No. 014
March 1969

FERRO-CEMENT

WITH PARTICULAR REFERENCE TO MARINE APPLICATIONS

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With Particular Reference to Marine Applications

by

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Presented to

The Quarterdeck Society

University of Michigan

October, 1968

Presented to

The Pacific Northwest Section

Society of Naval Architects and Marine Engineers

March 1, 1969

Revised

March 17, 1969

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ACKNOWLEDGMENT

I would like to thank the firm of M. Rosenblatt & Son, who contributed funds which made the presentation of this student paper possible. It is this contribution of private funds and private involvement in educational institutions that make our universities the finest in the world. Consequently, this involvement is only made possible by the free enterprise system which exists in our country. I hope it continues.

INTRODUCTION

In this paper I have compiled various methods which people have used to design and construct ferro-cement boats. I have also included experimental results and introduction, reason and theory for various practices. The bibliography contains a great number of references.

Ferro-Cement

Ferro-cement is a very thin, highly reinforced slab of concrete. The reinforcement consists of several layers of wire mesh and steel rods. The mortar is high quality, slightly moist and is pressed or pneumatically forced through the reinforcement. Steel content is approximately 35 lb/ft^3 and mortar density is approximately 150 lb/ft^3. A 50-ft boat would have a hull thickness of 3/4 to 1 in. with a density of approximately 185 lb/ft^3.

CHARACTERISTICS

Ferro-cement has several properties that make it very desirable for boat construction.

Shape

Any desired shape can be produced in ferro-cement.

Weight

Boats made of ferro-cement between 35 and 45 ft have hull weights comparable to boats made of wood, steel or fiberglass. Ferro-cement boats greater than 45 ft in length are usually lighter than boats made of wood, steel or fiberglass. The converse is also true.

Durability

Experiments made by Dr. Pier Luigi, a noted Italian architect, indicate that ferro-cement has good impact characteristics.

> The shock resistance experiment revealed not only the high strength of slabs only 3 cm thick (the tests were carried out by dropping a weight of 250 kg on to samples 1.5 meters square, from increasing heights to approximately 3 meters), but also the fact that failure, when it occurred, did not consist of an actual hole in the structure, but rather a weakening of the wire mesh and a relatively dispersed breaking away of the mortar, the pieces of which still retained certain cohesion, and a certain resistance to the passage of water. An obviously important point, this, in naval work. (1)*

*Numbers following sentences indicate reference number on reference page.

In practice these characteristics have been proven on the <u>Irene</u> (Nervi's mortar sailer) and other boats. After striking a submerged wreck the <u>Irene</u> was kept afloat through the remainder of a voyage by use of a simple hand pump. Repairs consisted of filling in the dented area with mortar.

Minimum Hull Maintenance

Ferro-cement will neither rot, rust, nor is it susceptible to electrolysis. This greatly reduces the work and worry of hull maintenance encountered in wooden or steel boats.

Homogeneous Hull

Because a ferro-cement boat is one piece, there are no seams which may leak.

Fire Resistance

Ferro-cement boats have survived fires on board. However, at high temperatures, due to rapid dehydration, the strength of ferro-cement is questionable.

Thermo Conductivity

Ferro-cement has a low thermal conductivity, thus making it easier to keep a boat warmer in the winter and cooler in the summer. This is claimed to be a desirable feature in fishing boats' fish holds.

Cost of Materials

The cost of materials for a ferro-cement hull is claimed to be 50 to 75 percent that of a conventional hull made of wood or steel. There has been quite a variance in estimated cost; however, to date it has been economical to build boats of ferro-cement up to 60 ft in length.

Resistance to Marine Borers

Cement is resistant to all known marine borers.*

Retained Strength

Cement continues to gain strength, with no loss in toughness, as long as hydration takes place.

Odor

Cement is almost odorless.

Sound Absorbing and Vibration Absorbing

Ferro-cement has very good sound absorbing and vibration absorbing characteristics.

Strength

Ferro-cement has a yield strength of approximately 4500 psi (bending) and a Young's modulus of approximately 1.3×10^6 psi. The yield stress in pure tension is approximately 1500 psi.

*See Supplement.

HISTORY

The first known ferro-cement boats were built by Lambot in 1849. One particular boat was used on a lake in Southern France until the year 1900, when it sank. In 1955, when the level of the lake dropped, during a drought, the boat was discovered and placed in a museum in Brignoles, France.

In 1877, a concrete sloop, Seagull, was built for duckshooting. The Seagull was in service in the pelican pond at the Amsterdam Zoo until 1968.

A third known ferro-cement boat was built in Michigan in 1934.*

The technical beginning of ferro-cement was in 1943 when Pier Luigi Nervi, an Italian civil engineer, investigated the properties of ferro-cement and stated these principles:

> The fundamental idea behind this new reinforced concrete material ferro cement is the well known elementary fact that concrete can stand large strains in the neighborhood of the reinforcement and that the magnitude of stress depends on the distribution and subdivision of the reinforcement throughout the mass of concrete. (2)

This phenomenon is known as the synergistic effect and is being investigated by John Collins, a student at MIT.

After World War II, Nervi built two boats which are still in use today, a 65-ton motor sailer and a 38-ft ketch. But because of the peculiar idea of boats being made of cement and the unsuccessful history of reinforced-concrete ships during World War II, ferro-cement has not become a popular boatbuilding material. Perhaps the first large scale

*See Supplement.

manufacturer of ferro-cement boats was Windboats Ltd. of England. This company has been quite successful in establishing a charter fleet of ferro-cement boats.

Today there are a few boat yards which specialize in ferro-cement boat construction. There are also numerous naval architects who claim to be experienced in the design of ferro-cement boats; however, their knowledge of the material is often sketchy.

Several hundred boats have now been made of ferro-cement, the majority being "one-shot, backyard, specials." The commercial application of ferro-cement has been confined to fishing boats, a tow boat, marine pontoons, and architectural designs on land. The probable reason is that established boat builders are skeptical of the new material and don't want to spend money on an experimental craft, whereas the amateur builder does not account for his time and his only cost is materials.

Numerous optimistic articles, the success of ferro-cement boats, and the growing interest in the material by cement companies seem to be gradually promoting the material.

EXPERIMENTAL RESULTS

Technical information on ferro-cement is at a minimum. To date, experiments have included tensile tests, compression tests, bending tests and fatigue tests. There is still much to be desired in the way of technical data. Information which would be useful includes the proportional limit of ferro-cement using different mixes, the fatigue strength of ferro-cement with a time lapse between applications of loading, bonding strengths between batches of cement, and the failure of right angle joints.

Following are charts, graphs and experimental results which may be useful to anyone designing in ferro-cement.

Results of Experiments by University of Michigan Students (3)

Mix:

Cement	16.5 lb
Pozzolan	4.5 lb
Sand	30.0 lb
Water.	3500 cc

Wire Mesh:

1/2 in. x 1/2 in. #19 Galvanized wire mesh

Yield strength = 91,800 psi

Ultimate strength = 107,000 psi

Steel Rods:

1/4 in.

Yield strength = 39,800 psi

Ultimate strength = 62,600 psi

3/16 in.

Yield strength = 72,000 psi

Ultimate strength ≈ 90,800 psi

Cement:

Compressive strength = 4760 psi

Curing:

Seven days

Stress and Strain:

Strain was calculated from the deflection of the beam.

$\sigma = \varepsilon E$ for both steel and mortar. (σ = stress, ε = strain)

Dimensions of Samples:

