Super Lightweight Bridge-Building Contest

by

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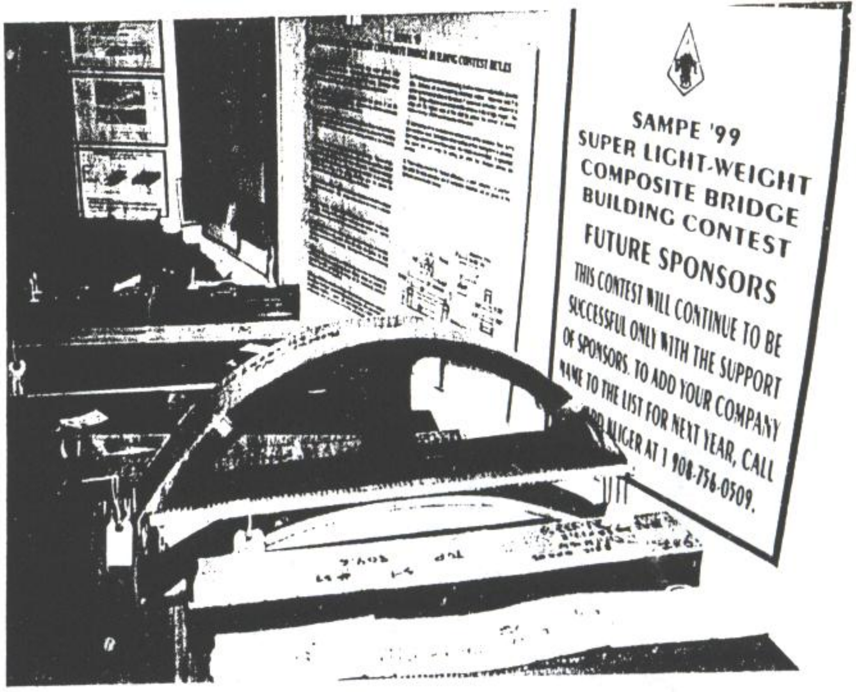


The second annual, super lightweight bridge competition was held at the 44th SAMPE Exhibition on May 25, 1999. Fifty-three teams registered and forty-three teams submitted bridges for testing, a 35 percent increase over the 1998 contest.

The full contest rules were published in the Jan-Feb 1999 issue of the SAMPE Journal. This year's contest was similar to the contest held last year — build a 24" long, 4" wide composite bridge with the winning entry having the highest ratio of ultimate load to bridge weight. The big difference this year was that the bridges were first subjected to a vertical impact, the so-called slow, cold meteor test. Also, all of the bridges were sonically scanned to insure that no hard spots or localized reinforcement were concealed within the structure.

There were four different classifications based on (1) use of materials (either limited to materials supplied in the kit or unlimited use of any materials the contestants could get their hands on) and (2) professional or student status. Awards were given for highest load to weight ratio and also for "most innovative design."

The first place winners in the professional class included Karl Gillette and Bruce Powell of Edge Structural Composites and Greg Paulson and Ian Fernandez of NASA Ames Research Center. Two teams from the University of Washington grabbed the first place prizes in both student classes. These teams consisted of Eric Oates, Marnie Huller, Carolyn Nyugon, Fuli Chavez, Ondre Sneed, Kurt Batson, Carl Bruce and Matt Tillman.

Brandt Goldsworthy, Clem Heil, and Kent Montgomery judged the innovation awards. Winners were Stan Stawski of Scaled Composites for the professional class and the Western Washington University team of Ryan Hauge, Kirk Desler and Cory Jenkins for the student class.

Prizes consisted of an assortment of composite tennis racquets, fishing rods, hockey sticks and baseball bats. We also gave away $1250 in prize money which was mostly donated by sponsors but also resulted from a small balance of funds after all contest related expenses were paid. Although no direct funds are provided by the SAMPE organization, SAMPE provides space, draped talbes, signs, pre-contest marketing and onsite security at no fee to the committee.

1999 Results below

Some of the winners (and their prizes) are shown in the attached photos:

The actual load testing was performed in the Instron booth at the Exhibition. Sonic inspections were performed at the QMI booth. The actual test results are shown in the charts below. Also load deflection plots were generated for all tests and an example is shown below. All of the data was extracted from Instron's Merlin software and transferred onto an Excel spreadsheet. The bridge designs varied quite a bit, as did their performances. Some of them are shown in the photo.

