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MANUFACTURE & DELIVERY OF DEMONSTRATION I-BEAM FRAMING COMPONENT

4 February - 4 March 1971

by

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1.0 Summary

An integrally woven, Quartz fiber Omniweave I-Beam, having uniform wall thickness and unequal width caps was successfully woven and molded using epoxy resin 68R as the resin matrix. This part was fabricated solely to demonstrate the capability of the GE-Omniweave Laboratory to produce an integral I-Beam shape.

The molded part measured 8 inches in length and an 8 inch unmolded length illustrating the fiber geometry was left attached to the molded beam.

Mr. H. M. Walker was the Program Monitor.

2.0 Introduction/Objectives

The purpose of this effort was to demonstrate the feasibility of weaving integral I-Beam components using the Omniweave technique to generate the desired shape.

The I-Beam shape selected for this feasibility study is shown in Figure 1. 12 end Quartz roving was selected as the weaving fiber.

A 6 inch (minimum) portion of the woven I-beam was to be impregnated with an epoxy resin, and cured under pressure with the remaining weave portion (6 inch minimum) left attached to the molded beam.

The contracted work period was February 4, 1971 to March 4, 1971.

3.0 Omniweave I-Beam Fabric Production

3.1 Weaving Pattern Design

The 3/3 blade motion, along with the 3/3 cam motion was utilized to produce the Omniweave I-Beam. Omniweave machine number 3 was used.

Table 1 reflects the loading pattern for the I-beam. Single loop 12-end quartz roving was used as the weaving element. The yarns in the "I" portion entered both cap regions producing an integrally constructed I-Beam. An unequal cap I-beam was intentionally designed.

The fiber weave geometry selected for the cap regions was the triaxial construction.

In this kind of construction a high percentage of the cap region fibers remain as longitudinals while the remaining fibers form a low axial angle Omniweave stitch around them so that a multidimensional fabric having high axial strength and stiffness is created. The fibers in the region between caps were designed as a regular, i.e., no longitudinals, Omniweave construction so that the beam would exhibit excellent shear resistance.

3.2 Yarn Preparation

The 12-end quartz roving, Astroquartz® Type 552, 9073 Binder, was coated with a 6% Scotchcast® 221 urethane resin in acetone solution during the skeining operation to minimize abrasion during weaving . Yarns were attached to the nest insert using a rubber band/nylon monofilament leader assembly.

3.3 Weaving Procedure

The weaving fibers were maintained under tension throughout the weave to minimize fiber slack.

Wooden blocks, measuring 1 3/4" wide by 7/16" thick were positioned between the caps to maintain beam width during the weaving process.

After every weave motion (which is defined as a blade motion (horizontal shift) followed by a cam motion (vertical shift)),a nylon filament leader was inserted between the last row of each cap region and the first row of the "I" portion, and combed down using aluminum blades. In other words, the nylon filament traveled between the caps and around the wooden guides, to stabilize the beam width dimension and to prevent the mid portion of the caps from necking down into the central "I" region. (Figure 2 illustrates the wooden blocks, the nylon fiber wrap around them and describes the aluminum combing blades.)

Then every stitch row of the cap regions were combed in the parallel-to-cap-face region (also shown in Figure 2) and then the central "I" portion was combed with similar combs in the perpendicular-to-cap direction (not shown). These combs remained in the weave until the next motion was made and another monofilament wrap was inserted. Then another set of combs were inserted and the next weave stitch was brought down to the weave forming surface.

Figure 3 illustrates the appearance of the 1" and 2" cap regions.

The weaving geometry of the cap regions were approximately $0^o/\pm 10^o$, and the "I" portion was approximately $\pm 20^o$.

Figure 4 is an overview of the woven beam.

4.0 Omniweave I-Beam Composite Fabrication

4.1 Preliminary Processing

Square tubular steel rods were positioned and clamped either side of the weave when the I-Beam fabric was cut down from the Omniweave equipment (Figure 5). This was done to prevent weave fiber slippage during transit and preliminary processing.

First, the I Beam fabric was heated to 850^{o}F for 16 hours in air to remove the protective urethane coating used to minimized fiber damage during weaving. Then the fabric was coated with a 1% solution of A-1100 (Union Carbide Corporation) silane sizing in water to enhance fiber wetting by the epoxy resin to be applied later. The silane-treated fabric was heated for 8 hours at 300^{o}F to remove water.

4.2 I-Beam Impregnation

Epoxy resin formulation 68R was used to impregnate the I-Beam fabric.

Formulation 68R Epoxy Resin

Epon 828	50 parts by weight
Epon 1031	50 parts by weight
Nadic Methyl Anhydride (NMA)	90 parts by weight
BenzyldimethylAmine (B MA)	1 part by weight
Acetone	190 parts by weight

The resin was prepared by dissolving Epon 1031 (solid) into an equal weight of Epon 828 through heating on a hot plate until a uniform solution was formed. Then the appropriate amount of NMA was added. Sufficient acetone was added to make a 50 percent solution of Epoxy 68R in acetone. This mixture was treated and stirred until it was uniform. Then the Benzyldimethylamine catalyst was added.

The fabric was dip impregnated using a warm solution of 68R and air dried at room temperature for 16 hours prior to molding.

