Session 362S

Pasta Bridge Building Contests

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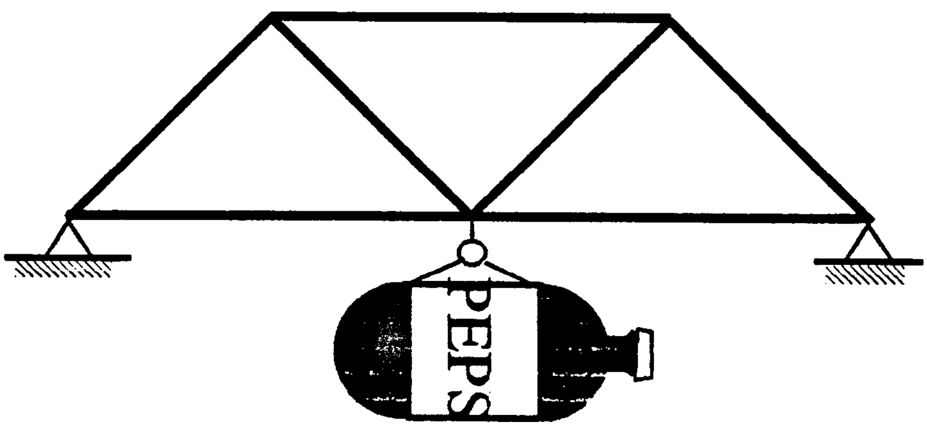
PASTA BRIDGE BUILDING CONTESTS



THE CONCEPT - For over twenty years now, the author has been teaching a course entitled "The Shape of Things". The intent of this course is to present technology as a Liberal Art to non-technology students. During this time, the author has developed various tools and methods with which to break down and simplify engineering principles, without distortion so that they can be understood by the general college population. One such teaching tool, the subject of this paper, is the "Pasta Bridge Contest".

THE EXTENDED TARGET GROUP - Although the author's classes are composed of college students, this concept has been presented to high school and middle school educators who have, in turn, used the bridge builing contest in their classes. The author has also used the "Contest" in Engineering Technology classes at Buffalo State College and m a class of engineering students in Malaysia.. Thus, the range of application of the "Contest" is approximately sixth grade through engineering school.

THE CONTEST - Students are required to design and fabricate a truss bridge to accommodate given load placed at the center of a span. The material is specified as spaghetti, fettucine, bucatini, or any pasta suitable for bridge construction. As in any engineering design, the lightest structure which does the job is the winner.

TEACHING TRUSSES - The basis of the bridge design is the two dimensional truss. Over the years the author has developed and refined a truss teaching system which consists of three pieces of apparatus. The first unit is a demonstrator/testing apparatus which can be used to identify each member of a particular truss as to tension, compression, or redundancy, and to approximate the magnitude of the internal forces or stresses in each member of that truss. Lower level classes can use this apparatus to observe the relationship between the applied load on the truss and the stress in all members. Advanced classes can use the apparatus as an introduction to the concept of stress analysis of the members of a truss, followed by instruction m the use of analytical methods.

The second unit is a model truss m which compression members, identified using the previously described apparatus, can be replaced, one at a time, with pieces of pasta, With this apparatus students can load the truss to the point of failure of each pasta compression member. The lower level students can experiment with various sizes of pasta until they are sure that their final bridge design will not fail. Students in advanced classes can use this apparatus along with the third unit, which will be described shortly, to determine the relationship between the applied load and the stress in each compression member,

Once the stress analysis is completed, it is then necessary to size the members. At this point, the distinction between compression members and tension members and how they fail must be noted. This can be nicely demonstrated with a long piece of pasta, such as spaghetti, which is quite difficult to pull apart by hand, but will bow easily and break under hand applied compression.

The relationship between the length of a compression member and the force required to cause it to fail can be determined by using the third unit, "the Pasta Compression Tester". With this apparatus, various lengths of pasta are loaded to the point of failure and the results are tabulated and plotted. A force vs. length plot will yield a typical Euler curve. However, a more useful plot is that of force vs. 100/length squared. his plot invariably yields a straight line, which proves Euler and, when the equation of the curve is determined, a table of length and corresponding load can be developed for each pasta under consideration Thus, it is possible to determine the force carried by a compression member by loading the model truss to the point of failure of the member m question. Knowing the length of that member and the Euler equation for that type of pasta yields the compression failure force and, therefore, the force being carried by that member at that particular applied load. Thus, the stress in all of the compression members for any given loading can be do termined experimentally.

