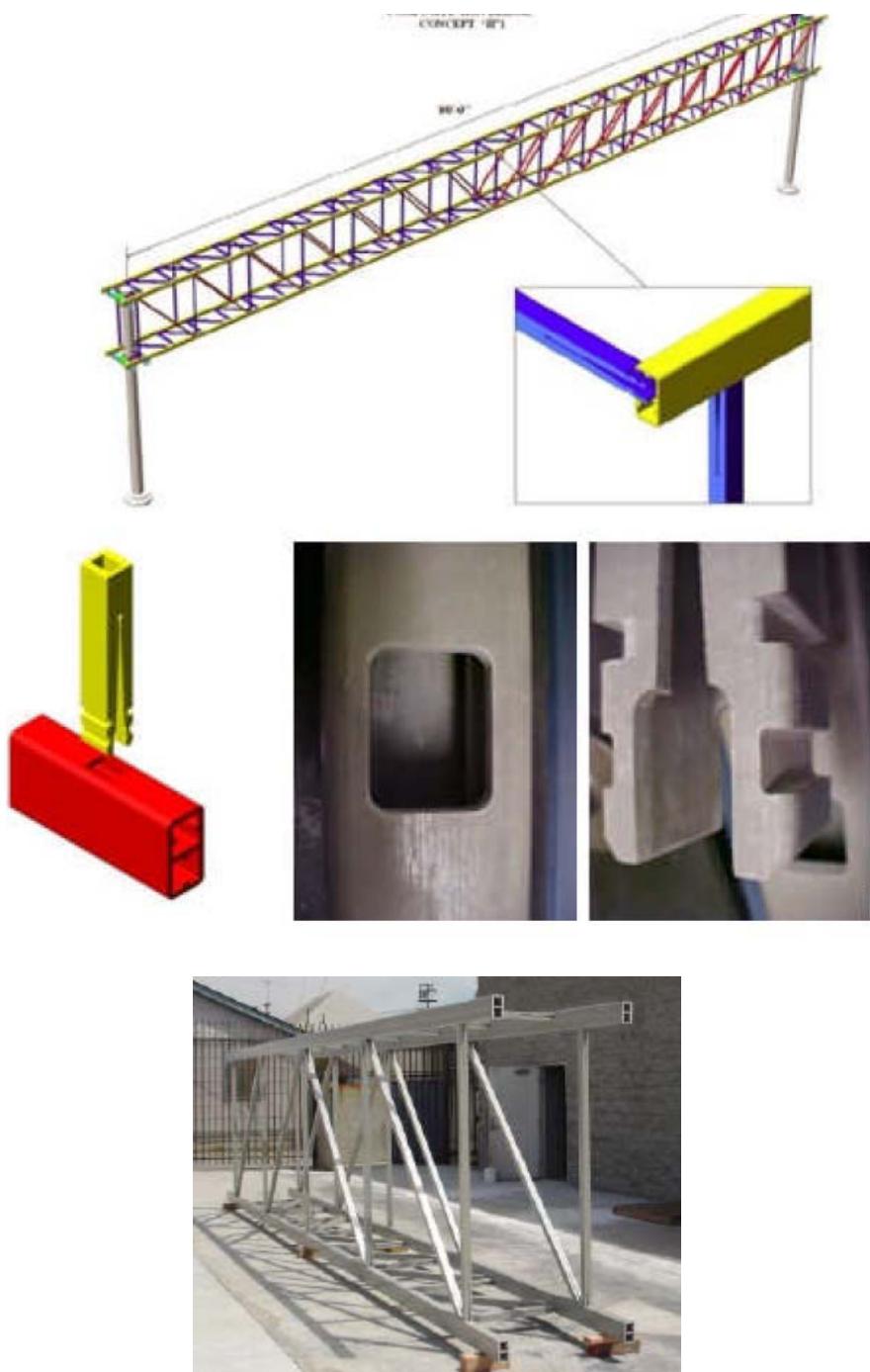# Snaplock Fiber Reinforced Composites Technology Applied to Overhead Sign Structures

Design, Construct, and Test a Fiber Reinforced Composite Overhead Sign Truss

Division of Research & Innovation

Final Report

Snaplock Fiber Reinforced Composites Technology Applied to Overhead Sign Structures

Design, Construct, and Test a Fiber Reinforced Composite Overhead Sign Truss

Final Report

Report No. CA07-0246

December 2008

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16. ABSTRACT

This report paper summarizes progress on a research program to investigate the use of composite materials for overhead sign bridges, as well as the assembly of these structures without fasteners.

A composite overhead sign bridge was designed and analyzed. The traditional profile shapes, which are in use for steel sign bridges, were not copied in composite materials. Instead two types "lineals" with a special rectangular cross sections for functionality were designed. The cross-sectional shape and fiber architecture of these tubes is dominated by the requirement for a "snap-fit" assembly. The complexities in geometry and fiber architecture can easily be handled by an automated "Pultrusion" process.

Since Pultrusion-dies are expensive the "lineals" were first manufactured by hand lay-up, and resin infusion on wood tooling. The snap-fit joint created by both parts was subsequently assembled and tested in order to provide a proof of concept without expensive Pultrusion-dies or the added cost of die modifications.

As a next step the most extensively loaded joint area in the sign bridge structure was assembled from the two Pultruded tubular sections and subject to the loads which were derived from the analysis. As such the load factors and failure modes have been established.

This report outlines a research program undertaken at CSSI to investigate the feasibility of a sign structure which can be erected quickly. The feasibility of a fastenerless 90-ft sign truss in composite materials has been investigated.

A two post sign truss with a clear span of 90 feet was selected as a benchmark. The layout of a fastenerless composite sign truss with two posts revealed significant weight savings. A newly developed composite "snap joint" which is pultrudable is the heart of this lightweight sign structure. Performance tests revealed that this joint has a static load capacity of more than 22,000 lbs.

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FINAL REPORT

DESIGN, CONSTRUCT, AND TEST A FIBER REINFORCED COMPOSITE OVERHEAD SIGN TRUSS

CONTRACT 59A0343

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ABSTRACT: This report paper summarizes progress on a research program to investigate the use of composite materials for overhead sign bridges, as well as the assembly of these structures without fasteners.

A composite overhead sign bridge was designed and analyzed. The traditional profile shapes, which are in use for steel sign bridges, were not copied in composite materials. Instead two types "lineals" with a special rectangular cross sections for functionality were designed. The cross-sectional shape and fiber architecture of these tubes is dominated by the requirement for a "snap-fit" assembly. The complexities in geometry and fiber architecture can easily be handled by an automated "Pultrusion" process.

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The report consists of eight sections.

The introduction summarizes our findings about the use of composite materials in overhead sign structures throughout the world.

Section 2 provides the basic information on a benchmark overhead sign truss and discusses four concepts which were considered for a composite overhead sign bridge

Section 3 summarizes the material system identification

Section 4 provides details of the pultrusion manufacturing process including the fiber dispensing system, and the fiber impregnation system and sequence.

Section 4 provides information about quality control, including a trial assembly of a 30 ft section of the overhead sign bridge design.

Section 5 gives the analytical and test results. Part of this section is dedicated to a critical review of the snap joint design, its failure modes, and possible ways to improve the design. Also provided is a full structural analysis of a benchmark composite overhead sign truss for the load cases which are identified by AASHTO

Section 7 gives the summary and the conclusions for this project.

REPORT OUTLINE:

1. Introduction

2. Design Methods

3. Material System Identification

4. Manufacturing Process

5. Quality Control Procedures

6. Analytical and Test Results

7. Conclusions and Recommendations

8. References

1. INTRODUCTION

The application of composite materials has been pursued technically and commercially in a variety of structural engineering applications. These applications cover a very wide range from power delivery infrastructure and bridge decks to maritime docking structures. One documented case [1] explores the possibility of temporary composite structures within the British Rail network. It concerns temporary structures which assist in revenue earning after disruptions by supporting overhead electrification conductors and associated equipment and temporary footbridges to provide across track access without disruption of service.

On 28 November 1995, a CMS structure located on Interstate I-15 in San Bernardino County, California, failed. As a result more than 200 CMS structures throughout the state of California were inspected to determine the extent of wind-induced cracking in their welded components. Cracked welds were found in the post-to-base plate connections and in the arm-to-post welded connections.

Many of the Nation's DOT's have documented cases [2, 3] of sign-truss structures and signal mast arms made of steel and aluminum which have experienced fatigue-failures in the welds. In a number of cases composite materials have been used for the repairs [4]. Other recommendations for increased reliability range from insuring weld quality to dampers on the mast arms.

Figure 1 Use of Composite Materials to Repair Overhead Sign Structures

Figure 2 illustrates some of the weld fatigue problems experienced by NYDOT for aluminum sign bridges.

Figure 2 Weld Fatigue Failure in Aluminum Sign Bridge as Experienced by NYDOT.

These sign bridges have been repaired with FRP wraps, which functioned as crack arrestors, when bonded over the failed area.

The U.K. Highways Agency has been a leader in efforts to use composite materials for sign structures as illustrated in Figure 3.

U.K. FIRM DEBUTS COMPOSITE OVERHEAD SIGN STRUCTURES

The Specialist Structures Group of White Young Green (WYG, Headingley, Leeds, U.K., formerly CETEC Projects Ltd.) and the U.K. Highways Agency are developing a composite solution for motorway overhead sign structures. Ranging from 15m to 50m (49.2 ft to 164 ft) in length, the structures will span the entire roadway width in both traffic directions without a central support. Developed as an alternative to steel or concrete structures, many of which are reaching their design life limits, the composite structures offer lighter weight, easier transport and erection, greater durability and lower lifecycle costs.

WYG's project manager, Dr. Mark Leaity, notes that horizontal beams are infused, using vinyl ester resin, uni and biaxial glass reinforcements and balsa core. Supports are resin transfer molded. "There are no impending installations but there is a lot of interest in the U.K.," says Leaity. "The main barrier is cost." The company is exploring automated methods to make the product more cost-competitive.

Figure 3 Overhead Sign Structures in the U.K.

As mentioned in the article, sign structures are technologically possible, but the main barrier is cost. The U.K. effort evidently uses sandwich panel construction in conjunction with resin transfer molding (RTM). As such the overhead sign structure manifests itself as a composite boxbeam, which is not the most economic and lightest construction, especially not for the longer overhead sign structures.

Figure 4 illustrates another example of an overhead sign structure, also from the U.K, of a prototype structure on Motorway M25.

Figure 4 Composite Variable Message Sign Structure with Steel Post
on the M25 Motorway in UK

This cantilever type is used as a variable message sign and is attached to a steel post. It's actual detail construction is unknown, but it is reasonable to assume that it is also an RTM type sandwich construction.

To the best of our knowledge, the examples shown in Figures 3 and 4 represent the state of the art in overhead sign structures.

In this report we have opted for an entirely different approach, which is to rely on automated pultrusion technology to manufacture truss elements which can easily be assembled into sign structures. This approach not only creates a light structure, but also makes it cost competitive with metal structures technology.

Additionally, composite materials are a natural for sign truss applications because of their inherent favorable fatigue characteristics, high damping, the fact that they don't corrode and thus for their inherent low maintenance potential. Composite sign structures have a substantially lower weight and can thus be installed with lighter equipment. Additionally the recent increases in the cost of energy, making steel, concrete, and transportation costs favor alternative solutions in the form of lightweight composite structures.

The research currently pursued by CSSI ads a novel element, which is the use of high performance structural snap joints. The state of the art has been discussed in a 1997 conference paper by Goldsworthy and Hiel [5]. These joints do not only provide for rapid

on-site assembly, but they also have shown the promise of substantial contributions to the structural damping capacity of the structure.

In an era where a twenty minute tie-up wastes over 2000 vehicle hours, causes a 3 mile backup and takes 2.5 hours to clear the world is moving towards IVHS (Intelligent Vehicle Highway System) [6] for which the "stealth" like qualities of fastenerless composites truss structures are an asset.

The section below illustrates the various design concepts which were developed during this project.

2. DESIGN METHODS/ CONCEPTS

In the United States, sign, signal and light support structures are designed using the AASHTO standard specifications for structural supports for highway signs, luminaires and traffic signals [7]

The benchmark steel sign truss for this research is a 90 feet structure with two posts as reproduced from drawing S5 in the Caltrans Standard Plans [8] below.
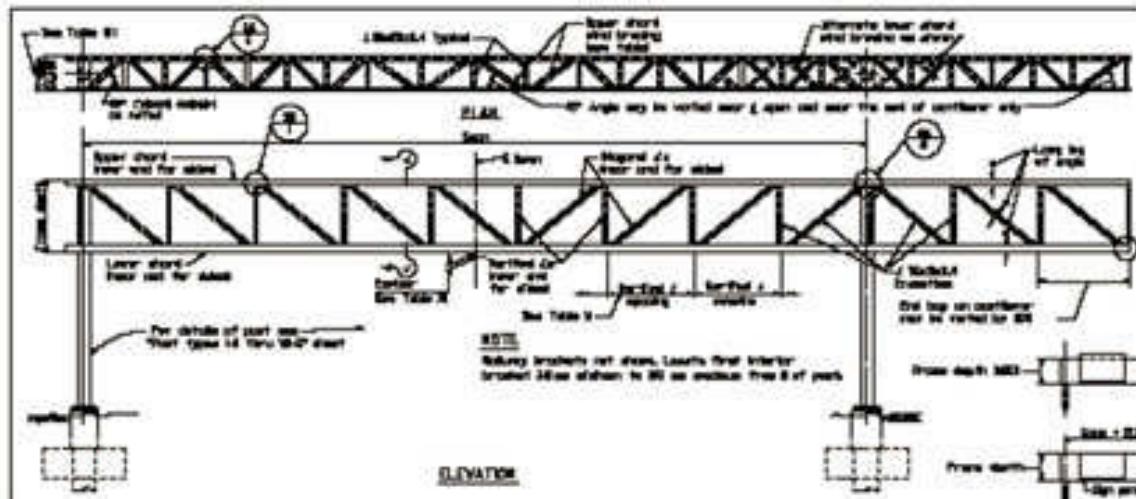
Figure 5 Benchmark Steel Sign Truss
From Caltrans Standard Plans [8]

The estimate for the weight of a sign truss with a 90 foot clear span is given in Table-I below.

WEIGHT OF STEEL STRUCTURE
(SIGN WEIGHT NOT INCLUDED)

LENGTH: 90 ft
HEIGHT: 76 in
WIDTH: 36 in

ITEM	DESCRIPTION	QTY	LENGTH (ft)	WEIGHT (plf)	TOTAL
1	Chord 152x102x12.7	4	90	16.2	5832.0
2	Vertical 89x89x7.9	32	6.33	7.2	1458.4
3	Diagonal 89x89x7.9	30	8.5	7.2	1836.0
4	Wind Lateral 64x64x6.4	58	2.9	4.1	689.6
5	Wind Diagonal 64x64x6.4	56	4.2	4.1	964.3
				TOTAL	10780.4 lbs

Table I Weight Estimate of Steel Sign Truss

Various approaches have been used towards the conceptual design of the overhead sign structure as discussed below:

1.1 Concept #1 Pultruded beam and corner elements

The Overhead Sign-Truss is conceptualized as truss members, shown in Figure 6, which can easily be assembled together with an interlocking type mechanism without the use of mechanical fasteners or adhesives.
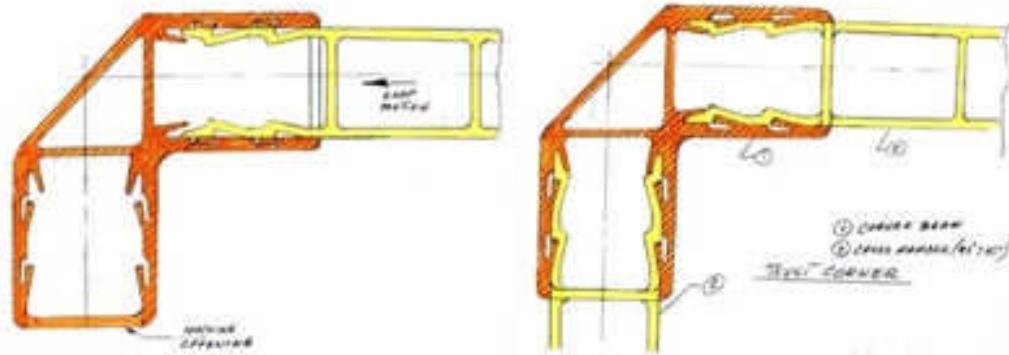

Figure 6 Concept for Sign Structure new Corner Joint

Figure 7 shows a pultruded connection detail that has sufficient flexibility to snap-fit into the pultruded corner elements.
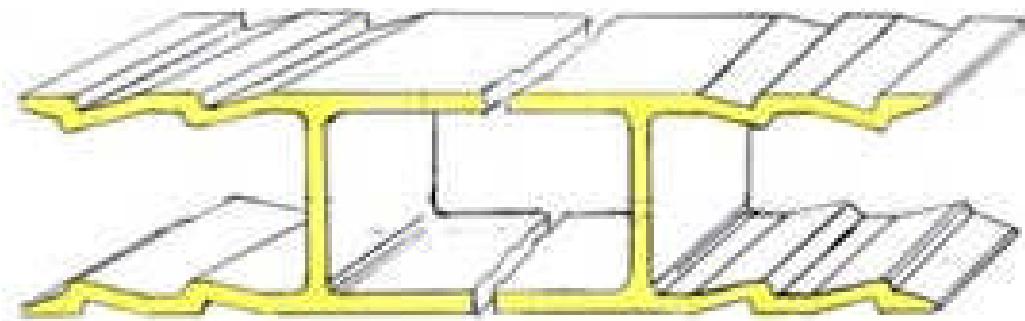
Figure 7 Pultruded Connection Detail

Figure 8 shows a slight deviation of this concept with more complicated corner joints.
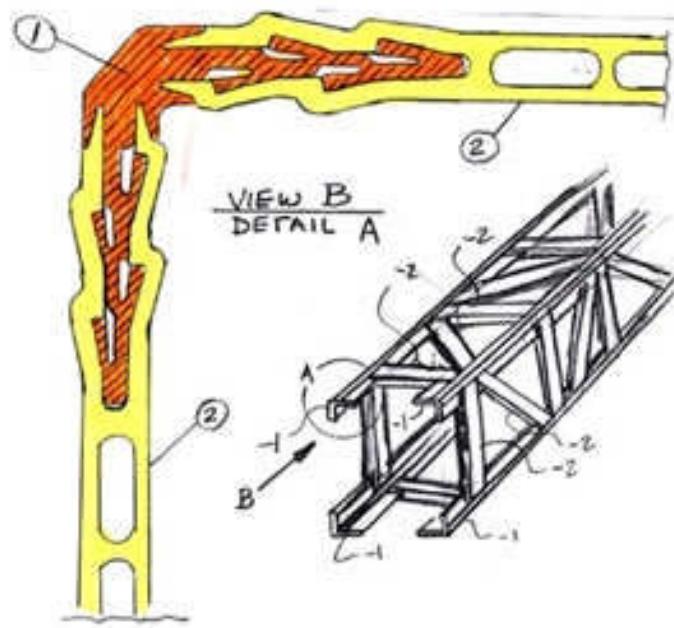
Figure 8 Other Concept for Sign Bridge Corner Joint

The second concept emphasizes the pultrusion of 6 to 8 ft wide sandwich panels or ribbed hollow panels. These panels are then cut along certain angles to provide the truss members which are needed for the fastenerless assembly of an overhead sign structure.