4.3 Mold Design

An I-Beam mold was designed and fabricated to the dimensions shown in Figure 6. When assembled, the mold would be aligned so that when the mold plungers were pressed flush against the top and bottom sides of the mold, an unequal cap I-Beam with each beam segment having an 1/8" thickness would be produced. Figure 7 shows several views of the assembled mold.

4.4 Mold Releasing of "I" Beam Mold

a. The mold was first degreased by thoroughly wiping with toluene.

b. The internal surfaces of the mold were then scrubbed with Comet cleanser and thoroughly rinsed in tap water and air dried.

c. The internal surfaces of the mold were then coated with chromic acid paste and allowed to stand 30 minutes. The mold was then thoroughly rinsed with cold tap water and allowed to air dry.

d. The internal surfaces of the mold were then sprayed with #856-200 clear FEP Teflon enamel and than allowed to air dry for 5 hours.

e. The coated mold was then placed in an oven. The temperature of the oven was adjusted to 560°C. The Teflon coating was sintered at this temperature for 1 hour and then allowed to cool gradually.

f. After wiping excess Teflon coating from the mold, a very thin layer of Dow Corning stop-cock grease was applied to the internal surfaces. Excess silicone was removed from the mold by wiping.

4.5 I-Beam Composite Molding

The impregnated I-Beam fabric was properly positioned within the mold and molded between platens under pressure to steps at 300°Ffor 2 hours to the desired dimensions (See Figure 1). The mold was water cooled to room temperature. The woven end was maintained attached to the molded beam throughout processing. Resin "wicking" did occur during impregnation and the uncured resin was partially removed through multiple rinsings with acetone.

The other end of the beam was latter impregnated and molded. to contain the fabric portion which was not molded.

Figure 8 shows an overview of the I-Beam after the end segments were molded.

Figure 9 shows the surfaces of the molded beam; Figure 10 shows the surfaces of the attached woven fabric; significant fiber breakage occurred through handling.

5.0 Discussion

Through this contract effort GE-RESPD has demonstrated the capability of producing a typical structural element shape such as an I-Beam using Omniweave weaving technology.

The next phase of effort should be directed towards fabrication and evaluation of high strength/stiffness-to-weight Omniweave integral resin matrix composites in the form of I-Beams, "hat" sections or other comparable structural shape to note the improved performance in comparison with state-of-the-art structural materials.

In addition, metal matrix Omniweave structural elements should be evaluated since these would offer potential weight savings for high temperature applications.

Recent experiments at GE-RESPD have shown that molten aluminum can be made to wet high strength high modulus graphite fiber surfaces following an appropriate chemical treatment. Metallographic examination of specimens formed by molten metal infiltration of treated Modmor II fibers showed that wicking of the molten aluminum occurred along the surfaces of treated fibers and that a tight bond had evidently formed. Flexure tests made on rods, 2" x 1/8" diameter prepared in this manner yielded strength values up to 73,000 psi at approximately 25 volume percent fibers, with load-deflection curves which were linear to failure. Untreated fibers subjected to the same formation procedure gave no evidence of wetting or penetration of the fiber bundles by aluminum; such specimens gave load-deflection curves typical for aluminum metal. At present experiments are in progress to optimize the filament treatment and to perfect casting and other formation techniques in order to open the way to preparation of three dimensional carbon fiber reinforced aluminum structures. Experiments with Modmor II Omniweave strips indicate a need for treatment of the fibers prior to weaving and compaction in order to permit all fibers in each bundle to be treated and wetted by aluminum. Penetration of aluminum among individual filaments in the exterior bundles and between internal bundles was achieved however, reflecting the need for all filaments in all of the bundles to be accessible to both treatment and infiltration steps.

6.0 Omniweave Machine for Weaving Continuous I-Beam Shape

The following is a rough design estimate for the manufacture of a continuous Omniweave machine.

The machine will be a vertical type with the yarn magazine at the bottom and the yarns feeding upward. The weaving head will be in the center and will be capable of motion along the axis of the yarn for the purpose of compacting the weave. A take-up mechanism located at the top will have a large grooved reel for handling the I beam shape and keeping some tesnion on the woven section. The machine will be motor drived, completely synchronized, and capable of weaving 50 feet of material in an 8 hour day. The elements of the machine will be as described below.

Weaving Head

The head will consist of a frame containg an insert bank 32 x 84 with provisions for selectively locking and/or inactivating portions of the bank for weaving the I-shape. The inserts will be fully supported and locked during the "beating-up" stroke. Insert motions will be controlled by cam drives built integral with the frame.

Supply Reels

The continuous yarn strands will be fed from previously loaded individual reels. Each reel will move in the supply bank, following the same pattern as its related insert. Constant tension devices and provision for compensating for the variation in length of unwoven yarn as the reels travel with respect to the insert bank will be a part of each reel assembly. Dummy units will be supplied for all positions not actively used.

Takeup Assembly

A large reel will be mounted over the insert bank for handling the woven material and taking it up as it is woven at a rate which matches the weaving rate, and such that the tension is maintained in the supply.

