DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
COMMANDER (mmt)
12th Coast Guard District
630 Sansome Street
San Francisco, CA 94126

5940/FIBERSTEEL VALEO CLA
18 October 1976

Fiber Steel ______________
P. O. Box 661
West Sacramento, California 95691

Attention: Mr. Louis L. Watson, Jr.

Subj: FIBERSTEEL VALEO CLASS
55' Ferro Cement Sail Vessel
Oceans
Fibersteel
Hull Structure Review

Ref: (a) Your letter dated 6 October 1976

Gentlemen:

Enclosure (1) is approved subject to the construction and installation being satisfactory to the cognizant Officer in Charge, Marine Inspection.

Enclosure (2) has been examined and filed for information. It should be noted that the testing data in Enclosure (2) is the basis for the approval of the concept of expanded metal in your ferro cement vessel.

Sincerely,

GARY [illegible]
Lieutenant Commander, U. S. Coast Guard
Chief, Merchant Marine Technical Branch
By direction of the District Commander

Encl:
(1) Dwg B-2, Sht 3 of 3, Construction Details
(2) U. S. Coast Guard Certification Program

cc: OCMI, San Francisco w/encl (1)

U. S. COAST GUARD CERTIFICATION PROGRAM

FIBERSTEEL VALEO CLASS

TABLE OF CONTENTS

ABSTRACT

U. S. COAST GUARD CERTIFICATION PROGRAM

FIBERSTEEL VALEO CLASS

To partially satisfy the Coast Guard requirements for "Small Passenger Carrying Vessels, Subchapter T", with regard to the 55' Valeo class boats manufactured by Fibersteel Co., West Sacramento, California, a special testing program was followed. Engineering calculations were made to determine the stress levels in the critical areas of the Valeo's construction when subjected to the highest service loads.

Lt. David B. Lorenz, Engineer for the U.S. Coast Guard, Dr. Lester H. Gabriel, C. E., of California State University, Sacramento, and Louis L. Watson, Jr., Owner and Engineer of Fibersteel Co. collaborated on a program to test the following:

1. Hull in bending, tension, impact and bending fatigue.
2. Bulkheads in bending, tension and impact.
3. Composite deck in bending; deck to hull in bending.
4. Floors in bending.
5. Tank tops in bending.
6. Bulkhead to hull joints in bending and tension.
7. Bulkhead to bulkhead joints in bending and tension.
8. Fibersteel's mortar mix in compression and tension.
9. Rhoplex E330 bonding agent in shear.
10. Integral diesel tankage under a cyclic pressure head.

Fibersteel made the test samples under observation of U. S. Coast Guard personnel. The samples were tested at the laboratories of the California State University, Sacramento. Prof. Lester H. Gabriel was in charge and Coast Guard personnel observed the testing.

Test reports were made for approximately 200 samples. Some samples were not tested if the results tended to be redundant or if deemed by the Coast Guard uncritical. Test stress levels were compared with the corresponding calculated stress levels. In all cases, the Valeo construction was found to meet or exceed design criteria.

Construction then proceeded on a particular Valeo (V-22). Fifty one mortar samples were taken at different stages of construction of the full scale boat and the test results were then compared with those of the previous sample tests.

Comparison indicates that V - 22 meets the structural requirements for which it is designed and for the service to be certified by the U. S. Coast Guard.

U. S. COAST GUARD CERTIFICATION
FIBERSTEEL VALEO CLASS
A DISCUSSION OF TEST RESULTS

The most significant test of the certification program was 231 ABC, the full scale cyclic pressure test on integral diesel tankage. This test effectively duplicated most all of the other tests and added the dimension of fatigue. All panels and joints of the tankage were subjected to tension, bending and fatigue loads approximately 2 to 6 times those they would encounter in service. (Hull bottom has 3 to 4 foot static water head clear of the thickened keel and the cyclic test head was as much as 24 feet at the bottom of the test tanks.) At the same time, deflections in the center of the tank panels were low (.032") indicating low stress levels.

The hull panel fatigue tests indicated no failure would occur at the simplified design stress level (868 psi.) Actually this simplified design stress level would be high because the hull has considerable double curvature. No failure after 72 million cycles at a 0 - 1200 psi. stress (sample 248 B) certainly indicates a hull that could take many more cycles in the 0 - 250 psi. range (roughly equivalent to a 2 foot chop).

Although the deck to hull joint test results met design criteria, Lt. David B. Lorenz, the engineering representative of the Coast Guard, felt that an additional layer of 3.4 expanded metal lath would be of value and this was done on V - 22. The shear bond tests on the Rhoplex E330 bonding agent indicate that a 1845 lb. force would be required to scrape (shear) a square inch of gelcoat from the hull (sample 248 ABC smooth). Test results of (sample 250 ABC rough) show an average shear strength of 3188 psi. which is the case in the deck to hull lamination. This is far in excess of what is required (2 psi. per design calculation number 3).