Professional Grade 1 (kit materials)		Load (kN)	Defl (mm)	Weight (grams)	Efficiency P/w
K.Gillette, B. Powell	Edge Structural Composite	30.8	25.1	1137.5	27.1
Paul, John, James	Charleston AFB	23.0	25.0	971.3	23.7
S. Stawski	Scaled Composite	3.0	17.3	149.4	20.2
Team 1	Texas Composite	10.7	25.1	678.0	15.7
M. Winterhalter	Ashland Chemical	8.1	25.1	711.1	11.4
Henry, Fritz, Steve	Obermeyer Hydro, Inc.	35.8	25.0	3279.4	10.9
Team 2	Texas Composite	2.5	20.9	238.7	10.4
A. Sholer	APS & Assoc.	2.2	25.0	863.9	2.6

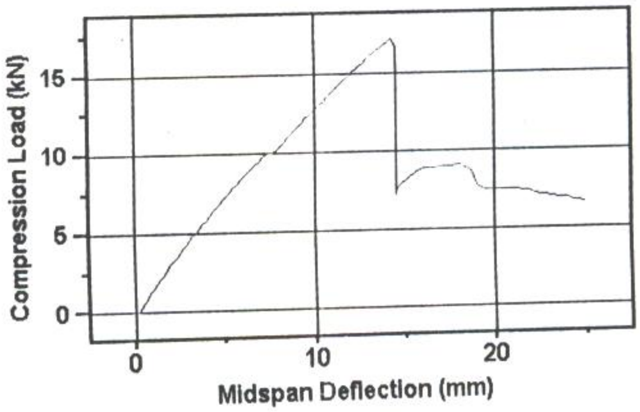
Professional Grade 2 (non-kit materials)		Load (kN)	Defl (mm)	Weight (grams)	Efficiency P/w
G. Paulson, I. Fernandez	NASA Ames	16.0	25.1	314.7	50.8
H. Neubert	PCI	26.9	16.8	723.3	37.2
M. Fenske	NASA Goddard	3.8	25.1	246.2	15.3
Brian, Scott, Dwayne	Hexcel Composites	16.7	25.0	1360.9	12.3
J. Green	Scaled Composites	7.0	25.1	851.5	8.3
S. Stawski	Scaled Composites	1.8	25.0	246.2	7.2
C. Longman	McChord Structural	4.9	25.1	972.4	5.0
C. Kaempen	Kaempen & Assoc.	0.9	25.0	3307.7	0.3

