Balsa Wood Cantilever Truss Design Challenge

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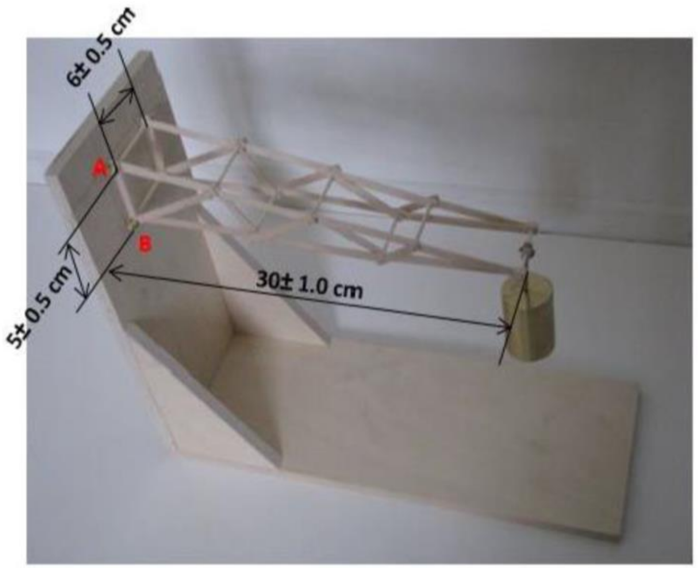


$$Performance\ Value\ (PV) = \frac{Maxmimum\ Applicable\ Load\ (g)}{Mass\ of\ Truss(g)}$$

Constraints and Criteria

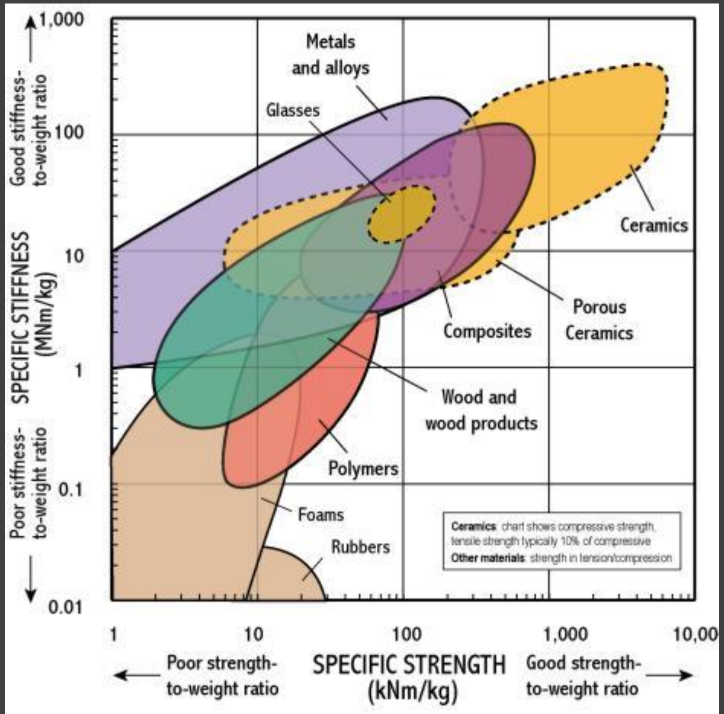
- Constraints
  - Given the geometric constraints
  - 1 sheet of balsa wood (1ft by 2ft and 3mm thick)
  - Bamboo dowels
  - All members are 2 force members (pinned connections must rotate)
  - Parallel identical trusses (can't taper inwards
  - Adhesives are permitted
- Criteria
  - Obtain the highest PV

Materials and their Properties

- The follow information on the construction materials provided were given.
- They were obtained through a tensile test for the ultimate tensile strength and a 3pt bending test (not to failure) was conducted to determine the young's modulus

	Dowels	Members
Density ρ (g/cm^3)	0.65	0.128
Ultimate Strength σ_{ult} (MPa)	117	7.157
Young's Modulus E (GPa)	17	2.539
Shear Strength τ_{ult} (MPa)	23	2
Max Bending Moment (Nm)	0.368	N/A