The factor of 3:1 strong to weak directional strength of expanded metal (as per previous experiments) has to be used to advantage as in the other directional strength materials.

No dogbone sample failed below 600 psi. tension (samples 241A through 245C). This is the force (per square inch) that holds the laminations together. Assuming that there is no adhesion to the steel and there is a 50% projected area of steel in the expanded metal there is still a 300 lb. tying force per square inch which would make through tie wires structurally insignificant. This same tensile strength is responsible for the integrity of Fibersteel's laminated joints. No joint tested failed in the joint. They all failed in the parts (sample 213 ABC, 214 ABC, 215 ABC, 216ABC and 229 AB).

Apparently there are no delamination problems in the mesh or composite samples when subjected to bending (samples 209 A through 212 C, 217 A through 218 C, 223 ABC, 232 A through 234 C and 247 ABC). Even in the fatigue tests (sample 223 ABCD) the samples that did fail broke essentially straight through all at once.

The impact tests indicate that should hull damage occur, it would tend to be localized with minor leakage. The size of the broken mortar bits is determined largely by the mesh openings.

Becuase of the laminating process used, it is possible to obtain additional strength in any part or joint by laminating additional layers of reinforcing mesh.

REPORT

Included herein is the report of Phase I of the study of FIBERSTEEL sections and structural elements used in ship hulls. The study and testing was conducted at the facilities of the Department of Civil Engineering of the California State University at Sacramento under the direction of L. H. Gabriel, P.E., Ph. D., Professor of Civil Engineering. The contracting agency for the University is the Foundation of the California State University, Sacramento; Hugh Mickelson, Acting Director.

All elements studied were supplied to the University by Fibersteel, properly coded for purposes of identification. Unless otherwise noted, the mix proportions (by weight) of the samples studied are as follows and identified as Mix A:

- 1 part Portland cement - Type V
- 0.18 parts pozzolan cement
- 1.18 parts minus 30 sand
- 0.42 parts water

In addition, 2 ounces of DAREX additive was added to the above mix. Based upon the total cement content (Portland plus pozzulan) the following important ratios represent the mix:

- Sand/total cement: 1.00
- Water/total cement: 0.36
- Pozzolan/total cement: 0.15

The samples were sprayed and kept damp at 50°F - 80°F from time of manufacture until no less than one hour before testing.

The following is a report of the findings.

1. Compression studies on mortar cubes.

   a. For mortar used in items 3 through 9 below.

   The mortar specimens studied in this series were 2" x 2" x 2" cubes.

The compressive stresses noted below each represent the average of three samples.

	Duration of cure (days)	Compressive stress (psi)
201ABC	7	5,700
202ABC	14	8,300
203ABC	28	9,500
204ABC	28	10,300

Note that the average 28-day compressive strength was 9,900 psi.

b. For mortar used in tank bulkheads. (235ABC)
Mix proportions (by weight) as follows (call Mix B):

1 part Portland cement - Type V
1 part minus 1/4 sand
0.32 parts water

Duration of damp curing: 10 days @50°F-80°F
4 days @120°F
Compressive strength (average of 3 samples): 7,700 psi

c. For mortar in tank fillets (236ABC)

Mix proportions (by weight) as follows:

1 part Portland cement - Type V
0.18 parts pozzolan cement
1.18 parts minus 30 sand
0.47 parts water
sand/total cement: 1.00
water/total cement: 0.40
pozzolan/total cement: 0.15

2 ox Darex addition

Duration of damp curing: 7 days 50°F-80°F

Compressive strength (average of 3 samples): 6200 psi 11 days
8200 psi 25 days

d. For mortar used in tank tops

Duration of damp curing (days)		No. in sample	Compressive strength (psi)
4 @ 50°F - 80°F 4 @ 120°F	238ABC	3	9,000
28	239AB	2	10,000

2. Tension studies on mortar "dogbones".

The standard specimen of 1 in^2 in cross-section at its narrowest point was used for the test results reported below.

a. For mortar used in the tank bulkheads. 241ABC

Mix proportions (by weight) as follows:

1 part Portland cement - Type V
1 part minus 1/4 sand
0.32 parts water
2 ounces Darex additive

Duration of damp curing: 14 days.

Tensile strength (average of 3 samples): 930 psi

b. For mortar used in tank fillets. 243ABC

Mix proportions (by weight) as follows:

1 part Portland cement - Type V
0.18 parts pozzolan cement
1.18 parts minus 30 sand
0.47 parts water

sand/total cement: 1.00

water/total cement: 0.40

pozzolan/total cement: 0.15

Duration of damp curing: 28 days

Tensile strength (average of 2 samples): 622 psi

c. For mortar used in tank tops. 244ABC

Duration of damp curing: 28 days.