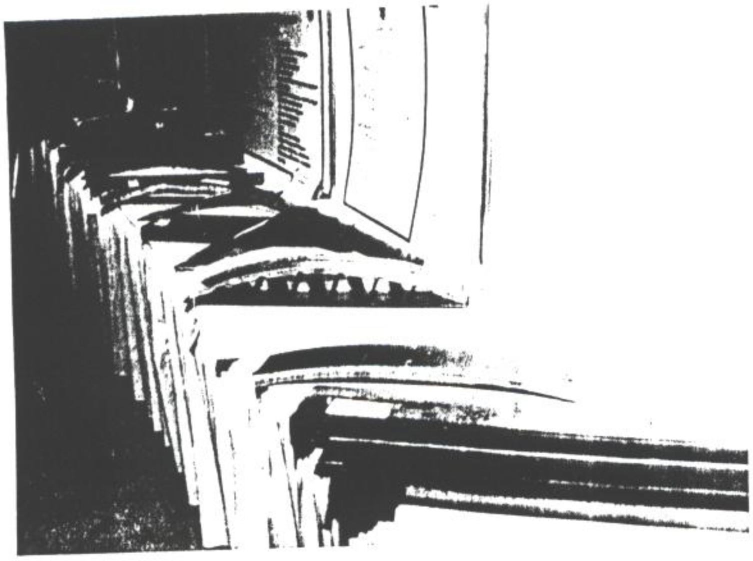
1999

Name	Company	Max Load (kN)	Max Defl (mm)	Bridge Weight (grams)	Bridge Efficiency P/w
Student Grade 1 (kit materials)					
Oates, Huller, Nyugon	University of Washington	17.2	25.0	804.6	21.4
G. Coker	Cerritos College	15.6	17.3	870.9	17.9
Damian, Bob	Cerritos College	11.3	18.9	793.6	14.2
Paul, Brian	Cal Poly SLO	20.6	25.0	1776.0	11.6
MikeB, MikeJ, Darren	Weber State University	9.1	25.1	815.3	11.2
K. Uleck	University of MD	3.3	25.1	329.8	9.9
Pitz 1	Cerritos College	5.3	25.0	654.6	8.1
A. Shahkarami	Univ. of British Columbia	4.6	25.1	712.5	6.4
Garret, James	Cal Poly SLO	9.1	25.1	1567.8	5.8
Chris, David	Cal Poly	5.8	25.1	1039.5	5.5
Coker, Palmer, Gregory	Cerritos College	2.3	25.1	468.1	4.8
E. Ashworth	University Of Nevada	2.0	25.0	509.7	3.9
Kristin, Jen	University of Washington	1.9	25.0	695.0	2.8
R. Scheer	Winona State	0.5	25.1	201.2	2.4
C. Schneider	Winona State	0.4	25.0	238.1	1.6

Name	Company	Max Load (kN)	Max Defl (mm)	Bridge Weight (grams)	Bridge Efficiency P/w
Student Grade 2 (non-kit materials)					
Fuli, Ondiea, Kurt, Malt	University of Washington	58.0	15.8	1081.7	53.6
AA257#1 Class	Stanford University	31.4	15.6	799.9	39.3
Hange, Desler, Jenkins	Western Washington Univ.	16.7	11.4	431.8	38.7
AA257#2 Class	Stanford University	30.8	16.3	851.0	36.2
Eric, Bryan, BJ	Western Washington Univ.	37.5	17.3	1183.0	31.7
K. Uleck	University of Maryland	6.5	21.2	339.8	19.2
Pitz 2	Cerritos College	20.4	25.0	1380.2	14.8
MikeB, MikeJ	Weber State University	10.5	25.0	940.2	11.2
Lori, Mojsiej	Winona State	12.2	25.1	1498.7	8.1
Todd Markins	Winona State	2.7	25.1	516.3	5.2
Eric Hartman	University Of Nevada	3.6	25.0	710.6	5.1
Reid Joel Jeff	University of Washington	3.4	25.0	1050.8	3.3

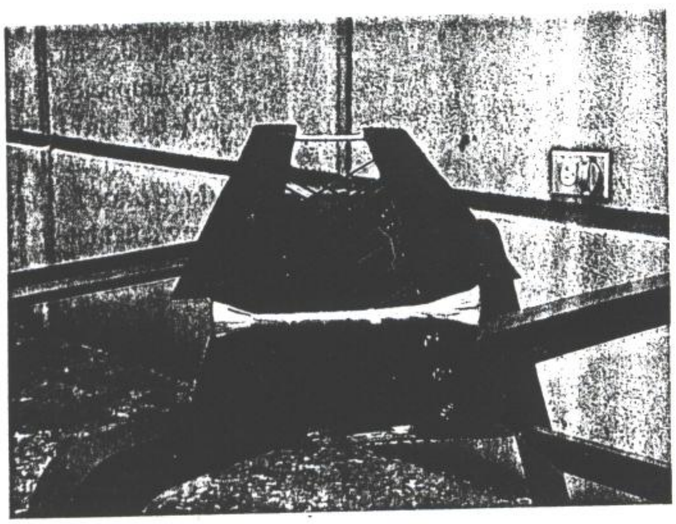
Deflection Diagram for Univ. Washington First Place Finish (Grade 1, kit materials)





We asked a few of the contestants to describe their development efforts. The Western Washington team (most innovative student bridge) provided the following description:

Using a double I-beam configuration, we designed a bridge with the webs of the beams placed directly below the wheels of the loading fixture. Assuming that the bridge would fail due to either compression of the top facing or buckling of the beams, we decided to use only a top facing to hold the two beams together. We felt that to add a bottom facing would add more weight where strength wasn't required. (See photo.)