Table 1
Loading Scheme--I Beam
Weave No. 300R-Q2BA

Blade	12 End Quartz Roving in Blade Positions
Rear Storage 1	35, 38, 41, 44, 47
Rear Storage 2	35, 38, 41, 44, 47
Rear Storage 3	1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34, 37, 40, 43, 47, 49, 52, 55, 58, 61, 64, 67, 70, 73, 76, 79
Blades 1A, 2B, 3A	1, 2, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, 19, 20, 22, 23, 25, 26, 28, 29, 31, 32, 34, 35 37, 38, 40, 41, 43, 44, 46, 47, 49, 50, 52, 53, 55, 56, 58, 59, 61, 62, 64, 65 67, 68, 70, 71, 73, 74, 76, 77, 79, 80, 82, 83
Blade 4 (3-move dummy)	36, 39, 42, 45, 48
Blades 5A through 27A	35, 38, 41, 44, 47
Blade 28 (3-move dummy)	25, 28, 31, 34, 36, 37, 39, 40, 42, 43, 46, 48, 49, 52, 55, 58, 61, 64
Blades 29A, 30B, 31A	24, 26, 27, 29, 30, 32, 33, 35, 36, 38, 39, 41, 42, 44, 45, 47, 48, 50, 51, 53, 54, 56, 57, 59, 60, 62, 63
All other Blade positions between 1 ——— 84 to be filled with MR inserts	
Locked Pushers	2, 5, 8, 11, 14, 17, 21, 23, 26, 29, 32, 50, 53, 56, 59, 62, 63, 65, 68, 71, 74, 77 80, 82, 83

