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FERRO-CEMENT CONSTRUCTION PANELS

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Two designs of multipurpose ferro-cement construction panels were evaluated as to their versatility for military applications and their strength under flexural loads. The recommended panel design has a thickness of 1/2 in., width of 12 in., length of 8 ft, cross-section of a modified channel, and weight of 86 lbs. Ultimate load carrying ability of the panel under single point flexure was 1,545 lbs which corresponded to an ultimate flexural stress of 4,300 psi for the ferro-cement material.

Tests on the corrosion resistance of ferro-cement were also conducted in a salt spray

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chamber for up to 6 months. Visual observation of the panel surfaces showed rust stains that indicated substantial corrosion of the steel reinforcement; however, the average ultimate strength of the specimens was not significantly reduced.

CONTENTS

OBJECTIVE

The objective of the study was to develop a multipurpose ferro-cement construction panel which would satisfy a wide range of military needs at advanced bases.

The study consisted of selecting a versatile panel configuration and then determining the flexural load carrying behavior of the panel. Additional work was conducted to study the durability of the ferro-cement material in a corrosive environment.

INTRODUCTION

Ferro-cement is a term applied to a highly steel reinforced portland cement mortar (mortar is a concrete which uses aggregate that passes the 1/4 in. sieve). The predominate present day application for ferro-cement is in the amateur boat building industry where hulls 30 to 50 feet in length are fabricated with wall thicknesses from 3/4 to 1 inch.

There is no innate reason why ferro-cement should be limited to floating craft. The physical property that makes ferro-cement desirable for boat hulls is the high flexural strength of a thin section of reinforced concrete material.

This same flexural property can be and has been utilized for on-land structures, for applications such as roofs, walls, and even diving boards. Yet these applications are isolated examples and ferro-cement is only slowly being recognized for its potential to on-land applications. Because it is a labor intensive construction material, its use in developed countries will always be marginal unless automated procedures are developed for manufacturing ferro-cement products. However, for underdeveloped countries, ferro-cement is an outstanding construction material. The Board of Science and Technology for International Development of the National Academy of Sciences, has recently completed a study on the various applications of ferro-cement for developing countries [1]. The range of applications is most impressive and realistic: from food storage bins to small water tanks to simple shelters. The main feature of ferro-cement is that the technology is not complex; the foreign nationals can fabricate their own structures from chicken wire, cement, and sand, and expect a long usable life from the structure because of the durability of ferro-cement.

It is this durability feature in marine and tropic environments that should be of interest to the military for advance base construction. Wood rots quickly and steel requires much maintenance in a marine or tropical environment. Ferro-cement has the durability of a concrete material and can withstand hostile environments. The steel reinforcement is protected from corrosion by the high alkalinity (high pH) content of the mortar matrix. An example of ferro-cement durability is a small, Dutch ferro-cement boat that was built in 1887 and was still afloat in good condition after 70 years use at the Amsterdam Zoo [1].

Besides durability, there are other advantages of ferro-cement to the military. It is a very adaptable construction material. Structures of any shape can be built without the use of forms. Chicken wire is layed up into the desired shape and mortar is plastered on. Ferro-cement is a nonflammable material, and this for some applications can be a very desirable feature. Military personnel not familiar with ferro-cement can build with the material when supervised by a knowledgeable person. This means that many men could be mustered to build defensive works, if necessary.

There are two approaches that can be taken in building with ferro-cement, one approach is to start with the individual components of steel reinforcing mesh, cement, and sand and build the structure in place from the ground up. The other approach is to use precast panels of ferro-cement to assemble the structure.

This report is directed mostly toward the concept of using precast construction panels. The same features of durability and fire resistance apply. Some "flexibility" in designs is sacrificed, but speed of construction is greatly improved.

A construction panel that is designed for multi-purpose applications could be thought of as a unit of construction--just as a 2x4 timber member is thought of as a unit of construction. With a ferro-cement panel many structural needs could be satisfied. If the panel could be used for different applications, the logistic supply of the advanced base could be simplified. Numerous different types of construction materials could be replaced with a large quantity of one item, the multipurpose ferro-cement panel.

Transportation costs of the panels could be reduced by allowing foreign nationals of an ally country or a friendly neighboring country to manufacture the panels. The panels could be manufactured by hand labor, a semi-automated process or a fully automated process.

One of the key ingredients in the concept of using precast multipurpose construction panels is the proper design of the panel itself. The following section discusses panel design.

PANEL DESIGN AND APPLICATIONS

Panel Design

Initial guideline criteria for the panel design were that the panel must be capable of sustaining flexural and compressive loads and that the panel should weigh less than 100 pounds. Length of the panel was defined as 8 feet because this corresponds to standard U.S. dwelling wall height.

To stay within the weight and length criteria, the other dimensions of the panel were limited to approximately 1/2 inches in thickness and

12 inches in width for a panel having a corrugated cross section. The corrugated cross section is required to increase the flexural load carrying ability of the 1/2 in. thick ferro-cement.

With the approximate dimensions roughed out, the shape of the cross-section had to be determined. Numerous shapes were evaluated (Figure 1) for their versatility in being assembled in different ways. Two basic shapes were selected as having merit, the modified channel section (Figure 2) and the hat section (Figure 3). The actual sizes of the corrugations were determined by a trade-off between section modulus and versatility in assembling panels. Figures 2 and 3 give the final dimensions of the panels. Weight of the panels was 86 pounds for the channel section and 93 pounds for the hat section.

Applications

Figures 4 and 5 show some of the different methods of assembling the panels. Using these assembly techniques, multipurpose panels would have the following applications at advance bases:

- bunkers
- foxhole covers
- revetments
- armor plating for existing structures
- protective barrier for bridge piers
- helicopter landing pads
- dead-man anchors
- retaining walls
- piles
- sheet piling
- coffer dams
- quay walls
- canal linings
- water tanks
- water cisterns
- rafts
- sampans
- personnel shelters
- warehouses
- sewerage tanks
- shower stalls
- foundations
- walls
- floors
- roofs
- built-up columns
- built-up beams
- forms for concrete

Several full scale panels of both the channel and hat cross-section were fabricated to demonstrate assembly methods and to undergo structural testing. Figures 6 through 11 show some of these panels assembled for various applications. A sketch of a bunker constructed of panels is shown in Figure 12. Both bunkers and revetments would use the double wall construction approach (see Figure 9) where the space between the walls is filled with soil.

Conventional means of joining panels together would be used: nails, forced-entry fasteners, bolts and nuts, pop-rivets, or adhesive bonding. For applications requiring watertightness, adhesive bonding may be sufficient alone or zinc-chromate compound should be used in conjunction with mechanical fasteners.

Ferro-cement materials can be "worked" in the field; that is, the panels can be cut or drilled using portable power hand tools. Portable saws need a masonry blade and drills need a masonry bit. If power tools are not available then a cold steel chisel can be used to cut or punch holes in the panel.

In summary it was determined that the channel section panel was more versatile in methods of assembly than the hat section panel. A wider range of applications could be serviced by the channel section panels.

TEST PROGRAM

Scope

The test program consists of two phases. Phase 1 evaluated the flexural load carrying capability of prototype ferro-cement construction panels and Phase 2 investigated the effect of a corrosive environment on the strength of ferro-cement.

Under Phase 1, six panels of two cross-sectional designs were subjected to single point flexural loads. The panels were full-scale prototypes of multipurpose construction panels. Two reinforcement schemes for the ferro-cement were used in the fabrication of the panels, a plain steel woven mesh and a galvanized chicken wire.

Under Phase 2, the construction panels were cut into small rectangular specimens, 3 by 12 in. and subjected to an accelerated corrosive environment in a salt spray (fog) environment. After 4 and 6 months in the salt spray environment, the ultimate flexural strength of specimens was determined and compared with the strength of control specimens.

Flexural Tests on Construction Panels

Test Specimens. The test specimens were full scale panels; three panels had a channel cross-section and the other three panels had a hat cross-section. The physical characteristics of the panels, such as, moment of inertia and section modulus are given in Table 1.

The ferro-cement material comprised a mortar matrix and steel reinforcement. The mortar consisted of Type II portland cement and river wash aggregate of the following sieve sizes:

Sieve Size	Percent Retained
30-50	61
50-100	27
on pan	12

Proportions for the mix were sand/cement ratio of 2.6, water/cement ratio of 0.65, a water reducing additive (Plastoment) of 2 oz/sack, and a chromium trioxide (CrO_3) additive of 300 parts per million by weight of the mixing water. The chromium trioxide additive was used to prevent galvanic cell activity within a freshly poured panel [2].

The compressive and split tensile strength of 3 x 6-in. control cylinders is given in Table 2. At the age of about 63 days, the average compressive strength was 6,080 psi and the average split tensile strength was 610 psi.

Two reinforcement schemes were used in the ferro-cement. The main system was selected from an earlier study [3] and consisted of a total of six layers of 1/4 x 1/4-in. plain woven wire mesh of 0.025-in. wire diameter. At the center of the six layers was a single layer of 1 x 2-in. galvanized welded wire of 0.0625-in. diameter. The other reinforcement scheme was for comparison purposes and it consisted of six layers of 1-in. hexagonal galvanized chicken wire of 0.0325-in. diameter. Also at the center of the six layers, was a single layer of 1 x 2-in. galvanized welded wire of 0.0625-in. diameter. The percentage of steel reinforcement for the panels in the longitudinal direction was 2.9 for the panels with 1/4 x 1/4-in. mesh and 2.6 for the panels with chicken wire. The ultimate tensile strength of the reinforcement was 93,000 psi for the 0.025-in. diameter wire used in the 1/4 x 1/4-in. mesh and 61,000 psi for the 0.0325-in. diameter wire used in the chicken wire.