1.2 Concept # 2

Figure 9 is entirely novel and virtually eliminates the machining which was an integral part of the first generation snaplock joints which were discussed in the background section above.
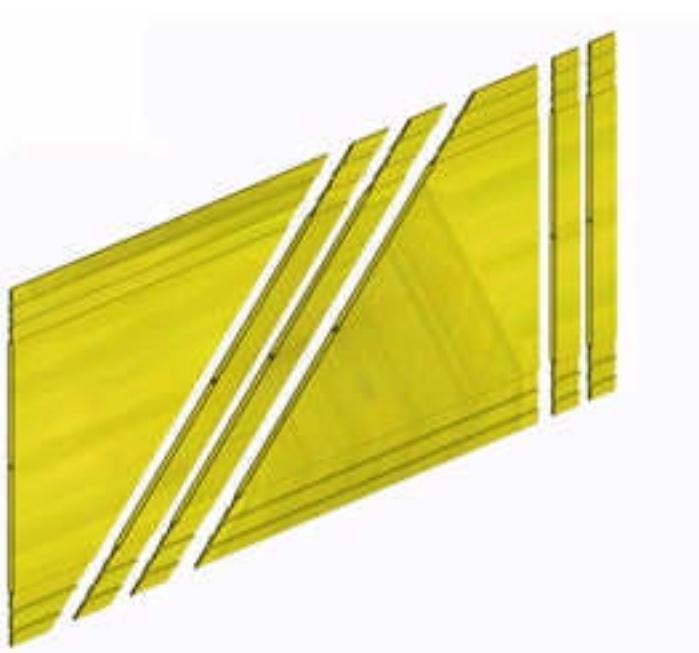
Figure 9 Pultruded Panel

The angled cross-members utilized for assembly and shown in detail in Figure 10 can be obtained by cutting a wider panel at the appropriate angle. This approach as visualized in

45" CROSSMEMBER—LATTICE TYPE
(HORIZONTAL)

TITLE: FASTENERLESS JOINT
CATEGORY: HEAVY STRUCTURAL MEMBERS FOR INFRASTRUCTURE
JOINT TYPE: UPPER/LOWER BEAM WITH VERTICAL/DIAGONAL MEMBERS
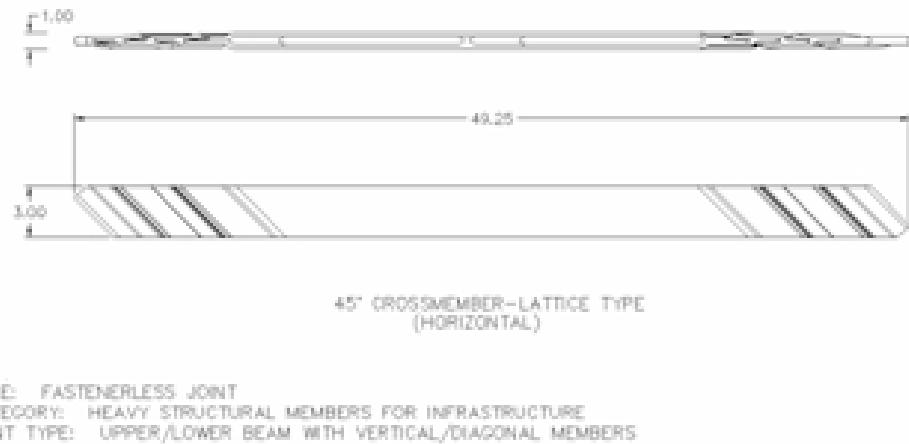
Figure 10 Angled cross-members and novel idea for pultrusion without the need for NC-machining

A key element of this task is the design of the fiber architecture which needs to be defined early on. A folded fiber architecture not only allows the joint to be functional but also introduces adequate interlaminar tension and shear resistance which translates into good durability. This is an example of our approach to designing durability into a structure by making vital load paths fiber dominated.

Another concept that was pursued was that of an "Isotruss" structure.

1.3 Concept # 3

Figure 11 shows an "Isotruss" structure which was assembled by snap-joining of tubular elements.
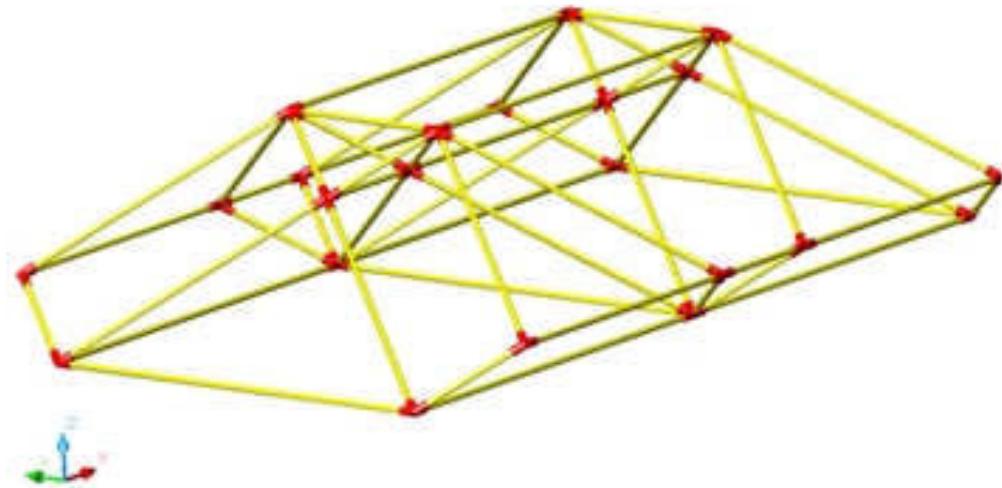

Figure 11 Isotruss Structure

This type of structure derives its stiffness from its geometry, much in the same sense as the geodetic structures which were designed by Buckminster Fuller.

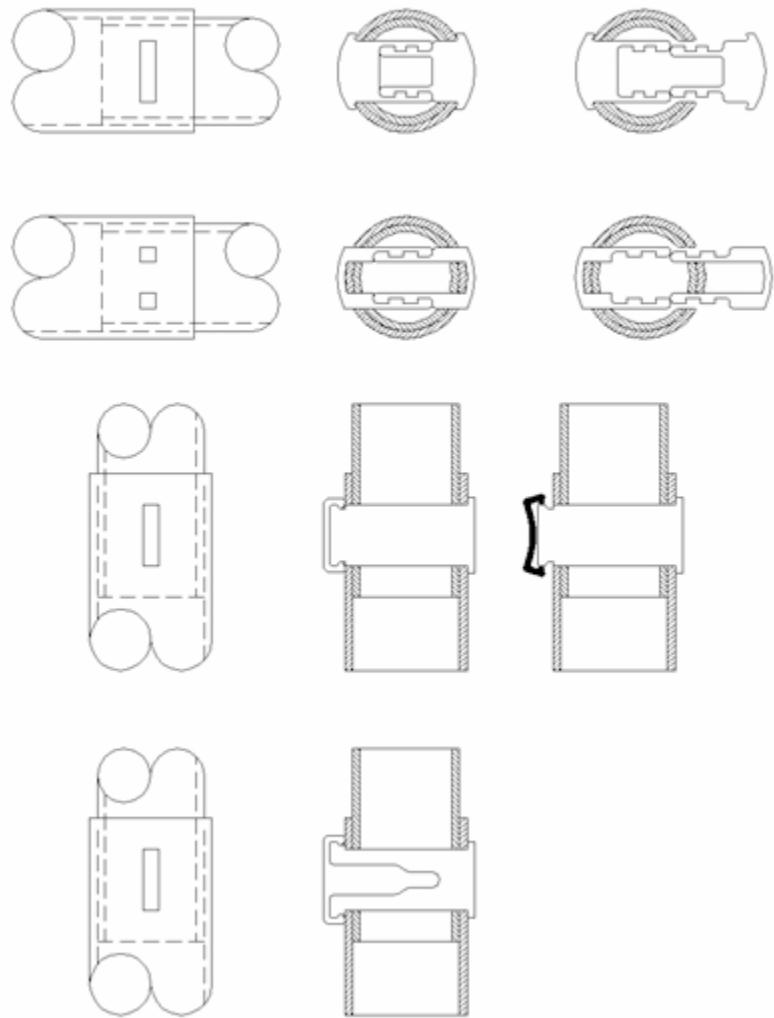Figure 12 shows concepts of the various joint configurations which would allow for snap fit assembly of these tubular structures.

Figure 12 Joint Configurations for Assembly of Tubular Structures

Figures 13, and 14 shows the actual assembly sequence of a complicated truss joint.

Figure 13 Joint Halves
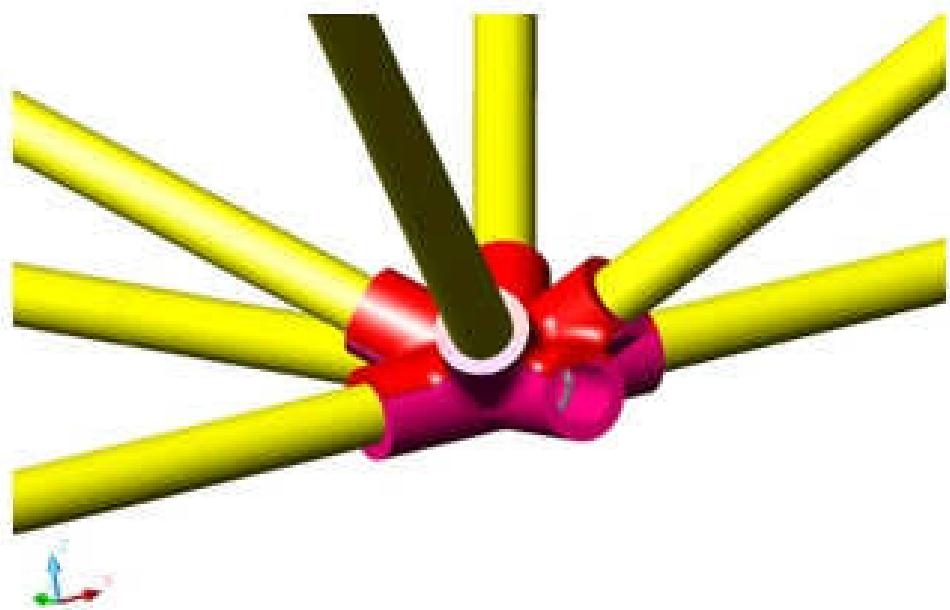
Figure 14 Joint halves Assembled

The concept that is discussed below is a more traditional snap-joint with a pultrusion that can accept cross-members in orthogonal directions.

Concept # 4

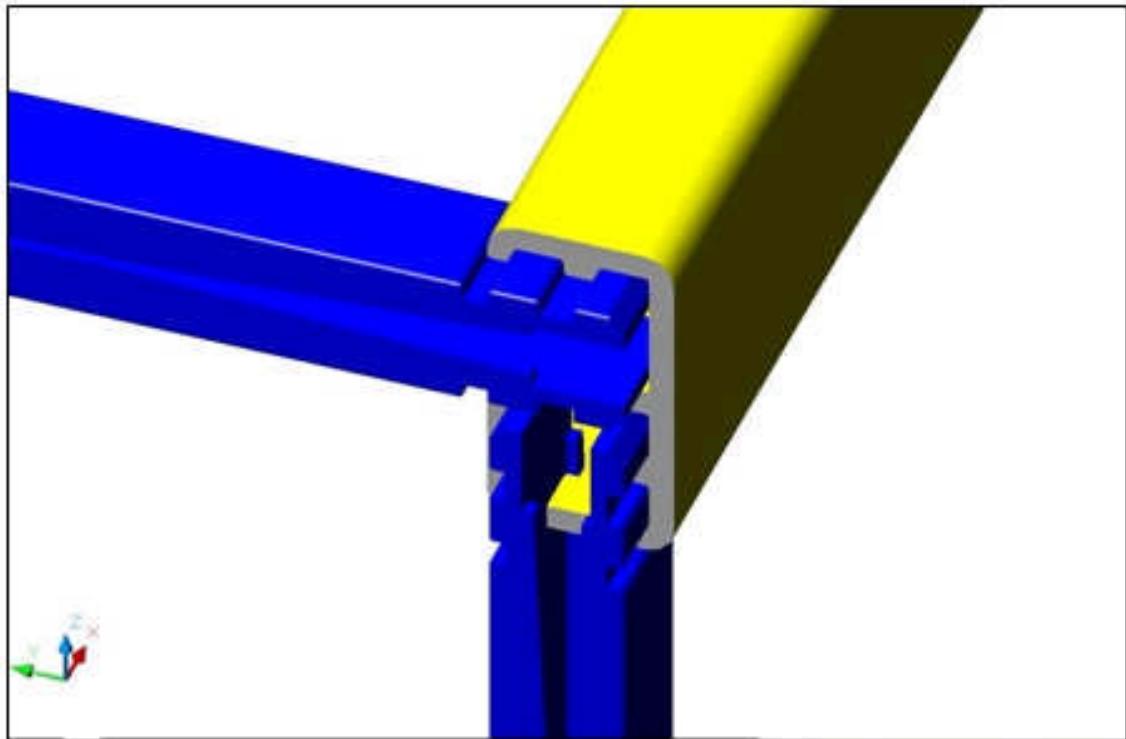Figure 15 illustrates detail of two perpendicular cross members entering the longitudinal beam.

Figure 15 Orthogonal Cross Member Entrance

Because this concept showed a lot of promise, we decided to prove its manufacturability by resin infusion. Figure 16(a, b) shows the snap joint which was made in this way. The reason for using resin infusion was that this is the cheapest way to create a hardware model of the concept. We did however respect at all times the fiber architecture in such a way that the part could later be manufactured by pultrusion.

Figure 16 a, b Snap-joint infusion and finished snap joint assembly

Figure 16a illustrates the infusion setup. The operator is using an ultrasonic leak detector to eliminate vacuum leaks at the edges of the vacuum bag and at the fittings.

Figure 16b shows the finished snap-joint. Because of the merit of this joint configuration, it was decided to select this concept for implementation.

