), New Zealand Concrete Construction**, V. 7, No. 2 Feb. 12, 1963, p. 21.

"Featherstone Ahoy," Concrete Construction, July 1963, p. 209.

"Ferro-Cement Boats," New Zealand Concrete Construction, V. 7, No. 2, Feb. 12, 1963, pp. 22-23.

Manning, A., "First N. Z. Made Concrete Boat," New Zealand Concrete Construction, V. 7, No. 2, Feb. 12, 1963, pp. 23, 24.

"Rubb-a-dubb-dubb," Concrete Products, June 1963, pp. 6, 8.

1965

"Concrete Motor Sailer Marire," Sea Spray* (New Zealand), Apr. 1965, pp. 54, 55.

*Sea Spray publisher is Universal Business Directories, Box 793, Auckland 1, New Zealand.

** New Zealand Concrete Construction is published by the New Zealand Portland Cement Association, 126 The Terrace, Wellington C.1, N.Z.

## 1966

"Chinese Build Concrete Boats," Concrete Products, Dec. 1966.

"Ferro-Cement," New Zealand Concrete Construction, V. 11, No. 9, Sept. 1966, p. 355.

## 1967

"Concrete Barges Multiply in Gulf," Concrete Products, V. 70, No. 1, Jan. 1967, pp. 56-58. Lightweight concrete vessels 30 x 70 ft, 12 ft deep; precast panels combined with shotcrete.

"Down to the Sea in Concrete Boats," Medusa Mirror, Summer 1967, pp. 11-13.

"Ferro-Cement Boats," Boating Industry, V. 30, No. 9, Sept. 1967, pp. 131-134.

"Ferro Cement Boats," Cement and Concrete Association of Australia*, 11 pages.

Fisher, Cassie, W., "Lambot's Boats--A Personal Rediscovery," Concrete (London), V. 1, No. 11, Nov. 1967.

Gardner, John, ----------National Fisherman, June 1967.

----------, Yachting Monthly, April 1967. (Comments on test results for ferro cement.)

## 1968

Boatbuilding with Hartley (book), Hartley's Boat Plans, Ltd., P. O. Box 30094, Takapuna North, Auckland, New Zealand. ($ 2.00 U.S. Funds, $ 5.00 for shipment by airmail)

"Canadian Builds Concrete Boat," Concrete Products, V. 71, No. 3, Mar. 1968, pp. 48-49. (reprinted in New Zealand Concrete Construction, July 1968)

"Concrete Boats--How and Why," New Zealand Concrete Construction, July 1968, 2 pp.

"Ferro-Cement" (editorial), New Zealand Concrete Construction, July 1968, p. 109.

"Ferro-Cement Tanks and Utility Buildings," New Zealand Concrete Construction, July 1968, pp. 110-114.

"Lambot's Boats," (correspondence) Concrete (London), Mar. 1968, p. 128.

"The Boatbuilders," New Zealand Concrete Construction, May 1968, pp. 87, 88.

Samson, John, and Wellens, Geoff, How to Build a Ferro-Cement Boat, Samson Marine Design Enterprises, Ltd., P.O. Box 98, Ladner, B.C., Canada, 1968, 120 pp, $9.75


* 147-151 Walker Street, North Sydney, N.S.W., Australia


1969-----"And Now--Prestressing at Sea," New Zealand Concrete Construction January 12, 1969, p. 14.