Fabrication of the specimens followed this procedure: (1) the mesh reinforcement was layed up as flat sheets and were all bent at the same time to the proper shape in a sheet metal bending machine, (2) the reinforcement was secured to the mold by tie wires passed through holes in the mold (Figure 13), (3) mortar was plastered into the mesh with the aid of vibration and then screeded tight against the mesh, (4) after 16 to 18 hours of moist curing, the top of the panel was wire brushed to expose some of the mesh of the top layer (Figure 14), (5) the panel was weighed so the correct amount of mortar could be plastered over the mesh in a thin coating to bring the final weight of the panel close to calculated weight.

The test set-up is shown in Figure 15. A single point load was applied to the panel at the center of a 7.5-foot span length. Loads were applied in 50-pound increments so that strain gage and Ames dial deflection readings could be obtained and inspection for the first visible crack could be conducted.

Results of Flexural Tests. Table 3 gives the flexural loads and stresses at visible cracking and ultimate conditions. For the mesh reinforced panels, a wide variation in stresses at visible cracking and ultimate was apparent. The average stress at visible cracking was 1,980 psi with an extreme range from 1,140 to 2,840 psi. The average stress at ultimate conditions was 3,130 psi with an extreme range from 2,460 to 4,300 psi. A possible reason for the variation in the results is that panels CM-2 and HM-1, which showed the lower strengths, had the drilled bolt holes (see Figures 6 and 10) on the tensile side of the panel. These holes were the locations of first visible cracks and the major crack at ultimate loading. However, the calculated stress at the cross-section with holes was higher than the stress at midspan (Table 3) by only about 100 psi.

The results from the two chicken-wire-reinforced panels showed good consistency. The average stress at visible cracking was 720 ± 40 psi and at ultimate loading was 2,120 ± 290 psi.

The load-deflection behavior for the panels is shown in Figures 16-18.

The cracking behavior of the mesh reinforced panels was superior to the chicken wire reinforced panels. At loads greater than the visible cracking load, the mesh panels showed numerous fine, closely spaced cracks (approximately 1/4 in. apart) on the tensile face, whereas the chicken wire panels showed large, widely spaced cracks (approximately 1 inch apart). After removing the load, the cracks in the mesh panels tended to close, except for the failure crack, while the cracks in the chicken wire panels remained sizable (Figure 19).

Failure behavior of the panels showed an important disadvantage of the 1/4 x 1/4-in. mesh reinforcement; this was the low ductility of the wires. At panel deflections between 1.4 and 2.4 inches, a sudden major crack would develop due to breaking many wires. The wires in the chicken wire reinforced panels never broke, they continued to yield even when the deflections were as great as 5 inches.

It is possible that one reinforcement scheme could be developed to combine the advantages of 1/4 x 1/4-in. mesh and chicken wire reinforcement. A combination of 1/4 x 1/4 mesh and chicken wire in a lay up using two layers of mesh on each extreme face and two or three layers of chicken wire in the center should result in a ferro-cement panel with good flexural strength, good cracking behavior, and high ductility.

Effect of Corrosive Environment

The purpose of this test was to obtain an indication of the effect of a corrosive environment on the steel reinforcement in ferro-cement. More basically, do the small diameter wires corrode to the point of reducing the strength of the ferro-cement without giving visual evidence of corrosion? Or, if corrosion is evident from visual rust stains, what effect does this degree of corrosion have on the ultimate strength of the ferro cement?

Test Description. Ferro-cement specimens were subjected to a salt spray (fog) test described in ASTM Method B117-64. The salt-spray solution was 5% by weight of sodium chloride dissolved in demineralized water and the temperature of the salt spray chamber was maintained at $95^{\circ} \pm 3^{\circ}F$.

In all, 39 specimens of size 1/2 x 3 x 12 inches were cut from the undamaged sections of the construction panels. Twenty-seven specimens had the 1/4 x 1/4-in. mesh as the reinforcement; three of these were tested at zero time, 9 were placed in the fog room, and 15 were placed in the salt spray chamber. Three of the specimens marked for the salt spray chamber were coated with an epoxy waterproofing material. The remaining 12 specimens had chicken wire as the reinforcement, of which three were tested at time zero, and the remaining 9 were placed in the salt spray chamber.

Specimens were tested under flexural loading after being exposed to the salt spray for 0, 4, and 6 months. The 6-month specimens were intended for 8 months exposure; however, at the end of 4 months the salt spray chamber failed and required replacement. Thus, for 2 months the specimens were stored at room conditions before testing was resumed.

Companion control specimens were stored in a fresh water fog environment and tested at 4 and 8 months.

The method used to determine the effect of the environment on the specimens was to compare the ultimate flexural strength of the salt spray chamber specimens with (1) zero time data, (2) the strength of fog room specimens, and (3) the strength of salt spray chamber specimens that were coated with an epoxy material.

Distribution of the reinforcement across the thickness of the panels was nonuniform. The layers of mesh or chicken wire were grouped more heavily on the bottom side of the construction panel; this side was designated as the tensile face for the test specimens.

Variation in test specimens was a problem; aside from a variable spacing of reinforcement layers, the thickness of the panels also varied from 3/8 to 9/16 inch. To avoid bias in selecting specimens for testing at 0-, 4-, and 6-month periods, a random selection procedure was used.

Results of Corrosive Environment Test. Ultimate flexural strengths were obtained from specimens exposed to the salt spr[illegible] environment for 0, 4, and 6 months and from control specimens expos[illegible] to a freshwater environment for 0, 4, and 8 months. Table 4 shows [illegible] ultimate flexural strengths and Figure 20 plots the strengths versus time. The results show no major decrease in strength. After 4 and 6 months' exposure to the salt spray environment, the standard deviation of the flexure strengths was quite large denoting that either corrosion had some effect or that mesh placement varied significantly for these specimens.

The important finding from the results was that no major decrease in strength occurred even though there was considerable visual evidence of steel corrosion (Figure 21).

Inspection of the steel reinforcement showed the following:

a. After 6 months' exposure to a salt spray environment, the 1/4 x 1/4-in. plain steel woven wire mesh was attacked rather significantly from a visual standpoint. Worst corrosion occurred at the intersection of two wires and in some isolated instances the wires were corroded through. Evidence of corrosion products were found at the center of the 1/2 in. thick panel.

b. After 6 months' exposure to a salt spray environment, the galvanized chicken wire showed white corrosion products on the wires, in some cases, even at the center of the 1/2 in. thickness. The attack was not advanced and the strength of the wires was not harmed. Wires having no mortar cover showed typical brown rust.

c. After 6 months' exposure to the salt spray environment, the 1/4 x 1/4 in. plain steel woven wire mesh specimens that were coated with an epoxy material showed some localized areas of corrosion which were not harmful to the strength of the wire and which were limited to the layers closest to the surface having a cover of 1/16 to 1/8 inch.

d. After 8 months' exposure to freshwater fog, the 1/4 x 1/4-inch plain steel woven wire mesh showed some localized areas of corrosion which were not harmful to the strength of the wire and which were limited to the layers closest to the surface having a cover of 1/16 to 1/8 inch.

Correlation between the salt spray environment of the test chamber and natural weather conditions is very poor; therefore, the results from the salt spray chamber cannot be translated into real time exposure data.

Table 5 gives the compressive strengths of 3 x 6-inch cylinders that were exposed to salt spray and freshwater fog. There was no indication that the salt spray environment deteriorated the mortar.

In summary, the galvanized steel reinforcement corroded less than the plain steel reinforcement, and the epoxy coating was an effective barrier to preventing corrosion. From a practical standpoint, it is valuable to know that corrosion of the steel reinforcement in ferrocement can be observed visually before the corrosion is severe enough to cause a weakening of the material ultimate strength. For the ferrocement construction panels, it is recommended that a waterproof coating be applied to assure an extended life.

DISCUSSION

A comparison of strengths between ferro-cement, wood, and steel panels, all 12 inches wide and 8 ft long is given in Table 6. The wood and steel items are off-the-shelf products so their strengths are tabularized (except for the steel decking under compression) [4,5]. The strengths for ferro-cement panels are given in Table 6 for both chicken wire and 1/4 x 1/4-inch mesh reinforcement; these allowable flexural strengths are equal to the average stress at visible cracking. This resulted in a factor of safety against ultimate strength of 3.0 for the chicken wire panels and 1.5 for the 1/4 x 1/4 mesh panels. The allowable compressive stress in the ferro cement was 0.45 f_c', which conforms to the ACI code [6].

The flexural strength properties of ferro-cement relate rather closely to wood; however, ferro-cement under compression can withstand greater loads than the wood, especially if the wood is wet.

As would be expected, the live-load-to-dead-weight ratio of the steel panel is superior to ferro-cement or wood; however, the steel panel is essentially a flexural member only. Its compressive capability is about one-eighth that of the ferro-cement panels. Hence, ferro-cement should be compared more closely to wood because wood is a flexure and compressive member, as is ferro-cement.

From a cost standpoint, ferro-cement appears to be competitive with wood (Table 6). The common basis for the cost comparison was retail prices (1973) in CONUS.* It was assumed that the ferro-cement panels were manufactured using fully automated procedures.

Between the two panel designs, the more versatile configuration was the channel section (Figure 2). From a flexural load carrying ability, the choice was not as straightforward. The channel section showed the highest and the lowest ultimate loads (Table 3) in its strong and weak orientations, whereas the hat section showed more nearly equal strength in the strong and weak orientations.

The authors believe that the channel section is the better configuration for the multipurpose panel. Versatility is the most important criterion, and the channel section is better in that category.