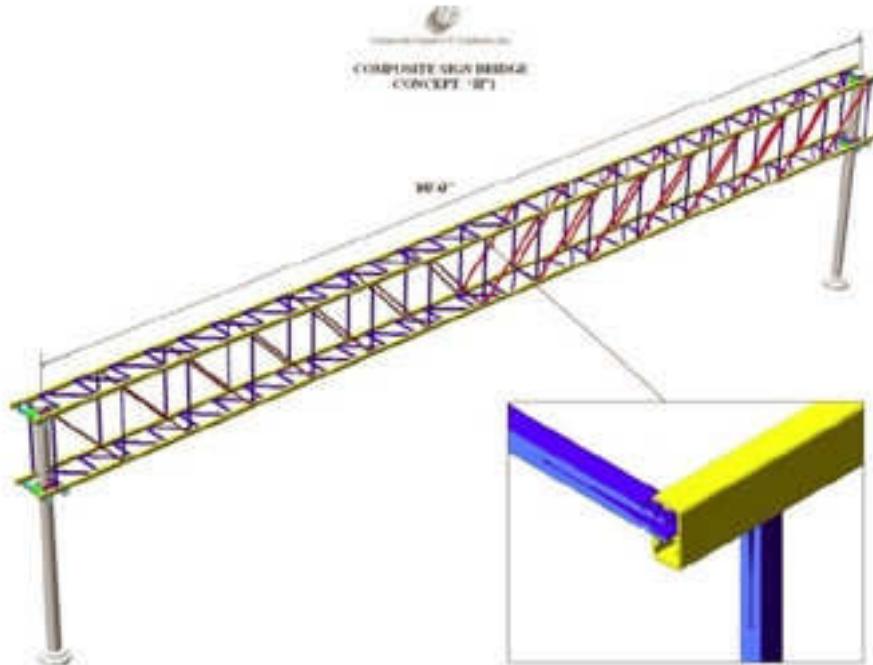The fastenerless (snap joint) composite configuration is reproduced in Figure 17.

Figure 17 Benchmark Composite Sign Truss

The detail inset in Figure 17 shows the fastenerless joint (snap joint) configuration. The two cross-members (bleu) snap into what is essentially a boxbeam (yellow) with two entirely separated cavities.

The weight estimate of the composite sign truss is given in Table-II

WEIGHT OF COMPOSITE STRUCTURE (CONCEPT II)
(SIGN WEIGHT NOT INCLUDED)

LENGTH: 90 ft
HEIGHT: 76 in
WIDTH: 36 in

ITEM	DESCRIPTION	QTY	LENGTH (ft)	WEIGHT (plf)	TOTAL
1	Chord 5.125x2.75x.375	4	90	5.1	1836.0
2	Vertical 2x2x.25	32	6.33	1.95	395.0
3	Diagonal 2x2x.25	30	8.5	1.95	497.3
4	Wind Lateral 2x2x.25	58	2.9	1.95	328.0
5	Wind Diagonal 2x2x.25	56	4.2	1.95	458.6
				TOTAL	3514.9 lbs

Table II Weight Estimate of Composite Sign Truss

The total weight comes out to 3515 lbs which is less than 1/3th of the weight of the benchmark steel sign truss.

3. MATERIAL SYSTEM IDENTIFICATION

The material system consists of E glass fiber and Vinylester resin.

The E-glass has the multipurpose sizing which is compatible with vinylester resin.

The vinylester resin has been formulated as shown in the table below.

RAW MATERIAL	LOT NO.	1 2 3 4 X-SMALL	1 2 3 4 SMALL	1 2 3 4 MEDIUM	1 2 3 4 LARGE	1 2 3 4 X-LARGE	PROCE DURE	MIX N0.
Dow 640-900		7.17 Lbs (3240grams)	14.29 Lbs.	28.57 Lbs.	57 Lbs.	114 Lbs.	Charge to mixer. Start agitation.	1 2 3 4
PS125/PUL24/ Molgard X		0.11Lbs. (50 grams)	0.22 lbs. (100 grams)	0.43 Lbs (200 grams)	0.88 Lbs. (400grams)	1.76 Lbs (800grams)	Add.	1 2 3 4
BYK 515		0.025 Lbs. (10 grams)	0.05 Lbs. (20 grams)	0.09 Lbs. (40 grams)	0.18 Lbs. (80 grams)	0.35 Lbs. (160 grams)	Add.	1 2 3 4
Kebus Beige pigment-45204		0.18 Lbs. (80 grams)	0.35 Lbs. (160 grams)	0.70 Lbs. (320 grams)	1.40 Lbs. (635 grams)	2.80 Lbs. (1270 grams)	Add.	1 2 3 4
ASP 600		1.43 Lbs. (650 grams)	2.85 Lbs. (1295 grams)	5.71 Lbs. (2590 grams)	11.40 Lbs. (5180grams)	22.8 Lbs	Add. Mix until uniform.	1 2 3 4
UV 5411		0.03 Lbs (10 grams)	0.05 Lbs. (23 grams)	0.10 Lbs. (45 grams)	0.20 Lbs. (90 grams)	0.40 Lbs. (180 grams)	Add.	1 2 3 4
Perkadox 16		0.04 Lbs. (20 grams)	0.09 Lbs (40 grams)	0.175 Lbs. (80 grams)	0.35 Lbs. (160 grams)	0.70 Lbs. (320 grams)	Premix with styrene.	1 2 3 4
ESPEROX 570P		0.04 Lbs. (16 grams)	0.07 Lbs. (33 grams)	0.14 lbs. (65 grams)	0.28 Lbs. (130 grams)	0.57 Lbs. (260 grams)	Add.	1 2 3 4
ESPEROX 10		0.015 Lbs. (8 grams)	0.03 Lbs. (15 grams)	0.07 Lbs. (30 grams)	0.13 Lbs. (60 grams)	0.26 Lbs. (120 grams)	Add	1 2 3 4
							Mix well.	
BATCH SIZE		8.95 Lbs.	17.90 Lbs.	35.80 Lbs.	71.60 Lbs.	143.20 Lbs.		

TIME	RESIN TECH	RESIN TEMP.	BROOKFIELD VISCOSITY, LVF SPINDLE 3, 30RPM, @77°F: (1500-1700cps)	180F SPI GEL TIME, Min., CURE TIME, Min., LPE, °F: (0.5-1.5/1.5-2.5/340-370)	RESIN MIX TIME, MIN.	

Table III Resin Formulation

The fiber layup schedules are provided in the drawing package that is attached as an appendix.

The structural properties of the pultruded sections were determined as:

> ➢ EL = 3.5 Msi (ASTM C1557)
> ➢ GLT = 0.425 Msi (ASTM D4475)
> ➢ Poisson Ratio: 0.33 (ASTM C1577)

These values a higher than for traditional, non-structural pultrusions which typically have an E modulus of 2.6 Msi.

Fiber volume fractions have been determined on the basis of weight measurements, and they are well over 50% for all samples tested.

4. MANUFACTURING PROCESS

Pultrusion is a continuous fabrication method, and as such it has become a preferred manufacturing method for most of the composite structures which have been pursued commercially in structural engineering. Our company (CSSI) owns two industrial capacity pultrusion machines dedicated to pultrude the hardware for extended test configurations and for full size sign trusses.

The components of the sign truss have been designed so that they can be fabricated by the pultrusion process that is schematically shown in Figure 18.
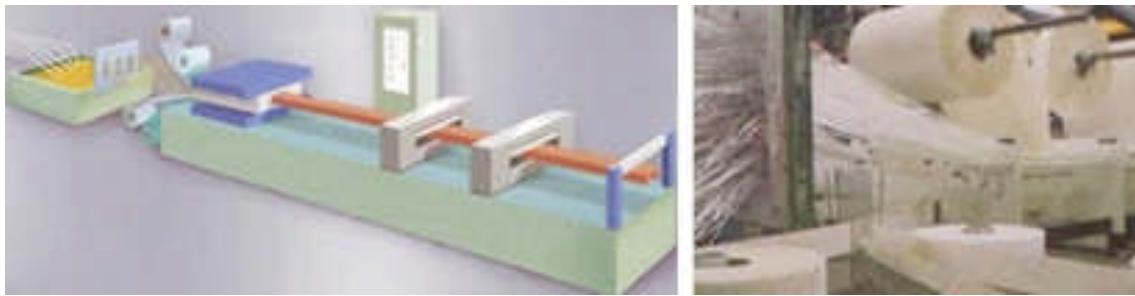
Figure 18 Fabrication of Sign Truss Elements by Pultrusion Process

Figure 19 shows a drawing of the fiber dispensing system.
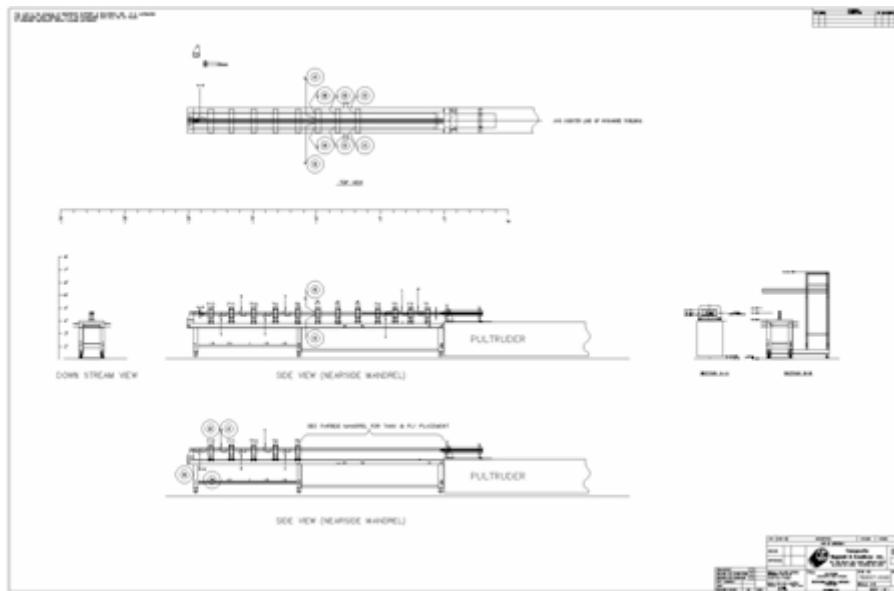
Figure 19 Fiber Dispensing System

This combination of fiber delivery towards the pultrusion-die and impregnation with resin in the process is the heart of the pultrusion operation.

Figure 20-22 show actual images of the pultrusion setup

Figure 20 Global view of the Pultrusion Setup

Figure 21 Detail of fiber Dispensing

Figure 22 Pultruded Component Exciting the Die

Figure 23 shows the pultruded elements which are stored for further machining and finishing operations

Figure 23 Finished Pultrusions

5. QUALITY CONTROL PROCEDURES

The quality control and storage of resins and fibers was conducted according to ASTM requirements.

The proper design of the fiber dispensing system is key to the quality of the pultruded components.

Figure 24 shows the section of a pultruded cross-member.
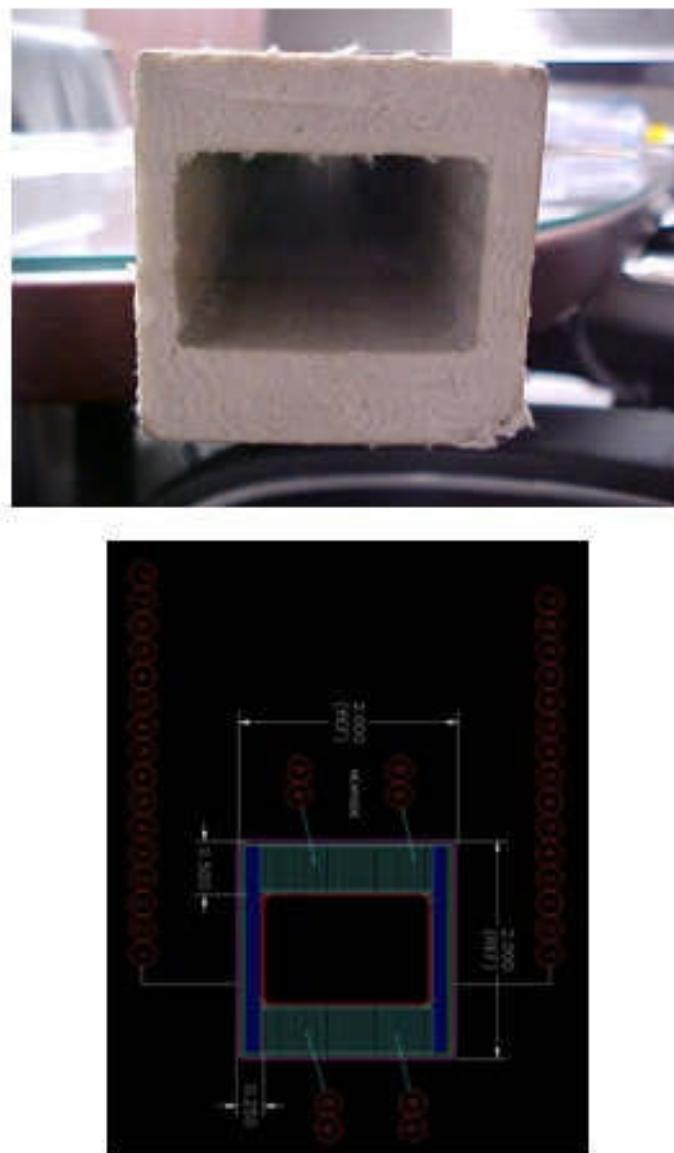
Figure 24 Section of Pultruded Cross-Member

These sections were examined for fiber density, and fiber distribution. Cuts were made every 60 ft and examined. No process variables were changed between cuts in order to assure the consistency of the pultruded component.

An important element in the determination of quality was in the ability to assemble the truss structure.

Figure 25 Assembled Overhead Sign Structure

Figure 26 Assembled Overhead Sign Structure

Figure 27 Detail Joint of Assembled Overhead Sign Structure

The connection of the truss to the vertical pole is shown in Figure 28
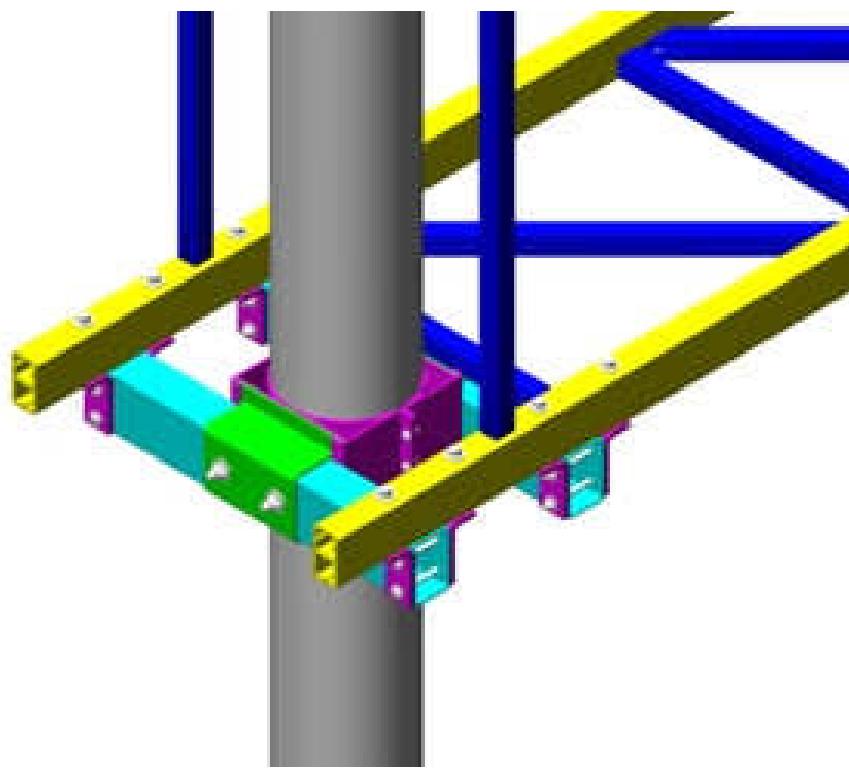
Figure 28 Connection of Truss to Vertical Pole

6. ANALYTICAL AND TEST RESULTS

Structural "snap-fits" for composite materials are a path-breaking approach for composite structures assembly which is capable of revitalizing some key opportunities for the U.S. industry and to define the tools, techniques, and ideas that can help put our efforts on a broad science and engineering footing.

Figure 29 illustrates our concept of creating a structural connection between two profiles without the need for fasteners.
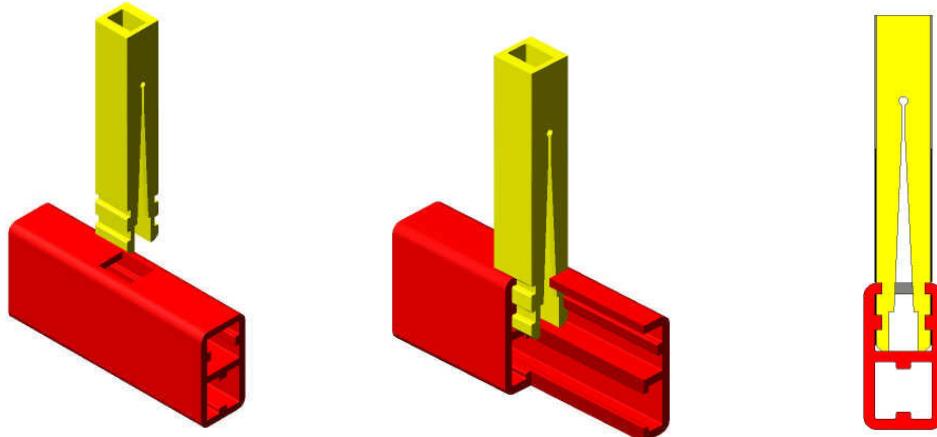
Figure 29 Snap Fit for Creating a Structural Connection

The yellow and the red profile are preferably fabricated by pultrusion, although we have used resin infusion for samples and small series as well. The methodology could be used with any of the composites manufacturing methods because snap-fit technology is merely a way of thinking about assembly and not tied to any particular method of manufacturing.