Tensile strength (average of 3 samples): 688 psi

d. For mortar used in items 3 through 9 below: 242ABC 246ABC

	Duration of damp curing (days)	Tensile strength (psi) (average of 3 samples)
242ABC	14	830
246ABC	28	880

e. For mortar used in hull to deck joint. 245ABC

Duration of damp curing: 28 days

Tensile strength (average of 2 samples): 700 psi

3. Tension on 3-7/8" x 3/4" plate sections reinforced with 5 layers of 3.4 lb/sq yd of black coated expanded metal. Average of 3 samples.

a. Strong direction of expanded metal placed in direction of pull. Ultimate stress: 1573 psi, with first crack close to ultimate stress. 205ABC

b. Weak direction of expanded metal placed in direction of pull. Ultimate stress: 452 psi. 206ABC

4. Bending studies on reinforced plate sections.

Samples of nominal cross-section 12" x 3/4" were loaded at 1/3 points with loads of equal magnitude on a simply supported sample of 45-inch span length. Unless otherwise noted, the aforementioned Mix A was used in the following studies. The effective flexure stress computed is based on the gross dimensions of the rectangular composite section.

a. Using 5 layers of expanded metal, black coated, 3.4 lb/sq yd.

Duration of damp cure (days)	No. in sample	Effective flume stress (psi) @ first crack	
14@ 50°F - 80°F	3	2204	209ABC
28@ 50°F - 80°F	2	1958	210AB

b. Using 3 layers of 1" x 1" x 14 ga. welded wire fabric. 211ABC,212ABC

Duration of damp cure (days)	No. in sample	Effective flexure stress (psi) @ first crack	Additional load capacity to ultimat (multiple of load at first crack)
14@ 50°F - 80°F	3	831	5.6
28@ 50°F - 80°F	3	942	(not determined)

c. Using 2 layers of 1" x 1" x 14 ga. welded wire fabric. The three elements included in this sample also differ from those of series 4b. in that they form a composite with a cement asbestos layer. During the tests, the cement asbestos layer was in compression. The nominal (and mean) thickness of the elements was thus increased to 1-1/8". Duration of cure was 14 days @50°F-80°F. The effective flexure stress (average of 3) was 2220 psi. 217ABC

d. Bending of 2" thick composite sandwich of a 1" thick layer of urethane foam bonded between two 1/2" thick layers of mortar of Mix A. Each of the outer layers is reinforced with 2 layers of 1" x 1" x 14 ga. welded wire fabric. Cure was 28 days @50°F - 80°F. The effective flexure stress (average of 2) was 1382 psi. 218AB

e. With curing of 14 days damp cure followed by 34 months of ambient weather conditions. 232ABC

A sample of these elements of Mix A and nominal size 6" x 18" x 7/8" reinforced with 5 layers of 3.4 lb/sq yd of black coated expanded metal was tested with third point loads. An increase in load capacity over that capacity at first crack was noted. Load of first crack itself was difficult to discern. Flexure stress at first crack was 4700 psi.

f. With curing of 14 days damp cure followed by 13 months of ambient weather conditions. A sample of three elements of aforementioned Mix B (see 1b.) Reinforcement was 3 layers of 1" x 1" x 14 ga. welded wire fabric in samples of 6" x 7/8" x 24". Loading was at third points. Failure loading produced a presumptive (assuming linear to point of failure) flexure stress of 3440 psi. 233ABC

g. A sample of 3 elements of 9-7/8" x 10" x 1" nominal size including a 1/4" layer cement asbestos on the tension face. Reinforcement of Mix A was with 2 layers of 1" x 1" x 14 ga. welded wire fabric placed near the surface of the compression face. Cure was 14 days damp cure followed by 43-1/2 months of ambient conditions. Average flexure stress, under midpt loading at first crack was 2800 psi. 234ABC

h. This sample of 3 elements differs from that of 4g. in that the cement asbestos layer is the compression face and the reinforced Mix A is the tension face. Average first crack flexure stress was 2170 psi. 247ABC

5. Impact studies on reinforced plate sections. Plates of 15" x 15" x 3/4" nominal size. Clear span of supports was 11 inches. Impact was 500 ft-lbs. of energy effected by a free fall of a 200 lb weight dropping 2'-6". All samples were of Mix A.