Blade Travel: 3/3
CAM Used: 3/3 Cam

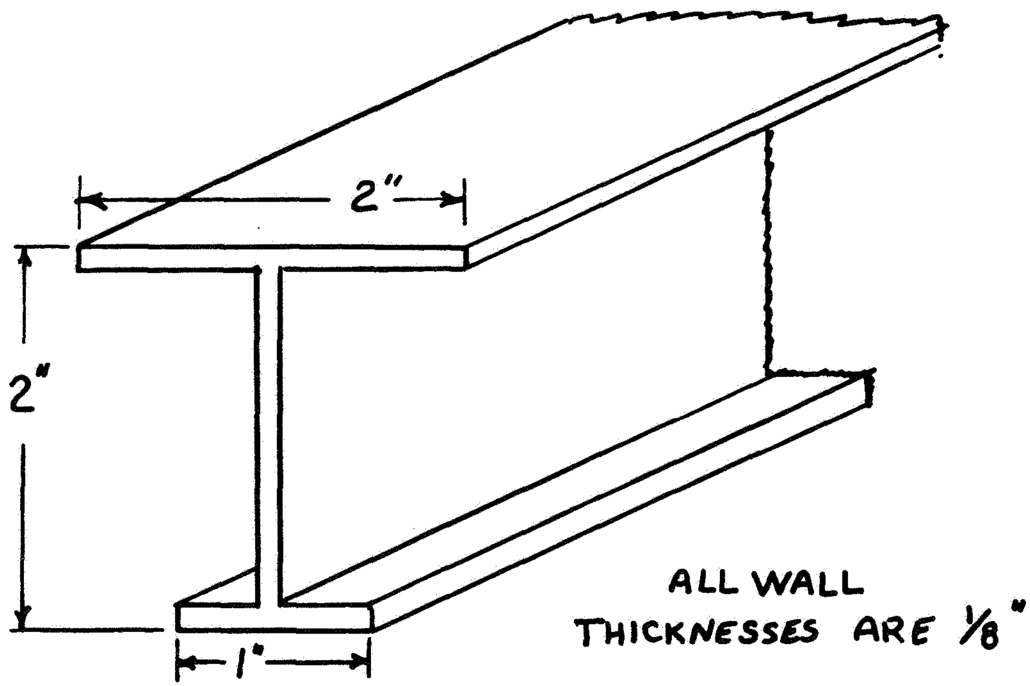


FIGURE 1 SELECTED I-BEAM DIMENSIONS

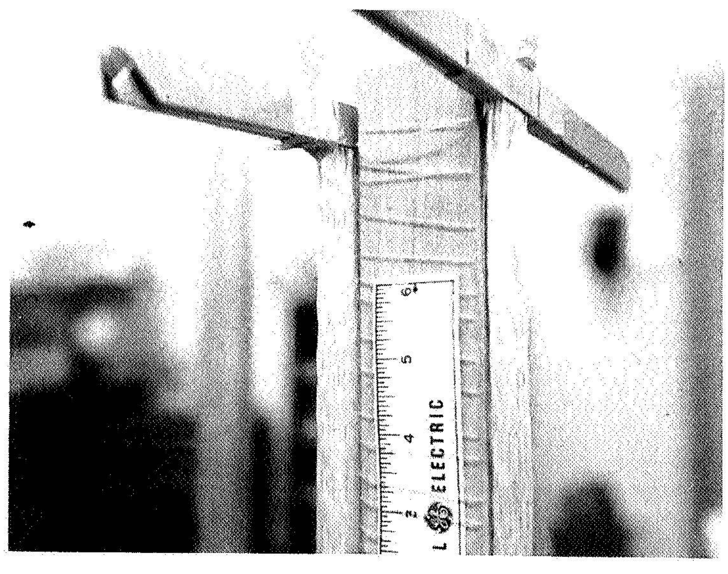
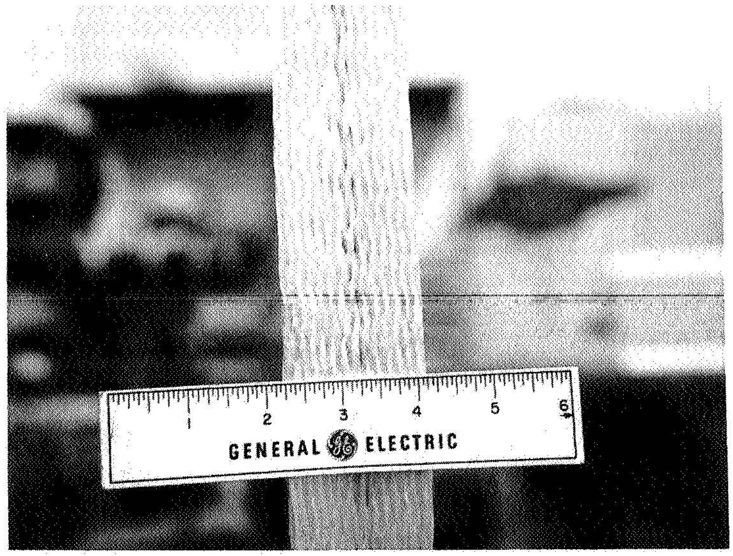
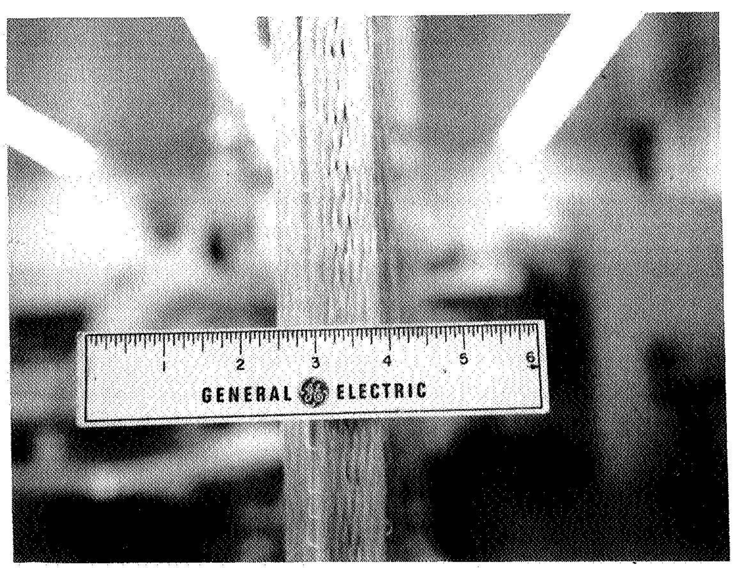