As a demonstration of the path-breaking potential of snap-fits we assembled the 9.14 meter (30 ft) truss structure shown in Figure 30 only 15 minutes.


Figure 30 Trial assembly of Snap-fit Truss Structure for this Project

The assembly sequence and steps have been documented in a separate internal report [9], which will be the basis for a future paper in a refereed Journal on composite materials technology.

The assembly in Figure 30 illustrates the ultimate goal for which we are developing this very cost competitive new assembly technology. The entire structure took only 15 minutes to assemble versus an estimated 2 hours for an equivalent metal structure. This result shows the practicality and the applicability of this approach and the opportunities which it embodies for further research and commercial application. By developing snap-fit technology for composite materials, we enable U.S. industry to remove the most formidable barrier that they are facing. This barrier is cost! Composite materials are always more expensive than traditional materials. Purchased cost or installed cost almost always favors the status quo. The U.S. industry is shoveling water upstream when it tries to overcome this barrier head-on or when they ask their customers to modify their perceptions and practices, or ask their customers to embrace "life-cycle" costing.

Figure 31 shows the snap fit connection which was shown above in Figure 30 as it is being loaded in a test frame. For reference we call this the benchmark snap-fit.

(a)   (b)

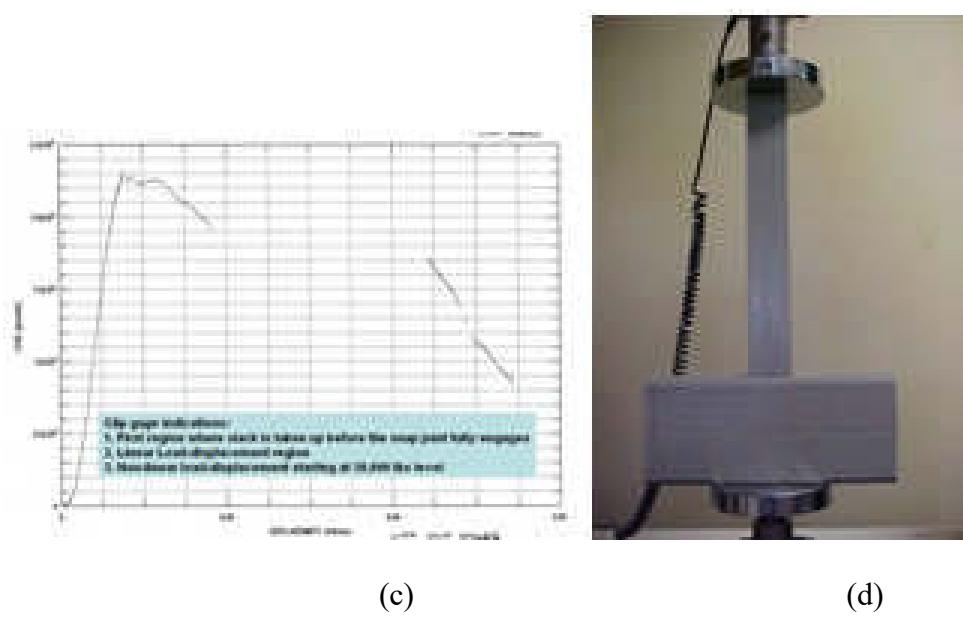(c)   (d)
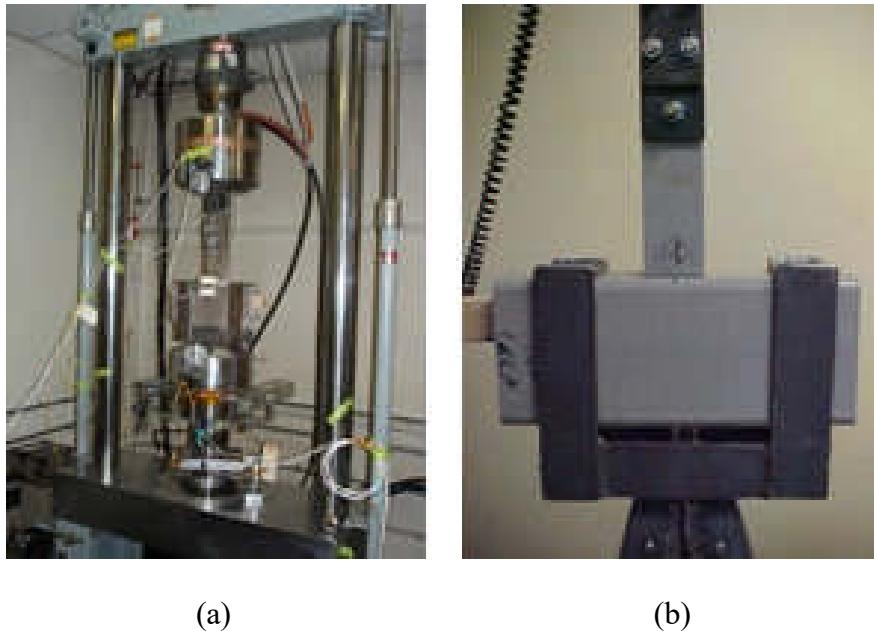
Figure 31 Benchmark Snap-Fit loaded in the Testing Machine

The load carrying capacity of the benchmark snap-fit is in the 104,540 N (23,000 lbs) range. We notice only a slight non-linearity prior to reaching the maximum load. This means that there are few non-linear phenomena acting. The snap-fit continues to carry a significant load once it has passed the maximum load point. This is shown further in results shown in Figure 37.

Figure 3d shows the setup of the snap-fit for compression loading. It was observed that the compression strength was on average 15% higher for all observed load cases.

SNAP-FIT FAILURE MODES

We did examine the failure mode of our benchmark snap-fit. Figure 32 shows the cracked component, after the joints was taken apart. It points to visible and stable cracking caused by a stress concentration at the radiussed corner of the opening in the double boxbeam part. This stress concentration could be alleviated in a number of ways

Figure 32 Critical Review of failure mode(s)

We notice that cracking has initiated at the corners and has then spread in the lengthwise direction of the part. This is explained by the stress concentration created by the small radius in the rectangular window opening. The corner had only a slight radius of 1/8". This radius gives us a stress concentration of a magnitude which was determined both theoretically and experimentally.

Residual stresses may be a factor, since the corner of the larger profile is participating in the load transfer as shown in Figure 33
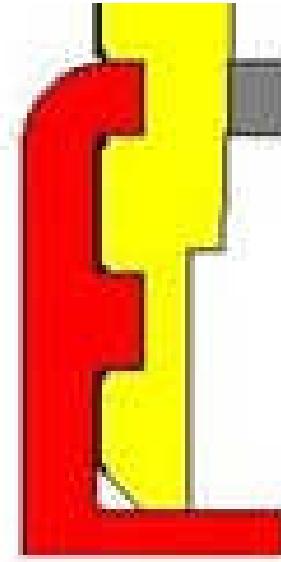
Figure 33 Contact surfaces

This could be determined by using a low shrink resin such as epoxy instead of the currently used vinylester.

Figure 34 shows the actual drawing of the fiber architecture. The table details the stitched fabric, the unidirectional fiber and the continuous strand mat. The resin was an Ashland Momentum vinylester resin. The orthotropic stiffness and the volume fraction were determined on the basis of this information.
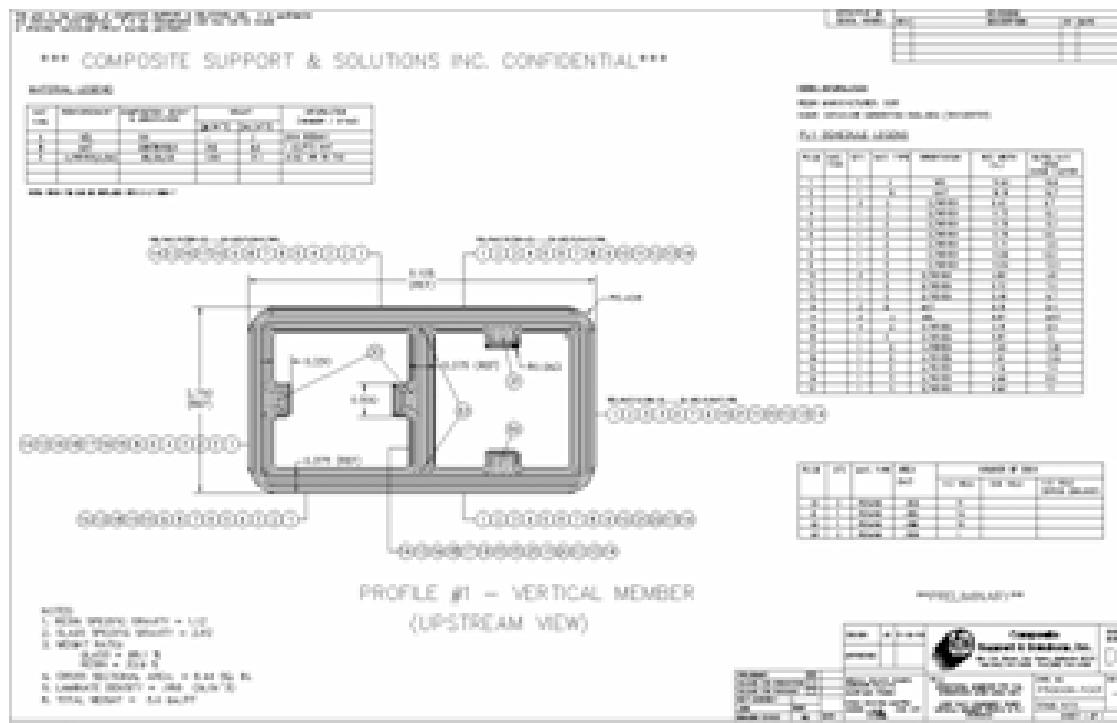
Figure 34 Fiber architecture

It was determined that this part has a 64% volume fraction of fibers by volume.

An examination of literature sources [10, 11] related to corner stress concentrations of plates with a square hole in bending has produced figures 35 a, b.
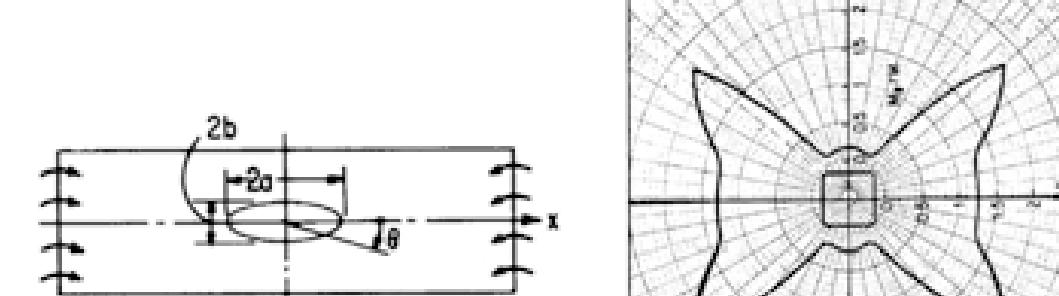

Figure 35 a, b Stress Concentration around a Square Hole in Bending

A stress concentration factor of 2.38 has been reported at the sharp corner.

A critical examination of the other component (the insert) revealed that there was no damage or cracking. This is due to the folded fiber architecture which we devised for this component. So far we have never been able to fail this component. It will be proposed to do this in our initial Phase-II effort, but this component does not appear to be a limiting factor.

STRESS/ STRAIN OBSERVATION METHOD TO OBSERVE THE SNAP-ENGAGEMENT AREA

Our company has direct working experience and operating knowledge with photoelastic coatings (photostress), moiré-Interferometry, and speckle-Interferometry. Based on the critical review of the failure modes in task 1, and based on communications with industry experts, we selected the photostress method [12, 13] for further examination of the areas of interest.

The Photostress method was invented by Dr. Felix Zandman [14]. It consists of bonding a transparent photoelastically sensitive plastic to the composite as shown in Figure 8. When putting the composite under stress, the stress equally affects the plastic. The plastic stretches in the same way as the composite it is bonded to. Its surface assumes the same deformations as the surface of the composite. The plastic has become a sensor for changes in the composite surface. Instead of speculating on equivalencies as is done in traditional transmission photoelasticity, this technique allows us to look at, and investigate the real thing.

Figure 36 Photostress method Applied to Composite Snap-Fit

The area of interest is the rectangular window with the rounded corners, which is the failure area as we discussed above.

The photoelastically sensitive plastic sheets were first calibrated in bending. The objective was to determine the fringe constant. The obtained value was 23 Mpa/ fringe. The detailed procedure has been outlined in a separate internal report [15].

Although the photoelastic method had fallen back with the emergence of FE (finite element) methods, it has made a come-back as is illustrated in ref's [16-18] which date from 2003 and 2006 and which investigate stress reduction and fatigue sensitivity in traditional bolts.

THREE DIMENSIONAL FINITE ELEMENT MODEL FOR BENCHMARK SNAP FIT SIMULATION AND IMPROVEMENT

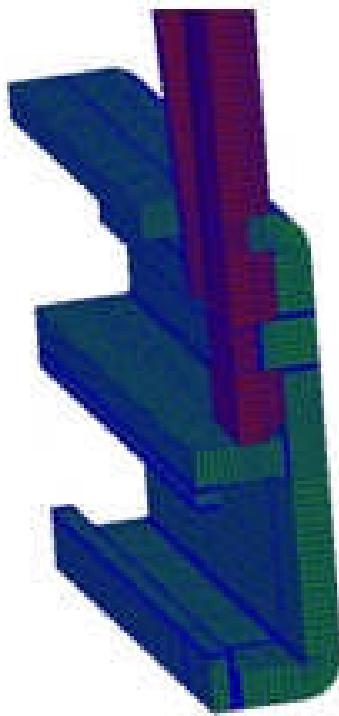Figure 37 shows the three dimensional model that was used for finite element implementation.

Figure 37 Three dimensional Snap-Fit FE-model

The CAD-file was transferred to Patran [19], which was used to mesh the geometry. The FE analysis was performed with NASTRAN. We performed a linear stress analysis, as shown in Figure 38, and assumed a uniformly distributed engagement load distribution applied by the insert.
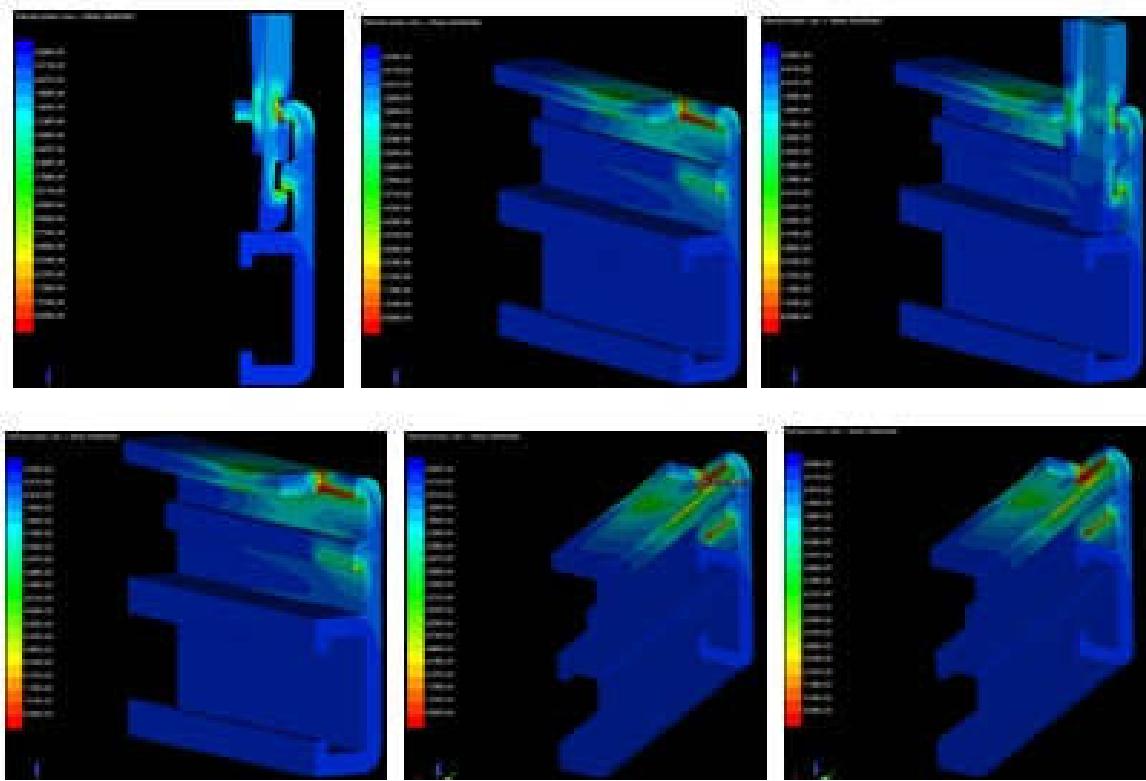
Figure 38 Typical Stress Distribution at the corners of the Window Section

The obtained stress distribution clearly puts most of the load into the engagement area around the window. The second, and lower, engagement protrusion is lighter loaded. An increase in the stiffness of the load path that engages this lower protrusion would help to equalize the load sharing between both engagement areas.