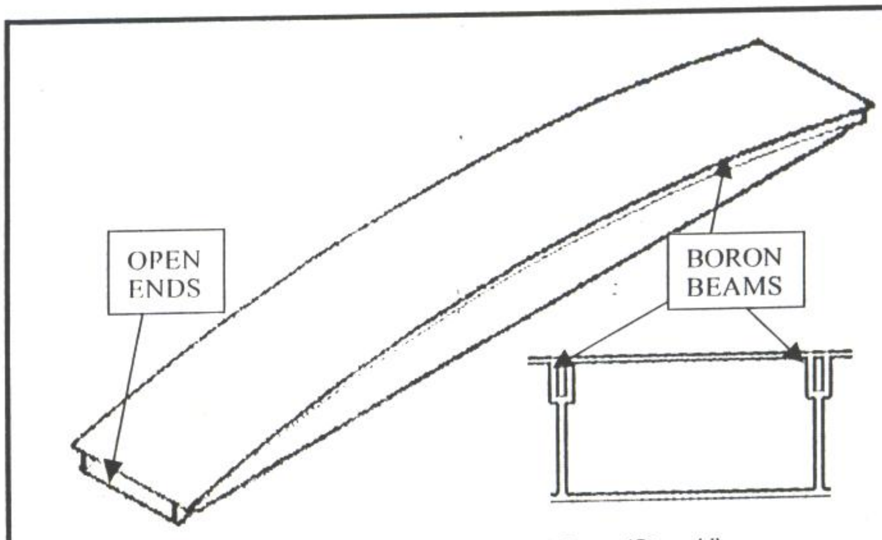


Western Washington bridge.

The first step in the design process was to determine the web and flange dimensions of the I-beams. Assuming a deflection of 1", a maximum load of 2500 lbs, an overall height of 2", and a width of 1", the dimensions of the web and flanges of each beam were calculated using standard bending equations for an isotropic material. After determining the geometry of the beams, we began to design the fabrication process. We decided it would be most efficient to use unidirectional carbon fiber prepreg to construct the I-beams and a portion of the top facing. We made two pairs of rectangular aluminum mandrels that were used to fabricate the I-beams. After coating the mandrels with the necessary mold release, a $[+45/-45]_3$ ply orientation was laid up on each mandrel making a C-shaped laminate. Next, the two pairs of mandrels were mated together to form the two I-beams now having a ply orientation of $[(+45/-45)_3]_s$. These two I-beams were then laid down upon the top facing comprised of a [0/90/0] laminate of unidirectional carbon fiber. Since the beams themselves were comprised of the +45/-45 orientation, we needed some additional tensile strength on the bottom flanges of the I-beams. A 1" strip of a [0/0/90/0/0] laminate of unidirectional carbon fiber was therefore added to the bottom flange of each I-beam. A wood spacer/intensifier was placed between the two inner mandrels and the entire laminate was bagged and cured in the autoclave at 250°F and 75psi. Once the laminate was fully cured, it was removed from the autoclave keeping the mandrels in place. Sandwiching one ply of woven aramid fiber between two plies of unidirectional boron fiber, the three-ply laminate was added to the top facing of the bridge in a wet lay-up operation under vacuum. Once the addition to the top facing had fully cured, the mandrels were removed and the bridge was trimmed to size. In an effort to prevent the beams from caving inward or collapsing to one side, approximately 24 crossbeams were bonded in place between the I-beams using the .080" diameter carbon fiber rods supplied in the kit. To prevent the beams from flaring outward, aramid roving was wrapped around the bottom portion of the web and secured tightly using multiple half hitches.

Stan Stawski (most innovative professional bridge) provided the following insights:

The bridge weighed five ounces and held 685 pounds. This was the lightest bridge in the contest and it still carried significant load. It also won third place for load. Material used to make the bridge was limited to supplied kit or equivalent material. There were at least fifteen different kit materials. Boron tape and graphite fabric were the strongest materials so they were chosen along with epoxy resin, as the materials to make the bridge. The amount of available material included boron unidirectional tape (10" x 25"), graphite plain weave fabric (24" x 24") graphite fabric, and room temperature cure epoxy resin (one quart). It was assumed the bridge was limited to using only the amount of kit material supplied. Using boron and graphite with minimum amount of resin possible, it was determined that the bridge would weigh less than six ounces. This was considerably less than any bridge last year so this was a good starting weight.