Ferro-cement appears to be a good choice as the construction material because it can resist flexural and compressive loads. The material has a history of good durability in corrosive environments, and this study showed that if and when corrosion of reinforcement does occur, the corrosion products will be seen on the surface of the panel. Hence, corrective actions can be taken before harmful deterioration of panel strength can occur, or stated another way, the panel will not lose its strength due to corrosion without visually alerting the users. A waterproof coating on the panel will lengthen the useful life of the panel.

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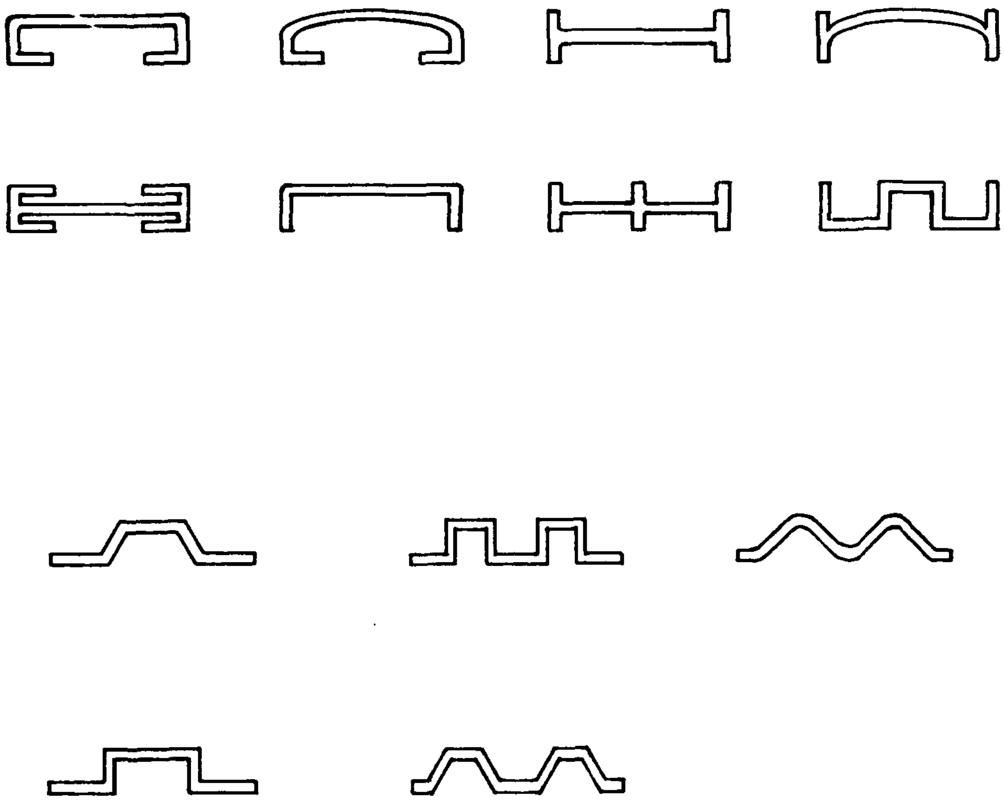
*Continental United States.

SUMMARY

A ferro-cement construction panel for multipurpose applications at advanced military bases appears to be feasible. The design for such a panel was selected as having a modified channel cross-section (Figure 2) and overall dimensions of 1/2 in. thickness, 12 in. width, and 96 in. length. The weight of the panel is 86 lb. The range of applications for this panel is broad, such as bunkers, armor for existing structures, sheet piling, water tanks, rafts, and permanent forms for concrete beams or columns to name a few examples. Further development of a specific application is not planned as of this writing.

Flexural tests were conducted on prototype construction panels to obtain stresses at visible cracking and ultimate conditions. Using 6 layers of 1/4 x 1/4-in. mesh of plain steel reinforcement, the stress at visible cracking was 2,630 psi and at ultimate was 4,300 psi.

Accelerated corrosive environment tests on ferro-cement showed that after 6 months exposure considerable visual evidence of steel reinforcement corrosion occurred; however, the ferro-cement materials did not show any significant reduction in flexural strength.



Approximate size 12″ wide
96″ long
1/2″ thick

Figure 1. Cross-sectional shapes considered for multipurpose construction panel.

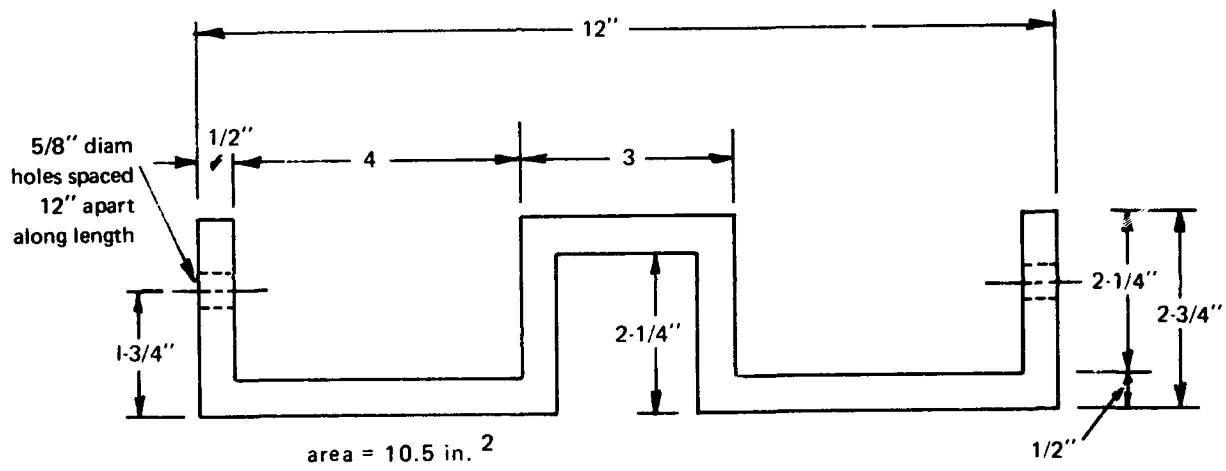


Figure 2. Channel cross-section panel.

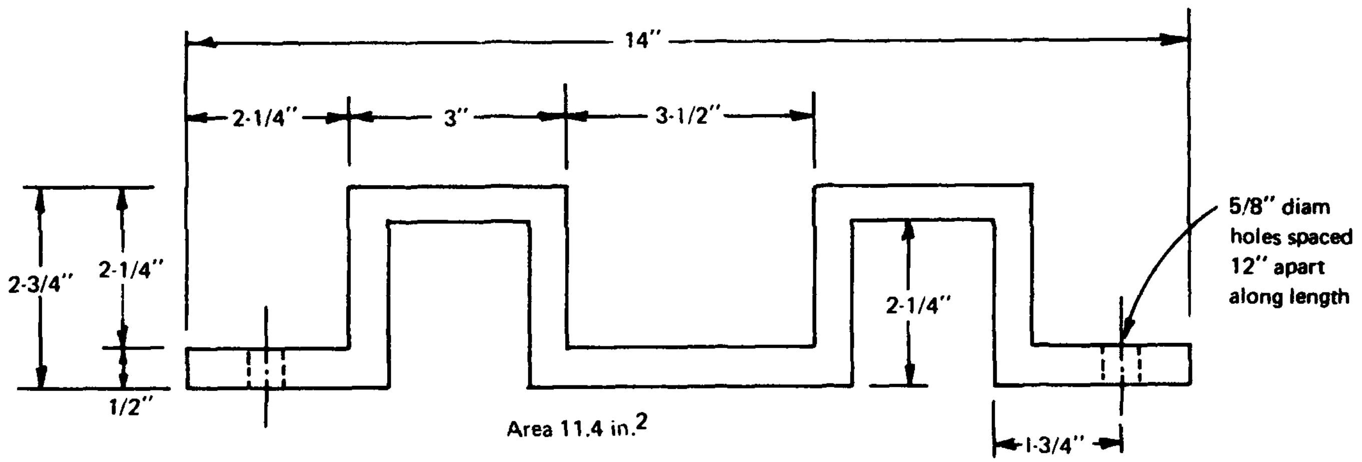


Figure 3. Hat cross-section panel.

