ENSC2004 Laboratory 1: Week 5 and 6 (Statics)

Overview

The purpose of this project is to:

1. Practice analysis and design for a scale-model system truss;
2. Compare truss analysis with measurements from a truss-loading experiment;
3. Reflect on the impact of failure of engineering structures on people and the environment.

In this project students will work in groups of 5 to analyse and test a truss to failure. This will be completed over two weeks.

Week 5 Lab Session

Each group will be assigned one of either a Pratt (Fig 1), Howe (Fig 2), or Warren truss (Fig 3) with a unique loading combination.

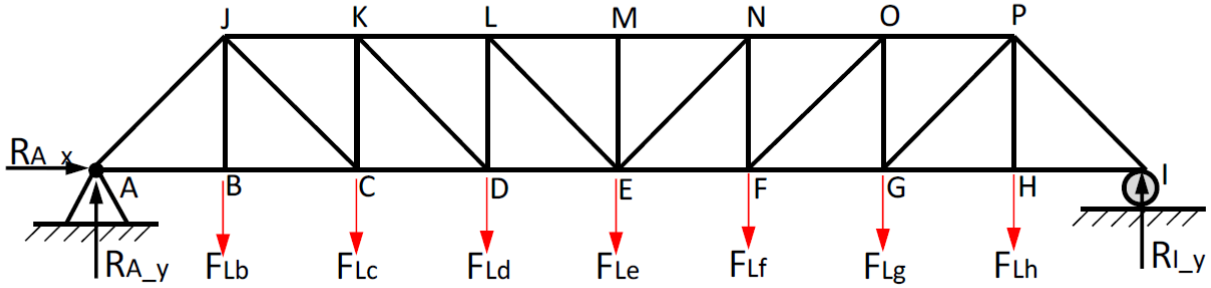

Figure 1: Pratt truss. Dead Load Location: D; Dead Load Magnitude: 20 N or 50 N; Live Load Location: E

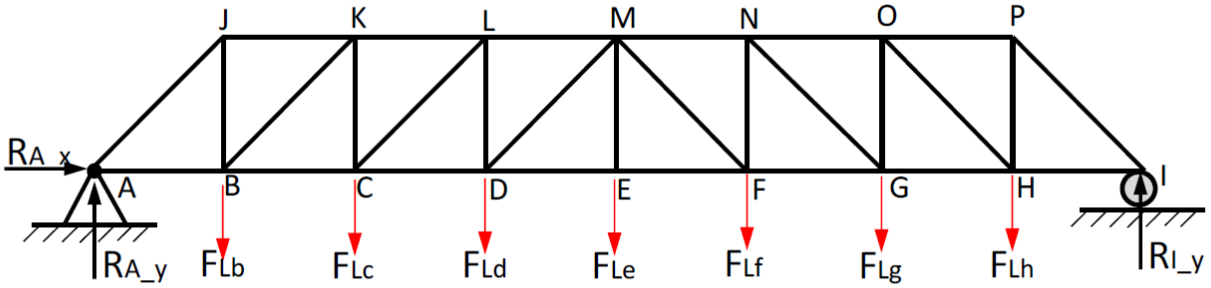

Figure 2: Howe truss. Dead Load Location: D; Dead Load Magnitude: 20 N or 50 N; Live Load Location: E

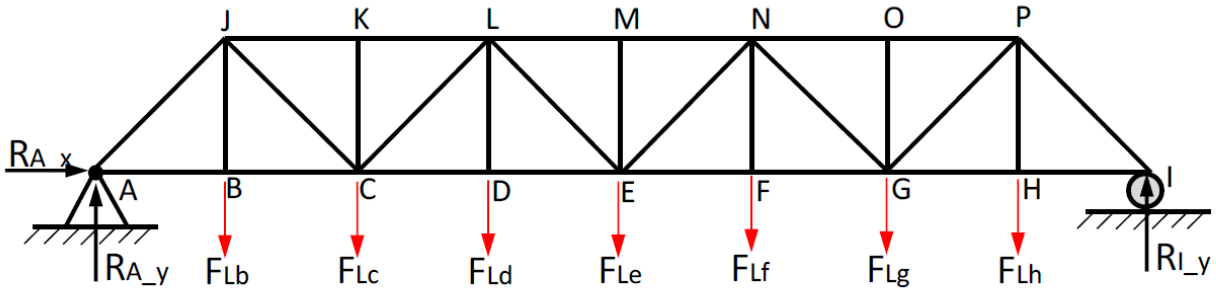

Figure 3: Warren truss. Dead Load Location: D; Dead Load Magnitude: 20 N or 50 N; Live Load Location: E

This loading combination will have a (constant) dead load and a (variable) live load. The live load will be increased until a sacrificial plastic (PMMA) member fails in the testing rig (see Fig 4). (The PMMA member will be provided in Week 6, on the day of testing). The application points of the dead and live loads are detailed in Figures 1 – 3, along with the magnitude of the dead load.