30 in. long

6 in. wide

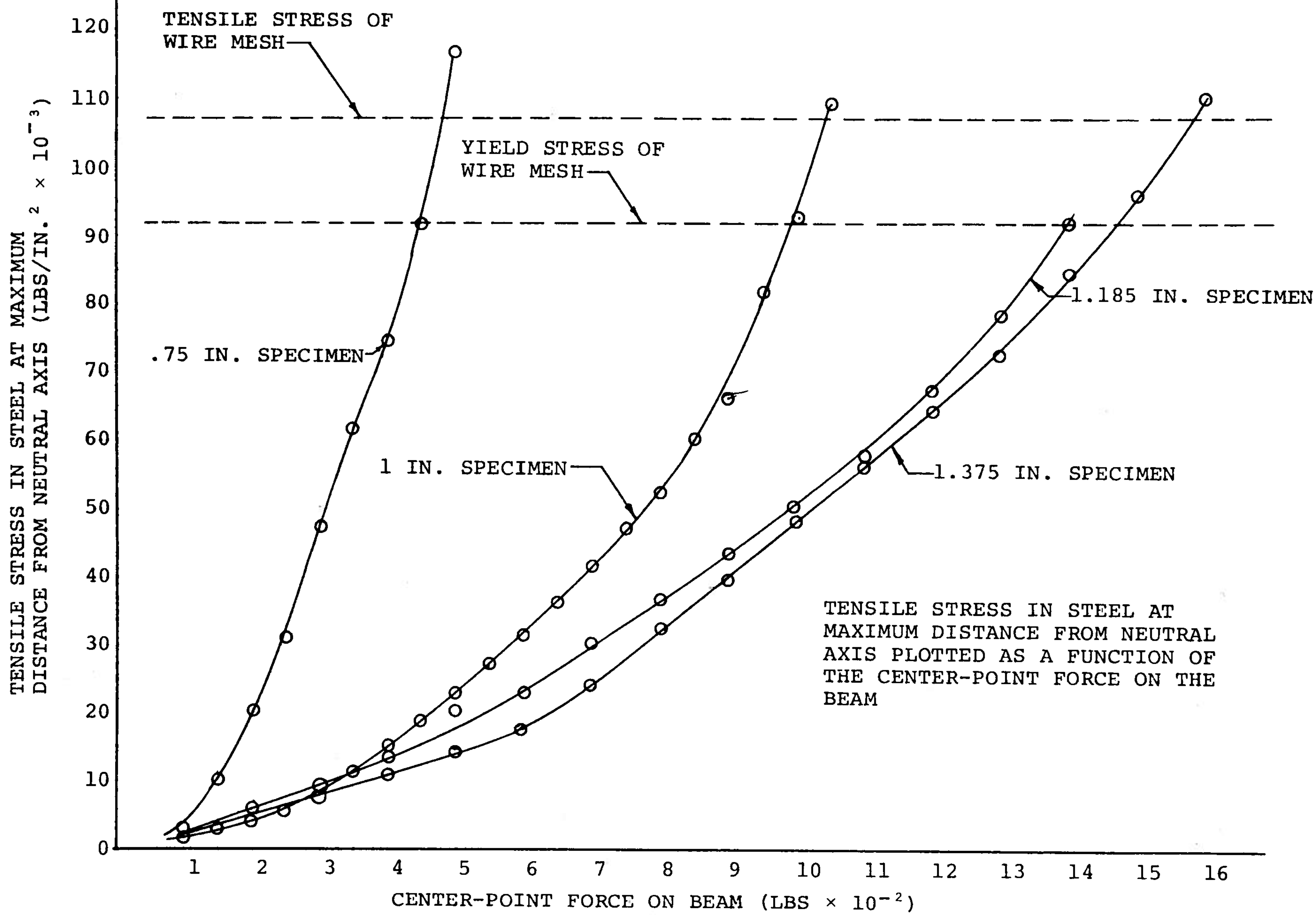
x in. thick

Loading:

Center loading (bending)

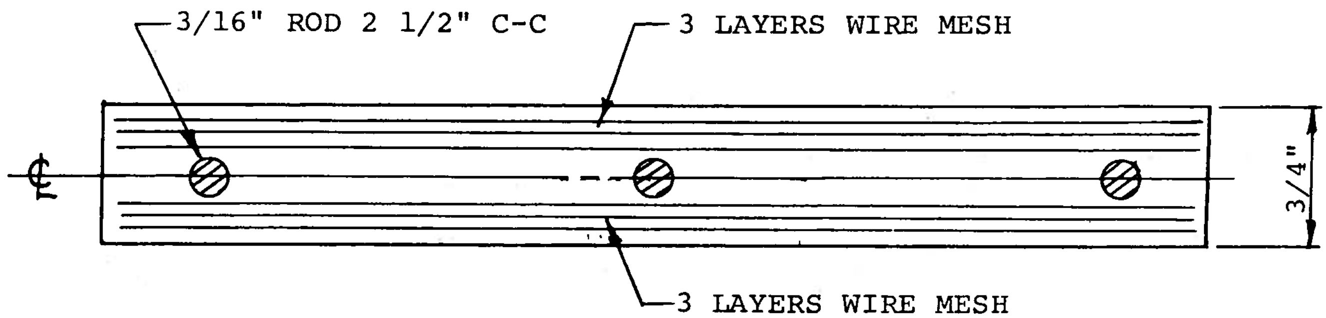
Span = 23.5 in.

REFERENCE (3)



TENSILE STRESS IN STEEL AT MAXIMUM DISTANCE FROM NEUTRAL AXIS PLOTTED AS A FUNCTION OF THE CENTER-POINT FORCE ON THE BEAM

TEST RESULTS, 3/4" SAMPLE (3)



(TRANSVERSE SECTION)

Force (pounds)	Deflection (inches)	Mortar Stress (compression) (lb/in.^{2})	Steel Stress (tension) (lb/in.^{2})
50	.0075	113.5	941
100	.0215	325.0	3,530
150	.0625	945.2	10,260
200*	.1275	1,928	20,920
250	.2075	3,137	31,140
300	.2905	4,392	47,680
350	.3755	5,676	61,620
400	.4545	6,869	74,560
450**	.5565	8,414	91,350
500	.7075	10,700	116,200

*Faint cracking heard

**Cracking observed

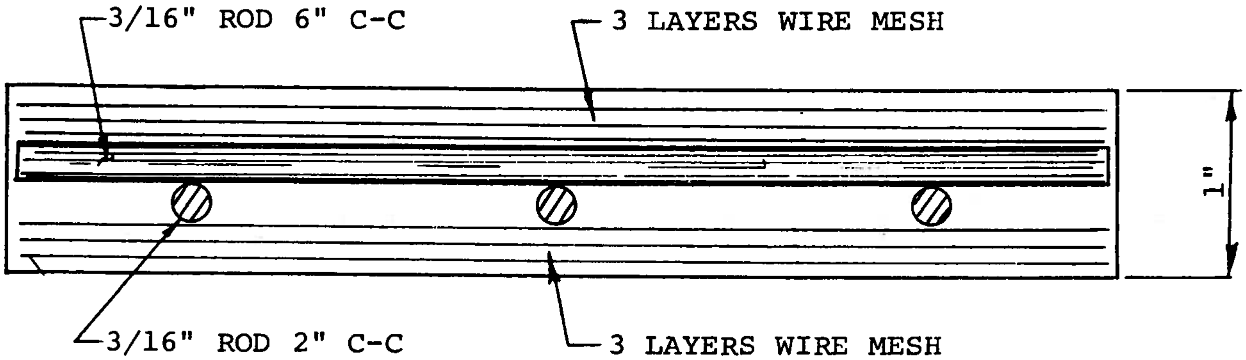
$E_c = 4.452 \times 10^6$

Centerpoint deflection

Span = 23.5 in.

$E_s = 29.0 \times 10^6$

TEST RESULTS, 1" SAMPLE (3)



(TRANSVERSE SECTION)

Force (pounds)	Deflection (inches)	Mortar Stress (compression) (lb/in.^{2})	Steel Stress (tension) (lb/in.^{2})
100	.009	117	2,036
200	.019	374	4,298
300	.0375	738	8,485
400	.068	1,339	15,385
500	.1025	2,018	23,190
600	.1405	2,766	31,780
650[1]	.161	3,170	36,430
700	.185	3,642	41,860
750[2]	.209	4,115	47,780
800[3]	.233	4,587	52,720
850[3]	.266	5,236	60,170
900[3]	.292	5,747	66,060
950[3]	.362	7,126	81,900
1000[3,4]	.408	8,030	92,310
1050[3]	.480	9,450	108,600

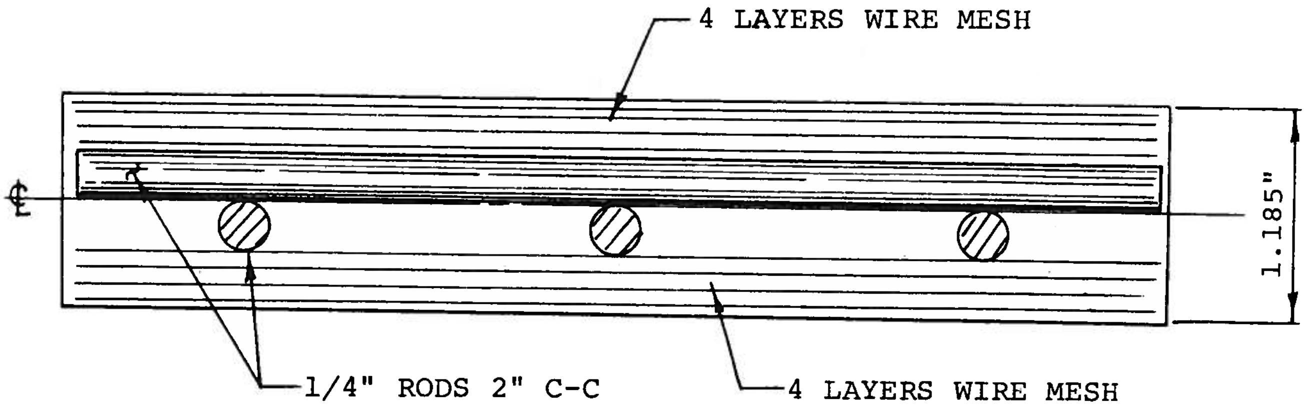
[1]Heard faint cracking

[2]More cracking heard

[3]Load unsteady

[4]Cracking observed

TEST RESULTS, 1 3/16" SAMPLE (3)



(TRANSVERSE SECTION)

Force (pounds)	Deflection (inches)	Mortar Stress (compression) ($lb/in.^2$)	Steel Stress (tension) ($lb/in.^2$)
100	.0105	271	3,312
200	.022	567	6,417
300	.031	799	9,040
400	.044	1,133	13,346
500	.0705	1,816	20,560
600	.080	2,061	23,330
700	.104	2,679	30,330
800	.127	3,272	37,040
900	.150	3,864	43,740
1000	.174	4,482	50,750
1100	.198	5,100	57,740
1200*	.230	5,926	67,080
1300	.268	6,905	78,170
1400**	.315	8,116	91,870

*Cracking heard

**Cracking observed

$E_c = 4.452 \times 10^6$

Centerpoint deflection

Span = 23.5 in.

$E_s = 29.0 \times 10^6$

Experimental Results and Properties (4)

by

Windboats Ltd.
Wroxham, Norwich, Norfolk. Nor 03 Z

Notes in Regard to the Physical Properties of Seacrete

"Seacrete" may be described as a very special form of concrete with steel wire reinforcement.