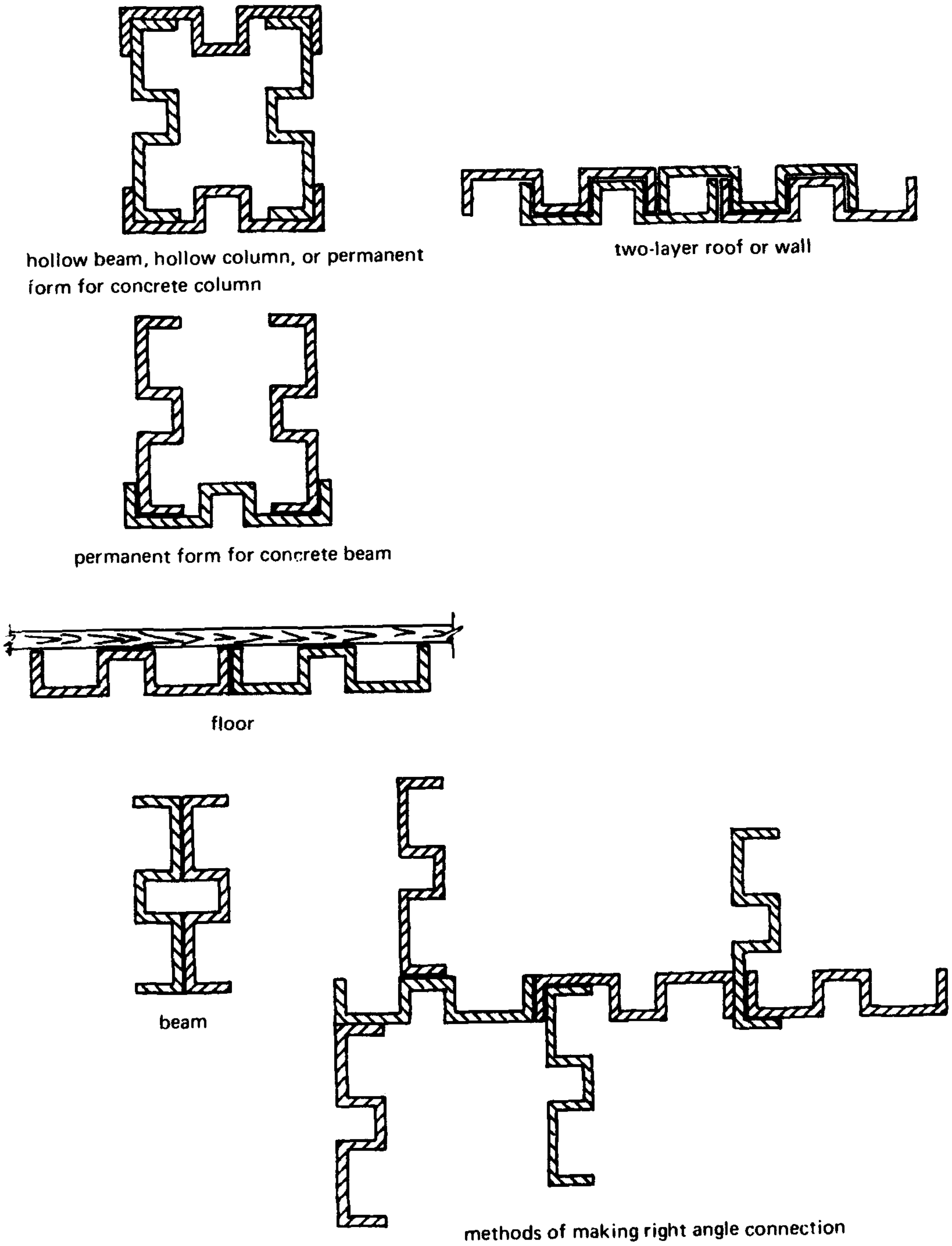


Figure 4. Different assemblies of channel section

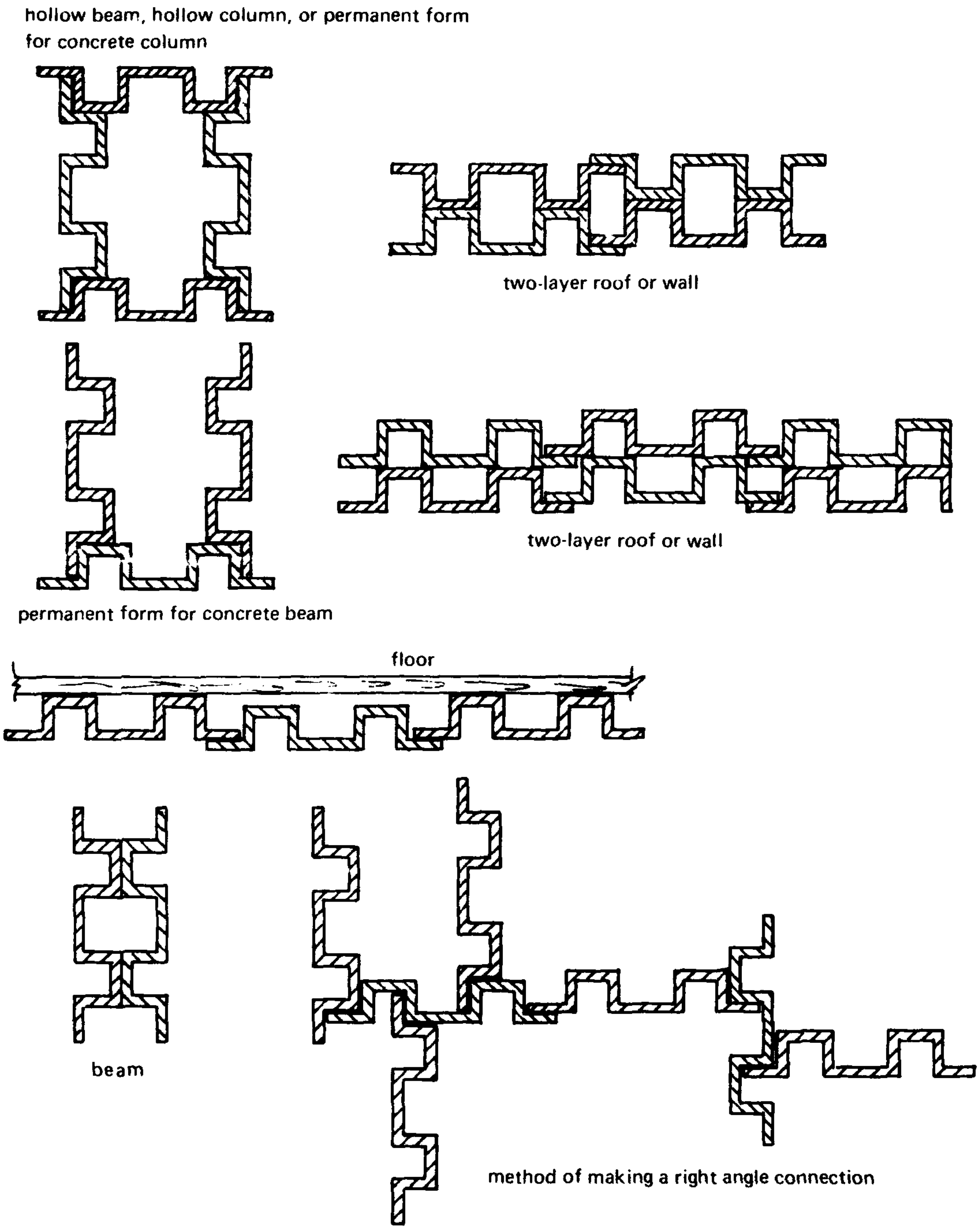


Figure 5. Different assemblies of hat section.

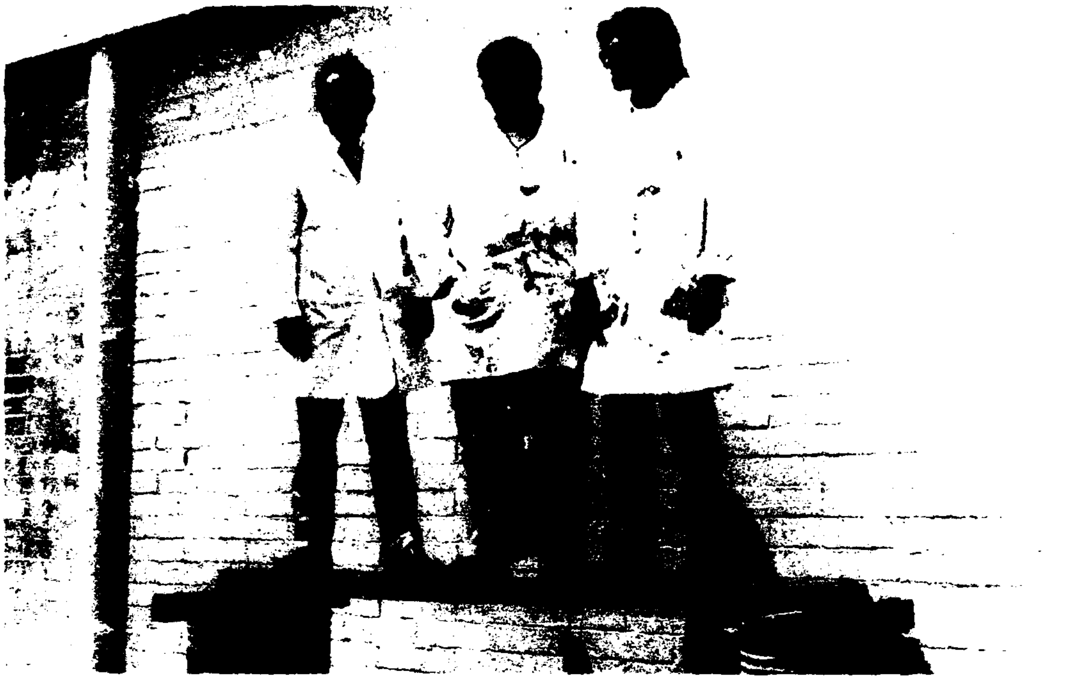


Figure 6. Channel section panel carrying a live load of 720 lbs.