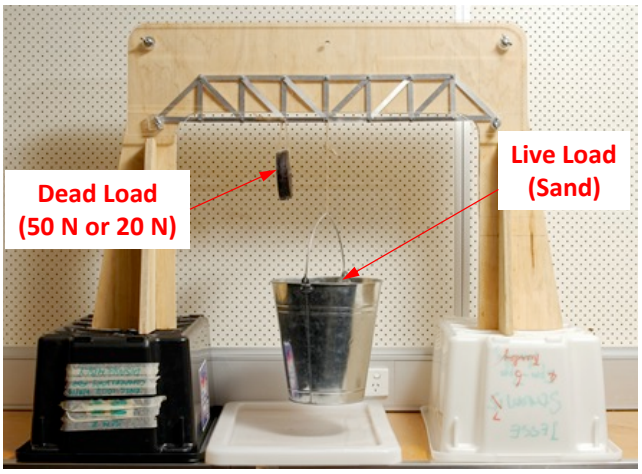

Figure 4: Experimental rig showing dead and live loads

The magnitude of the live load (the weight of the sand) that results in failure is an unknown. It will be predicted using the stress-strain properties of the PMMA members in tension, shown in Figure 5.

Your <u>predicted failure load</u> will be compared to the <u>measured failure load</u>.

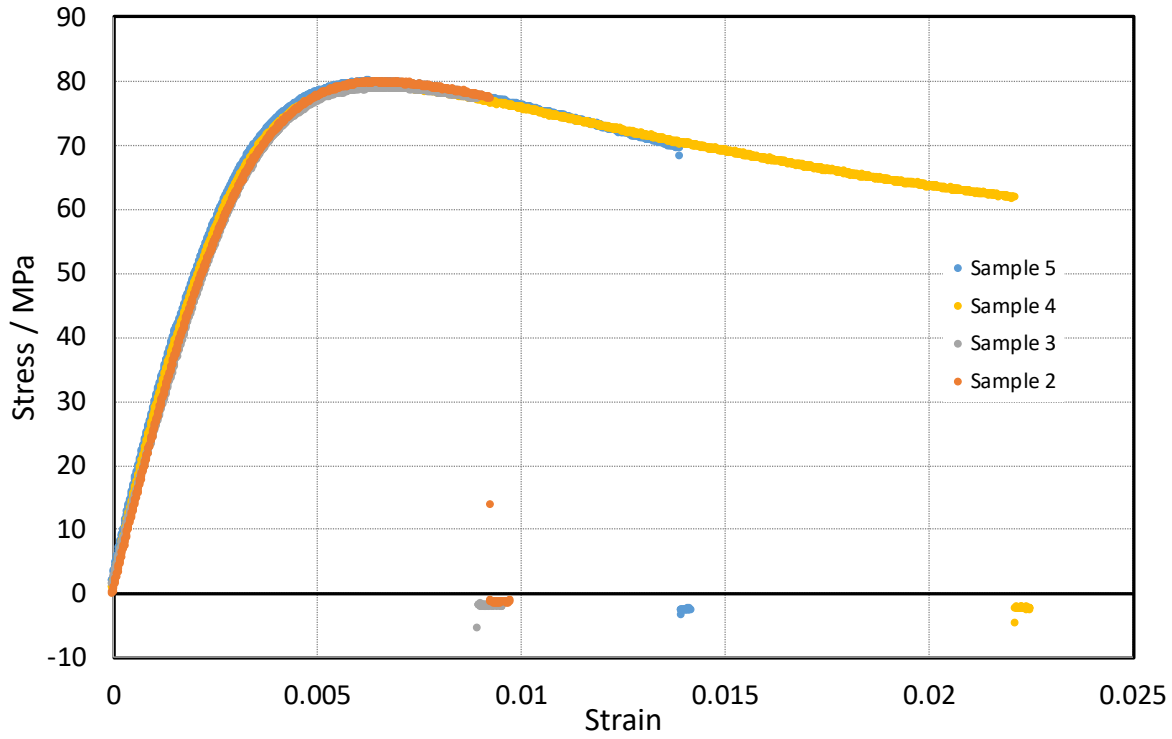

Figure 5: Stress-strain response of PMMA members

Procedure

In the first Lab Session, students will form groups of 5 students and be assigned a truss type (Pratt, Howe or Warren) and a dead load value (20 or 50 Newtons), which will be applied to pin position D as shown in Fig 1 to 3.