Density

151 lb/cu ft (Mahogany 36 lb/cu ft; reinforced plastic 100 lb/cu ft)

Ultimate Stress, Tensile

Tensile bending stress on panels 48 in. x 12 in. x 7/8 in. loaded at centre point:

Stress to crack	1900 lb/sq in.
At yielding	3600 lb/sq in.
At ultimate	5340 lb/sq in.

Tensile stress:

Stress to crack	1300 lb/sq in.
Stress to break	1690 lb/sq in.

Ultimate Stress, Compression

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

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

Young's Modulus

Modulus of elasticity = 1.30×10^6 lb/sq in.

NOTE: The only tests so far carried out took place 3 years ago. We are confident that current production would show an improved figure.

Bending Fatigue Tests

Four sample strips 21.65 in. long, 5 in. wide and .65 in. thick were tested. The distance of the loading point from one support point was 8.5 in.

The results were as follows:

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

Thermal Conductivity

Low--1/6th that of steel

Resistance to Chemical Agents

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

Acetic acid, carbonic acid in water, lactic acid, tannic acid, sulphates, milk or silage juices. Fair. Special surface treatment desirable.

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

Resistance to Mechanical Agents

e.g., Ice, shock, impact, explosion--High

Resistance to Fire

Test panels have withstood 1700°C for 1 1/2 hours with no effect on the material--Very high

Resistance to Marine Borers

Complete. They have no effect.

Aging Properties

Concrete boats are still in use after 42 years service and tests show that these are stronger now than when made. "Seacrete"-hulled craft in Windboats' Norfolk Broads Hire Fleet, where they are subjected to notoriously rough treatment, are in excellent condition after 5 years service.

Sound Absorbance

Good

Vibration Absorbance

Good

Odour

Nil

Surface Finish

Smooth and good

Features

No maintenance is required.

Damage, if it does occur, is usually very localized and is easily repairable. (A special repair kit can be furnished.)

Good thermal insulation minimizes condensation.

"Seacrete" hulls may be painted to enhance appearance and the surface will take a good paint coating.

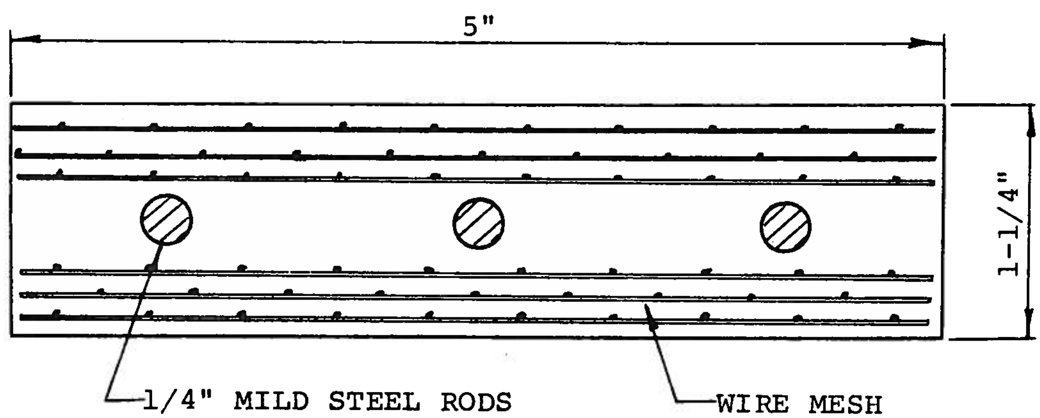
The bulk of the test data just given were extracted from a report prepared by Lloyds Register of Shipping, who have intimated that they will give Classification 100 A.1--their highest--to a vessel with a "seacrete" hull, provided that in all respects, e.g., superstructure, engine installation, electrics, etc., the construction complies with their rules.*

*See Supplement.

Ferro-Cement Properties

by

L. D. G. Collen (5)



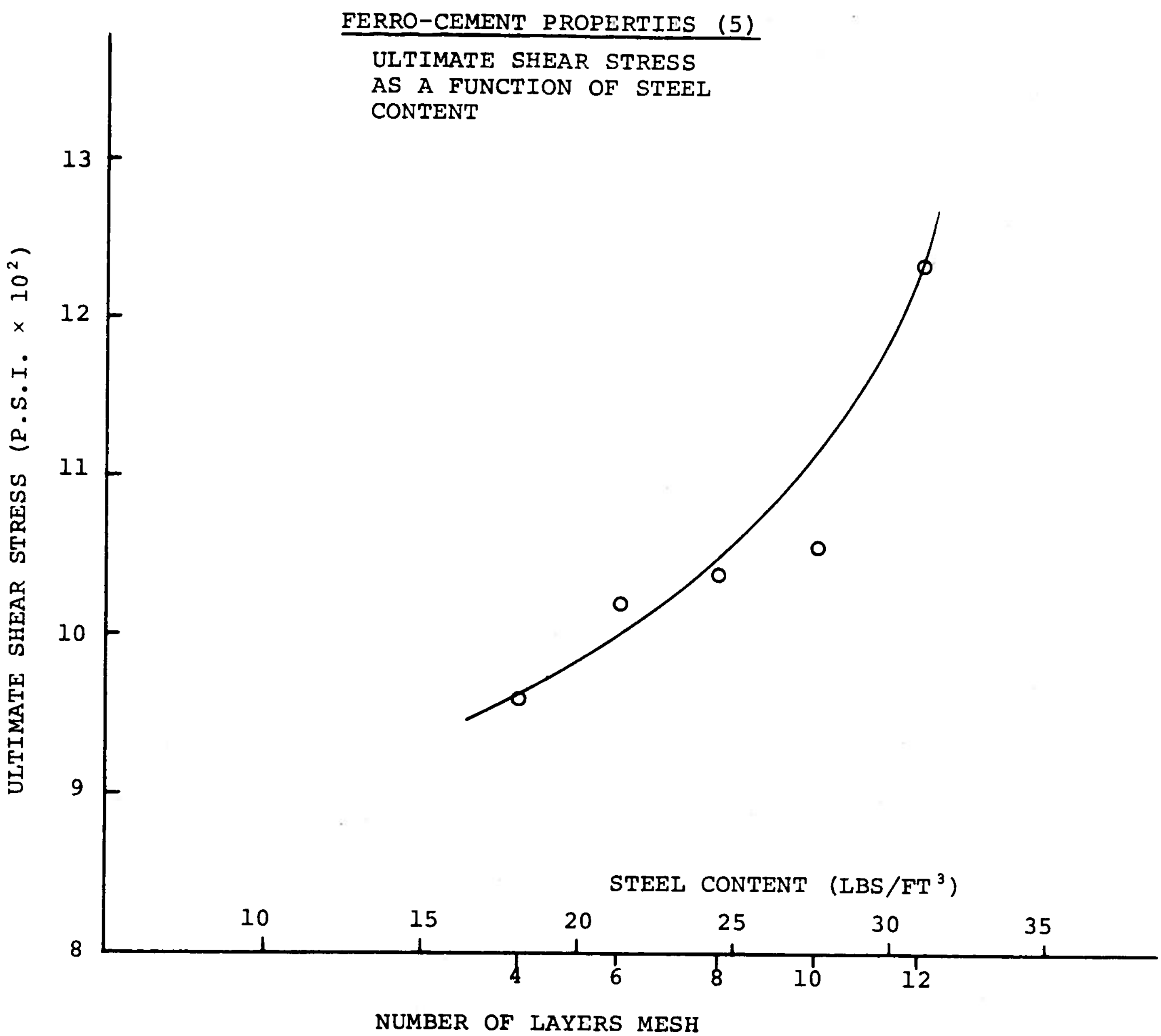
Typical Cross Section

Wire Mesh: Machine woven, non-galvanized, 18 SWG mild steel, twin wires in the wrap and single wires in the weft. 1.4 lb/yd^2

Cement: Rapid-hardening, Irish portland cement Irish std. spec. no. 1.

Sand: See "Mortar" in this paper.

Curing: 24 hours under damp rags, 6 days in 51F water, samples tested on 7th day.



