ENGR 214: Statics
Balsa Wood Bridge Project

What you will have to deliver and when:

Deliverable/Activity	Points	Due Date
Design Proposal	15	Monday 11/4
Bridge Model	20	Wednesday 11/13
Constructed Bridge (test day)	30	Tuesday 11/19
Failure Analysis	35	Tuesday 12/10
TOTAL		**100**

Introduction

Each team (2-3 students) will design a bridge that will be made of balsa wood and wood glue. The bridges will be modeled and optimized using the online modeling software. Teams will then build their bridges out of balsa wood and carpenter glue provided by the instructor. Bridges will be tested to failure and efficiency load will be determined. You will use the Vernier materials tester, which is a machine that exerts and measures an increasing force on the bridge until failure. At the conclusion of the test, each team will be required to perform a detailed failure analysis of their bridge.
Each team may build and test more than one bridge; however, you will only need to conduct the failure analysis on one of your bridges.

Contents of the bridge kit

- 1 bottle of wood glue
- About 18 2’ balsa sticks
- Sand paper
- 2 loading blocks (if testing the bridge at home)
- 1 balsa sheet (to make gussets at the joints)

Design Proposal

Prior to building your bridge, each team will write a design proposal outlining the specifics of your chosen design. Your design proposal must be typed and should consist of the following:

• A list of design constraints and objectives. Use the information listed under the bridge construction to help you come up with a complete list.

Example:

Design Constraint	Description
Materials	Bridges will be constructed with balsa wood and glue supplied by the instructor. Balsa wood will be no larger in cross section than 1/8 inch square.
Span	The bridge must span a gap of 30 cm between two level platforms

Design Objective	Description
Weight of Bridge	Keep the weight of the bridge as low as possible in order to maximize the efficiency loading.
Aesthetics	Bridge should be aesthetically pleasing.

• Sketches and descriptions of at least **three** design concepts for your bridge design.
• One paragraph for each design concept that outlines the advantages and disadvantages of the design, particularly in the context of the structural engineering concepts we have covered in class (e.g. two-force members, truss systems, stress concentrations, etc…).
• Selection of at least one concept to pursue for your final bridge design and construction.
• A paragraph explaining why you chose the design you did.

Bridge Modeling – Optimizing your Design:

Teams will model their bridges using free online bridge builder software. There are two programs available:

- https://ei.jhu.edu/truss-simulator/
- http://bridgedesigner.org/download/

Use either of the programs (or both!). You will want to use the software to model your bridge as closely to the actual design as possible.

You can also take a look at this website which gives very good advice:
https://www.garrettsbridges.com/design-it/

Start with the final design presented in your design proposal. Model the bridge you designed and use the software to determine the forces in each member (a scaled version of your bridge is acceptable). The Vernier bridge tester exerts a load at one location in the middle of the bridge. Model this load as one force applied in the middle of the top of the bridge. Change the design to

see what happens to the forces in the members (e.g. change the height of the bridge). Use the software to optimize your bridge design. You will probably need to go through multiple iterations of your design. Keep in mind that you want to keep your bridge as light as possible.
Summarizing your finding:

1. Introduction paragraph explaining how you designed your model. Discuss any external loading you applied to the bridge.
2. Include a printed copy of your original bridge design and your optimized bridge design. If you are not able to improve on your design, you will need to show adequate evidence (multiple plots of designs with higher forces in members). For each bridge, show the forces that exist in the members.
3. Include a paragraph explaining the difference between the original design and the optimized design. What are the advantages and disadvantages of the designs?
4. Based on the cross-section of your bridge members, determine the maximum stress in your optimized bridge. Note the location and value of this stress.
5. From your investigation and preliminary calculations, how and where do you expect your bridge to fail?
6. Conclusion: summarize your findings.