FIGURE 2 OMNIWEAVE I-BEAM FABRICATION--SIDE VIEW

FIGURE 3 OMNIWEAVE I-BEAM FABRICATION



2" Cap Surface



B) 1" Cap Surface

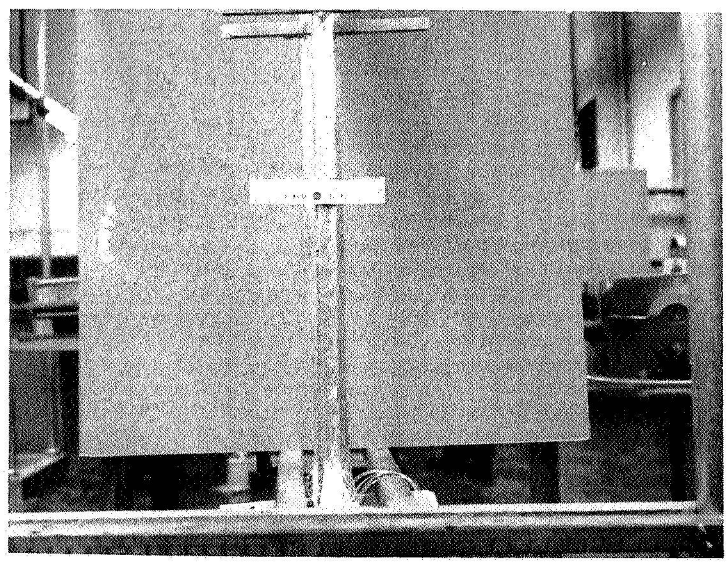


FIGURE 4 OMNIWEAVE I BEAM FABRICATION - OVERVIEW

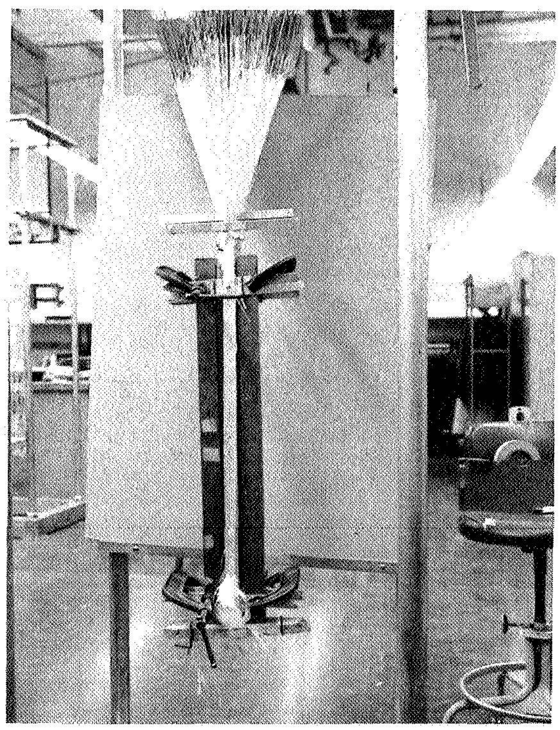
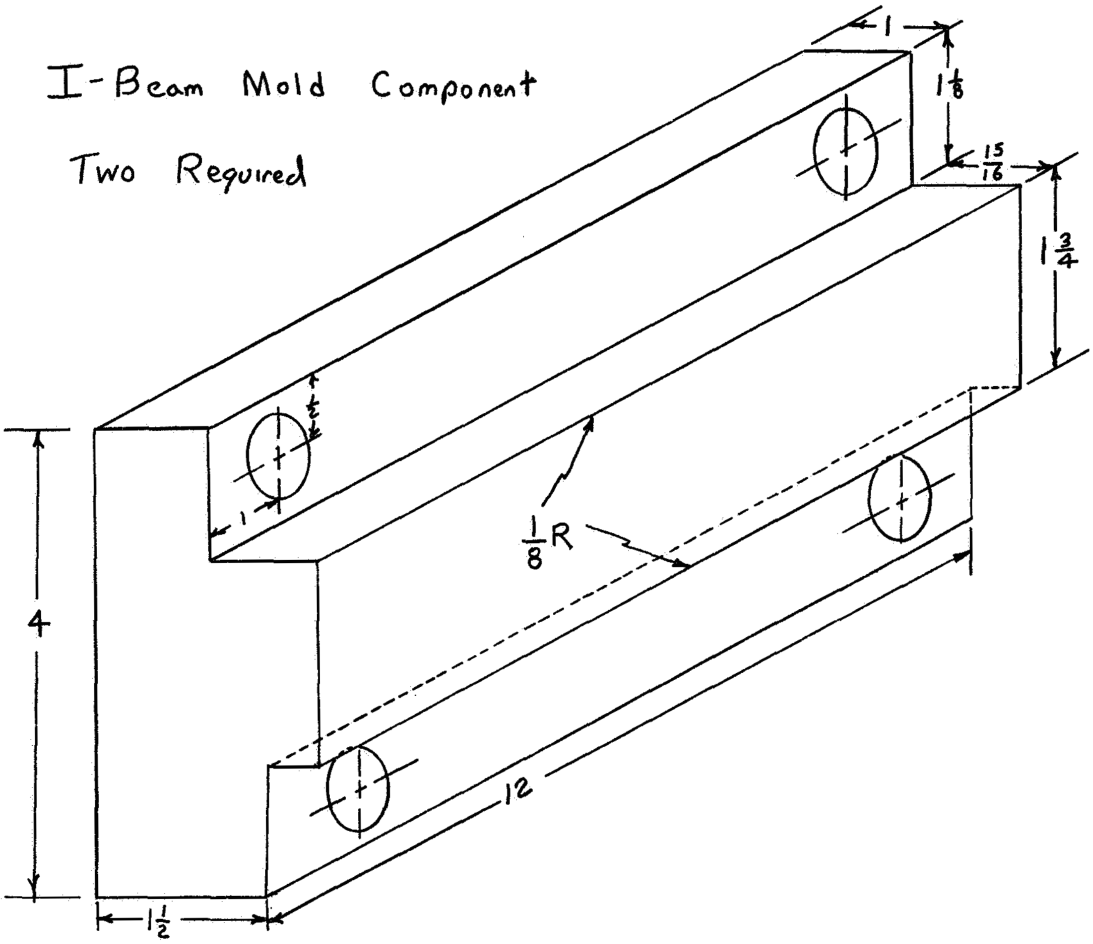
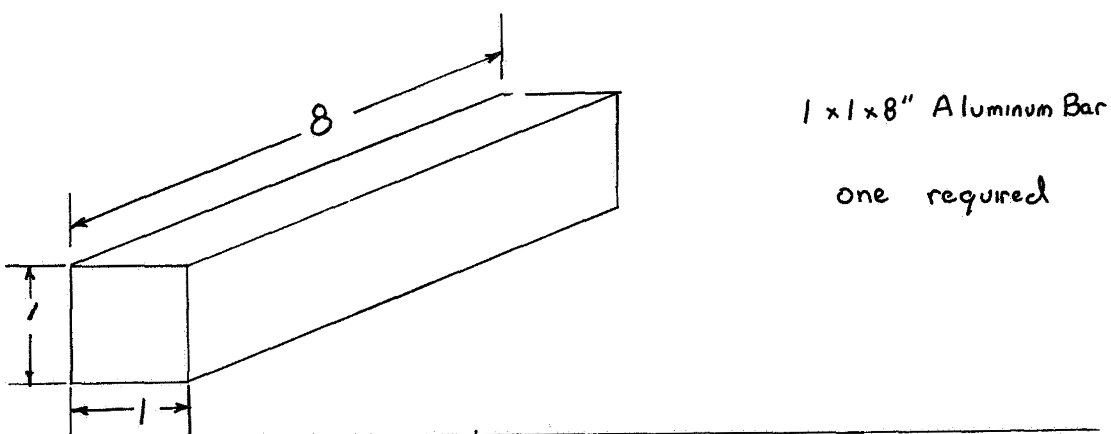


