Truss Lab Handout

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Contents

1 Overview

This lab will be completed over a three parts. At the end of each phase a team deliverable will be due leading up to the final report due at the culmination of the project. Trusses will be judged on their efficiency– the maximum weight they can support divided by the weight of the bridge itself. The timeline is broken down as follows:

Part 1:

- Sketches of three initial truss designs

- John Hopkins University Bridge Designer analysis of your initial designs

- Solidworks drawing of one final design and analysis as to why this design was chosen

- Submit your team's Truss design for cutting

Part 2:

- Use the joint-method to analyze your truss structure. You should find values for all internal forces and node displacements relative to the applied load.

Part 3:

- Assemble the truss

- Use the Instron to experimentally analyze the truss

- Final report

2   Part One

2.1   Truss Design Requirements

All trusses will be manufactured from 1/8" aluminum sheet. Trusses must span a distance of 12", have a maximum thickness of 3" and a maximum height of 3". The project is mainly one of two-dimensional truss design, however students are encouraged to order spacers to separate the trusses and form the bridge for the experimental testing. During the experimental testing, the trusses will be loaded from a top node. Students are, therefore, highly encouraged to place a node at the top center of the truss.

2.2   Bridge Designer

You are required to test your bridge designs in the John Hopkins University *Bridge Designer* program found on the following site: *http : //www.jhu.edu/virtlab/bridge/bridge.htm*. The program allows you to sketch out a model of a bridge design and displays the relative internal forces in tension and compression that are acting on each member to determine where forces are concentrated and to better optimize the design. In this program, the scaling on the grid is arbitrary so it only matters that the bridge you sketch has the same proportions as the one you decide to build.

To start constructing your bridge, press the "add node" button and click on the grid in the relative locations where you have nodes on your bridge. Once all nodes are created click the "add member" button and drag between two nodes to add a member. If you need to remove a node, click on the "remove node" button and then click on the node locations that you want to remove. The bridge must be constrained by a fixed node and a horizontal rolling node, so first determine the node you want to constrain These will be in contact with the ground during testing. Their distance apart accounts for the total span of the bridge. Assign one of these nodes as the fixed node and the other as the rolling horizontal node, as choices for each should not significantly affect your results. To apply a force, click the "apply force" button and click and drag the force downward from the node where the force will be applied (the highest central node). The amount of force applied doesn't matter as the internal forces of members will be measured relative to one another. I recommend starting with a value of 50 as it is easily scaled. Forces and members can be removed by clicking the respective button and then clicking the area to be removed. To determine the resulting stresses on individual members click the "calculate" button and then click the grid to display the resulting internal forces in tension and compression with values for stress given relative to the force being applied. Record which members are in tension and compression, which members are redundant, and which experience the highest internal forces. Use this data and make a printout of the design with calculated internal forces.

2.3 Solidworks Design

Once you've generated a proportional bridge design using the Johns Hopkins University Bridge Designer, generate a two-dimensional truss in Solidworks based on what you have learned. Make sure to include notches (partial through-holes) at the appropriate bridge nodes to seat firmly into the Instron. Also, it is recommended that you add through holes at the appropriate nodes to attach the trusses to the spacers. This will minimize assembly prep at a later time.

Once you have your completed part, optimize your truss design by running static CosmosWorks tests, minimizing dimensions while maintaining overall truss rigidity and strength. Include a full static report on deflection, factory of safety and maximum yield strength for this section.

2.4 Parts Submittal

The machine shop's waterjet cutter will be used to cut all of the truss structures out of a sheet of 1/8" stock.

You are required to finish their two-dimensional truss structure in Solidworks by the halfway point of Part Two (Given Date Here). To submit, upload your .SLDPRT file to a common directory that will be mailed out to students at the appropriate time. One hapless student (or teaching assistant) will then handle combining the Solidworks files into one waterjet work order. You will receive your parts back in time for Part Three

3 Part Two

3.1 Analytical Analysis

For this phase you are required to turn in a force diagram for your truss broken down by each node. This should include external forces, internal forces, and displacement values that you have solved for in this part. Attach all calculations and code you may have used for this section.

For further guidance I recommend the following resources:

- **Redundant Members:**
  Hibbeler, <u>R C. Statics and Mechanics of Materials</u>. 2nd ed. New Jersey: Prentice Hall, 2004. 218-220.

- **Truss Analysis:**
  Meriam, J.L., L.G. Kraige. <u>Engineering Mechanics: Statistics</u>. 5th ed. US: John Wiley & Sons, 2002. Chapter 4.

- **Using Linear Algebra to simplify the truss analysis:**
  Miller, Richard K. *Introduction to Matrix Structural Analysis*. 9-26-2004. (Posted to website/emailed out)

Warning: Despite this section having the least amount of text dedicated it to it, it is probably the most complex part. Do not let it deceive you.

4 Part Three

4.1 Truss Assembly

You will receive your truss faces back at the beginning of this phase To assembly your truss simply attach the nodes by the spacers. Some deburring might be necessary Be careful not to cut yourself on the sharp edges of the aluminum.