Materials Discussion: Balsa Wood

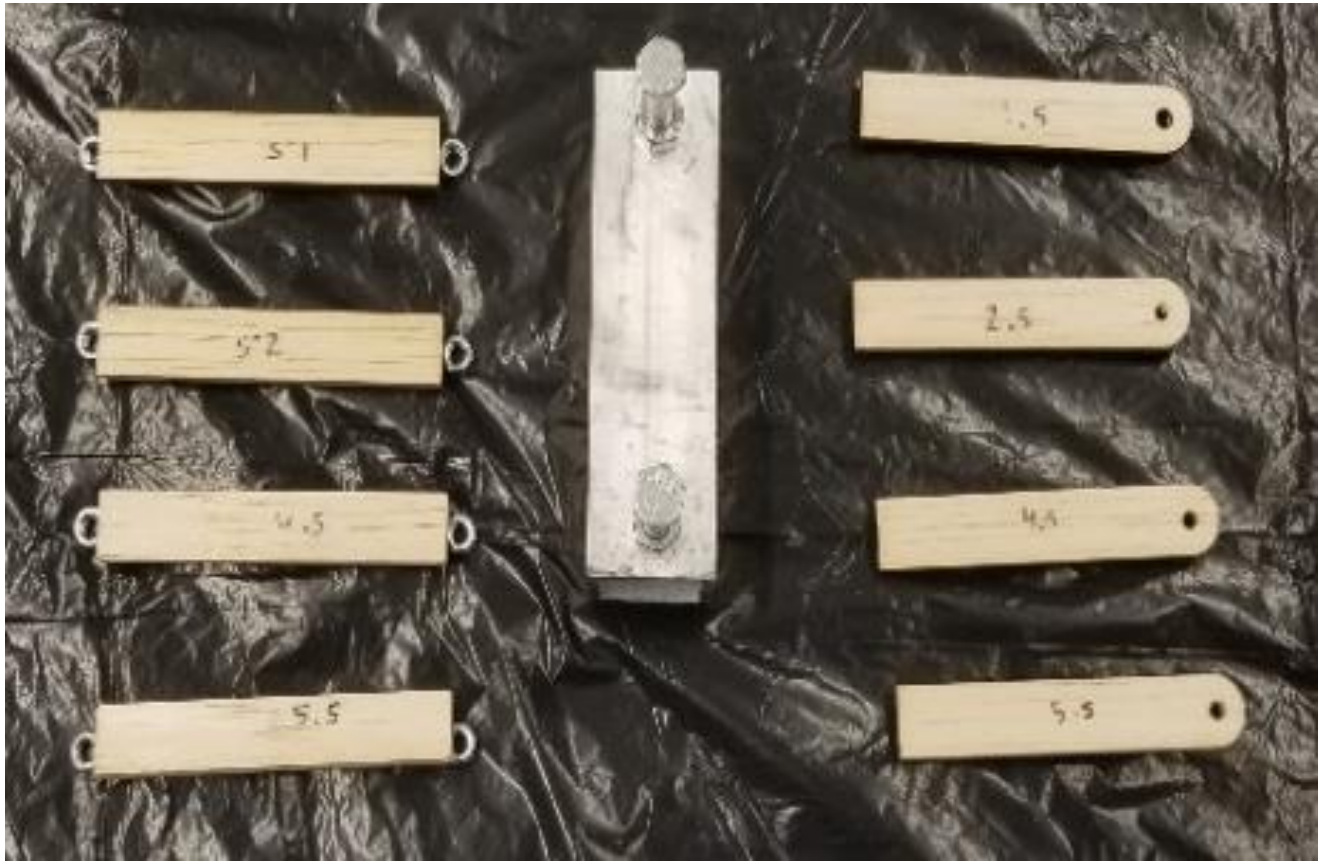


- High Strength and Low mass
  - Has a high specific strength in tension and compression
  - Its specific stiffness is fair, but lower than the bamboo dowels
- Porous
  - Wood is porous and is therefore susceptible to crack propagation under tension
- Grain
  - Balsa wood has its strongest uniaxial strength (tension and compression) along the grain
  - Its shear strength is highest against the grain
- Anisotropic
  - Due to the porosity and the grain of the balsa wood we can see that the strength is directionally dependant.
- Natural Material
  - Wood has imperfections and its properties are inconsistent trough out.
  - There is also lower quality control for wood compared to other materials such as metals, ceramics and composites.