a. Supported 2 sides. 5 layers of expanded metal. 14 days damp cure 50°F-80°F. All three specimens of the sample survived the impact test in that the weight did not penetrate the specimen. The deformed specimens had fine cracking with the outside layer of steel of the impacted surface was exposed. Range of permanent set 1-3/4" to 2". 219ABC

b. This series was the same as 5a. except that the cure for the three specimens was for 28 days at 50°F-80°F and that the specimens were supported on all four sides. All samples had a permanent set of range 1-1/2" to 1-3/4". Fine cracking radial in design resulted with only outside layer of reinforcement exposed. 220ABC

c. This was a test of a single specimen differing from those in series 5a. in that the reinforcement for this 2-sided supported plate was 3 layers of 1" x 1" x 14 ga. welded wire fabric. The sample failed in that it folded under impact. 221A

d. This series of two specimens is the same as that of 5c. except that support was on all four sides. These specimens survived with coarse cracking and with all three layers of reinforcement exposed. Permanent set was of 7/8" to 1" range. 221BC

e. This series of three specimens differs from series 5b. in that the reinforcement is composed of 3 layers of 1" x 1" x 14 ga. welded wire fabric. All three specimens survived with coarse cracking and a uniform permanent set of 3/4". 222ABC

6. Tension studies on joints. Bulkhead to bulkhead joints.

Specimens for these studies were cast out of the aforementioned Mix A and were damp cured for 14 days at 50°F - 80°F. Specimens were T-shaped in cross-section and were nominally 5-7/8" long in the third dimension. The flange of the section was 24" between points of support and the stem was 12" in depth. Fillets were cast at the intersection between stem and flange. During testing the t-section was inverted with the stem pointing upwards. The flange was held down at a distance of 12" from centerline of stem on each side and the load was pulling upwards on the stem. The moment and distance to first crack, noted below. are the averages of 3 specimens.

Reinforcement	Distance from reaction to crack (in)	Moment (ft-lbs)
Flange and stem: 3 layers 1" x 1" x 14 ga. welded wire fabric. 6" x 6" expanded metal (3.4 lb/yd^2) at face of each fillet 213ABC	5.1	89.2
Flange: 5 layers of expanded metal stem: 3 layers 1" x 1" x 14 ga. welded wire fabric. 6" x 6" expanded metal at face of each fillet. (Expanded metal 3.4 lb/yd^2) 214ABC	5.3	88.9

7. Bending studies on joints.

a. Deck to hull joints. Specimens for this series were in the shape of an L, the horizontal being a section of deck and the stem a section of hull. The section of deck measured 2" in thickness and was a composite of 1" of urethane foam sandwiched between two layers of Mix A mortar. Each layer of mortar was reinforced with 2 layers of 1" x 1" x 14 ga. welded wire fabric. The hull of 1-3/8 nominal thickness was cast out of Mix A. The loading was in a direction transverse to the plane of the hull. The averages for 3 specimens were: distance from load to first crack (in hull) was 10.8"; corresponding mome was 518 ft.lbs. 229AB

b. The specimens of this series were the same as those of series 6 except that the loading on the stem was trnasverse to the stem. The following are the averages of three specimens each:

Reinforcement	Distance from reaction to first crack (in.)	Moment (ft-lbs)
Flange and stem: 3 layers 1" x 1" x 14 ga. welded wire fabric. 6" x 6" expanded metal (3.4 lb/yd^2) at each fillet face 215ABC	3.75	141
Flange: 5 layers expanded metal Stem: 3 layers 1" x 1" x 14 ga. welded wire fabric. 6" x 6" expanded metal at face of each fillet. (Expanded metal 3.4 lb/yd^2.) 216ABC	5.2	99

8. Study of surface preparation and bonding agent.

Studies were made on 2" x 2" x 2" cubes of Mix A. A 45° seam was prepared by first casting one-half of the cube as a prism including this 45° surface. One day later the next half was cast using Rhoplex E-330 bonding agent at the interface on the 45° surface. Results noted below are the averages of three specimens each. Curing was 14 days damp cure 50°F - 80°F.

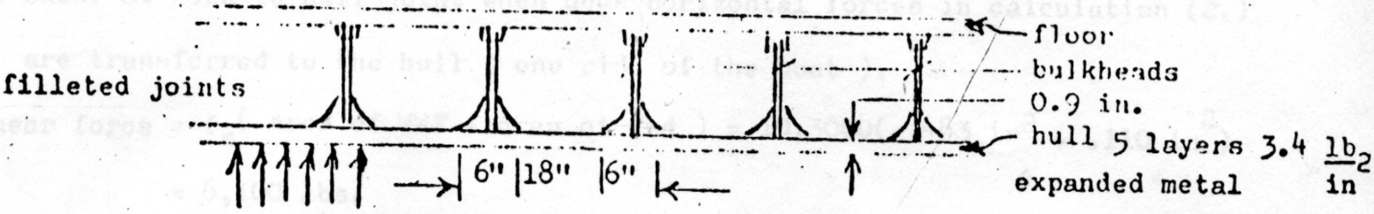
Texture of bonding surface	Compressive (lbs) load at ultimate (of seam)	
smooth	10,490	248ABC
medium	12,730	249ABC
rough	18,070	250ABC

9. Fatigue studies of specimens of 28 day minimum cure were loaded at 1/3 points to produce stress levels cycling between zero and a maximum. Samples were 9" between simple supports, 3" wide and 7/8" nominal thickness. They were of Mix A and reinforced with 5 layers of expanded metal (3.4 lb/yd^2) and arranged with the strong dimension parallel to the span.