The members of the truss will be made out of aluminium with the horizontal and vertical members having a nominal length of 10 cm and the diagonal members having a nominal length of 14 cm, the cross-section dimensions of all members are the same.

Task 1

Determine the reaction forces at the ends of your truss as a function of the dead and live loads. You may assume that the self-weight of the bridge is negligible. Compare your answers with the members of your group.

Task 2

Use **Method of Joints** to determine the force in each member as a function of the dead and live loads.

Use Method of Sections to check your calculation based on Method of Joints for at least "one cut". (The purpose here is to put these analysis methods into practice and to make sure you know how to use them.)

Task 3

Considering only the horizontal and vertical members in tension (or that will change from compression to tension as the live load increases), plot the force in the members (y-axis) as a function of the live load (x-axis).

Task 4

Your most critical member will be replaced with a sacrificial PMMA member during the second workshop. This sacrificial member has a nominal cross-sectional area of 2 mm^2 and tensile properties shown Figure 5.

- Calculate the force at which the PMMA member is expected to fail, based on its properties and dimensions, and plot this force as a constant line on your plot.

The critical-tension member is most at risk of failure in tension for the given loading condition. On your plot of force in members under tension, the first member to have a force equal to the force expected to cause failure in the PMMA member will be the critical member (on the graph the force in the member line will cross the constant force line).

- Identify the location of the most critical member of your truss.
- Write down the critical member and the live load at which you expect it to fail and bring this information with you to the second workshop.

<u>If you cannot complete these tasks during the first lab session you must finish them before the beginning of the second lab.</u>

Week 6 Lab Session

Procedure

Task 1

You will be given a sacrificial PMMA member. Use callipers to determine the cross-sectional area at the narrowest point. Does it match the nominal 2 mm^2 specifications? What is the uncertainty in your measurement?

Task 2

You will be supplied with a partially completed truss and a sacrificial member. Each group, in turn, will test their truss in the testing rig. Be very careful about keeping the sacrificial member under tension when placing it into the testing rig; ***it is easy to accidentally cause the sacrificial member to buckle if it's placed under compression***.

- With the truss in the testing rig, hang the correct dead load from pin D and the bucket for the live load from pin E.
- Announce, based on your calculations, at what live-load value you anticipate the sacrificial member will fail.
- Begin slowly adding sand to the live-load bucket until the sacrificial member fails.
- Weigh out the mass of sand and the bucket and record this value. Comment on and estimate the uncertainty in your measurement of the total live-load mass.

Task 3

After the Tests

- Talk over the results of the experiment with your teammates and discuss if they met with your expectations or not.
- If the actual cross section of the sacrificial member was different from the nominal 2 mm^2 recalculate the force that the member was expected to fail at and the associated live load. Does this better match your results?
- If the actual tensile strength of the PMMA was different than the expected value, how big would the difference have to be to explain your results? Would it fall with a range of ± 15 %)?

Task 4

Three truss designs have been tested by group in your class. Research what are the advantages and disadvantages of the three truss types used in this project (Pratt, Howe and Warren). Are the diagonals in tension or compression for each of the different truss types?

Task 5

(This will be completed outside of class) Review a documented example of engineering failure for a structure, relevant to what you have been learning in the statics part of this course. Describe the cause of failure (where did the design fail) and events that led to the failure situation. Consider the impact of this failure event on people and the environment.

Report

As a group, you will write a report of your findings using the format given in the next section.

This report must be the work of your own group, and all team members should be familiar with (and ideally contribute to) all sections. Reports will be checked for similarity with reports from other classes and other semesters. Any incident detected will be referred to the Academic Conduct Advisor.

Students will complete an individually-assessed quiz, testing your understanding and knowledge of topics covered in the laboratory sessions and report.