Innovative Bridge Showing Cross Section at Mid-Span (Stawski).

Designing the bridge started by creating ideas using boron, graphite, and resin. When designing bridges, the first idea that usually comes to mind is an 'I' beam. Good strength-to-weight ratios are achieved using 'I' beams but innovative thinking went beyond designing the best 'I' beam. Brainstorming lead to a two ply graphite hollow box bridge that was stiffened by two boron beams. Overall height of bridge was 2.0" tapering to 0.5" at the ends. (See Figure.) This was based on a rough estimate that a 2" high, 6 ounce bridge would have a large enough moment of inertia to be competitive. The problem was to make the configuration stable enough to carry large loads since a large moment of inertia does not always prevent buckling.

Boron unidirectional tape was folded to make two, .06" wide, 0.5" high curved beams. These beams carried most of the load and only weighed 0.75 ounces. The ends of the beams supported the bridge while force was applied at midspan. The 0.50" dimension was a height and not a width so that concentrated loads spread through the sides of the bridge. This also reduced the part of the web that was two plies thick to a height of 1.5" high instead of almost 2.0", while increasing web buckling strength. Two plies of graphite fabric formed a box to stabilize the boron beams and create a road surface. The two ply box was very flexible (oil canning) but yet it functioned well. An open bottom box was not used since a closed cross section is typically more stable. All fabric was layed up in 0/90° orientation. The box sides are considered shear webs but the earliest failure mode probably would not be shear if webs were +/-45°. A two ply web, 1.5" high subject to concentrated loads would probably fail in buckling before shear. Using 90° orientation increased the buckling strength. The 0° fibers in the shear web acted as tension fibers that worked well to stabilize the boron beams.

The bridge was made in two cure cycles. The first cycle cured the boron beams and the second cured the graphite box around the boron beams. Typically, one cycle, co-cured parts are lighter and stronger than multi-cure parts. However in this case, it was much easier to get the boron fibers sealed in resin before trying to lay up a graphite box.

Contest rules included an impact prior to loading bridge to failure. Impact damage to the road surface of this bridge would not reduce load capacity since the load was carried by the boron beams. The impactor depressed the road surface approximately 0.5"and then bounced as the road surface returned to its original form without damage. No testing was done prior to the contest. The bridge was made without any calculated load analysis. Weight was the only calculation and load was a wide open guess. The bridge failed in shear at the end of the 0/90° web. As mentioned earlier, if the web was +/-45°, buckling would probably have occurred before shear, reducing failure load.

Hans Neubert, last year's first place professional winner, offered this analysis:

Less than expected load was caused by the fixture load points being off center approximately 0.10" in the span direction from the internal vertical stiffener. My fault, but it was difficult to check with the plexiglass shield in the way. Therefore, the design is load point sensitive, which is not good either. Being off center, the internal vertical pieces were subjected to both compression and a local bending moment. Both internal vertical pieces were pushed over sideways in reaction to the moment.

Hans declined to offer a more detailed description of his design, citing secrecy issues and an expectation of reentering next year with slight modifications to overcome this year's localized bending problems.

It is interesting to note the differing approaches. Hans Neubert spent a considerable portion of his effort in designing and analyzing the structure while Stan Stawski simply conceptualized a solution and built it. Based on the diversity of the SAMPE membership, we expected that. For next year, the contest committee is considering the idea of each contestant predicting their failure load and then awarding a prize based on the best predicted to actual load ratio.

Finally, the support and contributions of the contest sponsors (see list) must be acknowledged. These companies contributed all of the composite materials that went into the kits sent to each team. Also, a number of companies provided composite related items and plain, hard cash, all used as prizes in the contest.

Lastly, special thanks to Terry Creasy, of the LA SAMPE Chapter, for packing and shipping all the kits and organizing the contest bulletin board; to Bob Fogg, of the San Diego SAMPE Chapter, who assisted at the booth and who will be handling the kits next year; and to Frank DaSilva of Instron who supervised the actual testing of the bridges.

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