Additional FE analysis was performed on models with an increased radius at the window corner [20]. It was found that a 0.5" radius was most practical in that it would delay the onset of cracking and at the same time be feasible from a manufacturing standpoint. These results are, to the best of our knowledge, the first to be obtained on a structural snap-fit configuration. Our plan is to perform a refined analysis in Phase-II with contact elements, which will serve the more complicated loading cases which occur in the truss-type configurations such as was shown in Figure 2.

TEST PLAN FOR SNAP-FIT

The test plan was written as an internal report [21]. It outlines the tension and compression tests which needed to be performed on the snap-fit. It also outlines the observations which needed to be made with the photostress method. The test plan called for three different window radius configurations in addition to the baseline snap-fit configuration.

SNAP-FIT SAMPLES FOR WHOLE FIELD OBSERVATION AND PERFORM TENSILE AND COMPRESSION TESTS ACCORDING TO TEST PLAN

Figure 39 gives a global view as we gradually step back and observe the polariscope and the Instron testing machine which is used to load the snap-fit samples.


Figure 39 Photostress Method Applied to Snap-Fit

On the left we observe the computer control of the testing machine. The area of interest is thus located inside one of the cells of the double boxbeam. As such any strain or stress observation method which we select needs to be capable of observing stresses and or strains by a reflection method, and needs to work within the very confined area described. This task basically duplicates the setup in Figure 3, but with this difference that the observations are dedicated to determining the stress concentration for various radii of the window corners.

EXAMINE EXPERIMENTAL AND THEORETICAL RESULTS

Figure 40a shows a view through the reflection polariscope as the sample is prepared for loading. The development of photoelastic fringes was observed as shown in Figure 39b.
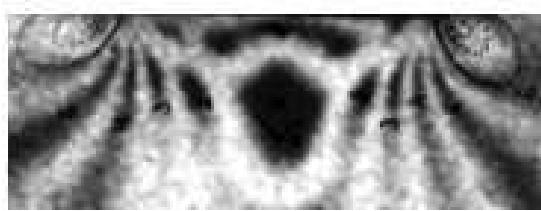
<center>(a)   (b)</center>
<center>Figure 40 Photoelastic Fringe Pattern</center>

This observation was made at a load level of 22,727 N (5000 lbs.) The fringes which we observe are the geometric locations of all points on the composite surface which have the same diameter of the Mohr circle. We labeled the fringes and observed they increase at the corner to an order of nine (9).

Figure 41 illustrates the first cracks which were observed at 83% of the ultimate failure load.

<center>(a)   (b)   (c)</center>
<center>Figure 41 First cracks observed in the Snap-Fit</center>

This observation sets the stage for the improved understanding of snap-fits. We now know that the limiting factor on the strength is the stress concentration at the window corners. In order to improve the snap-fit this stress concentration has to be reduced first. This can be achieved with the rounded window configuration which is shown in Figure 40c.

GUIDELINES FOR FUTURE GENERATIONS OF STRUCTURAL SNAP FITS

The guidelines for future generations of snap fits can be summarized as follows:

➢ The window radius is an important parameter for the strength of the snap-fit
➢ A window radius of 0.5" shows a potential for strength increase of 30%
➢ A "doubler" around the window section would further reduce the concentration around the window and thus further increase the strength of the snap-fit.
➢ The disadvantage of a doubler is that it requires an extra fabrication step and a secondary bonding step
➢ A design philosophy which creates a local stiff load path to minimize bending around the window would be beneficial
➢ For our current snap-fit design we used vinylester resin. Since this has a higher shrinkage than epoxy resin it is likely to set-up internal stresses which decrease the strength capacity of the baseline snap-fit. The use and the benefits of epoxy resin should be determined. The validity of this statement is supported by Figure 14 which compares the interlaminar strength of polyester and epoxy materials [14]. This data shows a potential for increasing the strength by a factor of 1.5 by selecting epoxy for the manufacturing process.
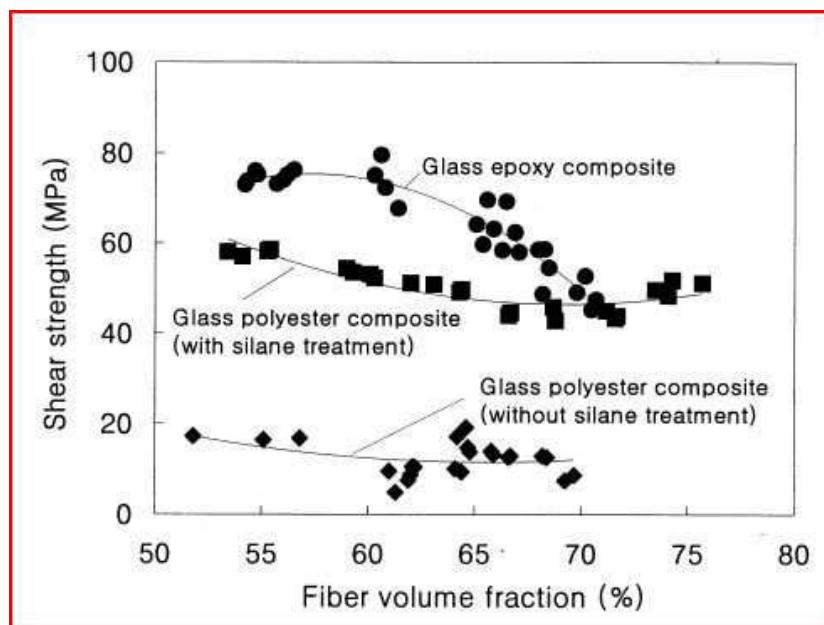
Figure 42 Improvement of Interlaminar Shear Strength [from Lee, 2001]

We should point out however that we expect the interlaminar shear strength for the vinylester-glassfiber composite which was used in this work to be higher than Lee's results for polyester. The glassfiber which we used had received the silane treatment.
Figure 42 also indicates that our fiber volume fraction of 64% may be too high. When using epoxy a fiber volume fraction of 58% seems optimal.

INCREASE THE LOAD CAPACITY OF BASELINE SNAP FIT (SSF-2) TO THE 136,363 - 181,818 N (30,000-40,000 LBS) RANGE

It was determined from the analysis that a radius of 12.5 mm (0.5"), as shown in Figure 43, would have a beneficial effect on load capacity and at the same time be manufacturable.

Figure 43 Snap-fit Geometry change for increased load capacity

It is noted from Figure 42c that the cross-member insert also needed to be radiussed in order to fit into the window.

Figure 44 illustrates the improvement in the local stress distribution at the rounded window corner. As was the case for the benchmark snap-fit, this stress distribution was observed at a load level of 22,727 N (5000 lbs).
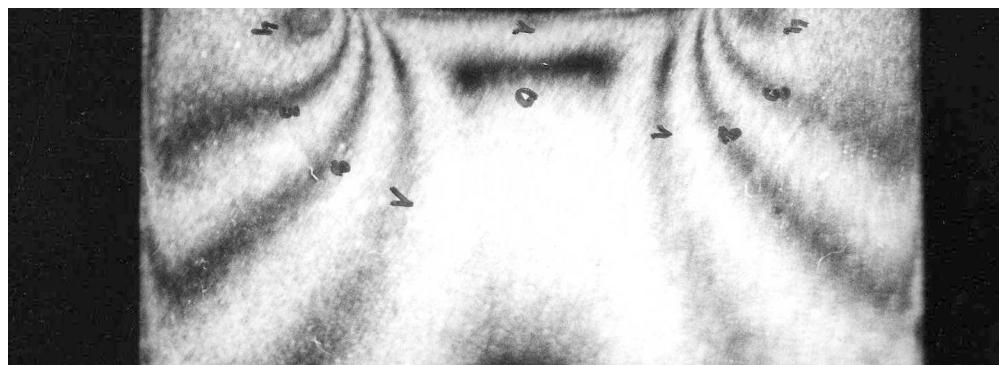
Figure 44 Photoelastic result with rounded window corner

As before, we labeled the fringes and observed that they are slightly higher than 4 at the corner. This means that the stress concentration is roughly half of what is was before.

Figure 45 shows the cracking that emerged from the rounded window.

| (a) | (b) | (c) |

Figure 45 Cracking at rounded window

The load capacity due to the reduced stress concentration increased to 127,272 N (28,000 lbs). This is within the expectations which we outlined in our Phase-I proposal. We also expressed a goal in the Phase-I proposal to be able to increase the load capacity with only a 5% increase in weight. In actuality we reduced the weight slightly. Near the end of the load cycle, the snap-fit did experience extensive non-linear behavior. Evidence of this behavior is shown in Figure 18c. There is also evidence that instead of one crack at each corner the window now experiences at least two cracks at each corner.

A very reassuring observation for designers is that the snap-fit fails very gradually and keeps holding load. Even the heavily damaged section which is shown in Figure 18c was able to still carry 50% of the failure load.

No damage on the radiused cross-member insert was observed.

PRELIMINARY DESIGN OF INNOVATIVE SNAP-FT CONFIGURATIONS FOR THE 40,000 TO 50,000 LBS LOAD CAPACITY RANGE

In the design guidelines we mentioned that a doubler plate would be beneficial in order to increase the load capacity of the snap-fit. An improved configuration is shown in Figure 46.
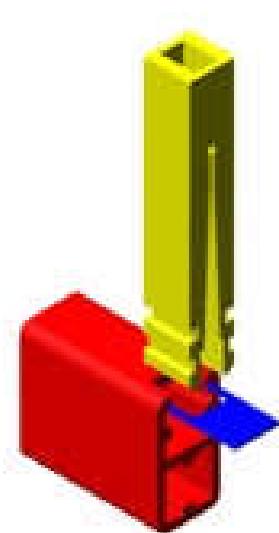
Figure 46 Configuration with underlying metal/ composite doubler (plate)

The blue plate which has been inserted underneath the surface of the red truss member will be bonded to the inside of the top surface and restrain the cracking from occurring. The plate will also help reduce the bending effect into the corner and increase the shear effect. The material for the plate could be steel, but it would be preferred to use a non-corrosive material such as a toughened ceramic or quasi-isotropic carbon or boron composite. Another candidate may be Glare. For compression loading we propose a cage-like configuration.

During the project we generated an idea for a displacement measurement procedure on the snap-fit by means of an optical microscope. This displacement data would be transformed into strain data with appropriate third party software. It will be used as the basis for a presentation to one of the technical societies such as SAMPE (Society of Advanced Materials and Process Engineers) or SEM (Society for Experimental Mechanics)

The load requirements for the complete structural analysis we obtained from AASHTO [7] The analysis was performed with Pro-Mechanica and the results are summarized in Figure 4 7
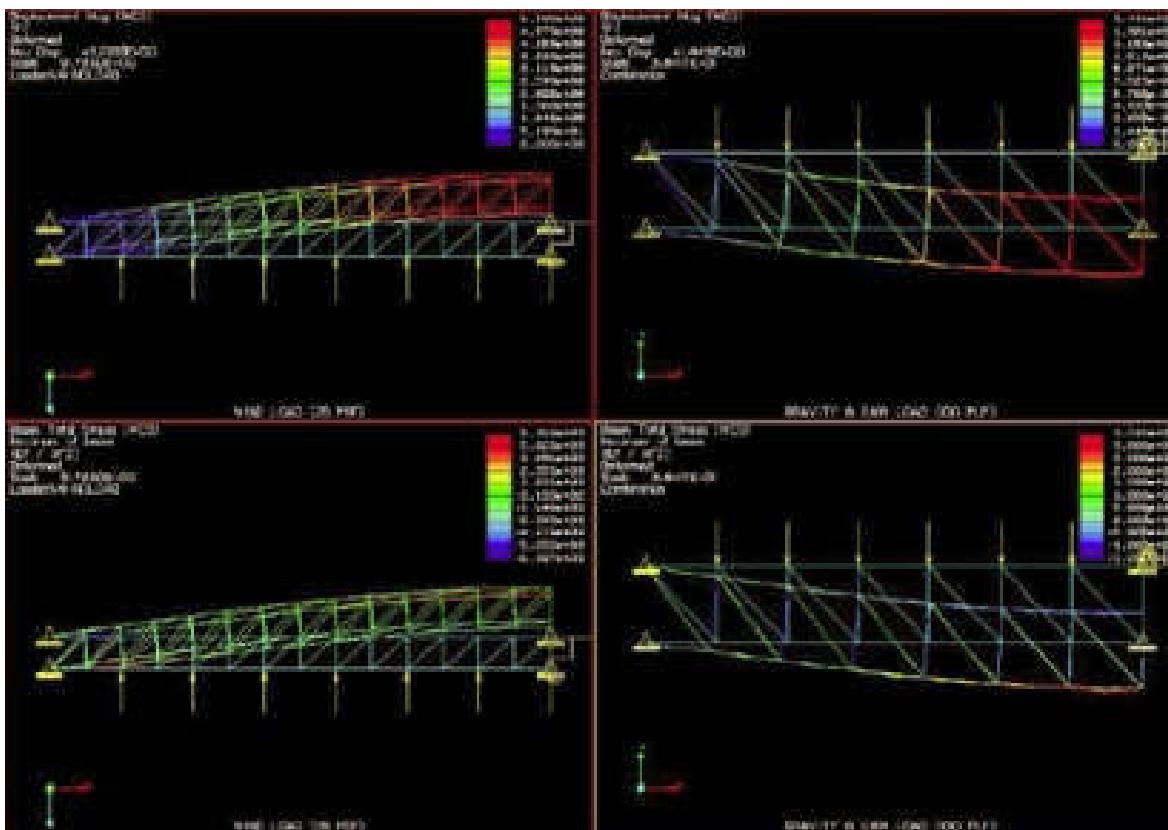
Figure 47 Sign Truss Deflections in Horizontal and Vertical Direction

Following AASHTO specifications, a wind load of 80 mph was assumed. For a 25 ft tall sign structure this translates into a pressure of 25 psf.

This wind pressure was applied to the entire face of the sign truss. For this load case the resulting maximum deflection was 4.94"

The vertical load consisted of the own weight of the sign truss plus a 50 lbs/ linear foot distributed load over the entire free span of 90 ft. The added distributed load accounts for the weight of the signs. For this load case the resulting maximum deflection was 1.37." This is L/790 which is well below the L/150 which is referred in section 10-2 of the AAHTO specification.

7. CONCLUSIONS AND RECOMMENDATIONS

In this project we successfully designed, manufactured, and assembled a overhead sign bridge structure.

This structure has been designed for pultrusion, and allows for fastenerless assembly, without the use of tools, with the exception of a few clamps. As such these newly designed structures have the potential to compete on cost with traditional steel construction.

A lightweight composite sign structure with a 90 foot clear span has been designed. This sign truss does not rely on fasteners but on a new "snap joint" which allows for rapid assembly. The "snap joint" which we designed has a load capacity which is well in excess of 22,000 lbs.

The weight of the composite sign truss is less than 1/3rd of the weight of the steel structure. As such it can be installed with light and less expensive lifting equipment.

In summary:

CSSI has designed, constructed and assembled a standard Overhead Highway Sign Bridge – two post truss type out of Fiber Reinforced Polymer (FRP) composite materials utilizing the pultrusion process. The design of the composite sign structure and sign bridge meets all of the requirements of the 1999 Caltrans Standard Specifications and Standard Plans, the 2001 AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and traffic Signals, 4th edition.

The Overhead Sign Bridge – two post truss type, has a span length of ninety (60) feet. The Overhead Sign Truss has a frame depth of ninety-six (96) inches.

All materials and tooling necessary for the fabrication of the Overhead Sign Bridge/Sign have been designed and/ or procured by CSSI. The basic materials are E-Glass for the fiber, and Vinylester for the resin system.

CSSI has developed the conceptual design for the FRP Composite Overhead Sign Bridge, posts, and connection details. Detailed drawings of the Overhead Sign Bridge/Sign Structure have been generated and include selected materials, material properties, fiber architecture, connection details, and assembly details.

CSSI has performed component structural analysis to verify structural performance as required in the 2001 AASHTO Standard Specifications for Highway Signs, Luminaries and traffic Signals, 4th edition, and to verify the structural integrity of the design.

CSSI has produced a 30 ft sign bridge section and a 60 foot sign bridge section. These are ready for field installation.

It is recommended that the lessons learned in this effort be applied to future overhead sign bridge designs. This will lead to structures which require virtually no maintenance, and which don't have the fatigue and cracking issues which plague their aluminum and steel counterparts.