Report Submission

Submit your report online to LMS by the deadline (***Midnight, Friday week 7)***

Each report must contain the following components:

a) University Assignment Cover Sheet.
b) Title page: include project title, your stream number, name of facilitator, and names of all group members.
c) Introduction: A section briefly discussing the three different truss types, their advantages and disadvantages. Pictures or schematic diagrams should be included to illustrate the truss types.
d) Methodology: A section describing the truss your group analysed and providing the background for the activity. Include a diagram of the truss, complete with sacrificial member location, dead and live load locations and the predicted value of the dead load.
e) Results 1 – Modelling: A section on how you determined the critical member, to be replaced by the sacrificial member. Include your original calculations for the force at which the sacrificial member would fail based on the nominal 2 mm^2 cross-sectional area and tensile strength from the graph provided. Also include your original plot of the force in the vertical and horizontal members under tension as a function of the live load and a statement of the predicted terminal live load. (All other calculations should go into an appendix.)
f) Results 2 – Experiment: A section detailing the experiment and any sources of uncertainty that could contribute to differences between the experimental results and your expectations.
g) Discussion: Comment on the comparison of your calculated and measured results. This should include:
    - Effects of cross-sectional area of the sacrificial member and how it would have affected your predictions for the terminal value of the live load.
    - Variations in the material properties of PMMA and its tensile strength. Give the range for expected failure live load, if the range in the tensile strength was varied by +/- 15%.
    - Assessment of other uncertainties and variability in the experimental procedure compared to calculations of the idealised model.
h) Case Study: Using an example of a documented event, discuss:
    - The causes of failure of an engineering structure, relevant to what you have been learning.

- What went wrong in the design and/or construction process.
- The impact that this failure had on people and the environment.
- What changes (if any) were made to engineering practice.

i) References: A list of any and all references used in the report.

j) Appendix: including your calculations of:

(1) The reaction forces;

(2) The force in each member of the bridge as a function of D and L (even though you will know the value of the dead load ahead of time please write force functions symbolically using D for the dead load and L for the live load);

(3) Calculations of the force on the PMMA member at failure based on the measured cross-sectional area and tensile strengths, and the specified tensile strength ± 15%;

(4) Calculations of the live loads associated with the forces you calculated in (3) for the sacrificial member.

Reports should be **formatted** as following:

- Ensure the document is formatted with 2.54 cm margins all around, typed using Times New Roman font of size 12 pt. and with a line spacing of 1.15.
- Adhere to the page limit: no more than 14 pages for the whole report.

Introduction	10% wt. Mark (/10)
Insightful and covers advantages and disadvantages of Pratt/Howe/Warren	8-10
Complete but lacks insight or appears to be “cut and paste” with citations	6-8
All trusses mentioned but some details incorrect or missing	4-6
One of more of Pratt/Howe/Warren not discussed	2-4
Essentially missing or “cut and paste” without citations	0-2

Truss Description	5% wt. Mark (/5)
Insightful and complete with clear diagram, labels and caption	4-5
Complete but lacks insight or has a lower quality diagram	3-4
Some details missing from description or diagram lacks labels and or caption	2-3
Substantial details missing from both description and diagram	1-2
Essentially missing or shows no effort	0-1

Determination of Critical Member and Terminal Live Load Prediction	30% wt. Mark (/30)
All work appears correct and is well presented	25-30
Work appears correct but presentation less clear	15-25
Work contains some minor mistakes or something is missing	10-15
Work contains some major mistakes	5-10
Essentially missing or shows no effort	0-5

Discussion of Experimental Results	30% wt. Mark (/35)
Insightful discussion of the experiment and re-evaluation of predictions	25-30
Average discussion of the experiment with possible minor errors in re-evaluation	15-25
Either a poor discussion of the experiment or missing details of re-evaluation	10-15
Both a poor discussion of the experiment and missing details of re-evaluation	5-10
Essentially missing or shows no effort	0-5

Discuss the causes and impact of failure of engineering structures on people and the environment	15% wt. Mark (/35)
Insightful discussion	12-15
Average discussion	9-12
Poor discussion	5-9
Essentially missing or shows no effort	0-5

Overall Quality	10% wt. Mark (/10)
Excellent formatting and attention to detail	8-10
Followed formatting instructions but had minor errors (i.e. figure numbering)	6-8
Followed only some formatting instructions or had major errors in formatting	4-6
Failed to follow formatting instructions or was multiple documents stapled together	2-4
Report was difficult to read or understand	0-2