Since the failure force, or stress, in a tension member is not a function of length, a simple tension test can be performed by hanging a piece of pasta by a string glued at one end. A string is glued to the other end and fitted with a hook to accommodate a series of weights. Weights are then added until the pasta fails. By using pastas of different cross sections, it is possible to demonstrate the concepts of unit stress and ultimate strength with this simple testing procedure.

BRIDGE CONSTRUCTION - After the design has been decided upon and all of the members have been selected, the bridge can be built using model airlplane building techniques as follows. Two identical trusses are hayed out over a full size plan which is covered with waxed paper. Socket joints are made at each intersection with a glob of quick drying glue. The identical pair of tresses are then connected with a lattice structure such that the trusses are either parallel, forming a rectangular end view or directly connected at the top, forming a triangle when viewed from the end,

SOME TEST DATA - As was stated earlier, the compression tester can be used to prove the Euler equation. The following is a typical test result obtained by testing the pasta known as **bucatini:**

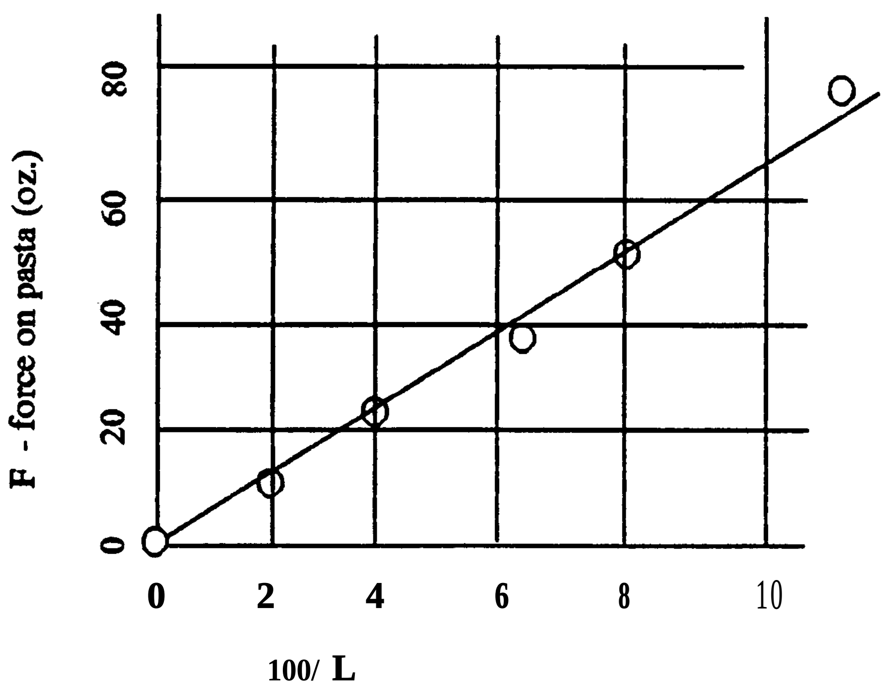
Compression Test of Bucatini (by DAVINCI)

-- Performed in ENT 301, Mechanics 1, section no. 1364- 10/24/95

DATA

L (in.)	F (oz.)	100/L sq.	x	y	x sq.	xy	
infinite	0	0	0	0	0	0	(assumed data)
7	12	2.04	2.04	12	4.16	24.48	.
5	23	4	4	23	16	92	
4	37	6.25	6.25	37	39.06	231.25	
3.5	52	8.16	8.16	52	66.59	424.32	
3	76	11.11	11.11	76	123.20	844.36	
				sums	249.01	1616.41	

Best fit: F vs. 100/L sq - straight line with y intercept of zero and a slope of 1616/249 = 6.49



The experimentally determined function is: F = 649/L sq.