4.2 Universal Tester Setup

All bridges will be tested on the base of the three-point flexure tester, commonly stored in the welding area of the machine shop. Placing the vertical edges of the pedestals against the sides of the flexure tester results in a gap of exactly 12", which is what will be used to test the bridges.
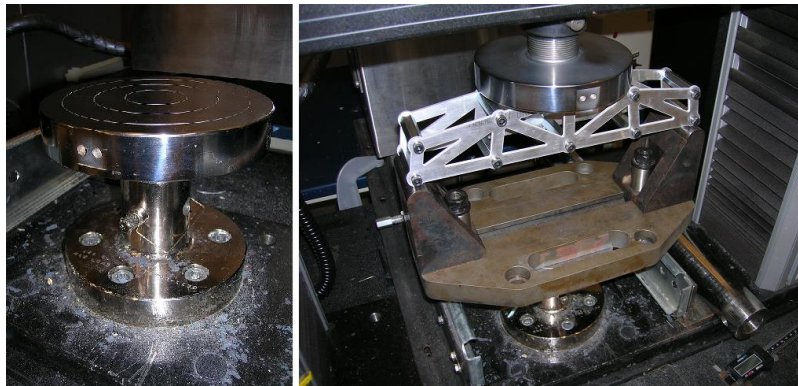

Figure 1: Left: A compression plate in the lower Instron mount. Right: Assembled flexure apparatus with sample bridge ready for testing.

Place the compression testing plates in the Instron mounts as shown in Figure 1. Set the flexure tester base on the bottom compression plate and a bridge to be tested on the testing base. Once placed, lower the top compression plate to just above the top of the bridge, using the jog and fine movement inputs on the control panel. Please note that the Merlin software must be open for the Instron to respond to the control panel.

4.3 Creating a Method

The following steps will step you through the generation of a flexural test method.

- Open Merlin software

- Click on the "Series IX" button

- Click on the "Methods" icon

- Click "File" on the menu bar, then "New"

- Change the method type to "Flexural"

- Assign a new number and name to your method, click "OK"

- Click "Main" on the menu bar, then "Global Parameters"

- Change the unit type and the description to suit you, ensure Results file and ASCII data are enabled

- Click "Specimen" on the menu bar

- Enter the general part dimensions and fixture type

- Click "Test" on the menu bar, then "Control"

- Ensure the direction is "Down", the control channel is "Position", and the crosshead speed between .1 and .2 inches per minute.

- Click "Test" on the menu bar, then "Limits"

- Set the load threshold for break detection (500 pounds), set the high load level to a reasonable maximum load (20,000 pounds)

- Click "Data" on the menu bar, then "Logging"

- Set the sampling rate to 10 $\frac{pts}{sec}$, ensure "Start test with computer" is selected

- Click "File" on the menu bar, then "Save"

- Click "File" on the menu bar, then "Home Screen"

4.4   Running a Test

The following steps will step you through the running of a flexural test with the method you just created.

- Open Merlin software

- Click on the "Series IX" button

- Click on the "Tests" icon

- Name the sample file and click "OK"

- Select "Flexural test", then select the method you created

- Use the Instron controller to bring the top compression plate as close to the top of the structure as possible, using the coarse and fine feeds

- Click the black cylinder icon in the upper right hand corner, then click "Balance Load"

- Click the green moving platform icon in the upper right hand corner, then click "Reset Gauge Length", then click "Done"

- Click "Start Test" in the menu bar and enter rough bridge dimensions

- Stop the test when the bridge begins to deform, or when the test autostops

- Click "End Sample" in the menu bar

- Click "Contine" in the menu bar

- Ensure "Report to File" is selected and retrieve your data from the directory indicated by the file path

4.5   Final Report

Your final report should draw from everything you have learned in this project. It should include the following sections:

- **Abstract/Introduction:**
  Give an overview of your project and an idea of what is covered in the report.

- **Overview of your truss design:**
  This should include a dimensioned view of your solidworks-ed part, the results from your *Bridge Designer* test, and a rationale for why you chose your design.

- **Analytical Analysis:**
  Include your force diagram for your truss broken down by each node as you turned in in Part II. Remember, this should include external forces, internal forces, and displacement values that you have calculated. Once again, include your calculations and/or code. Analyze what you learned from your analytical calculations.

- **Experimental Analysis**
  Make a force v. deflection graph from the results of your Instron test. How does this compare to your analytical results? To your *Bridge Designer* results? What was the point and mode of failure? Calculate your final score by the equation:

$$\frac{\text{maximum tested load (lbs)}}{\text{weight of bridge design (lbs)}}$$

- **Conclusion:**
  Tie together everything you have learned in this lab. What are the important characteristics of truss design? Would your design be able to withstand traffic? What would you do differently next time.

- **Bibliography:**
  Give credit where credit is due. Make sure to cite any sources you used in this project. Use MLA notation.