8. REFERENCES

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APPENDIX

CONTRACT 59A0343

DRAWINGS

Drawing   Description

P5007-0001   CONCEPT "I"

P5007-0002   CONCEPT "II", 90 FT BRIDGE

P5007-0003   TENSILE TEST FIXTURE

P5007-0004   CROSS ARM ASSEMBLY

P5007-0005   BRACKET

P5007-0006   WIND BRACE

P5007-0007   TENSILE TEST FIXTURE, TOP CLAMP

P5007-0008   PULTRUSION DIE ASSEMBLY (PROFILE #1)

P5007-0009   PULTRUSION DIE (PROFILE #1)

P5007-0011   PULTRUSION DIE ASSEMBLY (PROFILE #2)

P5007-0012   PULTRUSION ASSEMBLY (PROFILE #1)

P5007-0013   FINISH MANDREL

P5007-0014   DIE SUPPRT BAR

P5007-0015   UPSTREAM TRACK

P5007-0016   PROFILE #1 – PLY SCHEDULE

T5007-0017   WET-OUT TANK WELDMENT

P5007-0020   PULTRUSION SET-UP

P5007-0021   PROFILE #2 – PLY SCHEDULE

T5007-0022   ANCHOR FOR PROFILE #2

P5007-0024   24' SPAN BRIDGE ASSEMBLY

P5007-0026   TOP CHORD "A","B"

P5007-0028   BOTTOM CHORD "C","D"

P5007-0029   VERTICAL

P5007-0030   DIAGONAL

P5007-0031   WIND BRACE

P5007-0035   24' SPAN BRIDGE –OVERHEAD TRUSS ASSEMBLY

P5007-0032   54' SPAN BRIDGE ASSEMBLY

P5007-0033   54' SPAN BRIDGE –OVERHEAD TRUSS ASSEMBLY

P5007-0114   ROUGH MANDREL TYPE "C" FARSIDE

P5007-0115   ROUGH MANDREL TYPE "C" FARSIDE

P5007-1004   LOCK PLY-SCHEDULE

T5007-1013   PULTRUSION ASSEMBLY (PROFILE #2)

P5007-1112   LOCK PROFILE

P5007-1113   LOCK PULTRUSION DIE

P5007-0001-1

P5007-0002

90' SPAN BRIDGE ASSEMBLY

FRONT VIEW

TOP VIEW

SIDE VIEW

ISOMETRIC VIEW

PRELIMINARY

NOTES:
1. ALL DIMENSIONS ARE IN INCHES.

STEEL POST (REF)

80.00

TBD

1080.0

1118.0
(OVERHEAD TRUSS ASSEMBLY LENGTH)

36.0

Composite Support & Solutions, Inc.

P5007-0002

50

NOTES:
1. ALL DIMENSION ARE IN INCHES

CROSS ARM ASSEMBLY

36.02
(REF)

9.50 (REF)

9.50
(REF)

10.00
(REF)

PRELIMINARY

Composite
Support & Solutions, Inc.

CROSS ARM ASSEMBLY

P5007-0004

SHEET 1 OF 3

P5007-0004-1

CROSS ARM ASSEMBLY

PRELIMINARY

53

RECTANGLE 4"X6"
MAT: COMPOSITE

ANGLE
MAT: COMPOSITE

P5007-0005

MOUNTING BRACKET ASSEMBLY

10.00

15.00

STEEL POLE 12" DIAMETER (REF)

2 BRACKET
MAT: COMPOSITE

PRELIMINARY

0.00
2.00
5.00
8.00
10.00

0.00
0.56
4.50
10.50
14.44
15.00 (REF)

2.00
5.00
8.00

7/8" HOLE THRU
2 PLACES

7/16" HOLE THRU
6 PLACES

6.75 (REF)

55

6 — DIAGONAL WIND BRACE

7 — DIAGONAL WIND BRACE

45°

51.88

49.88

1.44

.41

1.00

35.27

2.000

1.0000

33.90

45°

0.17

0.25

2.00

1.500

0.500

0.00

2.375

2.000

1.375

1.250

0.750

0.000

7.52

Ø0.31

11.47

23.81

27.75

32.899

33.274

34.024

34.524

35.2736

PRELIMINARY

Composite
Support & Solutions, Inc.

TITLE
DIAGONAL WIND BRACE

DWG NO
P5007-0006

SCALE 1:3   SHEET 3 OF 7

P5007-0007

TOP CLAMP

1

qty: 4
rev: a

57

P5007-0008

PULTRUSION DIE ASSEMBLY (PROFILE #1)

UPSTREAM VIEW

MANDREL EXTENSION (REF)

NEARSIDE

FARSIDE

PRELIMINARY

58

PULTRUSION DIE (PROFILE #1)

UPSTREAM VIEW

BOTTOM VIEW

SIDE VIEW

TOP VIEW

MANDREL CAVITY

R 0.125 AROUND DIE CAVITY
TYP. 2 ENDS

DIE ALIGNMENT PINS
MATCH AND REAM FOR .375 DIA. DOWEL
PRESS FIT IN BOTTOM DIE
TYP 9 PLACES

DIE ANCHOR PIN HOLE ø.500 X 1.500 DEEP
COUNTERBORE THE BOTTOM DIE
(STATION 1.250)
DIA TOLERANCE IS +.0005/-.0000

DIE ASSEMBLY BOLTS
DRILL IN LINE TOP AND BOTTOM OF THE DIE
TOP-7/16 DIA THRU
MIDDLE-7/16 DIA X 3/4 DEEP
BOTTOM- DRILL AND TAP 3/8-24 THRU UNF-2B

JACKING SCREW
TOP- DRILL AND TAP 3/8-24 UNF-2B THRU
BOTTOM- C'BORE ø7/16 X 1 1/16 DEEP
TYP 8 PLACES

HEATER ATTACHMENT HOLES
10-24 UNC X 3/8 DEEP
(SEE SECTION B-B)

THERMOCOUPLE HOLES
DRILL ø.125
12 PLACES
(SEE SECTION C-C)

DOWEL (REF)

SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D

FINISH MANDREL (REF)

STA. 0.750
STA. 0.000
STA. 1.250
STA. 5.75
STA. 8.75
STA. 12.25
STA. 15.51
STA. 19.01
STA. 22.01
STA. 26.25
STA. 29.25
STA. 32.75
STA. 35.250

STA. 0.000
STA. 2.500
STA. 5.250
STA. 6.250
STA. 11.250
STA. 14.250
STA. 17.250
STA. 20.250
STA. 23.250
STA. 26.250
STA. 29.250
STA. 32.000
STA. 34.500

STA. 0.812
STA. 1.688
STA. 12.312
STA. 18.750
STA. 22.188
STA. 32.812
STA. 33.688

10-24 UNC X 3/8 DEEP
24 PLACES

NOTES:
1. ALL PARTS SHALL BE STRESS RELIEVE AFTER WELDING
2. DIMENSIONS SHOWN ARE FINAL INSPECTED DIMENSIONS AFTER MACHINING, PAINTING & PLATING
3. SURFACE FINISH —
4. TAPER AROUND MANDREL, START 15" FROM END .005" DROP PER SIDE
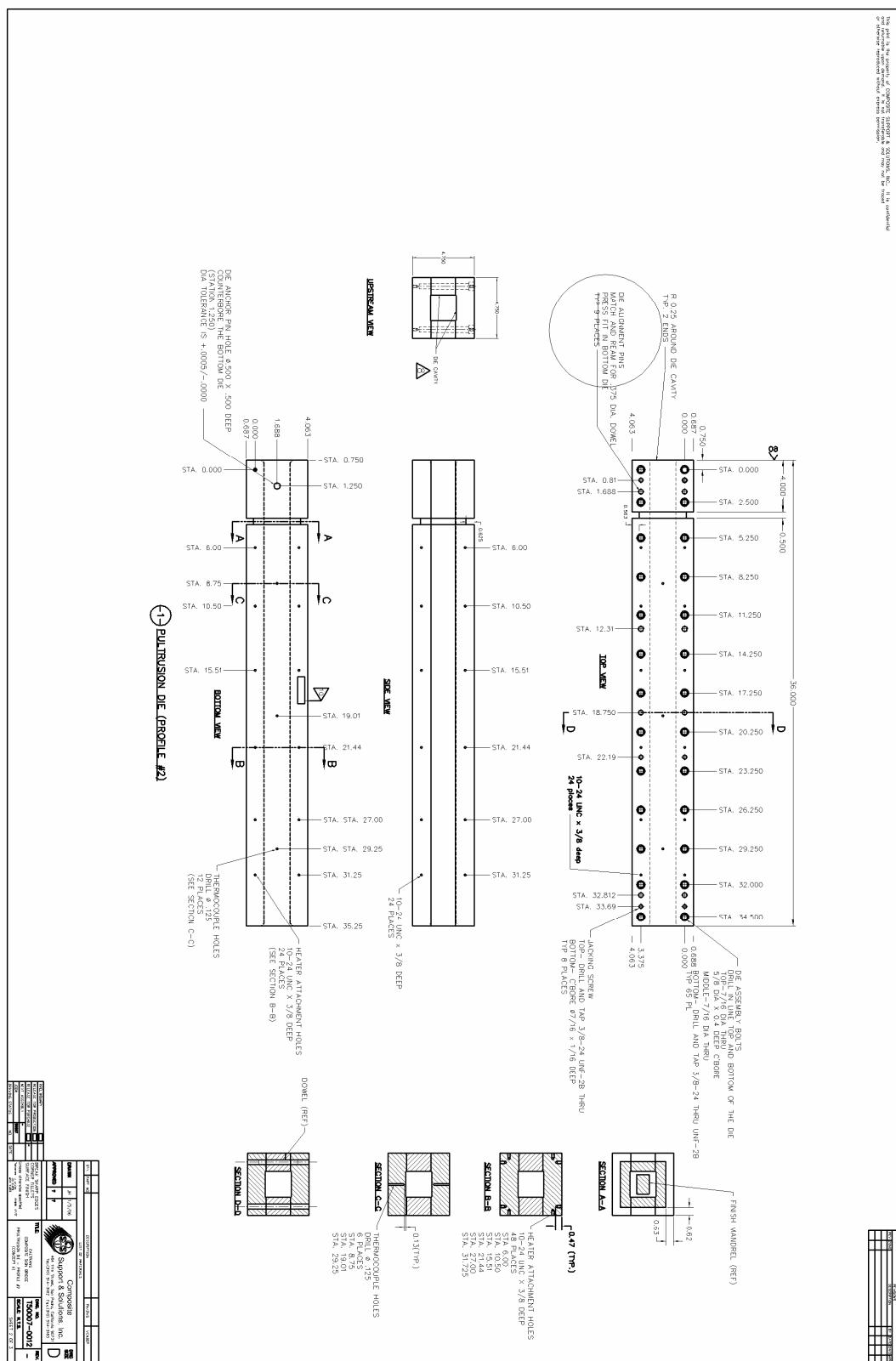
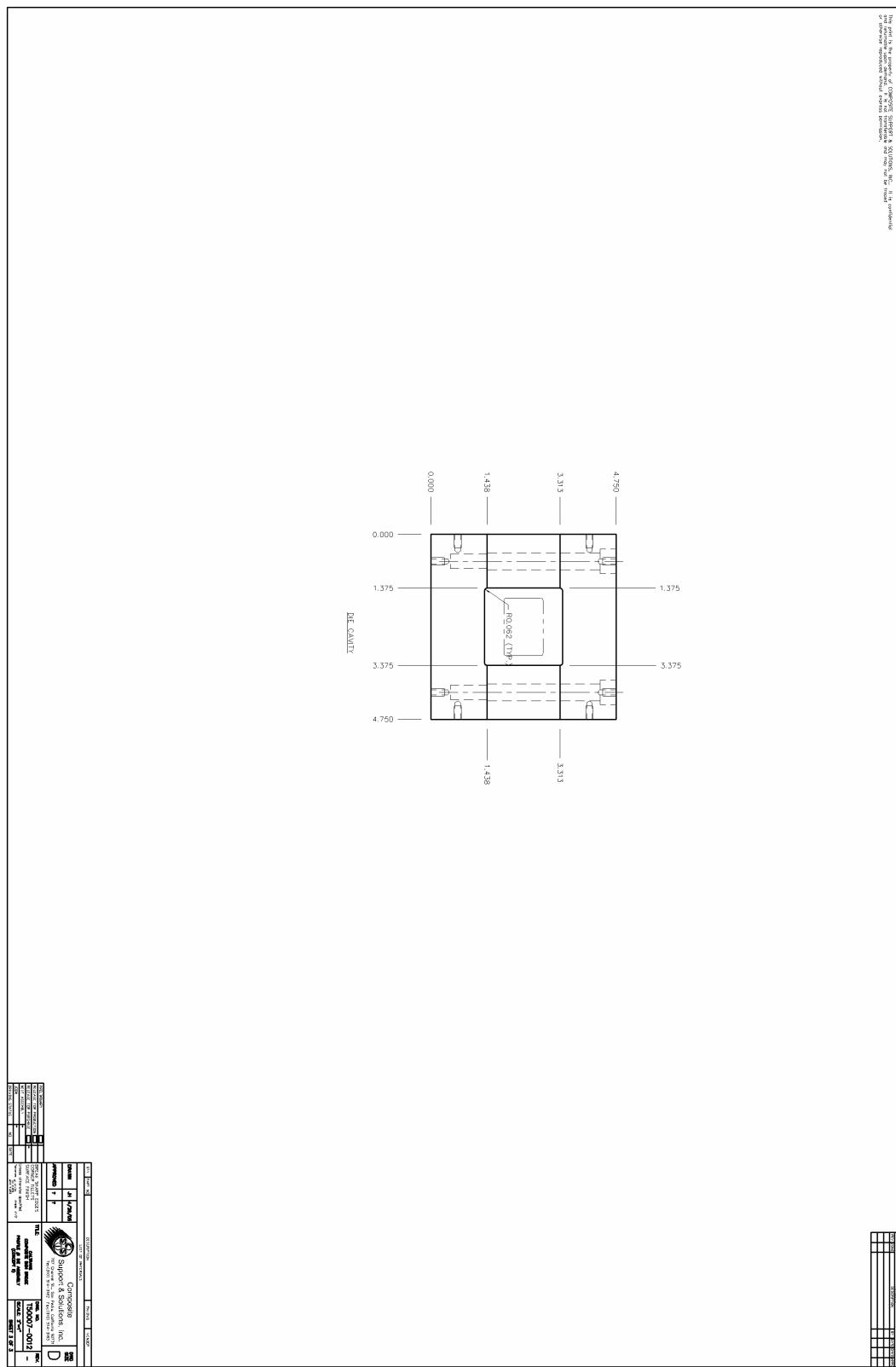P5007-0009-2

P5007-0009-3

NOTES: DIE SPECIFICATION

1. INTERPRET DRAWING PER ANSI Y14.5-1982.
2. MATERIAL 4130, - 4140 OR 4340 OR AIAI-P20. IF 4130, 4140 OR 4340 IS USED, HEAT TREAT TO Rc 32-35 BEFORE MACHINING. IF AIAI-P20 IS USED, HEAT TREAT TO Rc 38-42 BEFORE MACHINING.
3. IF WELDED, ALL WELDS ARE SOLID, CONTINUOUS, NON-POROUS (AIR TIGHT). WELDED PARTS TO BE STRESS RELIEVED AFTER WELDING AND ALL PARTS TO BE PRE HARDENED TO Rc 38-42 BEFORE MACHINING. WELDS INDICATED ARE TO BE AS LONG AS WELDING ACCESS WILL PERMIT.
4. UNLESS OTHERWISE SPECIFIED TOLERANCE   ON .XXX TO BE ±005 NON-ACCUMULATIVE.
5. DIE & MANDREL SURFACE FINISH TO BE 8 MICROINCHES OR BETTER BEFORE PLATING.
6. ALL DIE CAVITY SURFACES AND DIMENSIONS ARE AFTER PLATING AND GRINDING.
7. DIE CAVITY MATING SURFACES ARE TO BE PARALLEL AND/OR PERPENDICULAR TO DATUMS WITHIN .002" OVER ENTIRE SURFACE.
8. -HARD CHROME PLATING ON ALL DIE CAVITY AND MANDREL SURFACES TO BE .0015 - .0025 THICK AFTER GRINDING.
   -REGRIND AND/OR POLISH CHROME SURFACE FINISH TO 8 MICROINCHES OR BETTER.
9. BREAK ALL SHARP EDGES. CHAMFER ALL THREADED HOLES AT MATING SURFACES 45° × .03
10. STAMP TOOL NUMBER AND DETAIL NUMBER IN INDICATED AREA 50007-0009 IN .12 BLOCK LETTERS AS SHOWN.
11. ALL UPSTREAM/DOWNSTREAM (IN AND OUT) DIE RADIUS SHALL BE .25 (STANDARD).
12. ALL DIMENSIONS ARE IN INCHES.

61

P5007-00010

NOTES:
1. ALL PARTS SHALL BE STRESS RELIVE AFTER WELDING.
2. DIMENSIONS SHOWN ARE FINAL INSPECTED DIMENSIONS AFTER MACHINING, PAINTING & PLATING.
3. SURFACE FINISH- CHROME PLATED
4. TAPER AROUND MANDREL START "15" FROM END .015" DROP PER SIDE

THERMOCOUPLE HOLES
DRILL ⌀ .125 X .440 DEEP
(2 PLACES)

.375 -.000/-.003 DRILL THRU
2 PLS

0.000
0.750
1.000
1.250
1.438
2.000

0.000
0.250
1.000

1.750
2.000

1.000

R0.062
TYP.

NOTE:
DXF FILE OF SHAPE
WILL BE PROVIDED.

2.000
1.000
0.000

0.000
0.750
1.750

MATCH AND REAM FOR .375 DIA
DOWEL WITH TRASITION MANDREL
2 PLACES

-1- FINISH MANDREL

MATERIAL FLOW

⚠4 15.00"

.25" RADIUS ALL
AROUND

39.500

TITLE: FINISH MANDREL

Composite
Support & Solutions, Inc.