Stress range (psi)	Cycles to Failure (in millions)
0- 600	test terminated @25.661 w/o failure
0-1000	5.861
0-1200	test terminated @72,622 w/o failure
0-1400	0.232

calculations

1. Hull panel bending stress when water is 2 feet above deck (10 ft. head)



Hull is continuously supported 24 inches o.c. on supports 6 inches wide.

l = length of clear span = 1.5 ft.

b = width of assumed flat section = 1 ft.

w = distributed load = 62.4 x 10 = 624 lbs. per lin ft.

h = thickness of hull = 0.9 inches

M = max. moment at end supports = $\frac{wl^2}{12}$

f = design stress in hull surface fiber = $\frac{6M}{bh^2}$

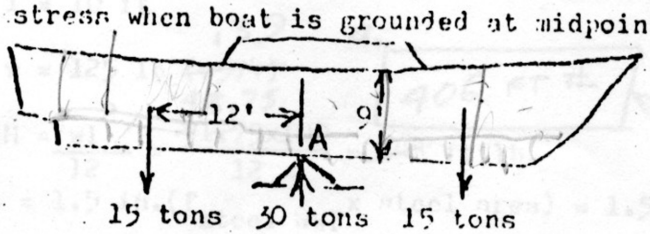
$f = \frac{6}{1} \times \frac{624 \text{ \#/ln ft.}}{12} \times \frac{(1.5)^2}{(0.9)^2} =$ **868 psi.** OK

$\frac{\text{Stress}}{2}$ to first crack: Test sample 209 A,B,C = 1102 psi

" " 210 A,B,C = 979 psi

" " 232 A,B,C = 2350 psi

2. Deck tensile stress when boat is grounded at midpoint.



Keel at A is 6 deep by 42 inches wide of heavily reinforced concrete in compression.

Resisting elements in tension and their moment arms to point A.

a. 4 layers 1x1x14 gauge WWF, 2 ft wide each side deck. 14 gauge = .080 in. dia.
Steel area = $2(4 \times 24)\pi(.04)^2$ = .965 sq in. Moment arm = 9 ft.

b. Using upper 4 ft. of hull (4 layers only). Average thickness = .00929 in / layer
Steel area = $2 \times 4(.00929) \times 48$ = 3.567 sq in. Moment arm = 7 ft.

c. Two 3/8 rebar (at deck shears) = .22 in² area. Moment arm = 9 ft.

$\Sigma M_A = 0 \quad 15T \times 12' = f_s(.956)9 + f_s(3.567)7 + f_s(.149)9 \quad f_s = \frac{360{,}000 \text{ ft lb}}{35 \text{ sq in}} = 10{,}300 \text{ psi}$

Compare to test samples 205 A,B,C ~~206 A,B,C~~ 207 A,B,C 208 A,B,C

OK ↑ NOT TESTED ↑ OK

calculations

3. Shear at deck to hull joint when deck horizontal forces in calculation (2.) are transferred to the hull (one side of the boat).

Shear force = f_s(area of WWF + area of Rod) = 10,3000(.483 in^2 + .110 in^2)

= 6,100 lbs.

Assume this force is transferred through 12' feet of joint.

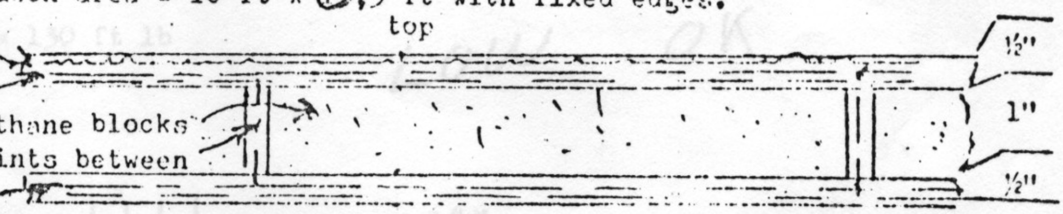
Then shear = $\frac{6{,}100 \text{ lbs.}}{12^{+}\text{ft.}}$ = 500 lbs / lineal feet of joint

Actual shear from test sample 230 A,B,C

NOT TESTED OK BY INSPECTION

4. Deck (sandwich construction) bending stress supporting 2 foot head of water (125#/sq ft.)

Maximum unsupported deck area = 10 ft x 6.5 ft with fixed edges.