Bridge Construction:

A. Design Specifications:

1. The bridge will span over a gap of 30 cm between two level platforms on the test stand. Since the span is 30 cm, the bridge will have to be somewhat longer to rest on the platforms.
2. The bridge supports will only be able to rest on the platforms. No glue or attachments can be made to the top or sides of the test stand. No braces can be placed against the sides of the test stand or extended to the floor.
3. The minimum bridge width is 5 cm.
4. The bridge will support a fixed load applied in the middle of its top part. Since it is not required to support moving loads, the bridge could more properly be termed a structure. No scale path or roadway for movement across the bridge is required.
5. The maximum mass of the bridge should not exceed 30 grams (approximately one ounce).
6. The center span of the bridge cannot deflect more than 2.0 cm below the surface of the platforms.
7. Each team will build and test at least one bridge. All team members are expected to participate equally in the design, testing and analysis of their bridge.

B. Material Requirements:

1. The materials used in the construction of the bridge should consist only of commercially available balsa wood stock and wood glue. The cross section of the balsa stock can be no larger than 1/8 inch square. No other materials are allowed.
2. The mass of the structure should not exceed 30 grams.
3. Unlimited lamination (bonding together layers of wood) is not allowed.
4. No coating the outside of the bridge with glue or paint is allowed.

C. Performance Goal:

1. The designs will be judged by measuring the maximum load (at failure) supported by the bridge near the center of the 30 cm span. This number will then be divided by the initial weight of the bridge to determine the efficiency load. The design that has the best efficiency load will be the winner.

Efficiency Load = Load Supported (Newtons) / Weight of the bridge (Newtons)

2. The total load supported is the force measured by the Vernier bridge tester.
3. Measure the weight of the bridge with a kitchen scale.

D. Testing:

You will use the Vernier materials tester. The tester applies and measures an increasing force at the center of the bridge.

E. Tips:

1. Clamp glued pieces for about half and hour (use protective strips to avoid damaging the balsa). If you don't have any clamps, you can use clothespins.
2. Reinforce key joints with balsa plates to increase strength.
3. Design for strength at the load application point.
4. Check your weight well ahead of time. A good plan is to weigh materials and develop a materials budget. Remember to reserve 15% for glue and extra reinforcement weight.

Failure Analysis:

Each team will select one of their bridges for the failure analysis.
Using the failure load, please calculate the following:

1. Determine the breaking strength of the bridge = stress = tension or compression / cross-sectional area. You will need to conduct an analysis of the bridge to determine where it broke. Compare your value to the breaking strength of balsa wood given in tables (search for "breaking strength of balsa wood to get some estimates).
2. Conduct a simple force analysis (method of joints, method of sections) on your bridge. Determine the force in **at least** 5 key members of your bridge. Use this to determine the stress in these members.
3. Speculate as to why your bridge failed. Briefly discuss your bridge design – how did it fail? What was the stress in the bridge at the point of failure? How does this compare to the stresses in the other members? Where was the weak link? Did your bridge fail where you expected it to fail?

Final Report Poster

Your Final Report poster (or a powerpoint presentation) should include the following:

1. A basic outline of what you did (project statement, design objectives & constraints, testing method)
2. A large drawing or photo of your bridge
3. List of assumptions made for analysis
4. Detailed calculation showing how you found the **breaking strength (stress, i.e. force/area of the cross section)** and at point of fracture and in key members of your bridge. Show the location of the members on which you chose to conduct the force analysis. Why did you decide to analyze these members? (you may want to show a sketch of your bridge here)
5. Compare your breaking strength with that of balsa wood. Explain any discrepancies.
6. Summarize key results (forces/stress in all members analyzed)
7. Expectations: where did you expect your bridge to fail? Why? Show the model of your optimized bridge design. Compare of your modeled bridge to the actual bridge (did it fail as expected?).
8. A brief conclusion.

Note: You may want to include sample calculations on additional paper outlining the steps you took to determine the force and stress in one of the bridge members.

The report should be submitted in a **poster format or powerpoint format** that will be presented in class.