FIGURE 5 OMNIWEAVE I-BEAM FABRIC PRIOR TO REMOVAL FROM WEAVING MACHINE

FIGURE 6 OMNIWEAVE I BEAM MOLD DESIGN





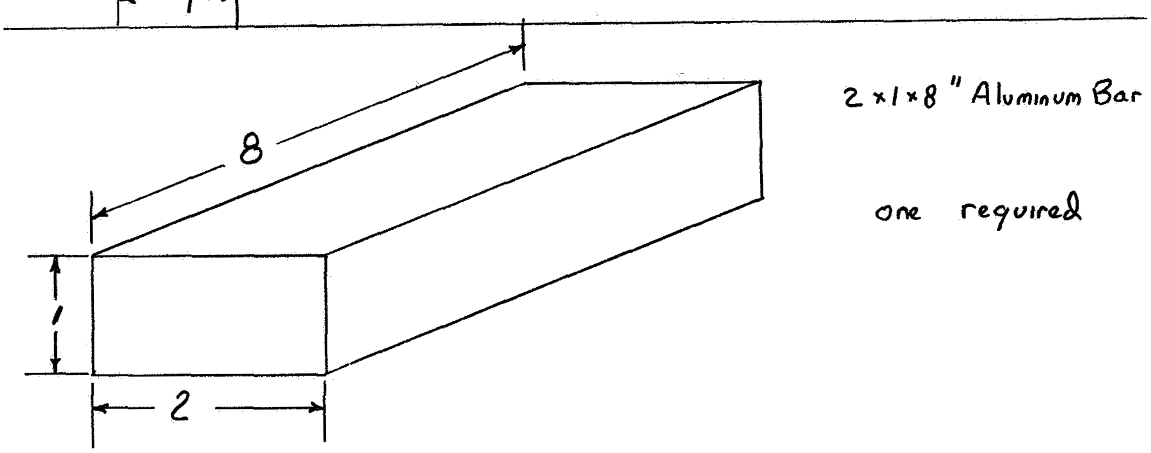
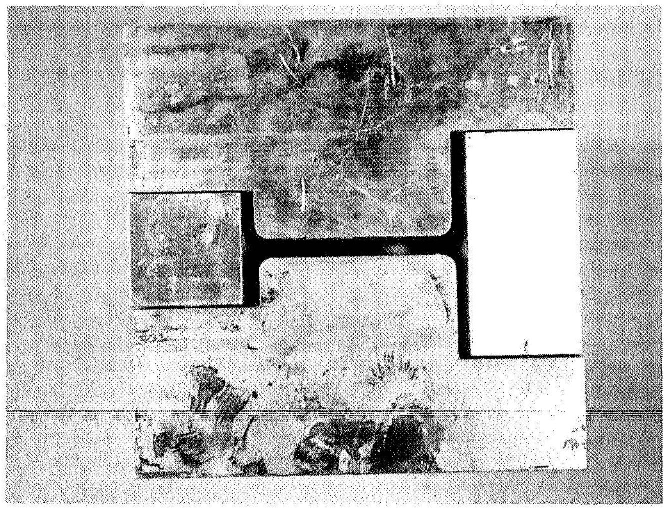
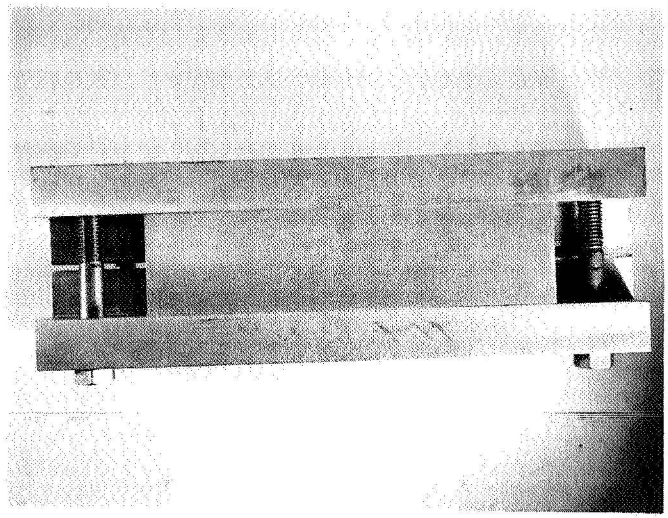