P5007-00010

SCALE 1:2   SHEET 1 OF 1

D

PULTRUSION DIE ASSEMBLY (PROFILE #2)

UPSTREAM VIEW

MANDREL EXTENSION (REF)

NEARSIDE

FARSIDE

PRELIMINARY

NOTES: DIE SPECIFICATION

1. INTERPRET DRAWING PER ANSI Y14.5-1982.
2. MATERIAL 4130, - 4140 OR 4340 OR AIAI-P20. IF 4130, 4140 OR 4340 IS USED, HEAT TREAT TO Rc 32-35 BEFORE MACHINING. IF AIAI-P20 IS USED, HEAT TREAT TO Rc 38-42 BEFORE MACHINING.
3. IF WELDED, ALL WELDS ARE SOLID, CONTINUOUS, NON-POROUS (AIR TIGHT). WELDED PARTS TO BE STRESS RELIEVED AFTER WELDING AND ALL PARTS TO BE PRE HARDENED TO Rc 38-42 BEFORE MACHINING. WELDS INDICATED ARE TO BE AS LONG AS WELDING ACCESS WILL PERMIT.
4. UNLESS OTHERWISE SPECIFIED TOLERANCE ON .XXX TO BE ±005 NON-ACCUMULATIVE.
5. DIE & MANDREL SURFACE FINISH TO BE 8 MICROINCHES OR BETTER BEFORE PLATING.
6. ALL DIE CAVITY SURFACES AND DIMENSIONS ARE AFTER PLATING AND GRINDING.
7. DIE CAVITY MATING SURFACES ARE TO BE PARALLEL AND/OR PERPENDICULAR TO DATUMS WITHIN .002" OVER ENTIRE SURFACE.
8. HARD CHROME PLATING ON ALL DIE CAVITY AND MANDREL SURFACES TO BE .0015 - .0025 THICK AFTER GRINDING. -REGRIND AND/OR POLISH CHROME SURFACE FINISH TO 8 MICROINCHES OR BETTER.
9. BREAK ALL SHARP EDGES. CHAMFER ALL THREADED HOLES AT MATING SURFACES 45° x .03
10. STAMP TOOL NUMBER AND DETAIL NUMBER IN INDICATED AREA 50007-0012 IN .12 BLOCK LETTERS AS SHOWN.
11. ALL UPSTREAM/DOWNSTREAM (IN AND OUT) DIE RADIUS SHALL BE .25 (STANDARD).
12. ALL DIMENSIONS ARE IN INCHES.

PULTRUSION DIE (PROFILE #2)

UPSTREAM VIEW

TOP VIEW

SIDE VIEW

BOTTOM VIEW

SECTION A-A

SECTION B-B

SECTION C-C

SECTION D-D

DIE CAVITY

R 0.025 AROUND DIE CAVITY
TYP. 2 ENDS

DIE ALIGNMENT PINS
MATCH AND REAM FOR .375 DIA. DOWEL
PRESS FIT IN BOTTOM DIE
TYP. 2 PLACES

DIE ANCHOR PIN HOLE Ø.500 X .500 DEEP
COUNTERBORE THE BOTTOM DIE
(STATION 1.250)
DIA TOLERANCE IS +.0005/-.0000

STA. 0.000
STA. 0.750
STA. 1.250
STA. 6.00
STA. 8.75
STA. 10.50
STA. 15.51
STA. 19.01
STA. 21.44
STA. STA. 27.00
STA. STA. 29.25
STA. 31.25
STA. 35.25

STA. 0.000
STA. 0.81
STA. 1.688
STA. 2.500
STA. 5.250
STA. 8.250
STA. 11.250
STA. 12.31
STA. 14.250
STA. 17.250
STA. 18.750
STA. 20.250
STA. 22.19
STA. 23.250
STA. 26.250
STA. 29.250
STA. 32.000
STA. 32.812
STA. 33.69
STA. 34.500

4.063
0.687
0.000
0.750
4.000
0.500
0.563
3.375
4.063
36.000

10-24 UNC x 3/8 deep
24 pieces

DIE ASSEMBLY BOLTS
DRILL IN LINE TOP AND BOTTOM OF THE DIE
TOP-7/16 DIA THRU
5/8 DIA X 0.4 DEEP C'BORE
MODULE-7/16 DIA THRU
BOTTOM- DRILL AND TAP 3/8-24 THRU UNF-2B
TYP. 65 PL

JACKING SCREW
TOP- DRILL AND TAP 3/8-24 UNC-2B THRU
BOTTOM- C'BORE Ø7/16 x 7/16 DEEP
TYP 8 PLACES

0.688 BOTTOM-
0.000 TOP-

THERMOCOUPLE HOLES
DRILL Ø .125
12 PLACES
(SEE SECTION C-C)

HEATER ATTACHMENT HOLES
10-24 UNC X 3/8 DEEP
24 PLACES
(SEE SECTION B-B)

10-24 UNC x 3/8 DEEP
24 PLACES

DOWEL (REF)

THERMOCOUPLE HOLES
DRILL Ø .125
6 PLACES
STA. 6.00
STA. 8.75
STA. 19.01
STA. 27.00
STA. 29.25

Ø.13 (TYP.)

HEATER ATTACHMENT HOLES
10-24 UNC X 3/8 DEEP
48 PLACES
STA. 6.00
STA. 8.75
STA. 10.50
STA. 15.51
STA. 21.44
STA. 27.00
STA. 31.725

FINISH MANDREL (REF)

Ø.47 (TYP.)
0.63
0.62

Composite Support & Solutions, Inc.

T50007-0012

D

DIE CAVITY

0.000
1.438
3.313
4.750

0.000
1.375
3.375
4.750

1.375
3.375

1.438
3.313

R0.062 (TYP)

UPSTREAM VIEW

.375 +.003/-.000 DRILL THRU
2 PLS

1.000
0.50
0.000

0.000
0.28
1.500
1.22

R0.062
TYP

NOTE:
DXF FILE OF SHAPE
WILL BE PROVIDED

NOTES

THERMOCOUPLE HOLE
DRILL ø .125 X .440 DEEP

SIDE VIEW

1.000
0.750
0.250
0.000

0.000
2.500

39.500

1.500
0.750
0.000

0.000
0.750
1.750

MATCH AND REAM FOR .375 DIA.
DOWEL WITH TRACTION MANDREL
2 PLACES

MATERIAL FLOW

15.00"

⟨4⟩

—1— FINISH MANDREL

NOTES:
1. ALL PARTS SHALL BE STRESS RELIVE AFTER WELDING.
2. DIMENSIONS SHOWN ARE FINAL INSPECTED DIMENSIONS AFTER MACHINING, PAINTING & PLATING.
3. SURFACE FINISH—CHROME PLATED.
4. TAPER AROUND MANDREL, START 15" FROM END, .015" DROP PER SIDE

Composite Support & Solutions, Inc.

TITLE: FINISH MANDREL

P5007-0013

P5007-0014

DIE SUPPORT BAR

-1-

PRELIMINARY

Dimensions and annotations visible on drawing:
- 3.75
- 1.500
- 0.000
- 0.25
- 0.000
- 0.570
- 1.70
- 1.750
- 3.73
- Ø0.531 HOLE 2 PLACES
- Ø2.25 COUNTER BORE 2 PLACES
- 20.500 (REF)
- 20.27
- 22.250
- 24.00
- 1.500
- 0.8500
- 12.000
- DIE ANCHOR PIN HOLE Ø.500 X .500 DEEP DIA TOLERANCE IS +.0005/-.0000
- 24.000
- 1.70

Composite Support & Solutions, Inc.

DIE SUPPORT BAR

P5007-0014

DOWNSTREAM TRACK

UPSTREAM TRACK

PRELIMINARY

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MATERIAL LEGEND

MAT. TYPE	REINFORCEMENT	COMPOSITION WEIGHT % ORIENTATION	WEIGHT (gr/m^2)	WEIGHT (oz/yd^2)	INFORMATION (VENDER / STYLE)
A	VEIL	-	100	1	2014 REEMAY
B	MAT	CONTINUOUS	305	9.0	1 OZ/FT2 REEMAY
C	0/WOVEN(0/90)	50/25/25	1054	31.1	A130/ MR 18 7X5

NOTE: MR18-7X5 CAN BE REPLACED WITH E-LT 1800-7

PLY SCHEDULE LEGEND

RESIN INFORMATION
RESIN MANUFACTURER: DOW
NAME: DERAKANE MOMENTUM 640-900 (VINYLESTER)

PLY #	QTY.	MAT. TYPE	ORIENTATION	NET WIDTH (in.)	113 YIELD	250 YIELD	110 YIELD (EP620 (BULKED)	SUITED MAT. NECK DOWN FACTOR
1	1	A	VEIL	14.99				15.75
2	1	B	MAT	14.83				15.75
3	2	C	0/WOVEN	9.45				8.7
4	1	C	0/WOVEN	11.72				12.0
5	1	C	0/WOVEN	11.70				12.0
6	1	C	0/WOVEN	11.75				12.0
7	1	C	0/WOVEN	11.71				12.0
8	1	C	0/WOVEN	11.69				12.0
9	2	C	0/WOVEN	11.64				12.0
10	1	C	0/WOVEN	4.69				4.8
11	1	C	0/WOVEN	6.72				7.0
12	1	C	0/WOVEN	6.48				7.0
13	2	B	0/WOVEN	9.18				9.4
14	2	A	MAT	8.67				9.67
15	4	C	VEIL	2.19				2.3
16	1	C	0/WOVEN	6.87				7.0
17	1	C	0/WOVEN	7.05				7.25
18	1	C	0/WOVEN	7.01				7.25
19	1	C	0/WOVEN	7.16				7.25
20	1	C	0/WOVEN	6.68				7.0
21	1	C	0/WOVEN	6.92		1		7.0

PLY #	QTY.	MAT. TYPE	AREA (in2)	113 YIELD	250 YIELD	110 YIELD
30	2	ROVING	.063	11	14	
31	1	ROVING	.082		16	
32	1	ROVING	.089			
33	2	ROVING	.005			

PROFILE #1 – VERTICAL MEMBER
(UPSTREAM VIEW)

2.750 (REF)

0.250

0.375 (REF)

0.500

5.125 (REF)

0.375 (REF)

R0.063

R0.438

VEIL/MAT./0/(90-0)......(0-90)/0/MAT/VEIL

NOTES:
1. RESIN: RESIN SPECIFIC GRAVITY = 1.12
2. GLASS: GLASS SPECIFIC GRAVITY = 2.62
3. WEIGHT RATIO:
   GLASS = 66.1 %
   RESIN = 33.9 %
4. CROSS SECTIONAL AREA: = 6.44 SQ. IN.
5. LAMINATE DENSITY: = .065 (lb/in^3)
6. TOTAL WEIGHT = 5.0 lbs/FT

PRELIMINARY

EFFECTIVE ON / SERIAL NUMBER
REVISIONS
DESCRIPTION BY DATE

T5007-0017

WET-OUT TANK WELDMENT

71

P5007-0020

72

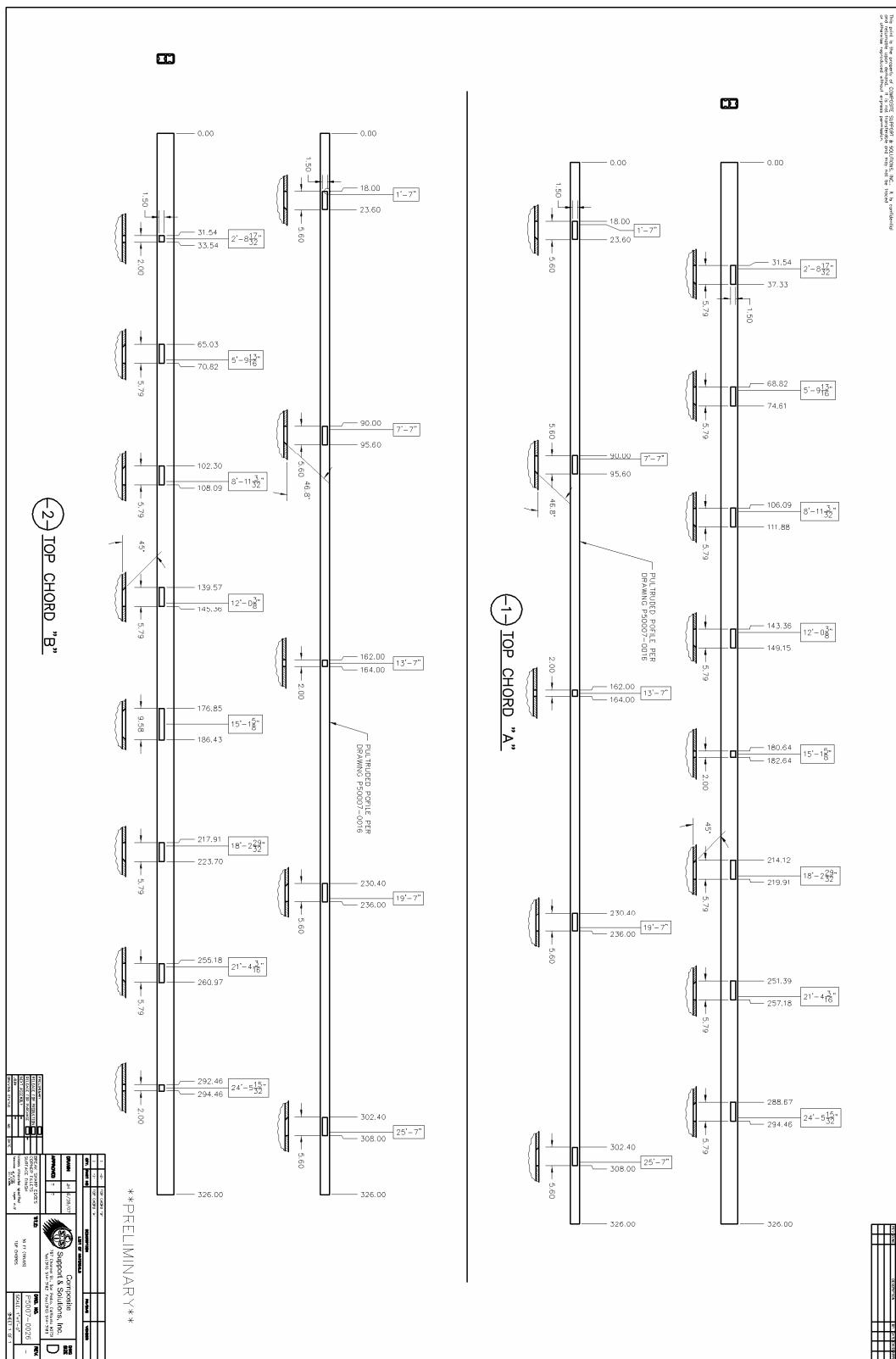P5007-0021

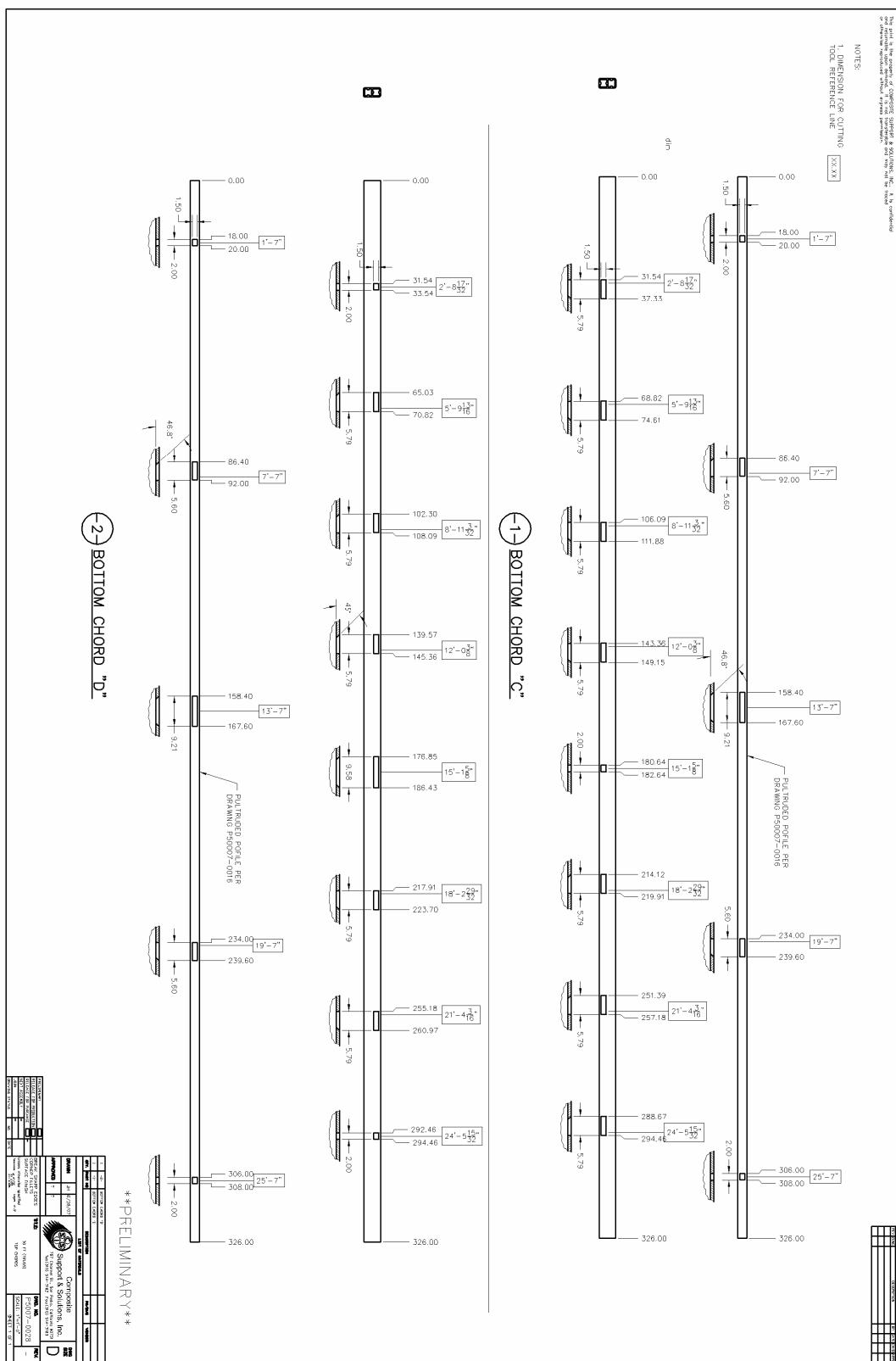*** COMPOSITE SUPPORT & SOLUTIONS INC. CONFIDENTIAL ***