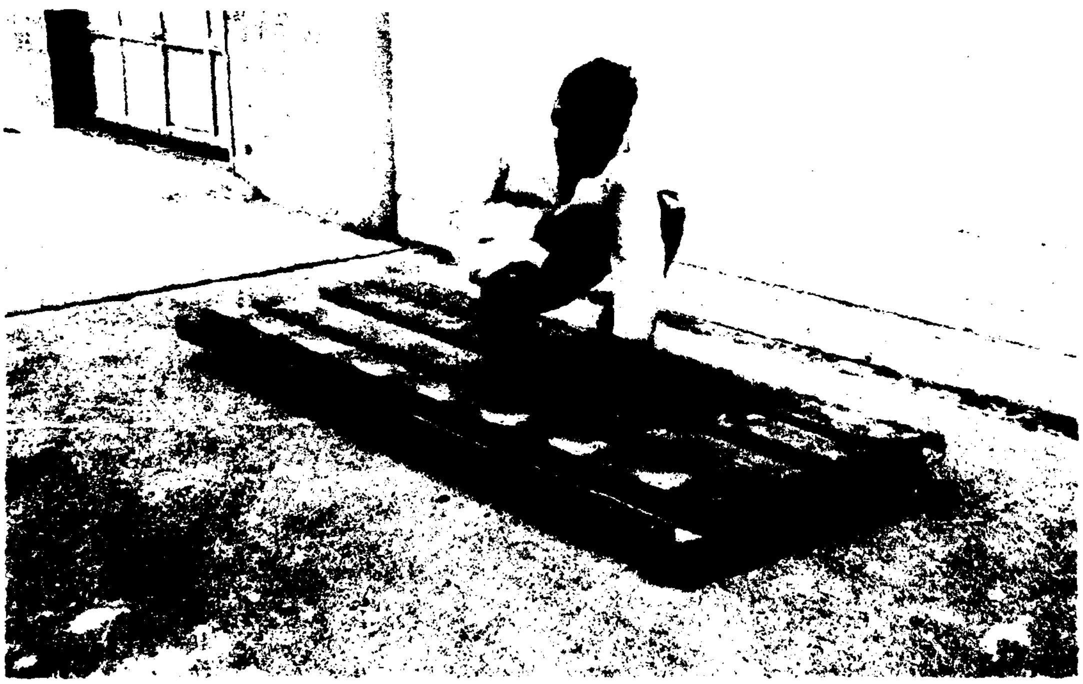


Figure 7. Channel section panels assembled for roof or wall construction.

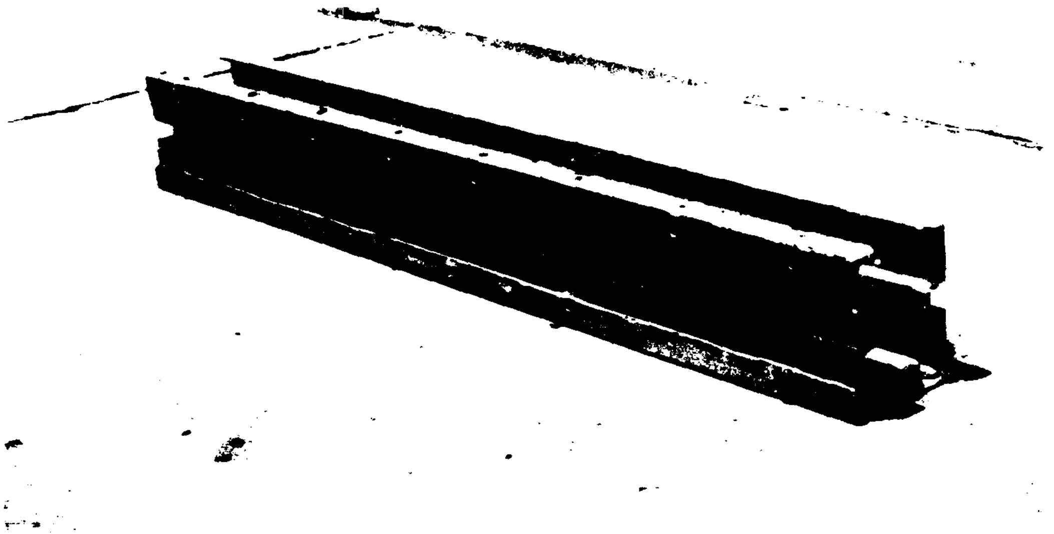


Figure 8. Channel section panels assembled as permanent form work for a concrete beam.

Figure 9. Channel section panels assembled as revetment where interior space would be filled with sand or gravel.

Figure 10. Hat section panels assembled as load-bearing wall or armor for existing structure.

Figure 11. Rapid assembly method for making permanent formwork for concrete column.

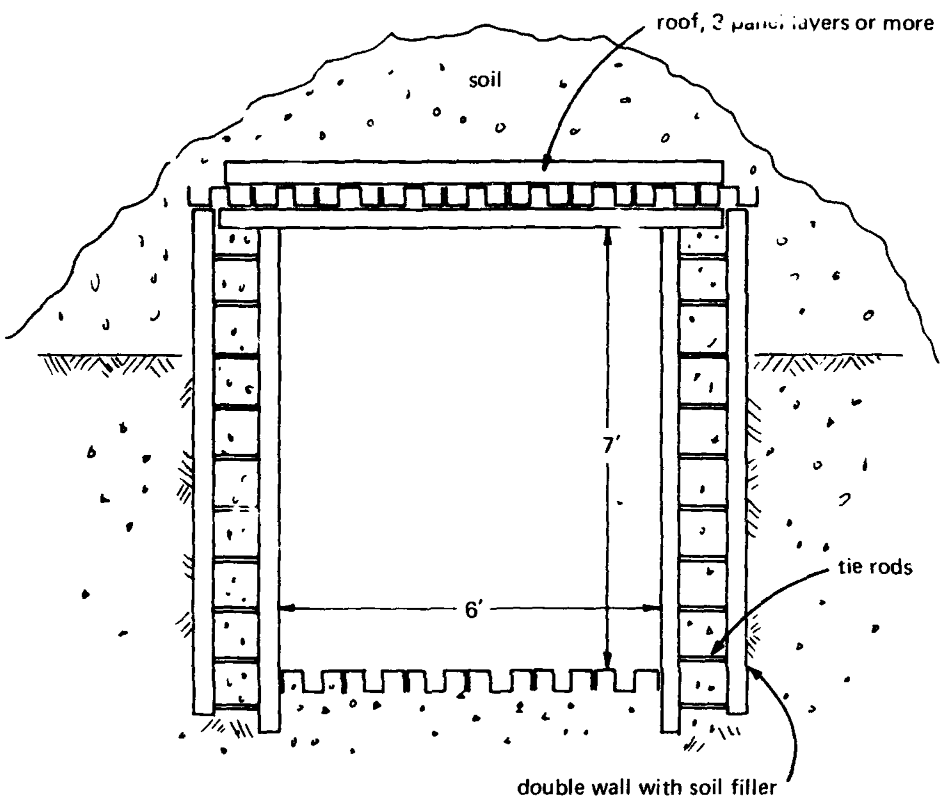


Figure 12. Bunker constructed of panels

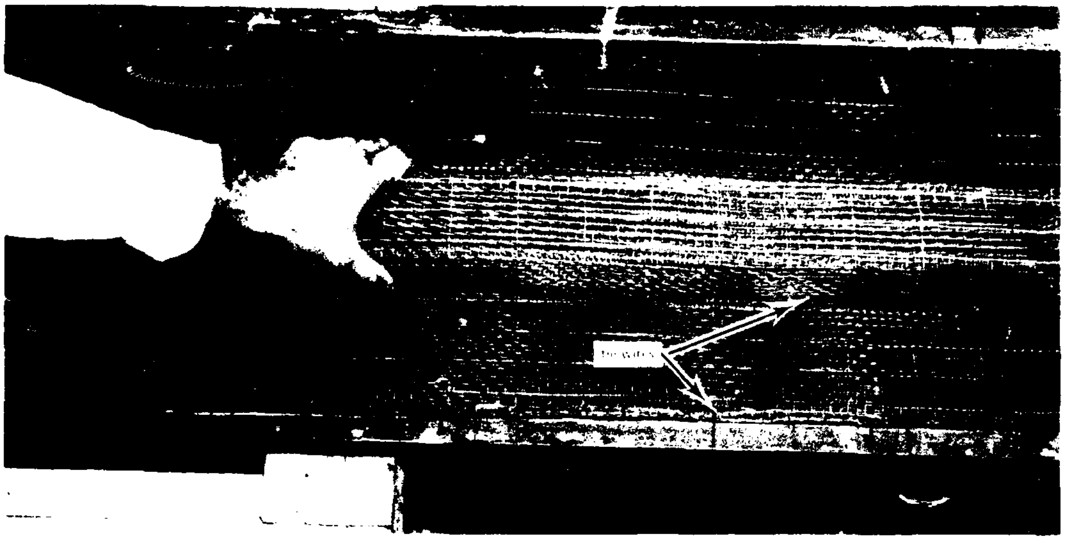


Figure 13. Tie wires securely hold mesh to the mold.

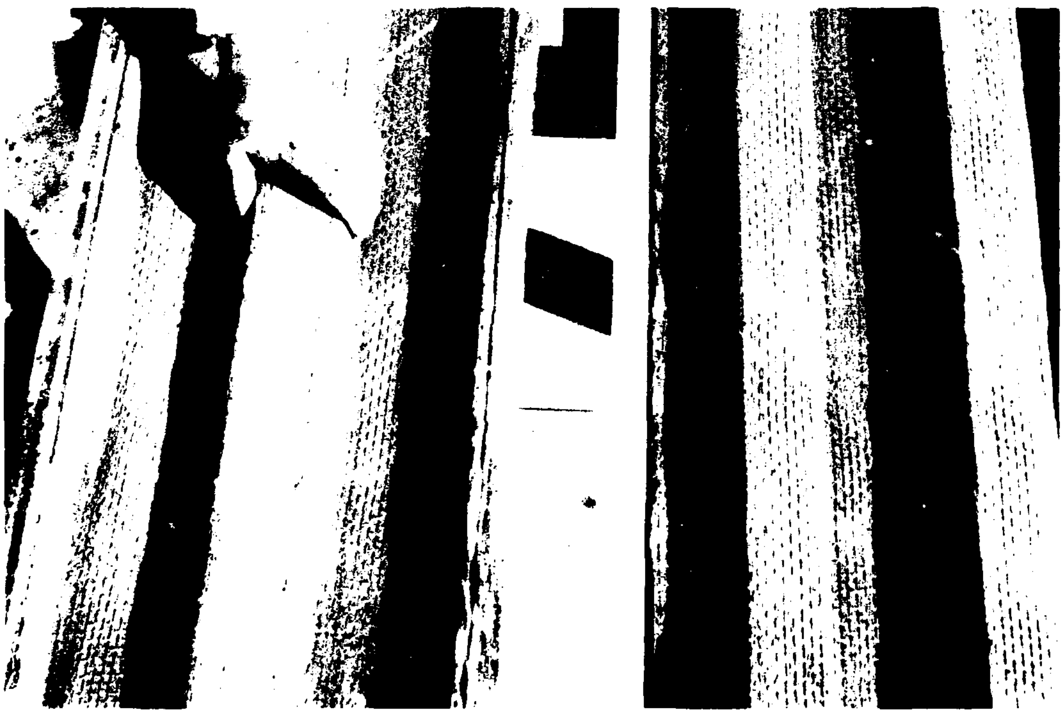


Figure 14. After 16 to 18 hours of moist curing, the surface of the panels were wire brushed to expose some mesh in preparation for the final mortar cover.