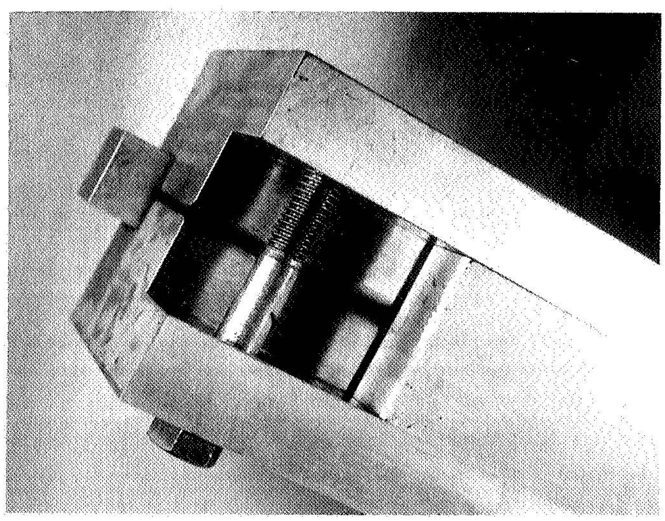
FIGURE 7 OMNIWEAVE I-BEAM MOLD



A) Front View



B) Top View



C) Overview

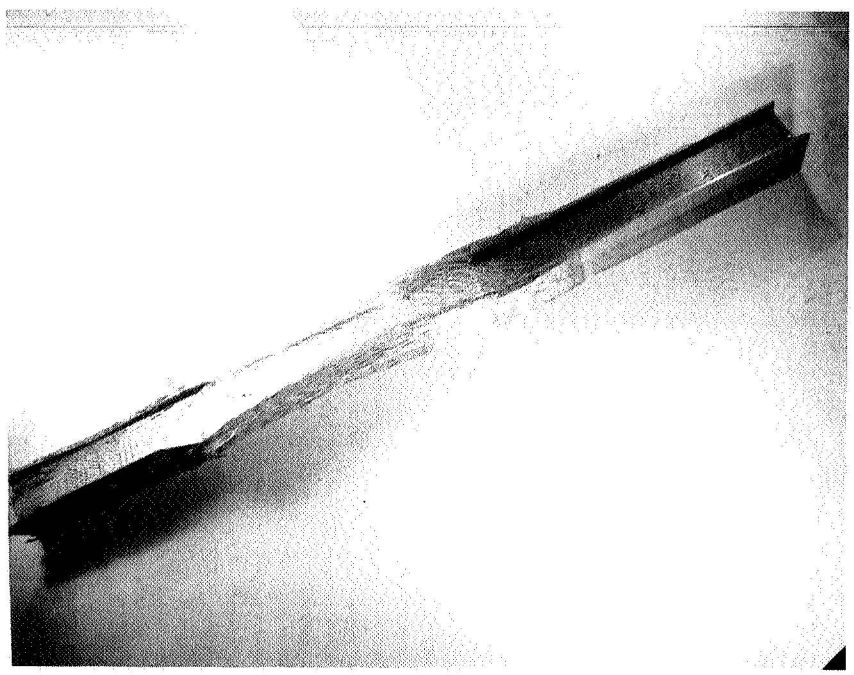
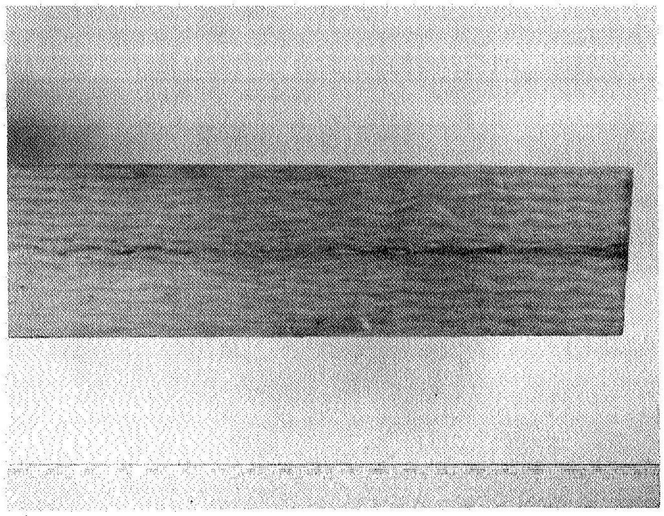
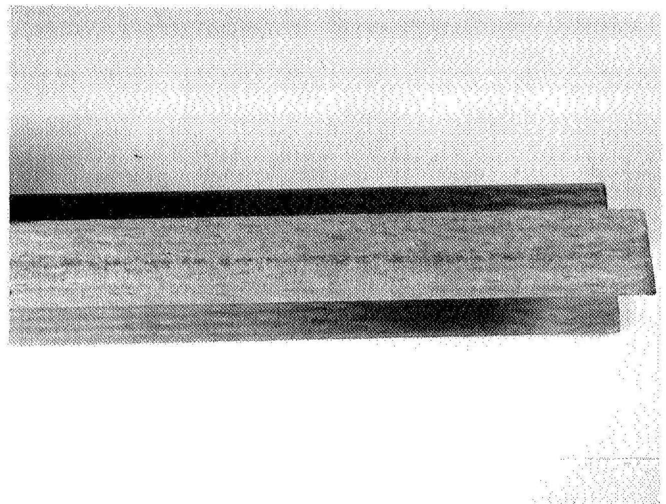