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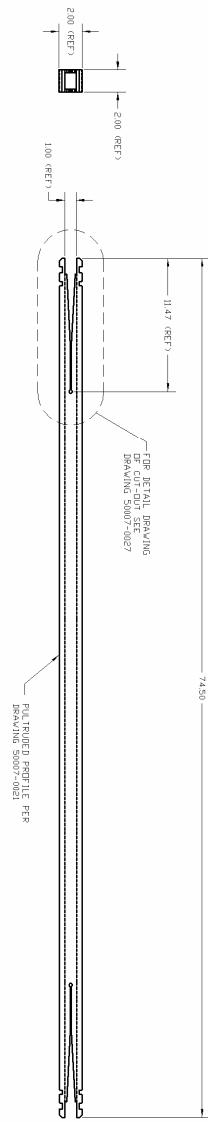
MATERIAL LEGEND

MAT. TYPE	REINFORCEMENT	COMPOSITION WEIGHT % ORIENTATION	WEIGHT (gr/m^2)	WEIGHT (oz/yd^2)	INFORMATION (VENDER / STYLE)
A	VEIL	100	-	1	2014 REEMAY
B	MAT	CONTINUOUS	305	9.0	1 OZ/FT2 MAT
C	0/WOVEN(0/90)	50/25/25	1054	31.1	A130/ MR 18 7X5

NOTE: WR18-7X5 CAN BE REPLACED WITH E-LT 1800-7

NOTE:
2014 REEMAY THICKNESS = 0.005"
A130A THICKNESS = 0.014"
WR18 THICKNESS = 0.019"
1 OZ/FT2 MAT THICKNESS = 0.022"
E-LTM 1808-7 THICKNESS=0.019"

PROFILE #2 – HORIZONTAL/DIAGONAL MEMBER (UPSTREAM VIEW)

NEARSIDE

2.000 (REF)
0.500
2.000 (REF)
0.231

VEIL/0/0/(90-0)....(0-90)/0/MAT/VEIL

9 8 7 6 5 4 3 2 1

NOTES:
1. RESIN: RESIN SPECIFIC GRAVITY = 1.12
2. GLASS: GLASS SPECIFIC GRAVITY = 2.62
3. WEIGHT RATIO:
   GLASS = 62.8 %
   RESIN = 37.2 %
4. CROSS SECTIONAL AREA: = 2.5 SQ. IN.
5. LAMINATE DENSITY = .062 (lb/in^3)
6. TOTAL WEIGHT = 1.86 lbs/FT

RESIN INFORMATION
RESIN MANUFACTURER: DOW
NAME: DERAKANE MOMENTUM 640-900 (VINYLESTER)

PLY SCHEDULE LEGEND

PLY#	MAT. TASK	QTY.	MAT. TYPE	ORIENTATION	NET WIDTH (in.)	SUITED MAT. NECK DOWN FACTOR
1		1	A	VEIL	8.83	9.0
2		1	C	MAT	8.83	9.0
3		2	C	0/WOVEN	2.0	2.0
4		2	C	0/WOVEN	2.0	2.0
5		2	C	0/WOVEN	2.0	2.0
6		2	C	0/WOVEN	12.91	13.0
7		2	C	0/WOVEN	13.79	14.0
8		1	B	MAT	6.15	6.25
9		1	A	VEIL	6.15	6.25

ELA-1312-7 (ref)

PLY#	QTY.	MAT. TYPE (in2)	AREA	NUMBER OF ENDS
20	?	?	113 YIELD	250 YIELD	110 YIELD (EPR620 (BULKED))

PRELIMINARY

PRELIMINARY		
RELEASE FOR PRODUCTION		
RELEASE FOR PURCHASE		
NEXT ASSEMBLY		
DRAWING STATUS	NO.	DATE

DRAWN | JH | 9-15-04
APPROVED |

BREAK SHARP EDGES
CORNER FILLETS
SURFACE FINISH
Unless otherwise specified

TITLE:
CALTRANS
COMPOSITE SIGN BRIDGE
PLY-SCHEDULE FOR PROFILE #2
(CONCEPT II)

CSS
Composite
Support & Solutions, Inc.
464 11th Street, San Pedro, California 90731
Tel.(310) 514-3182 Fax.(310) 514-3183

DWG. NO. P50007-0021
SCALE: 1/2"=1'-0"   SHEET 1 OF 1   REV. -
DWG SIZE D

ANCHOR BASE (PROFILE 2)

8.00

6.00 (REF)

8.00 (REF)

1/2" DIA. THRU
(MATCH LOACTION
WITH FRAME A.T
ASSEMBLY)

0.50(REF)

3.19

0.63

24.00

1/2

1/4

6.00

1.00

2.00

Ø0.62

6.00 (REF)

1.50

2.50

8.00

PRELIMINARY

Composite
Support & Solutions, Inc.

ANCHOR BASE FOR PROFILE #2

P5007-0023

NOTES:
1. ALL DIMENSIONS ARE IN INCHES.

24' SPAN BRIDGE ASSEMBLY

FRONT VIEW

TOP VIEW

SIDE VIEW

ISOMETRIC VIEW

STEEL POST (REF)

STEEL POST (REF)

(OVERHEAD TRUSS ASSEMBLY LENGTH)

PRELIMINARY

Composite Support & Solutions, Inc.

TOP VIEW

36.02 (REF)

FRONT VIEW

79.56 (REF)

326.00 (REF)

BOTTOM VIEW

ISOMETRIC VIEW

SIDE VIEW

OVERHEAD TRUSS ASSEMBLY
MAT'L: COMPOSITE
WEIGHT: 3515 LBS

PRELIMINARY

Composite Support & Solutions, Inc.

P5007-0026

PRELIMINARY

TOP CHORD "A"

TOP CHORD "B"

P5007-0028

78

2.00 (REF)

2.00 (REF)

1.00 (REF)

11.47 (REF)

74.50

FOR DETAIL DRAWING
OF CUT-OUT SEE
DRAWING 5007-0027

PULTRUDED PROFILE PER
DRAWING 5007-0021

-1- VERTICAL

PRELIMINARY

Composite
Support & Solutions, Inc.

P5007-0029

D

SHEET 1 OF 1

NOTES:
1. ALL DIMENSIONS ARE IN INCHES.

FRONT VIEW

80.00

648.0

STEEL POST
(REF)

STEEL POST
(REF)

-1-

54' SPAN BRIDGE ASSEMBLY

TOP VIEW

686.0
(OVERHEAD TRUSS ASSEMBLY LENGTH)

36.0

SIDE VIEW

36.0

PRELIMINARY

ISOMETRIC VIEW

Composite
Support & Solutions, Inc.

P5007-0032

P5007-0033

OVERHEAD TRUSS ASSEMBLY
MAT'L: COMPOSITE
WEIGHT: 2166 lbs

PRELIMINARY

83

NOTES:
1. ALL PARTS SHALL BE STRESS RELIEVE AFTER WELDING
2. DIMENSIONS SHOWN ARE FINAL INSPECTED DIMENSIONS AFTER MACHINING, PAINTING & PLATING.

MATCH & DRILL WITH PART # T5007-0010-1

UPSTREAM VIEW

SECTION A-A

SECTION B-B

SECTION C-C

SECTION D-D

ROUGH MANDREL "TYPE C" -FARSIDE

MAT: ALUMINUM

1 B.O.

2.5

2.0

0.000

2.0

6.0

8.0 (REF)

R0.062

233.84 (REF)

144.59 (REF)

2.500

0.750

SLOT TO MATCH FINISH
MANDREL

1/8

TRANSITION LENGTH

89.25

91.25

Ø.375 HOLES
IN LINE (2) PLACES
MACTIH & DRILL
W/ PART#T5007-0010-1

1.000

0.75

235.84

0.00

DOWNSTREAM VIEW

Composite
Support & Solutions, Inc.

TITLE:
ROUGH MANDREL

P5007-1114

SHEET 1 OF 1

D

WELDMENT DRAWING

FLAT BAR 3/4" x 5/8", LENGTH=231.34"

FLAT BAR 2 1/4" x 3/4", LENGTH=233.84"

FINISH PART OUTLINE

TYP.

1/4

SECTION B-B
(MACHINING DRAWING)

1.000
2.000
0.125
0.869
0.566
2.000
R1/4
R5/32
R1/16

SECTION C-C
(MACHINING DRAWING)

2.000
0.625
0.250
0.500
0.750
0.750
2.000
R1/16
R1/16

PRELIMINARY

Composite Support & Solutions, Inc.

P5007-0115-1

ROUGH MANDREL "TYPE C" —FARSIDE

NOTES:
1. ALL PARTS SHALL BE STRESS RELIEVE AFTER WELDING
2. DIMENSIONS SHOWN ARE FINAL INSPECTED DIMENSIONS AFTER MACHINING, PAINTING & PLATING.

86

WELDMENT DRAWING

FLAT BAR 3/4" x 5/8", LENGTH=231.34"

FLAT BAR 2 1/4" x 3/4", LENGTH=233.84"

FINISH PART OUTLINE

1/4 TYP.

SECTION B-B
(MACHINING DRAWING)

2.000
2.000
0.869
0.566
R 1/4
R 1/32
R 1/16

SECTION C-C
(MACHINING DRAWING)

2.000
2.000
0.750
0.500
0.250
0.625
0.750
R 1/16
R 1/16

PRELIMINARY

Composite
Support & Solutions, Inc.

5000P-1115

SHEET 2 OF 2

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update w/ notes

PROFILE #4 – LOCK
(UPSTREAM VIEW)

2.34 (REF)

4.85 (REF)

0.231

SYM

1 –113 yd

1 –113 yd

1 2 3 2 3 2 3 2 3 2 3 2 3 2 3 2 3 2 3 2 3 2 1
VEIL/MAT/0/MAT/0/0/0/MAT/0/MAT/0/MAT/VEIL

MATERIAL LEGEND

MAT. TYPE	REINFORCEMENT	COMPOSITION WEIGHT % ORIENTATION	WEIGHT (gr/m^2)	WEIGHT (oz/yd^2)	INFORMATION (VENDER / STYLE)
A	VEIL	100	-	1	2014 REEMAY
B	MAT	CONTINUOUS	305	9.0	1 OZ/FT2 MAT
C	0	100%	-	13.0	A130

NOTES:

RESIN INFORMATION
RESIN MANUFACTURER: DOW
NAME: DERAKANE MOMENTUM 640-900 (VINYLESTER)

PLY SCHEDULE LEGEND

PLY# TASK	QTY.	MAT. TYPE	ORIENTATION	NET WIDTH (in.)	SUITED MAT. NECK DOWN FACTOR
1	1	A	VEIL	12.0	?
2	1	B	MAT	10.6	?
3	2	C	0	10.6	?

PLY#	QTY.	MAT. TYPE	AREA (in2)	NUMBER OF ENDS			
				113 YIELD	250 YIELD	110 YIELD (EP620 (BULKED)	
20	2	ROVING	.040	9			

PRELIMINARY*

TITLE:
STRUCTURAL MEMBERS FOR TALL STRUCTURES (DOD–PD4–2BT)
LIGHT DUTY COMPOSITE TOWER
LOCK PROFILE & PLY SCHEDULE

DWG. NO. P50009–1004 REV. A

SCALE: NTS SHEET 1 OF 1

DWG SIZE D

DRAWN JH 9–15–04
APPROVED

BREAK SHARP EDGES
CORNER FILLETS
SURFACE FINISH
Unless otherwise specified

PRELIMINARY
RELEASE FOR PRODUCTION
RELEASE FOR PURCHASE
NEXT ASSEMBLY
DRAWING STATUS NO. DATE

EFFECTIVE ON SERIAL NUMBER	REV	DESCRIPTION	BY	DATE
	A	CHANGED LAY-UP	JH	7/19/07

REVISIONS

DOWN STREAM VIEW

SIDE VIEW

SIDE VIEW

TOP VIEW

PULTRUDER

PULTRUDER

.000 (CENTER LINE OF GUIDANCE TOOLING)

SECTION A-A

SECTION B-B

Composite
Support & Solutions, Inc.

-1- LOCK

PRELIMINARY

Composite
Support & Solutions, Inc.
444 11th Street, San Pedro, California 90731
Tel.(310) 514-3182   Fax.(310) 514-3183

TITLE: STRUCTURAL MEMBERS FOR TALL STRUCTURES (DOD-AF04-287) LIGHT DUTY COMPOSITE TOWER LOCK PROFILE

DWG. NO. P50009-1112

SCALE: NTS   SHEET 1 OF 1

DWG SIZE B   REV. -

PULTRUSION DIE (PROFILE #4)

UPSTREAM VIEW

DIE CAVITY

BOTTOM VIEW

SIDE VIEW

TOP VIEW

SECTION A-A

SECTION B-B

SECTION C-C

SECTION D-D

DOWEL (REF)

R 0.025 AROUND DIE CAVITY
TYP 2 ENDS

DIE ALIGNMENT PINS
MATCH AND REAM FOR .375 DIA. DOWEL
PRESS FIT IN BOTTOM DIE
TYP 9 PLACES

DIE ANCHOR PIN HOLE ø.500 X .500 DEEP
COUNTERBORE THE BOTTOM DIE
(STATION 1.250)
DIA. TOLERANCE IS + 0.0005/- 0.0000

DIE ASSEMBLY BOLTS
DRILL IN LINE TOP AND BOTTOM OF THE DIE
TOP—7/16 DIA THRU
MIDDLE—7/16 DIA THRU
BOTTOM— C'BORE ø7/16 x 3/4 DEEP
5/8 DIA X 3/4 C'BORE
DRILL AND TAP 3/8-24 THRU UNF-2B
TYP 85 PL

JACKING SCREW
TOP—DRILL AND TAP 3/8-24 UNF-2B THRU
BOTTOM— C'BORE ø7/16 : 1/16 DEEP
TYP 8 PLACES

HEATER ATTACHMENT HOLES
10-24 UNC X 3/8 DEEP
24 PLACES
(SEE SECTION B-B)

THERMOCOUPLE HOLES
DRILL ø .125
12 PLACES
(SEE SECTION C-C)

STA. 0.000
STA. 0.750
STA. 1.250
STA. 5.75
STA. 8.75
STA. 12.25
STA. 15.51
STA. 19.01
STA. 22.01
STA. 26.25
STA. 29.25
STA. 32.75
STA. 35.250

STA. 0.000
STA. 2.500
STA. 5.250
STA. 8.250
STA. 11.250
STA. 14.250
STA. 17.250
STA. 20.250
STA. 23.250
STA. 26.250
STA. 29.250
STA. 32.000
STA. 34.500

STA. 0.812
STA. 1.688
STA. 12.312
STA. 18.750
STA. 22.188
STA. 32.812
STA. 33.688

10-24 UNC x 3/8 DEEP
24 PLACES

HEATER ATTACHMENT HOLES
10-24 UNC X 3/8 DEEP
24 PLACES
STA. 5.75
STA. 8.75
STA. 12.25
STA. 15.51
STA. 22.01
STA. 26.25
STA. 32.75

THERMOCOUPLE HOLES
DRILL ø .125
12 PLACES
STA. 8.75
STA. 19.01
STA. 29.25

0.15 (TYP.)
0.47 (TYP.)
0.56
0.59

NOTES
1. ALL PARTS SHALL BE STRESS RELIEVE AFTER WELDING
2. ALL DIMENSIONS SHOWN ARE FINAL INSPECTED DIMENSIONS AFTER MACHINING, PAINTING & PLATING
3. SURFACE FINISH —
4. TAPER AROUND MANDREL, START 15" FROM END .005" DROP PER SIDE