$\frac{\text{CEMENT}}{\text{SAND}} = .56$

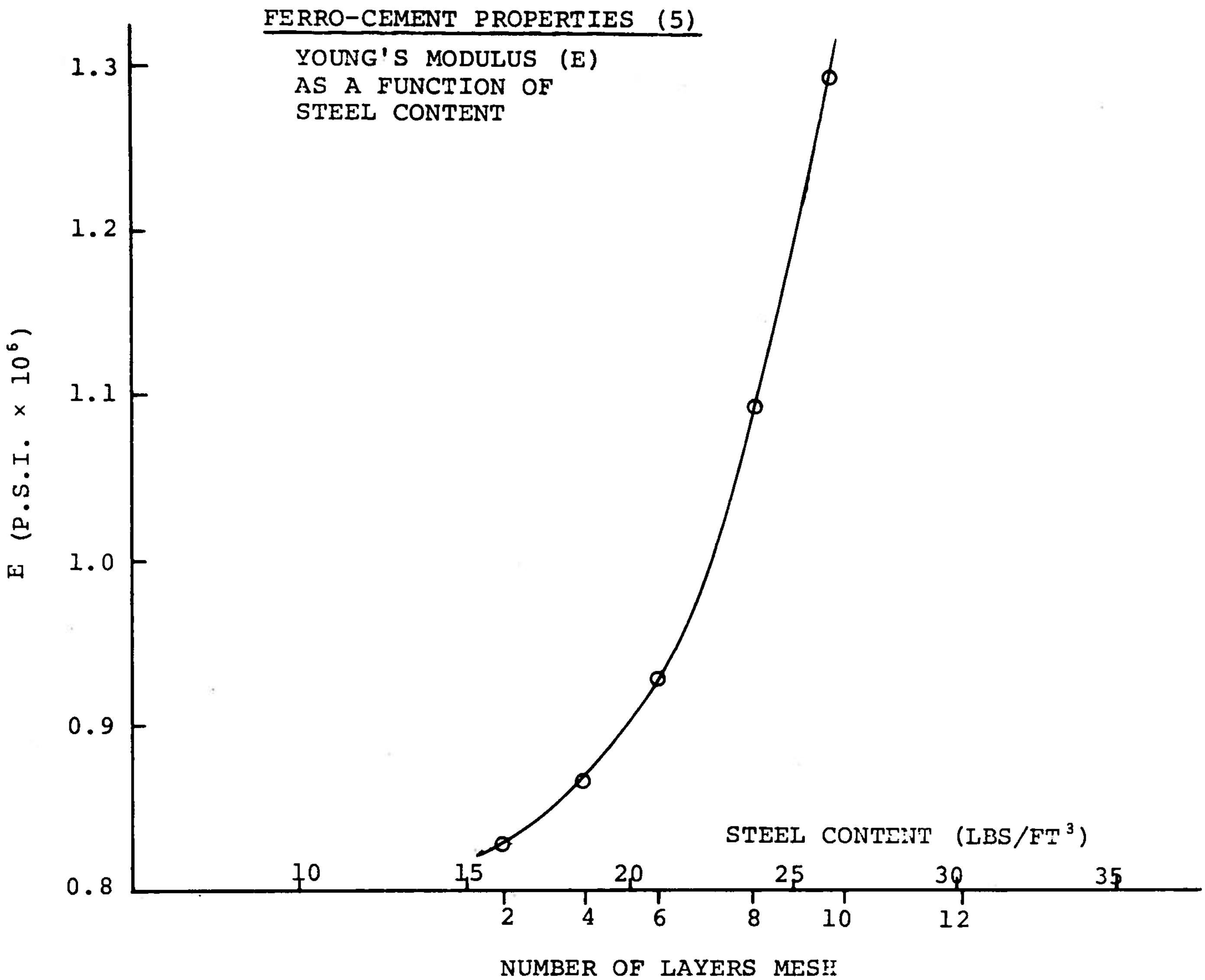
$\frac{\text{WATER}}{\text{CEMENT}} = .35$

SPAN = 5.75"

BEAM: 5" x 1 1/4"

BEARINGS: SOLID

U.D.L. 4 1/2" x 4 1/2"



CEMENT = .56

WATER = .35

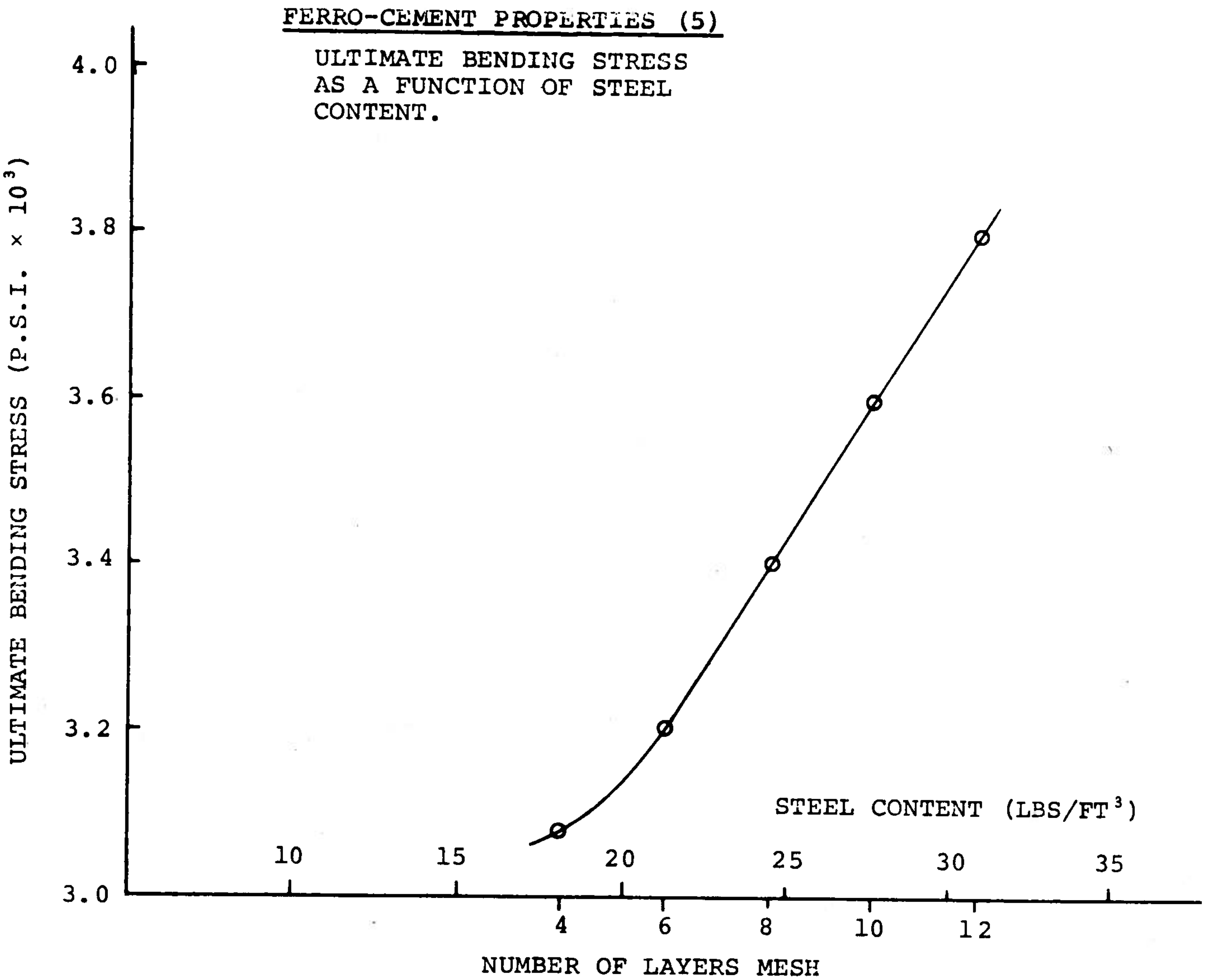
SPAN = 24"

E, CALCULATED FROM DEFLECTIONS

BEAM 36" x 5" x 1 1/4"

BEARINGS: ROCKER

POINT LOAD AT ℄



$\frac{\text{CEMENT}}{\text{SAND}} = .56$

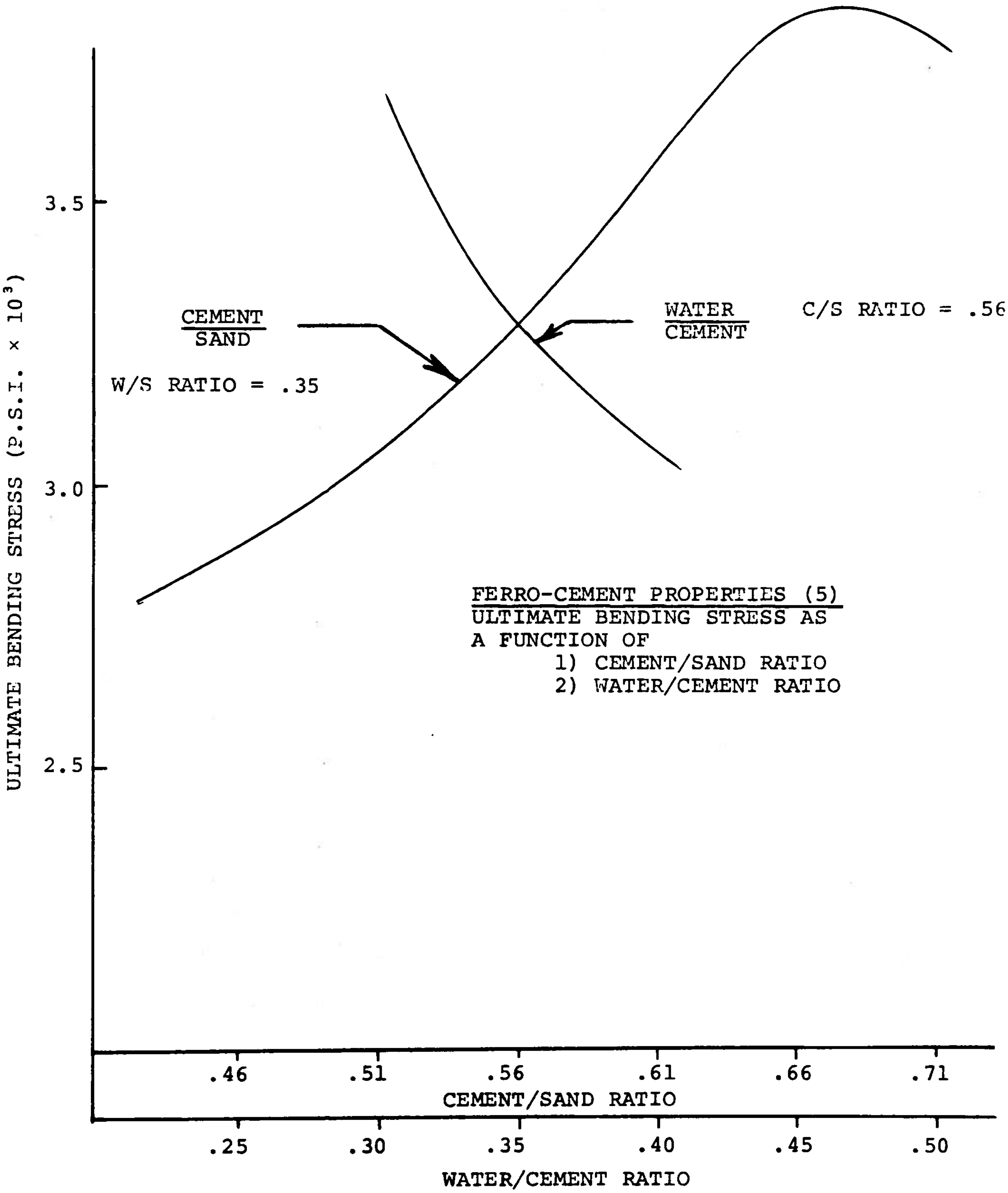
$\frac{\text{WATER}}{\text{CEMENT}} = .35$