Part of load taken by 10 foot span = $\frac{6.5}{10+6.5}$ = ~~.574~~ .39

Part of load taken by 6.5 ft span = $\frac{10}{10+6.5}$ = ~~.426~~ .61

For 10 ft span: l = 10 ft

w = 125 lb ~~(.574)~~ .39 = 48.75

Max moment (end) M = $\frac{wl^2}{12}$ = $\frac{\text{~~71.75~~}48.75 \times 100}{12}$ = ~~598~~ ft lb. a. 406 FT #

Resisting moment = 1.5 in.($f_{\text{steel WWF}}$ x steel area) = 1.5(f_s 2x12π(.04)^2)

$f_{\text{steel WWF}}$ = $\frac{598 \text{ ft lb}}{1.5''(.1206 \text{ in}^2)} \times \frac{12 \text{ in}}{1 \text{ ft}}$ = 39,700 psi

Compare with test samples 207 A,B,C NOT TESTED

208 A,B,C NOT TESTED

218 A,B,C 461 FT # ½ CRACK

OK 229 ABC

For 6.5 ft span: l = 6.5 ft

w = 125 (.61) = 76.25 #/ft

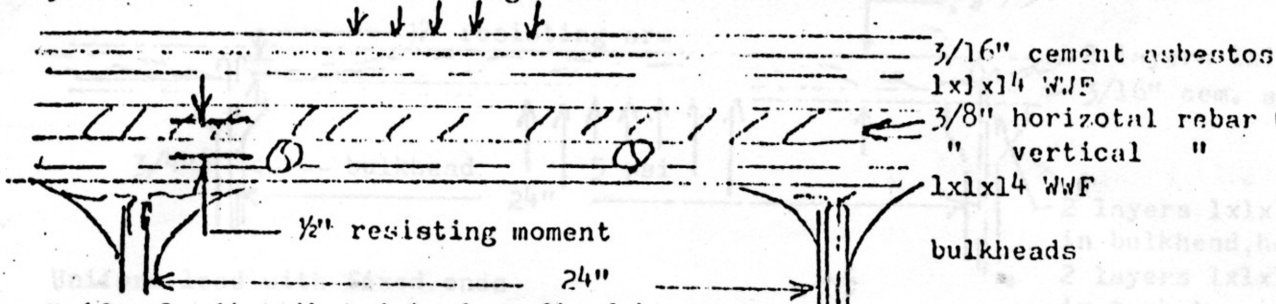
Moment @ Deck to Hull joint = $\frac{wl^2}{12}$ = $\frac{76.25\,(6.5)^2}{12}$ = 268 FT

b. 259 FT OK

½ CRACK

calculations

5. Center board trunk bending stress under 10 ft head of water



Uniformly distributed load on fixed beam

M_{max} at support = $\frac{wl^2}{12}$

w = 62.4x head = 624 lb / ft   l = 1.5 ft

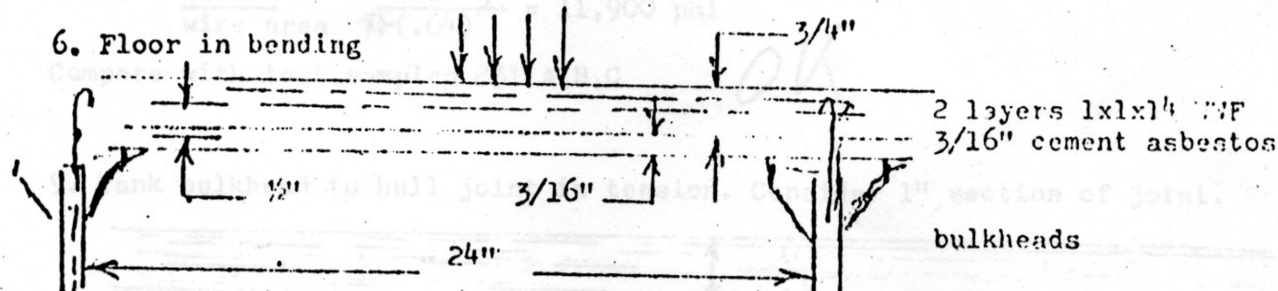
$M_{max} = \frac{624\ (2.5)}{12} =$ 130 ft lb