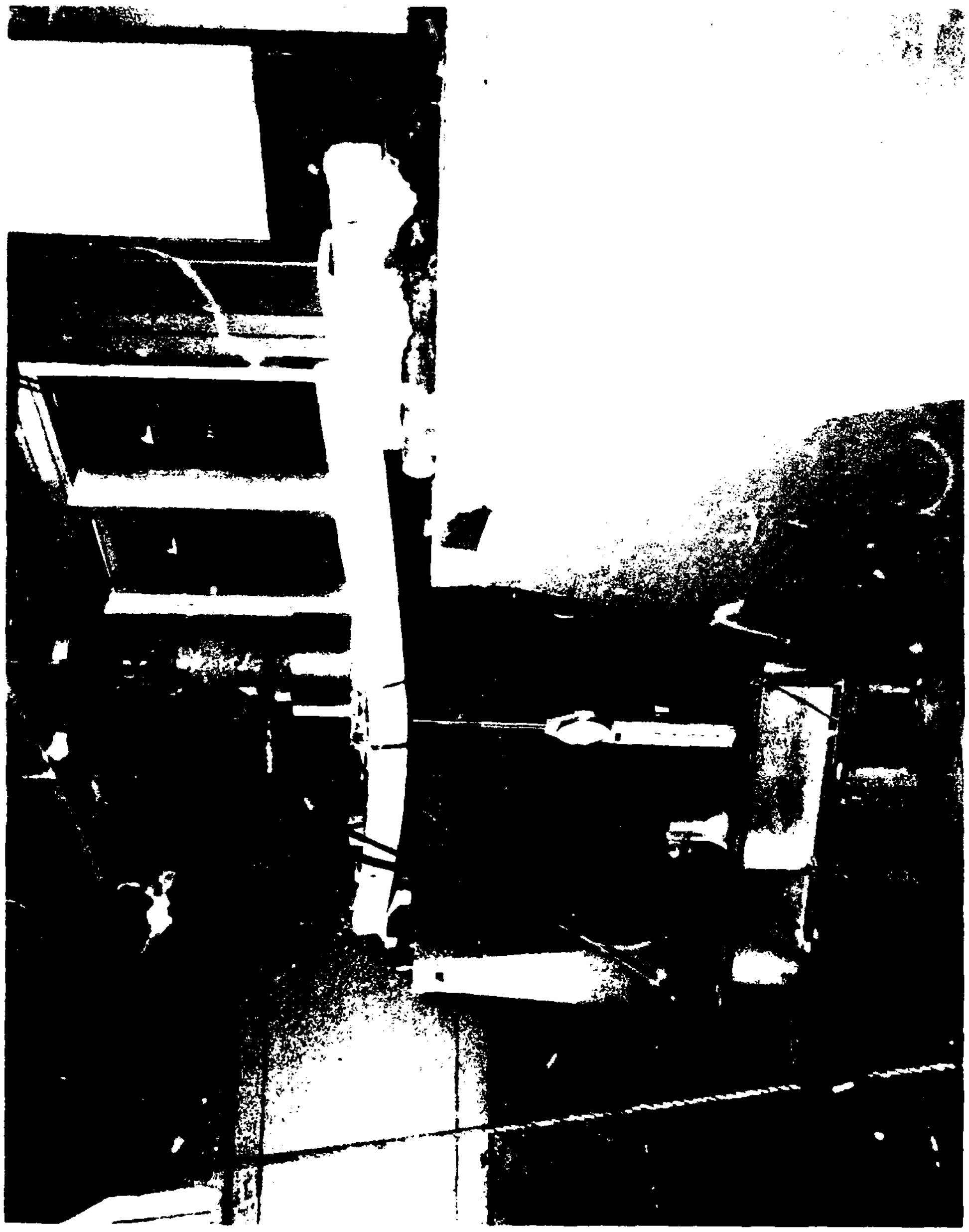


Figure 15 Test set up

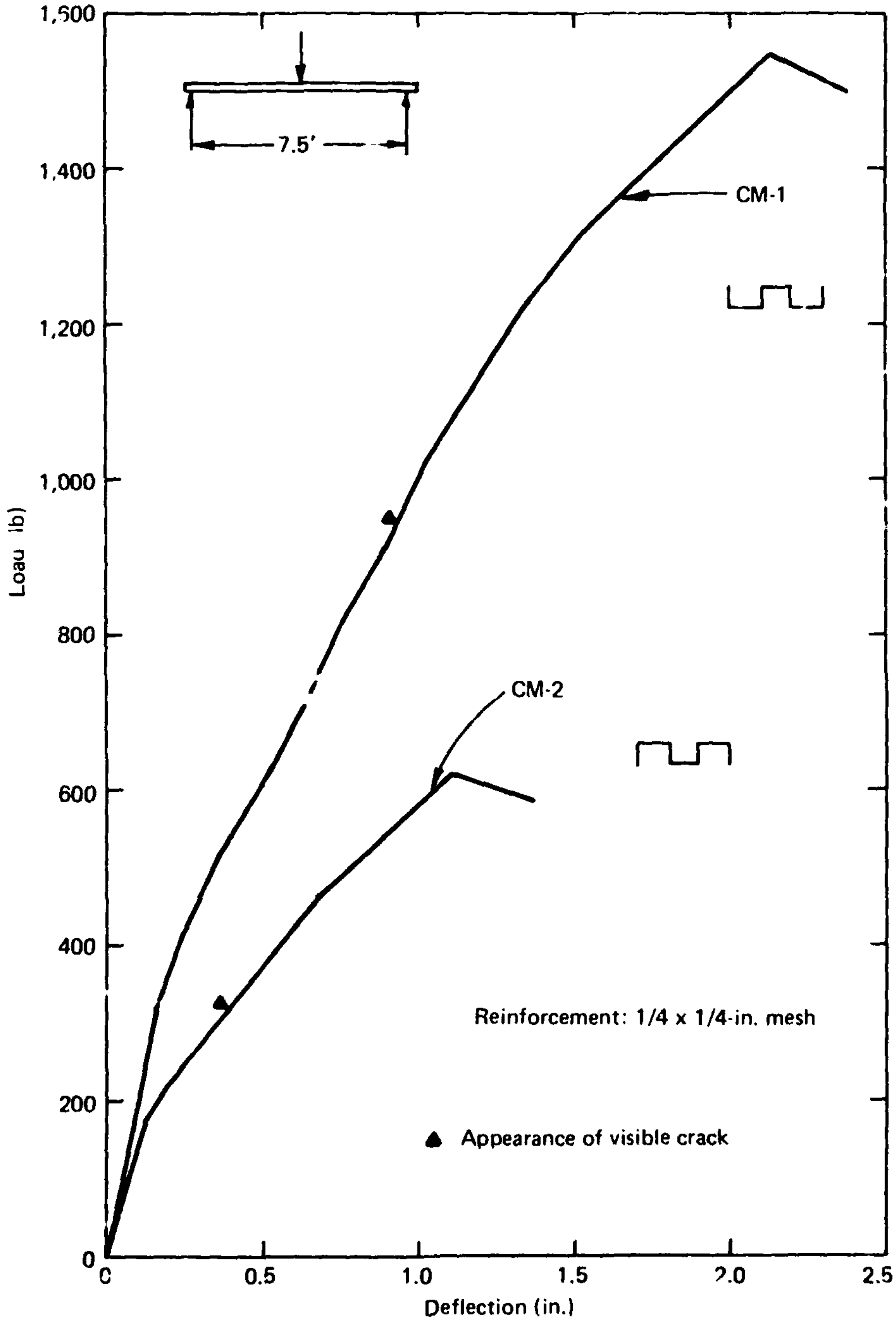


Figure 16. Load-deflection relation for channel cross-section panels reinforced with 1/4 x 1/4-in. mesh.