SPAN = 24"

BEAM 36" x 5" x 1 1/4"

BEARINGS: ROCKER

POINT LOAD @ ℄



BEAM: 36" x 5" x 1 1/4"
SPAN: 24"
BEARINGS: ROCKER

STEEL CONTENT = 15.9 LBS/FT^3
POINT LOAD @ ℄

Discussion of Experimental Results

The fatigue test results, made by Lloyds for Windboats Ltd., indicate that structures should be designed to a stress of only 600 psi if the structure is to undergo an infinite number of cycles over one long continuous period. However, because concrete continues to gain strength over years, and because it has the property of being "autogenous healing," 600 psi is lower than is really necessary. That is to say, between periods of cycling, the concrete can regain its strength. Fatigue experiments with interrupted periods of cycling would be most interesting.

In the design of a 100-ft fishing trawler, three University of Michigan students used a design stress of only 1200 psi (tension) even though their samples failed at a stress of approximately 5000 psi (tension). A low design stress was used because the yield point was not known. However, experiments made by the students indicated the proportional limit of their samples was 1200 psi (tension).

Presently, Hans Muhlert, a graduate student in naval architecture and marine engineering at the University of Michigan, is doing extensive tests with ferro-cement. His ultimate goal is to determine the strength of ferro-cement given the strength of the cement, the strength and quantity of the reinforcement and the distribution of the reinforcement in a ferro-cement specimen. To date he has been quite successful in his analysis using "the transformed area concept."

Nervi states that the principle of ferro-cement is that the concrete can stand large strains in the neighborhood of the reinforcement. The exact meaning of "large strains" should not be overestimated. Mr. Muhlert has found hairline cracks in the surface of his specimens where the cement was stressed to the ultimate strength of the cement alone. This important finding may limit the design strength of ferro-cement if all surface cracks are to be avoided. This finding necessitates the use of a flexible, non-cracking, water impermeable paint.

DESIGN OF FERRO-CEMENT VESSELS

Most ferro-cement boats have been designed without strength calculations being carried out and have instead been designed after previously built ferro-cement boats which have appeared sound. However, a detailed strength analysis can be made if the properties of the material are known. The most detailed design I have seen was made by three University of Michigan students. (3)

Two theoretical approaches may be used in a design. The first assumes the material is homogeneous. The second is "the transformed area concept."

Homogeneous Method

The homogeneous method assumes the material to be homogeneous with a given yield strength, Young's modulus and Poisson's ratio. These properties may be determined experimentally. However, as mentioned before, the determination of the properties, by mathematical analysis, is under study by Mr. Muhlert. The homogeneous method is only suitable for rough design estimates.

Transformed Area Concept

The transformed area concept uses the fact that the unit stress in steel reinforcement is n times as great as the stress in the concrete. Therefore, 1 sq in. of steel may be considered equivalent to n sq in. of concrete. In applying the method, all rods in a beam are assumed to be replaced by an equivalent number of square inches of concrete in the same location with regard to the neutral axis.

$$n = \frac{E_S}{E_C} = \frac{\text{Modulus of elasticity of steel in compression}}{\text{Modulus of elasticity of concrete in compression}}$$

This method of design is described in almost any book on reinforced concrete design. The transformed area concept is applicable for the design of scantlings, frames, stringers and other heavy members. This method of stress analysis has correlated nicely with test results.

Hull Shape

Since a hull made of ferro-cement is a thin-wall structure using a minimum of internal bracing, membrane theory and shell theory must be kept in mind. Both theories use the principle that the curvature of a load-bearing member is such that the principal stresses are placed in the plane of the surface. The limiting case of the theory is that a flat membrane cannot support any lateral loads by bending stresses. Hence, the membrane must deflect and stretch to develop both the necessary curvatures and membrane stresses.

Keeping this idea in mind, the hull shape should be such that loads on the hull can be absorbed by the skin in tension or compression. Also, bending moments should not be applied to the shell at such places as the decks, floors and bulkheads.

These requirements are satisfied with a well-curved hull shape. Curved surfaces may be obtained with deadrise, tumblehome and flare at the bow. Deck beams should be such that their end moments are not transmitted to the shell.

These requirements are typical of steel, fiberglass and plywood when a light structure is desired. With the use of proper stiffening consisting of transverse and/or longitudinal members, flat sections can be used.

In the adoption of plywood designs to ferro-cement, Drake-Craft Shipyard of Ventura, California, is using a composite construction. It consists of a 5/8-in. layer of ferro-cement on either side of a 1 1/4-in. foam core. Each 5/8-in. layer consists of #4 rebar* spaced 12 in. centers, with 4 layers of expanded metal. The hull is approximately 60 ft in length. The idea behind the construction is to increase the section modulus of the skin so it may withstand bending moments.

Design Examples

The following is a list of properties of boats which have been built of ferro-cement. Note, the 100-ft fishing trawler has not been built.

100-Ft Fishing Trawler (3)

The design of a 100-ft fishing trawler, made by the University of Michigan students, was based on the following material properties:

*Rebar is a hot rolled steel shape used in reinforced concrete.

$E = 1.3 \times 10^6$ psi

$\lambda = 0.1$ (λ = Poisson's Ratio)

σ yield pt. = 4800 psi ave.

σ ult. = 5500 psi ave.

Allowable stress = 1200 psi.

The material was assumed to be homogeneous and the analysis was based on the St. Denis report. (5) The following table outlines the design, comparing it to a wooden boat.

SCANTLINGS FOR 100-FT FISHING BOAT

	Wood	Ferro-Cement
Hull Thickness	3 in. (Birch & Oak)	1.25 in.
Frame Spacing	22 in.	20 in.
Frame Size		
At Keel	10 3/4 in. x 6 in.	10 in. x 1.9 in.
At Sect. 8	9 in. x 6 in.	8 1/2 in. x 1.25 in.
At Turn of Bilge	8 3/8 in. x 6 in.	6 in. x 1.25 in.
At Deck	5 3/4 in. x 6 in.	6 in. x 1.25 in.
Deck Thickness	3 in. (Pine)	1 in.
Deck Frames	8 in. x 6 in. (Oak)	6 in. x 1 in.
Keel	12 in. x 21 in. (Oak)	12 in. x 21 in.
Keelson	12 in. x 12 in. (Fir)	None
Sister Keelson	(2) 9 1/2 in. x 8 in.	None

<u>Pier Luige Nervi's 165-Ton Motor-Sailer</u> Irene (7,2)

Hull thickness = 1.4 in.

Reinforcement = 3 layers (two longitudinal and one intermediate transverse) of 1/4-in. steel bars with 4-in. spacing.

Wire mesh = 0.24 lb/ft^2, four layers inside and four layers outside.

Mortar = 7.5 lb of pozzolanic cement per cubic foot of sand. It was applied by hand from the inside of the hull, forced through the mesh and smoothed out from the outside. The mortar had the consistency of paste.

<u>38-Ft Ketch (7)</u>

Hull thickness = 1/2 in.

Reinforcement - One layer of 1/4-in. longitudinal bars spaced 2 in. Frames, 1-in. steel tubing, 3 1/2 ft apart.

<u>28-Ft Yawl</u> Featherstone (Reference *)

LOA = 28 ft

LWL = 21 ft

Beam = 7 ft 2 in.

Draft = 3 ft

Displacement = 5500 lb

Approximate cost = $3600 (material only, 1959)

The concrete yacht is formed of 3/16-in. steel rods laced in a layer of 4,000-psi concrete about 3/8 of an inch thick. The concrete was applied as a plasterer would finish a wall. A high-strength mix with sharp clean sand and as little water as possible was used, and the builders made certain the hull was well curved. (Title of reference unknown)

*See Supplement.

A scratch coat and finish coat were applied and the hull was curved under sheets of plastic.

<u>English Cutter by Joseph Miller, Tiburon, California (8)</u>

LOA = 40 ft

Beam = 11 ft

Draft = 6 ft 6 in. (built June 1967)

Hull thickness = Unknown

Reinforcement = Six layers of #3 galvanized hardware cloth (three spaces to the inch each way), three layers inside and three layers outside. Longitudinals, 3/8-in. deformed reinforcing bar secured to a welded pipe frame.

NOTE: Joseph Miller wishes he had used chicken wire instead of hardware cloth in order to get better mortar penetration.

The wire mesh was fastened to the 3/8-in. bars with a pneumatic stapler.

<u>42-Ft x 13-Ft Towboat</u> (Reference unknown)

Mortar = Plastered with mortar mixed on site. Mortar was pumped onto the steel network using a concrete placing pump.