Resisting moment = force in 2 (3/8) rods times 1" moment arm

$f_{rod} \times 2\pi(3/16)^2 x1 = 130$ ft lb

$f_{rod} = 588$ lb / in^2 LOW   OK

6. Floor in bending



Floor loading: 50 lb live load; 10 lb dead load

Uniformly distributed load with fixed ends

M_{max} at bulkheads = $\frac{wl^2}{12} = \frac{60 \text{ lb / ft} \times 4}{12} = 20$ ft lb

Resisting moment = ½" x f_{WWF} x $Area_{WWF}$

Resisting as uniform beam

$f = \frac{6M}{bh^2} = \frac{6 \cdot 20}{1 \cdot (.75)^2} = 213$ psi

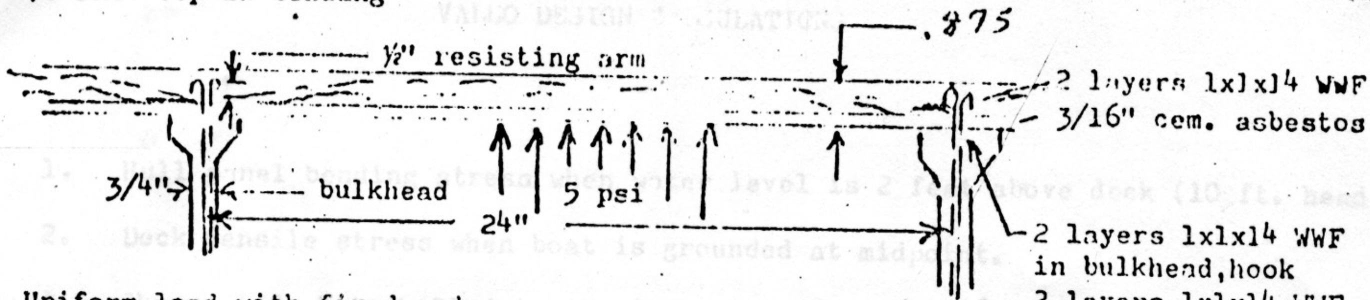
$f_{WWF} = \frac{20 \text{ ft lb}}{½"(24\pi)(.04)^2} = 332$ psi

Compare with test sample results 234 A,B,C

(1400 psi) ← OK

calculations

7. Tank top in bending



Uniform load with fixed ends

M_{max} at bulkheads $= \frac{wl^2}{12} = \frac{5\ psi(12"x12")(2ft)^2}{12} = 120$ ft lb

Resisting moment = ½" x f_{WWF} x $Area_{WWF}$

$f_{WWF} = \frac{120\ ft\ lb}{½" \times 2(12)\pi(.04)^2} = 200$ psi

(1110 psi)

Resisting as uniform beam

$f_s = \frac{6M}{bh^2} = \frac{6 \times 120}{1K(.875)^2} = 940$ psi

(1055 psi)

Compare with test samples 217 A,B,C and 231 A,B,C and 247ABC → 10 psi tank pressur

8. Tank top joint in tension. (see figure above)

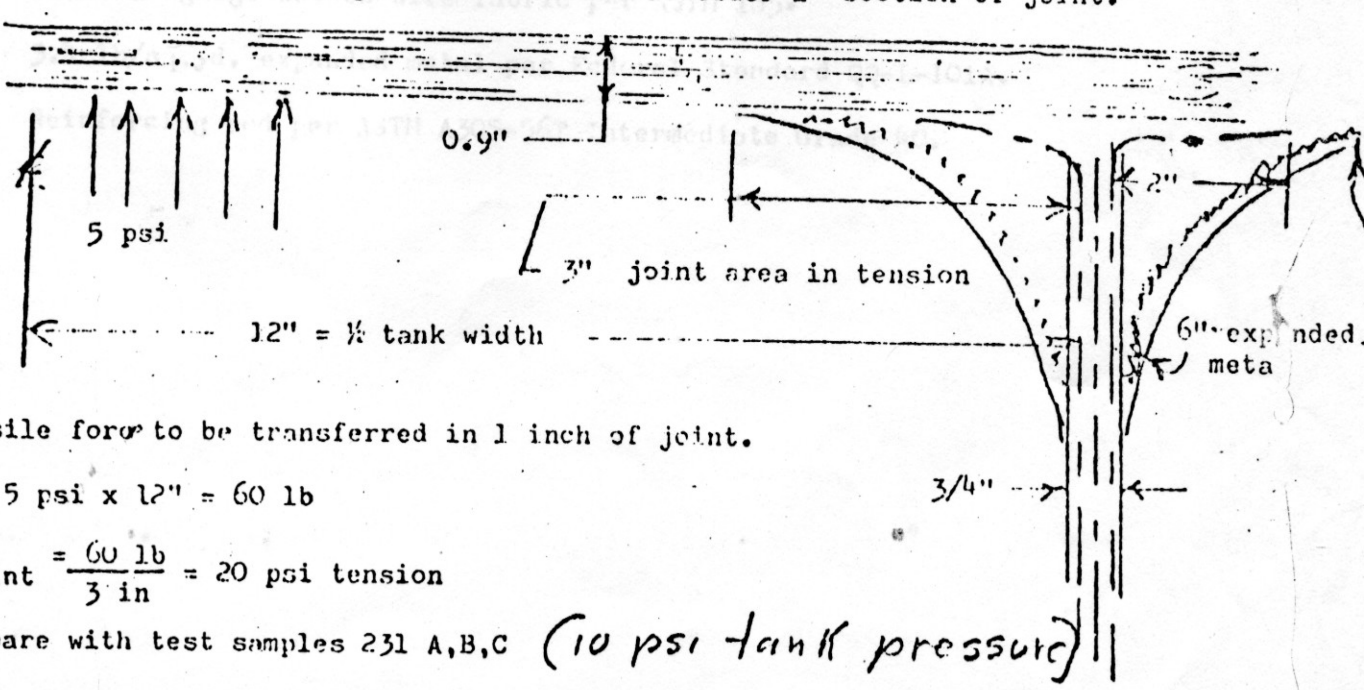
$\Sigma V = 0$ 1" wide (5 psi) 12" = 60 lb