FIGURE 8 OMNIWEAVE I BEAM COMPOSITE SHOWING MOLDED ENDS AND UNMOLDED WOVEN BEAM COMPONENTS

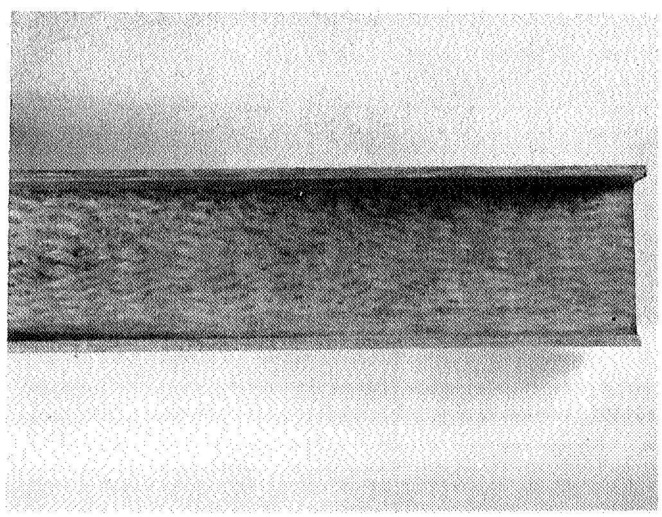
FIGURE 9 MOLDED OMNIWEAVE I-BEAM COMPONENT



A) 2" Cap Face

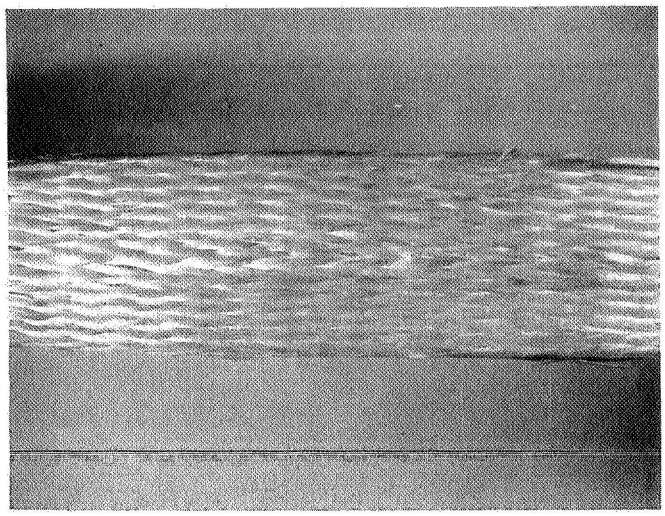


B) 1" Cap Face

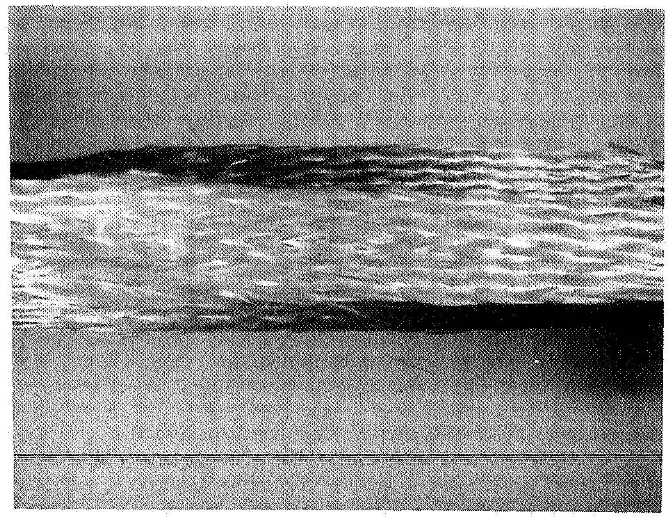


C) Perpendicular to Cap Direction

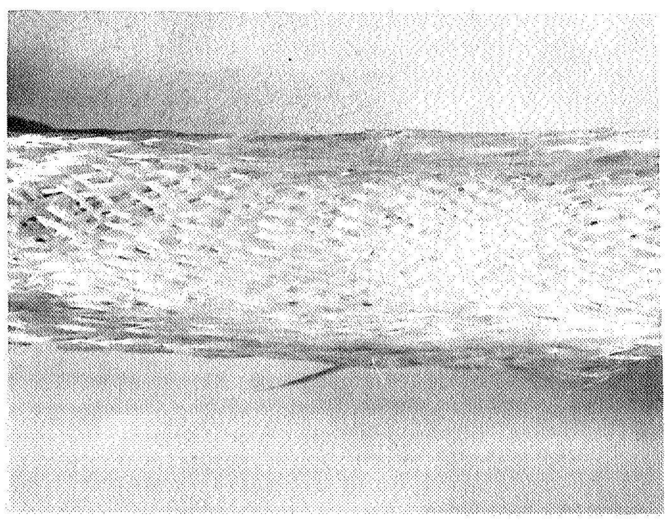
FIGURE 10 CLOSEUPS OF WOVEN I-BEAM FABRIC ATTACHED TO MOLDED BEAM COMPONENT



A) 2" Face



B) 1" Face



C) Perpendicular to Cap Direction