Reinforcement = 1/2-in. I.D. pipe, 2 ft on center. Eight layers, 1/2-in. spacing, woven wire netting.

44-Ft x 12-Ft Fishing Boat (12)

Mortar = 3/4 in. thick, rich, quick setting

Reinforcement = 1/2-in. water pipes. Rods = 3 in.-4 in. spacing.

Wire mesh = Eight layers of 1/2-in. wire mesh (chicken wire).

Paint = Long-lasting epoxy, sanded smooth.

CONSTRUCTION

There are three methods of building in ferro-cement. They may be labeled as: (1) the pipe frame method, (2) the cavity mold method and (3) the cedar mold method. Each is discussed below. This compiled information is from various sources.

The Pipe Frame Method

The pipe frame method is the most popular, most suitable for a one-design construction and very successful.

A firm foundation should be set down so that there is no settling of the ground when the cement mortar is applied. The construction may be exposed to the weather, as rusting is not a great concern. The lines are lofted full size. Frames are shaped out of 1/2-in., 3/4-in. or 1-in. galvanized water pipe, depending on the size of the vessel. The lines of the stem, keel and stern are shaped from water pipe using either the lofted lines or wooden templates. Some builders shape frames and longitudinals by driving small nails at intermediate points along lofted lines. The member is then bent until it touches each nail along a line.

It is best to have a building bay around the hull to increase the accessibility to parts of the hull. This makes the construction of the reinforcing system simpler and is also necessary for plastering.

The basic framework, consisting of frames, longitudinals and deck beams, is faired and welded together. Longitudinal 3/16-in. to 1/4-in. high tensile steel rods spaced 2 in. to 4 in. are bent around the structure. These rods are tied in place with soft wire and should be absolutely fair. It is not advisable to weld these, as distortion may occur. When the longitudinal rods are in place, vertical rods are tied inside the longitudinals to partially fill the void between the water pipe frames and provide for a more compact structure. In addition to vertical rods, or instead of vertical rods, diagonal rods may be placed to aid in the fairing process.

Six to eight layers of wire mesh are used. Three to four layers are placed on the outside and tied in place every 6 in. to 8 in. Large stapling guns or "bull-nose ring staples" are often used in this process. The outside layers should be smooth. The inside layers are formed around the basic framing system. The ends of the wire should be directed inward to avoid protruding wires when plastering. There should be 9-in. overlaps of two pieces of wire mesh.

After the longitudinal rods, vertical rods and wire mesh have been laced to the basic structure, fairness should be checked with battens. Distortions can be corrected by beating the light reinforcement into place with round-faced, 2-lb., rubber hammers.

Because this reinforcing <u>will bear considerable weight when the mortar is applied</u>, it must be perfectly rigid. The frames should be supported by overhead beams and by vertical props. If the reinforcing deflects when the mortar is applied, a weak structure may result because areas which have started to cure may be upset. Also, if the reinforcing deflects by the weight of the mortar, the boat will end up with an incorrect hull shape.*

Planks and temporary structure should be placed inside the hull for plasterers to work from. The application of the mortar requires skills in the techniques of plastering. It is therefore advisable to hire a professional for this work.

A limited amount of mortar should be mixed because the mortar has a finite working time. If the mortar becomes dry, it should be thrown out, because it has started to set. More water should not be added. The use of revived mortar can result in a weak structure.

The mortar is usually applied to the inside of the hull and forced through the reinforcement by a man wearing gloves. The plasterer works on the outside of the hull and trowels the surface smooth.** The mortar can also be applied using a concrete placing pump. Vibrators can help force the mortar through the reinforcing.*** As the plaster is applied, the hull should be checked for fairness with battens. Props may be left in place while plastering. After the hull has cured for a few days or weeks, the props may be removed and these places faired in. The mortar on the outside of the hull should not be thicker than 1/8 in. Irregularities should not be filled with excess mortar because crazing or surface cracking will occur. It must be remembered, the subdivision of the reinforcing

*,**,***See Supplement.

close to the surface gives the hull its resistance to cracking. The finished product must be completely free of voids. The inclusion of voids can result in leakage and a weak hull due to discontinuities.

Some believe gunite* techniques can be used to apply the mortar. However, I have not read of any completed "pipe frame" boats using this method.**

Most builders recommend that the entire plastering process be completed in one day. If this is not possible, some believe an epoxy resin can be applied to the aged concrete and plastering can be continued.*** Again, I have not read of any completed boats where this method has been used.

Curing of the hull, and finishing will be discussed later.

Cavity Mold Method****

The cavity mold method is more suitable for production, as it eliminates having to accurately form the frames and fair the reinforcing for each boat. However, as the name implies, a mold must be built.

This method is used by Fibersteel Co. of West Sacramento, California. Fibersteel Co. uses a floating mold. After the boat is completed the wing tanks of the mold are flooded, vents leading to the inside of the mold are opened, and the hull is floated out. This floating mold method makes it possible to remove the finished boat from the mold before it

*Gunite (tradename) Gunite is a process of applying a mixture of sand, cement and water by pneumatic pressure through a specially adapted hose.
,*,****See Supplement.

has reached its design strength, which may take several weeks, the reason being the floating hull will experience nearly uniformly distributed forces across the bottom and only small bending moments will be induced in the new structure.

The construction process used by Fibersteel is claimed to be secret because at the present they are applying for a patent. However, the basic method consists of the following: A parting compound is sprayed or brushed on the surface of the mold. A gel coat, believed to be white portland cement with "marblelite" is sprayed inside the mold. Expanded metal (1/4-in. x 1/2-in. openings) is laid inside. Spring steel rods are laid inside with more layers of expanded metal and spring steel rods. Over each layer of expanded metal and spring steel, a layer of cement is applied using gunite techniques. Any hull thickness can be achieved using this method. Fast-setting cement is used. The deck is constructed in a second complete set of operations. The reinforcement of the hull is run into the deck. After the hull and deck have been completed, the inside of the boat is supposedly sprayed with a portland cement containing "marblelite."

The gel coat mentioned has the texture of porcelain, being very smooth and hard.

I have visited the Fibersteel Co., and in my opinion this method is most suitable for production purposes. The method is simple and unskilled labor can be used as long as there is a supervisor to assure quality control of the process.

The Cedar Mold Method*

The cedar mold method was devised by John Samson of Marine Enterprises. (8) It is claimed, by Mr. Samson, to reduce building time and cost no more than a boat built using the pipe frame method. Also, the finished product has a fine timber lining.

The cedar mold method is as follows: The boat is built upside down over a timber mold. The mold consists of a permanent plywood transom, a laminated stem, bulkheads and temporary frames. After the transom, stem, bulkheads and frames have been located, the structure is planked with 1-in. x 2-in. strips of red cedar or an equivalent light, rot resistant material. The planks, which will be the cabin lining, are edge nailed, leaving an expansion gap of one nail thickness. Removable secret or finishing nails are used where the planks are nailed to temporary frames. Below the cabin sole the planks are spaced 6 inches apart. The entire planked structure will serve as a framework for wire mesh and steel rods. The outside surface of the planks are painted and covered with two layers of tar paper. The edges of the tar paper are overlapped. Between the layers of tar paper a coat of bituminous paint is applied. Four layers of wire mesh are laid over the tar paper and stapled in place. Rods of 1/4-in. steel, spaced 6 inches apart, are run transversely. A second layer of similar rods, spaced 2 inches apart, are run longitudinally. The rods are intermittently spot welded together. The structure is then covered with four more layers of wire mesh which are stapled to the planking.

*See Supplement.

Plastering is similar to that of the pipe frame method. A vibrator should be used over the planked sections which are inaccessible from inside the hull. After curing, the hull is turned over for finishing.

The major difficulty builders have had with the cedar mold method is lack of mortar penetration through the reinforcement. The plasterer is "working blind," that is, he cannot see if the mortar is completely penetrating the reinforcement. For this reason, John Samson now recommends that the lining be ripped out and the hull back plastered.

Curing

Hull strength is greatly dependent upon the curing process. The principle of curing is that water reacts with cement particles to form a hydrous calcium silicate gel which binds the aggregate together. As long as there is water in the cement, this process will continue for years.

The reaction is very slow and requires much time for its completion. Therefore, it is necessary to maintain the presence of water in order that the reaction may continue. Curing with the lack of proper moisture will result in a weak, porous cement with poor durability. Curing temperature should be maintained between 50F and 90F. Curing must be controlled to ensure that the reaction proceeds at an even rate and shrinkage does not occur with consequent cracking of the surface of the hull. During curing the hull must be kept out of direct contact with sunlight and drying winds.

There are two methods of curing a ferro-cement hull. The first method, natural curing, takes two to four weeks and gives the strongest hull. It consists of building a plastic house around the boat in which a high humidity atmosphere is maintained by use of a mist spray, or the evaporation of water from buckets placed over electric hotplates. Gas heaters should not be used because the products of combustion can affect the curing process.* Natural curing can also be accomplished by hanging wet rags on the hull, inside and out.

The curing of cement is an exothermic reaction and therefore can be accelerated with the application of heat. In this case, steam generators are used in a plastic house. This method is most suitable for commercial operations as it reduces curing times from approximately 21 days to approximately 24 hours.

Sealing compounds may be applied to the hull to seal in moisture during curing, but there is a question as to whether or not vapor, caused by heat from the sun, will form under the membrane and produce tiny ruptures of the seal through which water will escape unnoticed. Also, there is a question of whether or not these seals affect subsequent paint application.