$f_{WWF} = \frac{60\ lb}{wire\ area} = \frac{60\ lb}{\pi(.04)^2} = 11,900$ psi

Compare with test samples 231 A,B,C

OK

9. Tank bulkhead to hull joint in tension. Consider 1" section of joint.



Tensile force to be transferred in 1 inch of joint.

F = 5 psi x 12" = 60 lb

$f_{joint} = \frac{60\ lb}{3\ in} = 20$ psi tension

Compare with test samples 231 A,B,C (10 psi tank pressure)

OK

U. S. COAST GUARD CERTIFICATION

FIBERSTEEL VALEO CLASS

A DISCUSSION OF TEST RESULTS

The most significant test of the certification program was 231 ABC, the full scale cyclic pressure test on integral diesel tankage. This test effectively duplicated most all of the other tests and added the dimension of fatigue. All panels and joints of the tankage were subjected to tension, bending and fatigue loads approximately 2 to 6 times those they would encounter in service. (Hull bottom has 3 to 4 foot static water head clear of the thickened keel and the cyclic test head was as much as 24 feet at the bottom of the test tanks.) At the same time, deflections in the center of the tank panels were low (.032") indicating low stress levels.

The hull panel fatigue tests indicated no failure would occur at the simplified design stress level (868 psi.) Actually this simplified design stress level would be high because the hull has considerable double curvature. No failure after 72 million cycles at a 0 - 1200 psi. stress (sample 248 B) certainly indicates a hull that could take many more cycles in the 0 - 250 psi. range (roughly equivalent to a 2 foot chop).

Although the deck to hull joint test results met design criteria, Lt. David B. Lorenz, the engineering representative of the Coast Guard, felt that an additional layer of 3.4 expanded metal lath would be of value and this was done on V - 22.

The shear bond tests on the Rhoplex E330 bonding agent indicate that a 1845 lb. force would be required to scrape (shear) a square inch of gelcoat from the hull (sample 248 ABC smooth). Test results of (sample 250 ABC rough) show an average shear strength of 3188 psi. which is the case in the deck to hull lamination. This is far in excess of what is required (2 psi. per design calculation number 3).

The factor of 3:1 strong to weak directional strength of expanded metal (as per previous experiments) has to be used to advantage as in the other directional strength materials.

No dogbone sample failed below 600 psi. tension (samples 241A through 245C). This is the force (per square inch) that holds the laminations together.

Assuming that there is no adhesion to the steel and there is a 50% projected area of steel in the expanded metal there is still a 300 lb. tying force per square inch which would make through tie wires structurally insignificant. This same tensile strength is responsible for the integrity of Fibersteel's laminated joints. No joint tested failed in the joint. They all failed in the parts (sample 213 ABC, 214 ABC, 215 ABC, 216ABC and 229 AB).

Apparently there are no delamination problems in the mesh or composite samples when subjected to bending (samples 209 A through 212 C, 217 A through 218 C, 223 ABC, 232 A through 234 C and 247 ABC). Even in the fatigue tests (sample 223 ABCD) the samples that did fail broke essentially straight through all at once.

The impact tests indicate that should hull damage occur, it would tend to be localized with minor leakage. The size of the broken mortar bits is determined largely by the mesh openings.

Becuase of the laminating process used, it is possible to obtain additional strength in any part or joint by laminating additional layers of reinforcing mesh.