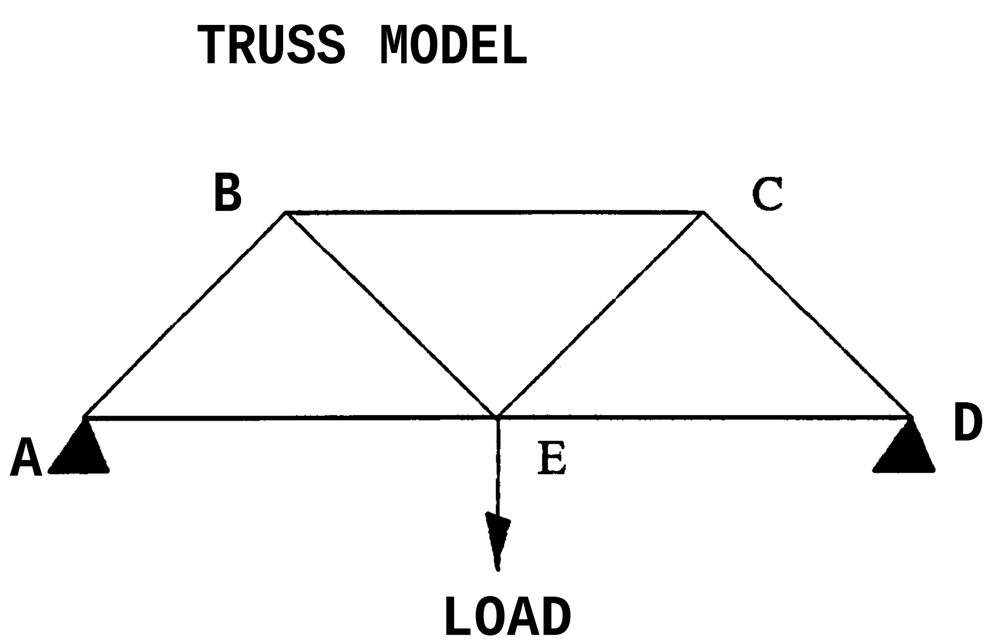
USING COMPRESSION TEST DATA - After **proving Euler with the pasta compression test, a pasta strength table, such as the one shown below, can be produced by plugging a progression of lengths rnto the experimental equation (F = 649/L sq.).**

Bucatini Table

Length (in.)	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**.8**	**9**
Strength (oz.)	**72.1**	**53.0**	**40.6**	**32.0**	**26.0**	**21.5**	**18.0**	**1504**	**13.2**	**11.5**	**10.1**	**9.0**

By performing similar tests the author has found pasta constants of 156 for #9 spaghetti, and 82 for #11 spaghetti. It should be noted that the author has discovered that the pasta constant can vary from manufacturer to manufacturer and from box to box. Also, the age of the pasta can effect the pasta constant. For these reasons it is advised that the pastas to be used for the contest be issued by the instructor and tested as close to the date of the contest as possible.

USING THE TRUSS MODEL - In the truss model shown below, the compression members A-B and B-C can be replaced by a piece of pasta of the same length. When the member B-C was **replaced,** in a recent **demonstration,** by **an** 8 **3/8 inch length of bucatini, the**



The truss model consists of three 45 degree right triangles.

load, placed at point E, required to cause it to fail was 7 ounces. To compensate for the amount of stress in the member owing to the weight of the structure, the member B-C was removed and a spring scale was attached at point E such that the structure was supported by the external supports and the spring scale. The force indicated on the spring scale was 1.75 ounces. It can be assumed that the weight of the structure behaves like an additional concentrated load of 1.75 ounces at point E and thus, the stress in the member at failure was caused by the equivalent of an externally applied load of 7 + 1.75 = 8.75 ounces (8.8 or 9 ounces rounded off to a more

reasonable number of significant digits). Using the equation obtained from the compression test, the stress m the 8 3/8 inch bucatini at failure was 649/ (8.375 sq.) = 9.25 ounces. Thus, an externally applied load of about 9 ounces causes a stress of about 9 ounces in the member B-C. An analytical solution such as method of joints yields the same results.

CONTEST RESULTS - The **all-time record for efficient truss bridge design was a structure made of #9 spaghetti weighing only 17 grams which held a 2 liter bottle of Pepsi (2000 grams) at the center of a 16 inch spare In contests where the span is 24 inches and the load is a 3 liter bottle of soda, typical successful structures weigh anywhere from 70 grams to over 300 grams. Of course, contest rules are written so as not to reward the students whose structures are excessively heavy.**

CONCLUSION - The author has found that the Pasta Bridge Contest format is an effective way to teach structural mechanics to technically oriented students as well as those enrolled in non-technical curricula. The various pieces of apparatus can be used as visual aids and/or testing devices such that even the most technically disinclined student can participate as a contributing member of a pasta bridge building team

It is also important to note that the contest promotes the design of a successful structure. The structure is not deliberately loaded until it fails, The true meaning of engineering, [The lightest (and cheapest) structure that does the job is the winner.], is taught here.