Finishing

After the hull is cured, any stray wires protruding through the cement may be cut back and the areas patched

*See Supplement.

with epoxy or mortar.

The hull can be rubbed down with a carborundum stone a few days after being plastered. In some cases a finishing coat containing a rich mixture of portland cement and "marblelite" is applied. When this is done, the first layer of mortar should be finished flush with the wire mesh. The hull should then be wire-brushed or sandblasted to remove any laitance (a weak, nondurable, chalky-colored collection of cement and fine aggregates which is flushed to the top of a pour of concrete having an excess of water). The finishing coat should not be greater than 1/8 in. thick, otherwise crazing or surface cracking will occur. Crazing will also occur if the finishing coat is applied in too hot weather.

I have seen a hull finished by this process and was most impressed with the results.

Painting

The hull must be dry before painting. Epoxy paints adhere most successfully to cement mortar and for this reason are used. An epoxy aluminum primer or an epoxy-tar compound and an appropriate undercoat and top coat provide the best finishes.

Vinyls and acrylics have also been successful. Enamels are not recommended. Some P.V.A.-based* paints exhibit hygroscopic characteristics.

*Poly-vinyl acetate.

Keel

The keel may be made in two ways. The first method is to cast it, using a heavy aggregate, before the remainder of the hull is plastered. This gives a firm base for later plastering. Or second, the keel may be made by pouring a heavy aggregate into the ferro-cement shell which was made when the entire hull was plastered.

Following is the procedure of the second method. (9)

> Four lengths of 8" x 2" timber laid side by side to form a 16" wide platform are laid on the building blocks for the length of the keel. On this four layers of wire net are laid, overlapping at 9" intervals. The keel pipe and frames are then mounted on this and set up. The netting on the hull sides can then be married to the keel netting. The plastering is carried out (from the inside forcing the mortar through), as far down as can be reached. After the work has cured, the hull building blocks and platform are removed by stages so that the bottom of the keel can be plastered. After all has cured, the ballast is poured.

Heavy aggregate for the keel can consist of boiler punchings, chain, scrap steel, etc.

Bulkheads

Bulkheads can be installed in four ways.

First, bulkheads may be made of ferro-cement and plastered when the hull is plastered or after the hull is plastered. In either case, their reinforcement should be continuous with that of the hull. Such joints should be designed so that bending moments from the bulkheads will not crack the hull.

Second, bulkheads may be made by bolting a wooden or steel bulkhead to an approximately 6-in. deep web frame made of ferro-cement. A rubber sealant can be used to make the joint watertight.

Third, very light bulkheads may be grouted or fiber-glassed in place.

Fourth, bulkheads may be bolted to brackets which are welded to the reinforcement and protrude through the mortar.

<u>Engine Mounts, Chain Plates, Stern Tubes</u>

In order to assure proper distribution of loads and vibrations, forces must be distributed through the hull, from the source, by the use of reinforcement. Engine mounting plates and chain plates should be welded to the reinforcing bars which are in turn flared out in all directions through the structure. Undistributed forces can result in a weakening of the structure and ultimate failure of the structure.

Removable chainplates can be made by imbedding chainplates in the hull with reinforcement welded to them and flaring out through the hull. Provide holes in the imbedded chainplates so that removable chainplates may be bolted in place. Dowels or bolts can be used to maintain the bolt holes during plastering. This procedure is important if concentrated loads on the hull and excessive bearing loads on the cement are to be avoided.

<u>Portholes (7)</u>

Portholes are made of 1/8-in. steel plate with a 1 1/4-in. boarder. The 1/8-in. steel plate is welded to the reinforcing rods. A removable wooden blank is fitted where a plastic window will eventually be bolted to a flange. The wooden blank should be of such a size that a 1/2-in. flange remains after plastering. A mastic sealant is used to provide for watertightness. An additional cover plate is needed if glass is to be used.

Wooden Decks

Wooden decks can be made by first welding bolts to the reinforcement. The bolts then protrude through the mortar. A timber beam shelf is bolted in place and deck beams are installed. Instead of welding bolts to the reinforcement, holes can be drilled through the hull.

Fenders or rubrails can also be constructed in this manner.

Hull Penetrations (Through-Hull Fittings)

Hull penetrations for exhaust, drains, etc., can be made by placing a wooden dowel through the reinforcing. After plastering, when the hull has cured, the dowels are driven out. A second method is to weld bushings to the reinforcement. They may or may not have a flange welded to them.

Drilling

Holes may be drilled through the hull using a carborundum-tipped masonary drill. It is best to check the location of heavy reinforcement by first drilling a small pilot hole.

Metals

Steel, stainless steel, bronze or brass may be inserted in cement without any reaction between the metal and cement.

> Galvanized metal is attacked by caustic solutions such as calcium hydroxide and is, therefore, attacked upon embedment in fresh concrete or mortar. Moisture and hydroxide react with zinc to form calcium zincate. Available evidence indicates that usually only the surface layer of the zinc is corroded because a dense adherent film of zincate protects the underlying metal from further attack. (10)

If the reinforcement is of galvanized material, it should be allowed to oxidize before being plastered.

Aluminum should not be imbedded in cement because it reacts with the cement.

Insulation of Fish Holds

> Insulation of fish holds should be allowed for at the design stage by the provision of suitable steel ties in hull and bulkheads. After completion of hull and bulkheads, foam plastic insulating material can then be laid and a 1/2" internal skin of ferro-cement tied in and plastered directly onto the insulation. This will provide a strong sandwich construction with a smooth and easily cleaned fish hold lining. Access to the shaft tunnel and drainage wells should be provided. (11)

Welding Next to the Hull

It is not advised to weld directly near a ferro-cement hull as excessive heat will cause the cement to spall.

Bonding Cement to Cement

There are several products on the market that are specially made for wet-to-dry bonding of cement. An example is "Coast-Pro-Seal," which is used by the California Diversion of Highways. Bonding compounds are basically a fifty-fifty mixture of poly sulfide and epoxy. The original cement can be recently poured or can be several years old. The two-part epoxy is used by wire brushing the original cement, cleaning away all loose particles, applying the epoxy, and applying the wet mortar directly to the wet epoxy.

Repair

Dents are patched in several ways. In all cases the loose cement should be chipped away as much as possible. The area should be cleaned of loose pieces and dust. The dented area can be pounded back into shape or the dent can be simply faired in. For best results, a wet-to-dry epoxy should be used if the dent is patched with cement. Repairs can be made under water using cement mortar. Fiberglass and resin can also be used to make repairs. Note, polyester resins commonly used with fiberglass are sensitive to moisture so must be used with great caution. Therefore, wet-to-dry epoxy compounds are recommended.

COMPONENTS OF FERRO-CEMENT

The strength of ferro-cement is dependent on the aggregate used; the quantity and distribution of reinforcement used; the proportions of cement, water and aggregate; admixtures, workmanship and ambient conditions.

Reinforcement

Amateur builders have used almost all types of reinforcement, ranging from water pipe and chicken wire to construction rebar and expanded metal. All have worked.

The most important features of the reinforcement are, first, that it contains an adequate amount of steel and second, that the mortar can be made to penetrate the reinforcement. Therefore, samples of typical sections should first be constructed and tested.

Frames

Galvanized waterpipe is most commonly used for frames. Size ranges from 1/2 in. I.D. to 1 in. I.D. Ungalvanized pipe and removable wooden frames can also be used.

Rods

Most builders have used 1/4-in. steel rods, while others have used #4 rebar. Martin Irons of Fibersteel Co. suggests spring steel rods be used because of their increased strength-to-weight ratio.

Wire Mesh

Several amateur builders have used chicken wire; others, galvanized wire mesh of 3/8-in. x 3/8-in., 24 gauge. Expanded metal has been used, but its use often results in penetration problems. Note, expanded metal is approximately three times as strong in one direction as another.

Galvanized Reinforcement and Rust

Galvanized reinforcement presents no problems, even though it introduces a soft metal in the structure which may shear more easily. If used, it should be allowed to oxidize before the mortar is applied. An experiment was made leaving both galvanized and ungalvanized expanded metal exposed. The bare metal left rust marks when it corroded, while the galvanized metal showed no corrosion marks. This experiment was done in fresh water and the exposed areas were on the inside of the hull.

The reinforcement may be corroded, as this helps form a mechanical bond between the mortar and steel. Flaky mill scale and excessive rust must be removed. Any slight film of oil may be left on the reinforcement, as the alkali of the cement will cut the oil.

Steel

In regard to steel, the strength of ferro-cement is a function of (1) steel strength, (2) the quantity of steel, and (3) the location of steel.

In reference to the previous graphs, there is a direct relationship between the ultimate bending stress and steel content. The University of Michigan students (3) used a steel content of 57.3 lb/ft^3, of which 28.7 lb/ft^3 were placed in the direction of the stress. Nervi found that samples with a steel content between 6 and 12 lb/ft^3 were as stiff as samples with no steel at all, while steel contents between 25 and 32 lb/ft^3 greatly improved the flexibility of samples. This implies that there is a minimum steel content at which the addition of steel affects the flexibility characteristics of cement with reinforcement.

An interesting experiment would be to investigate the effects of the direction of the wire mesh in relation to the direction of stress. In several experiments, when hairline cracks formed in the surface of a ferro-cement test sample, they were parallel to the wires in the mesh. In these cases the wire mesh ran perpendicular and parallel to the lines of stress. Diagonal placement of the wire mesh should be investigated.