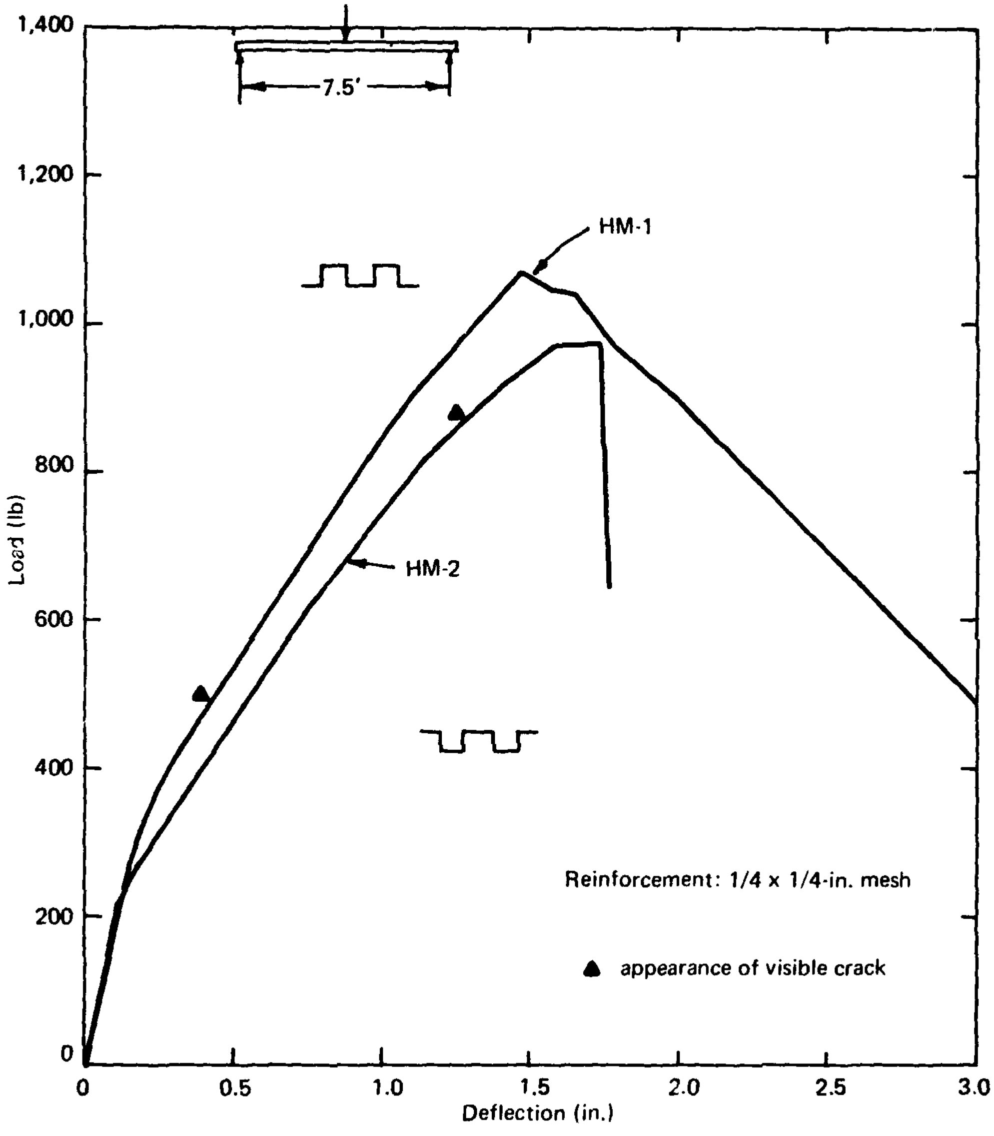


Figure 17. Load-deflection relation for hat cross-section panels reinforced with 1/4 x 1/4-in. mesh.

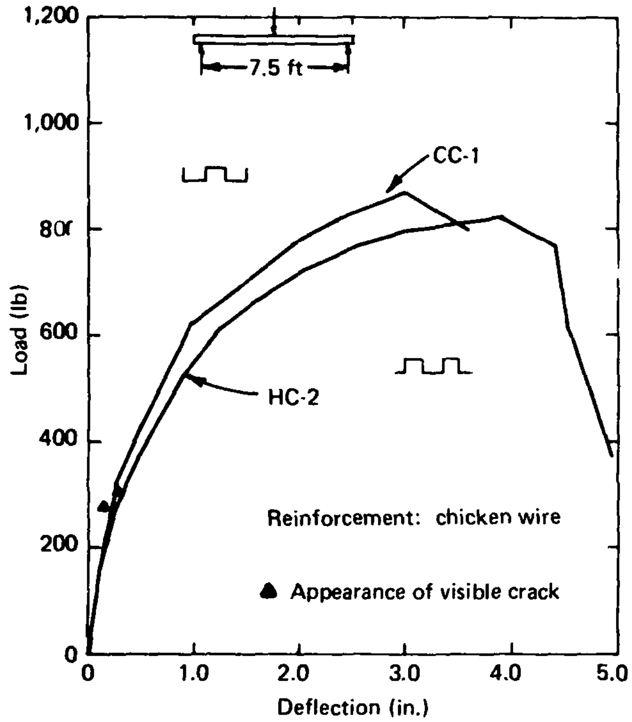


Figure 18. Load-deflection relation of panels reinforced with chicken wire.

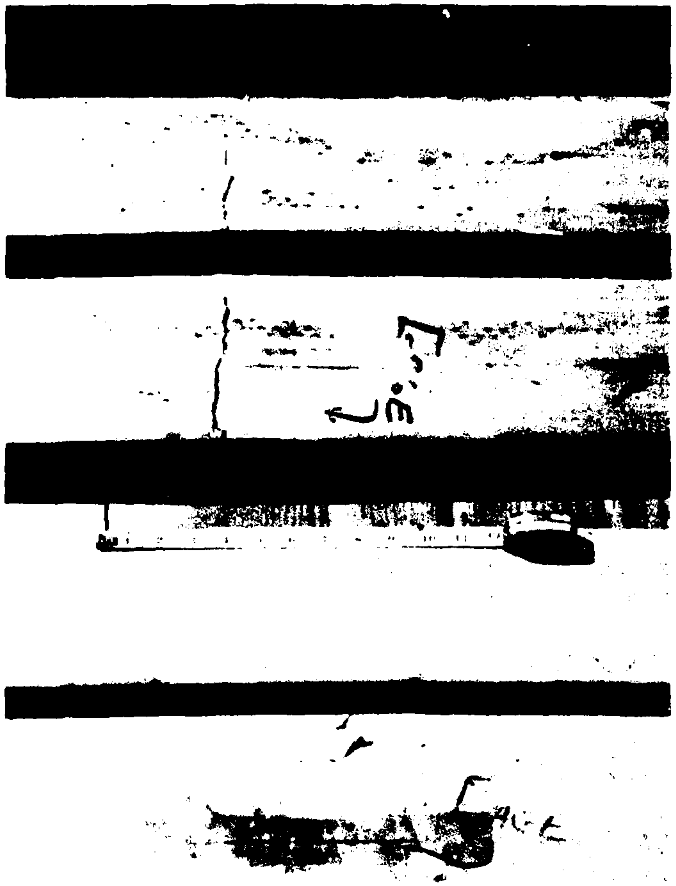


Figure 19. Cracking behavior of mesh and chick wire reinforced panels.

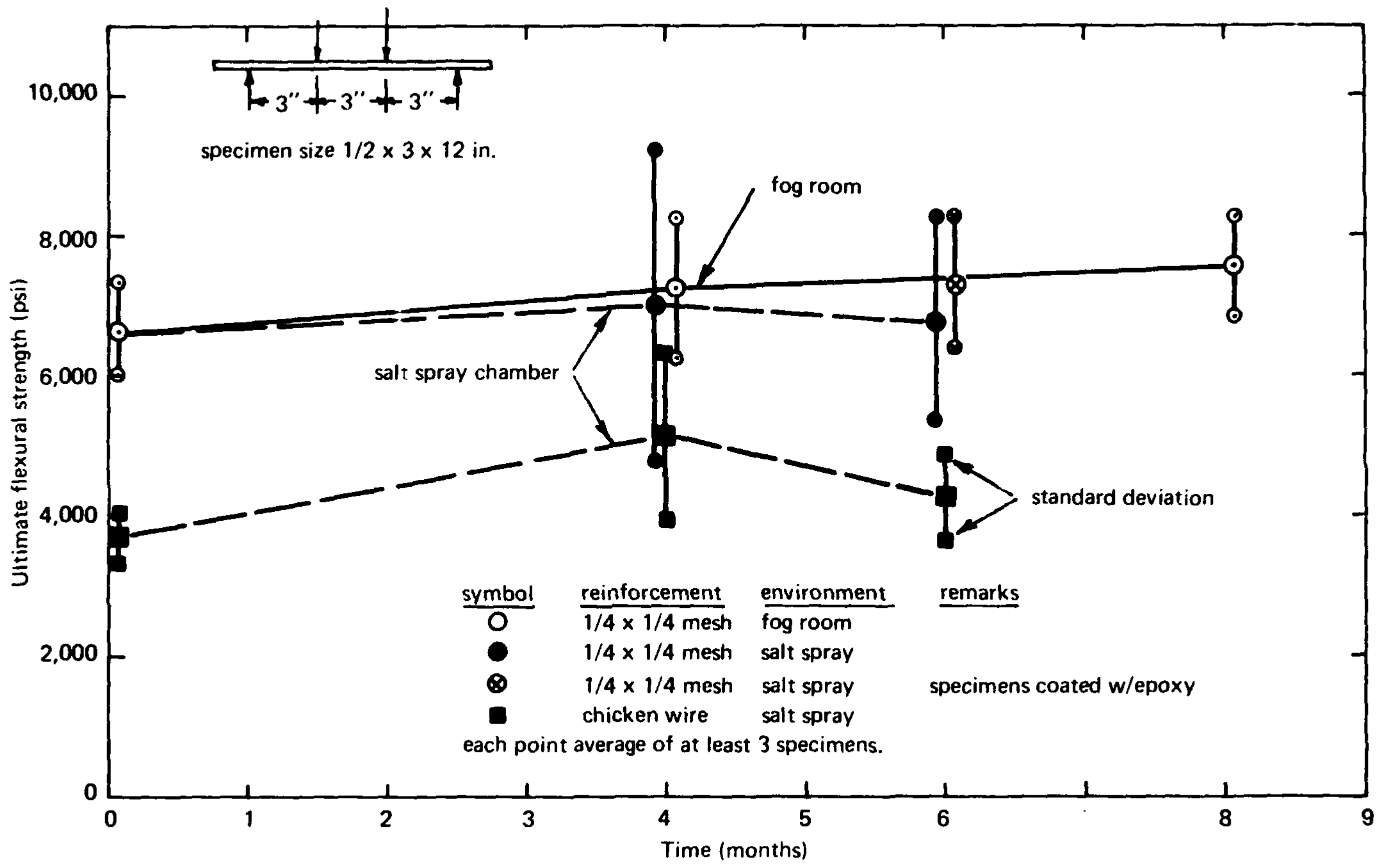


Figure 20. Ultimate flexural strength of panels exposed to a corrosive environment.

