AME 21241 Laboratory 2: Build a Beam for 3-Point Bending

In this laboratory exercise, you will design a beam that will be subjected to three-point bending. The objective of the beam design is to achieve the maximum possible load before collapse. The material for the beam will be foam board. Each group will receive one 10 by 40 in. piece of foam board, one hot-glue gun and four glue sticks. The thickness of the board is 3/16 in. The entire beam is to be constructed exclusively with the materials provided. (You cannot bring in steel reinforcements, or any other reinforcements for that matter.)

One of the ATS machines will be used to load the beam using the configuration shown in Figure 1. **The beam must span 30 in. so, in reality, it will have to be a bit longer to have a bearing surface at each end**. The personal computer will be used to record the load applied to the beam and the displacement of the lower crosshead of the testing machine.

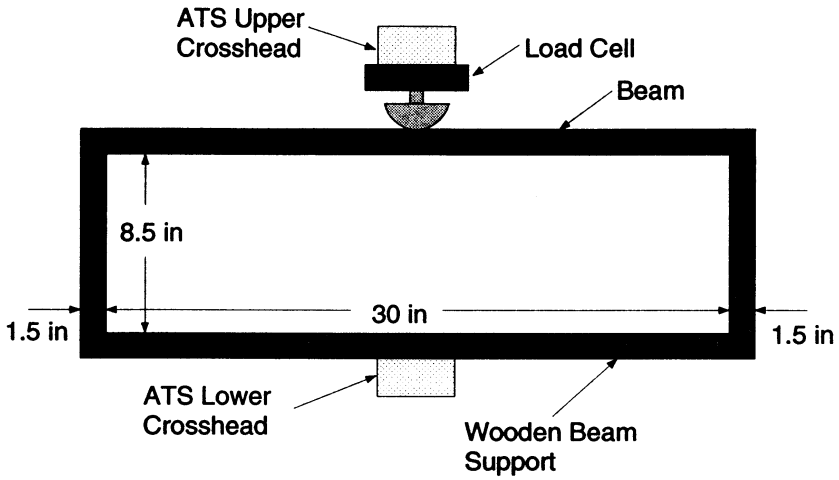

Figure 1: Support for three-point bending test of your beam design

Because of its nature, you are not provided with much background information for this laboratory exercise. The purpose is to provide an "open-ended" problem that does not have a single solution and that is not easily solved from similar examples provided.

Some of the characteristics of this problem which are typical among those normally encountered by engineers include:

- There is a problem to be solved phrased in the most general of terms. Typical engineering problems are "build a bridge to cross the span" or "design a plane to carry 200 passengers across the Atlantic" or "we need something to hold the yaktum on the squeegee".
- You have some, probably not all, of the theory needed to solve the problem. Some of this theory comes from this class and some from other classes or experiences you have had.
- There are an infinite number of geometries to consider. I-beams, boxes, triangles, C-channels, etc.
- You have a limited number of resources like time, materials or money. Here, the limit is the amount of foam board available. Frequently, the resource limit is expressed in terms of money or funds for a project.

There is no right or wrong answer. There are only designs that are better or worse than others. The idea here is to expose you to the characteristics of design problems in solid mechanics. In regard to the theory behind your design, use the equations from solid mechanics as a starting point. Be sure to examine

1. The expression for the bending stress: $\sigma = \frac{Mc}{I}$
2. The approximations for the shear stress in a square or flanged beams, as appropriate for your design.
3. The moment and shear diagram for the beam, which will give you the value of M and V to be used in the equations mentioned above.
4. The material in the book on built up beams and shear flow.

Do not, however, limit yourself to these items. Try to consider all possible failure modes. Feel free to use any references except designs from previous years or reports containing information about designs from previous years.

In previous years, students have constructed beams that could support loads in excess of 100 lbs.

Design of the beam

You should work with your group prior to your scheduled lab time to design your beam. For this lab, it will be fun to see more beams tested, so divide up into groups of two to three. You must provide the TA with a copy of the design at the beginning of the laboratory time. It should consist of two drawings: one of how the board is to be cut, and one showing an orthographic projection schematic of the fabricated beam.

Design requirements:

- The beam must be constructed solely from the materials provided
- The beam must fit within the testing apparatus (Fig. 1).
- The beam may not touch the vertical walls of the testing apparatus (Fig 1).

Fabrication

There will be hot glue guns and Exacto knives available to be checked out in the Engineering Learning Center, located on the first floor of Cushing Hall. There will also be sheets of plywood. Please put these down on the tables or workbenches while you are working. This will protect the table-tops from being cut or covered in glue during your work. Do not add material or glue beyond that given to you by your TA. This would be cheating, very poor sportsmanship, and if it is discovered your group will receive no credit for this lab.

Testing

Following fabrication, you will test your beam on the ATS testing system. You will use the data from the test to determine:

- The linear stiffness of the beam (applied force per unit deflection)
- The force and deflection where nonlinear behavior begins
- The ultimate strength of the beam (maximum force sustained by the beam)
- The deflection of the beam at the maximum load

While the testing of the beams may appear to be a competition, please, no wagering.

Laboratory Procedure

Equipment

- ATS Testing Machine
- Personal Computer
- Magnetic Displacement Transducer
- Data Acquisition Board and Software

Objectives:

1. To design, construct, and test a maximum strength beam out of foam board to span 30 inches and carry a concentrated load at mid-span.

Homework: Design Preparation & Building

The design must be firmly documented when you get to the laboratory to test your beam. You must provide the TA with a copy of the design at the beginning of the laboratory time. It should consist of two drawings: one of how the board was cut, and one showing an orthographic projection schematic of the beam.

The beam may be built anywhere, however, we are providing supplies and a location in the Engineering Learning Center. After the beam is built, store it carefully at home until the day of testing. On that day, all groups will meet during their regularly scheduled lab session for the testing competition.

Report Guidelines

The laboratory report for this lab will be slightly different than the other labs. Your report should contain the sections:

1. **Abstract**
   Provide a short abstract of your lab report.
2. **Objective:**
   State the objective of the problem, and the constraints within which you will design the beam.
3. **Design rationale:**
   Explain how you went about selecting the design for the beam, including any theoretical calculations you made. Explain the tradeoffs that were required due to the amount of material, time, and tools that were provided to you. This section should refer to figures showing:
   - An orthographic projection schematic of your beam.
   - A drawing of how the components of the beam were cut from the foam board.

   You should be able to write this section *before* you do the experiment.
4. **Experimental testing:**

Describe the test that was done to determine the strength of your beam, and the data that was collected during the test. This can be brief, since all engineers know what a 3-point bending test is.

5. **Results:**

   Give the results of your experiment, including the beam stiffness (in lbs/in), the maximum force for linear response, the maximum deflection for linear response, the maximum force carried by your beam, and the deflection at the maximum force. This section should refer to a plot of the load-displacement response of your beam.

6. **Discussion**

   Discuss load displacement response of the beam emphasizing how it failed. Had you considered the failure mode in your initial design? Refer to the response plot to support your conclusions.

   Use your experimental results to suggest possible improvements to the design while remaining within the requirements and constraints of the problem.