Mortar

Various authorities recommended the following mixes:

Reference (9)

A. One part by volume portland cement.

B. Two parts clean, sharp sand grading 2 or 3 (BS 882).
Note: Never use flat plasterer's sand.

C. Water, not in excess; mortar is mixed until easily workable.

D. Ten to fifteen percent of the weight of the cement may be replaced by pozzolan.

Reference (5)

A. Water/cement ratio 0.35.

B. Cement/sand ratio 0.56.

C. Sand, conforming to the following grading analysis: Unwashed, pit sand.

B.S. Sieva	200	100	52	25	14	7	3/16
Percentage Passing	2	7 1/2	21	54	80	96	100

Reference (11)

A. One part good-quality portland cement.

B. One and three-fourths parts clean, sharp sand.

C. Water: add until workable.

D. Ten percent of the cement may be replaced with pozzolan.

Reference (10)

A. Fifty to sixty pounds of cement per cubic foot of sand.

B. A sand with the coarser fractions removed using either of two grading systems.

Grading System A

B.S. Sieve Size or No.	3/16	7	14	25	52	100	200
% Passing by Weight	100	100	85	55	15	4	3

Grading System B

B.S. Sieve Size or No.	3/16	7	14	25	52	100	200
% Passing by Weight	100	100	100	98	30	2	1

C. Use finer sand for finer work.

D. Mix with a motorized mortar mixer, paddle type.

E. Use as little water as possible.

Aggregates

Aggregates should be clean, their surface being free of clay, silt, crushing dust and organic matter. If the surface is not clean, proper bonding will not take place at the interface of the cement paste and aggregate. Poor bonding results in, first, reduced shear strength at the interface of the cement and aggregate and, second, the formation of channels for percolation of water into the concrete mass. Aggregates should be nonreactive with the water and sand and structurally sound, strong and durable.

There is some question regarding the shape of the aggregate. A prismoidal-shaped rather than a round-shaped aggregate produces a structure with a greater modulus of elasticity. Martin Irons of Fibersteel recommends a round-shaped sand if gunite techniques are used. He claims it is more suitable because it flows more easily and is more workable.

Lightweight aggregates can be used; however, there is a proportional reduction in strength with weight. All tests I have seen regarding lightweight aggregates have been carried out in concrete where the aggregate is very large compared to fine sand. Because lightweight aggregates are very porous, their use in an entirely cement-sand mixture may even result in a heavier product due to their increased surface area being able to absorb more water.

Air Entrainment

Air entrainment involves whipping microscopic bubbles of air into the concrete during the mixing operation. They are purposely retained or stabilized by foam-stabilizing organic agents, which greatly increase the surface tension around the bubbles and so prevent their collapse or escape.

Air entrainment is used for the following reasons:

1. Permits a reduction in mixing water
2. Increases durability
3. Acts as tiny cushions when the structure is frozen
4. Helps absorb shock loads
5. Makes mobilization of the mortar easier when plastering
6. Helps increase durability of cement exposed to seawater.

Air entraining agents should be used with caution because they are organic and because the correct amount is very difficult to gauge.

Cement

Portland cement is most commonly used; however, many people do not realize that there are several types of portland cement. Referring to the Federal Specification SS-C-192, either of the following types are recommended:

Type II	For use in general concrete construction exposed to moderate sulfate action, or where moderate heat of hydration is required
Type V	For use when high sulfate resistance is required
Types II-A & V-A	Same as Types II & V but where air entrainment is required.

Pozzolan

The essential component of pozzolanic materials is a siliceous material, amorphous silica.

As portland cement cures it produces calcium silicates which contribute to the strength and watertightness of cement. At the same time, large amounts of lime are produced which do not contribute to the strength of cement. If a finely divided siliceous material, pozzolan, is added to the cement, at the time of mixing, it will react with the lime, in the presence of moisture, to form more calcium silicates. As cement continues to cure over years more and more lime is produced. If there is no siliceous material available to react with the lime, the lime will be leached out of the cement by water thus making the structure porous and less water resistant. Therefore, it is important to add pozzolan to the mix.

Pozzolans also add to the "fattiness" or workability of fresh mortar and reduce the amount of water required.

Natural pozzolans include pumicite or volcanic ash, diatomaceous silica and pulverized opaline cherts and shales. Artificial pozzolans include pulverized aluminous and siliceous slags, calcined clays and fly ash. Fly ash from boiler smokestacks is most commonly used. Its quality is dependent upon the type of coal burned and the efficiency of burning.

Water

Given the proper mixture of cement and aggregate, the more water used, the weaker the concrete. A mixture with too much water may be cohesionless, susceptible to segregation during placing, and permeable to water after hardening. Moreover, it may fall through the reinforcement. Water content should be kept to a minimum.

Note on Admixtures

There are many admixtures on the market, such as asbestos, bentonite and other clays, waxes, oils, soaps and cement dispersing and wetting agents. Before using, they should be investigated and tested, as some have counteracting effects. Many may be beneficial to ferro-cement construction and their properties should be investigated.

CONCLUSION

As one can see, specific facts regarding strength, design and construction techniques of ferro-cement structures are lacking. This condition presents the following problems: First, it discourages investment in ferro-cement construction. Second, it causes structures to be under or overdesigned. Third, it causes builders to question what method of design and construction should be used. Investigation into all of the above problems is greatly needed if there is to be an advancement in ferro-cement construction.

It is hoped that this paper along with its bibliography will be of use to anyone investigating ferro-cement.

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SUPPLEMENT

Since writing this paper for presentation in Seattle on March 1, 1969, I have continued to gather information on ferro-cement. The sources of information have been comments on the paper, published articles, and personal observations and conversations. In order to include this information, without rewriting the paper, I have included this supplement.

Page 5 The resistance of cement to any marine borer is a function of the strength of the cement. Ferro-cement is resistant to all known marine borers including the Pholadidea Penita, a species of rock oyster. There is a well known case of this mollusk boring into concrete floats in which a light weight aggregate was used. It must be remembered that the use of light weight aggregates results in a weaker than usual structure.

Page 6 This boat, the Rolling Stone, was built at Kalamazoo, Michigan. The Rolling Stone is 30'-0" by 9'-3" with a hull, deck and house of ferro-cement. The boat is still in use on Spring Lake, Michigan and is exposed to winter icing conditions.

Page 17 Lloyd's Register of Shipping has given some "Seacrete" hulls a Classification of 100A.1. The first of these classed hulls was built in 1965. See paper:

Lloyds Register of Shipping
Yacht Tech. Office
Technical Note: FC/REQ/1
January 2, 1969

Page 29 For references see:

1) Concrete Products Magazine, December 1960.

2) Concrete Construction Magazine, July 1963.

Page 34(*) "Builders will look ahead far enough to brace their frame to support the weight of the wet mortar itself but do not foresee the dynamic loading which will be placed on the frame in trying to force the mortar to penetrate the mesh. These deflections become worse of course, near the close of the work day, when the dead weight of the wet mortar is almost all present and the workmen are still trying to push more mortar into place. The whole framework may be pushed out of fair. If this is noticed soon enough, temporary shoring can be provided to give some support to the sagging areas. Unfortunately, it usually happens near the close of a hard work day when the light is poor and it is not discovered until the next morning, too late to do anything. One such builder is reported to have brought in a bulldozer at this point, dug a trench alongside the boat, shoved the boat into the trench and buried it."

Comment from Martin E. Iorns of FIBERSTEEL COMPANY, Feb., 1969.

Page 34(**) There should be a man to act as an inspector and coach the applicator in securing penetration. After penetration from the inside is accomplished in an area, mortar should be forced from the outside of the hull through to the inside. The reason being, there are shadows behind the wires of the mesh caused by incomplete flow of the mortar around the wires. For best results, the mortar should finally be pushed through the hull, from the inside, a second time. After complete mortar penetration the hull can be trowelled smooth.

Page 34(***) Excessive vibration tends to separate the sand and the cement, and cause lack of cohesion. Therefore, this tool should be used sparingly.

Page 35(**) Since writing this paper I have seen a completed hull in which gunite techniques were used. The mortar was applied in two coats with a few weeks between the coats. An epoxy was used between the layers. The second layer was a finishing coat. The mortar was not as strong as most ferro-cement mortars. The loss in mortar strength was possibly due to an additional amount of water which was required to pump the mixture.

Page 35(***) "Windboats Ltd. have made a policy decision that they will only plaster a certain number of square feet in a day. I know of three large trawlers that were plastered in three stages and have been very successful."

Comment by D. A. Slater, V.P. and General Manager of Star Marine

Ind., Tacoma, Washington. The reason for this policy is due to physical exhaustion and loss in quality of workmanship after a hard day's work.

Page 35(****) Additional information on the cavity mold method, which is used by Fibersteel, follows.

1) Fibersteel uses "velocity placement" instead of gunite techniques for the following reasons. First, they had rebound problems with the gunite process. Second, they had quality control problems involving porous areas due to the fluxuating intentiveness of the "nozzle man."
2) In their gel coat they use a white portland cement.

Page 37 For more information on the cedar mold method see:

"How to Build a Ferro-Cement Boat"
By: John Samson
Published: 1968

Page 39 This applies to unvented gas heaters because of the susceptibility of fresh cement to carbonation. However, after the first twenty-four hours of curing, carbonation is no longer detrimental and gas heaters can be safely used.

Page 40 I have recently (March 3, 1969) seen a 45-foot fishing boat which was completely plastered and finished in one coat. (Made by Star Marine Ltd., Tacoma, Washington.) The hull was as smooth as sanded wood (#50 grade paper) and perfectly fair. I was amazed at how smooth and perfectly fair the plasterer finished the hull.