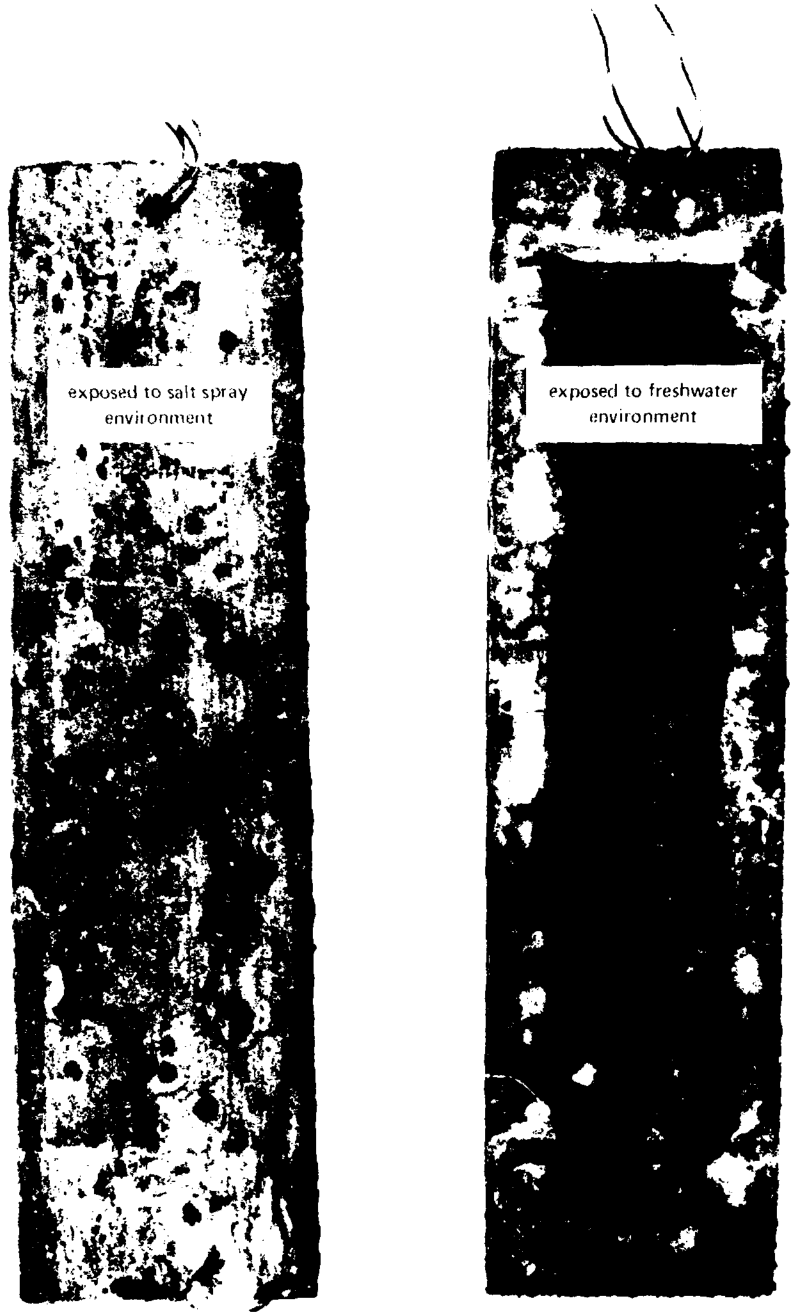
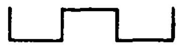
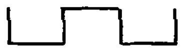


Figure 21. View of tensile side of mesh reinforced specimens (1/2 x 3 x 12 in.) after 4 months of exposure.

Table 1. Test Program and Specimens

Specimen[a] Designation	Cross-Section	Orientation Under Flexural Load	Reinforcement	Reinforcement (%)	Weight (lb)	Moment of Inertia (in.^{4})	Section Modulus (in.^{3})
CM-1	channel		6 layers of 1/4 x 1/4 in. plain steel woven wire mesh of 0.025 in. diameter and one layer of 1 x 2-in. galvanized welded wire mesh of 0.0625 in. diameter at center	2.9	80.6 (86.0)[b]	8.9	8.1
CM-2	channel			2.9	80.6 (86.0)	8.9	5.4
HM-1	hat			2.9	89.2 (93.1)	10.7	8.9
HM-2	hat			2.9	93.8 (93.1)	10.7	6.9
CC-1	channel		6 layers of 1-in. hex galvanized chicken wire of 0.0325 in. diameter and one layer of 1 x 2-in. galvanized welded wire mesh of 0.0625 in. ciameter at center	2.6	89.4 (86.0)	8.9	8.1
HC-2	hat			2.6	93.8 (93.1)	10.7	8.9

[a]Designation system is: Channel or Hat, Mesh or Chicken Wire - Specimen Number.

[b]Calculated weight for dimensions in Figure 2 and 3.

Table 2. Control Cylinder Data for Construction Panels

Specimen Designation	Age of Cylinders (days)	Average[a] Compressive Strength, f'_c (psi)	Average[a] Split Tensile Strength (psi)
CM-1	69	6450	620
CM-2	58	5830	690
HM-1	69	6450	620
HM-2	58	5830	690
CC-1	64	5960	520
HC-1	64	5960	520

[a]Average of three 3 x 6 in. long specimens.

Table 3. Test Results

Specimen Designation	Orientation	Reinforcement	Flexural Loads at		Flexural Stresses at	
			Visible Cracking (lbs)	Ultimate (lbs)	Visible Cracking (psi)	Ultimate (psi)
CM-1		mesh	945	1545	2630	4300
CM-2		mesh	320	620	1330	2590
HM-1		mesh	495	1070	1140	2460
HM-2		mesh	870	975	2840	3180
CC-1		chicken wire	270	845	750	2400
HC-2		chicken wire	295	795	680	1830

Table 4. Ultimate Flexural Strength of Specimens Exposed to a Corrosive Environment

Type of Reinforcement	Environment	Time Period in Environment (months)								
		Zero			Four			Six		
		Number of Specimens	Ultimate Flexural Strength (psi)	Standard Deviation	Number of Specimens	Ultimate Flexural Strength (psi)	Standard Deviation	Number of Specimens	Ultimate Flexural Strength (psi)	Standard Deviation
1/4 x 1/4-in. plain steel woven wire mesh	field conditions	3	6,670	660						
	fog room				4	7,240	1,000	5	7,560[a]	710
	salt spray chamber				4	6,980	2,240	8	6,790	1,470
	salt spray chamber (specimens coated with epoxy)							3	7,300	900
chicken wire 1-in. hex galvanized	field conditions	3	3,710	360						
	salt spray chamber				4	5,160	1,190	5	4,280	600

[a]Strength at 8 months.

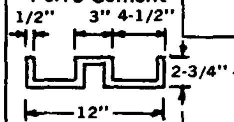
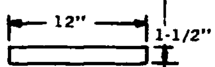
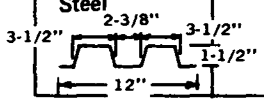
Table 5. Control Cylinder Data for Corrosive Environment Test

(Average of Three 3 x 6-In. Long Specimens.)

Environment	Time Period in Environment (months)					
	Zero		Four		Six	
	Compressive Strength, f'_c (psi)	Standard Deviation (psi)	Compressive Strength, f'_c (psi)	Standard Deviation (psi)	Compressive Strength, f'_c (psi)	Standard Deviation (psi)
field condition	6,300	450				
freshwater fog room			7,070	490	7,550[a]	330
salt spray chamber			6,760	1,000	7,010	690

[a]Strength at 8 months.

Table 6. Strength and Cost Comparison

Cross-Section	Reinforcement or Type Material	Allowable Flexural Stress (psi)	Uniform Live Load For 7.5-ft Span $\left(\frac{lb}{lin\ ft}\right)$	Live-Load to-Dead-Weight Ratio	Elastic Modulus x 10^6 (psi)	Deflection (in.)	Allowable Compressive Stress (psi)	Concentric Column Load (lbs)	Weight $\left(\frac{lb}{lin\ ft}\right)$	Cost[b] $\left(\frac{\$}{lin\ ft}\right)$
Ferro-Cement 	chicken wire	700	56	5	1.7	0.32	2,700	28,400	10.8	0.75
	1/4 x 1/4 mesh	2,000	181	17	1.7	0.90	2,700[a]	28,400	10.8	0.85
Wood 	Douglas Fir	1,600	78	20	1.7	1.06	(dry) 1,200 (wet) 800	(dry) 20,700 (wet) 14,000	4.0	0.70
Steel 	20 Gauge	18,000	62	26	30	0.66	5,760	3,700	2.4	0.41

[a] $0.45 f'_c$.

[b] August 1973.

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