- Designs considerations for balsa wood
  - Since our members are two force members we will make all member along the grain to maximize their strength
  - Since we already know the tensile strength, and it is apparent that the wood will be slightly stronger under compression (neglecting buckling), than we will model members as being isotropic when along the grain
  - Also due to the inconsistency in quality we decided to optimize to infinity, and make the largest truss system possible to make small imperfection negligible to the overall geometry

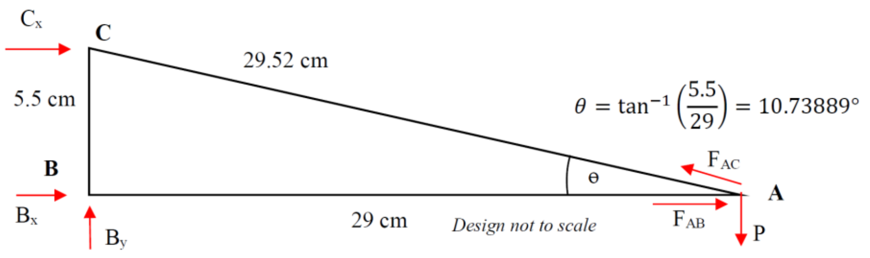
Additional Testing

- Improve strength and reduce crack propagation
  - Made test samples treated with various adhesives
- Tested modulus and ultimate strength
  - Results showed either a decrease in specific strength or a no significant benefits, this paired with the lack of control on how much adhesive was made this an unviable option

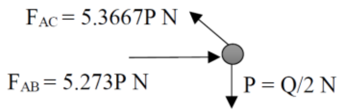


Truss Design and Force Analysis

- Truss design was done by assuming that each truss system in the cantilever beam system would take half of the applied load (Q)
- After iterating through a few different truss designs it was found that a simple triangle allowed for the lowest force relative to the length of the members
- Also fewer member and fewer pinned connections made for a higher torsion stability in the cantilever beam



Force Analysis: A



Moment About B:

$$\sum M_B = -C_x(0.055) - P\,(0.29) = 0$$

$$C_x = \frac{58}{11}P = 5.273P\ N$$

Moment About C:

$$\sum M_C = B_x(0.055) - P\,(0.29) = 0$$

$$B_x = \frac{58}{11}P = 5.273P\ N,\ \ B_y = 0\ N$$

As the truss has a parallel design, the relative force for each member is shown in terms of P, which is half of the applied load Q. By setting Q = max shear force before pin failure which is determined below:

$$Q = \tau_{ult} * Area = (23\ MPa) * \left(\frac{\pi * (3.175mm)^2}{4}\right) = 182.098\ N$$

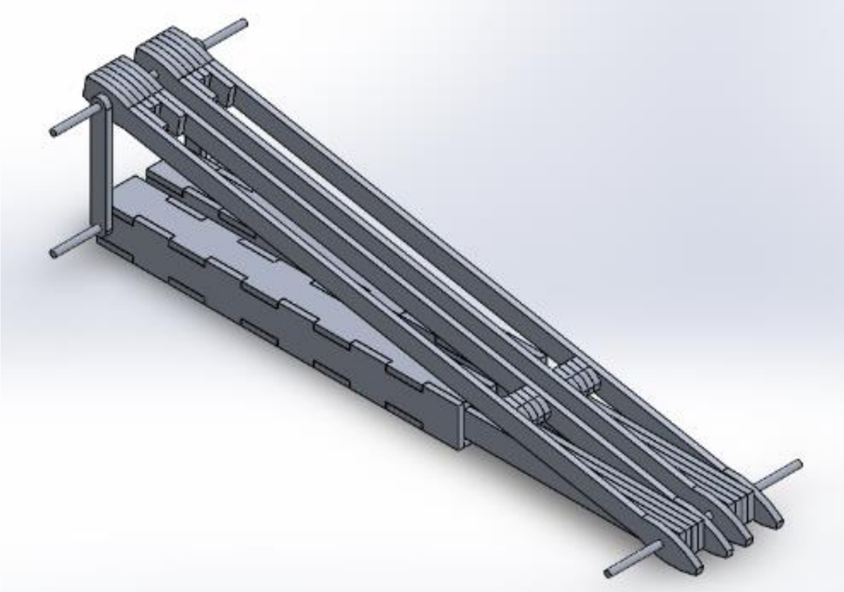
$$P = \frac{Q}{2} = 91.05\ N$$

$$F_{AC} = 5.3667P = 488.64\ N$$

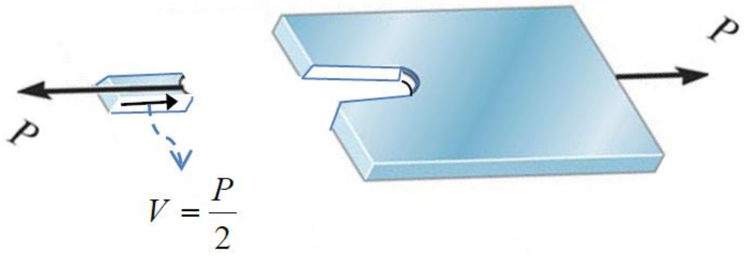
$$F_{AB} = B_x = C_x = 5.273P = 480.076\ N$$

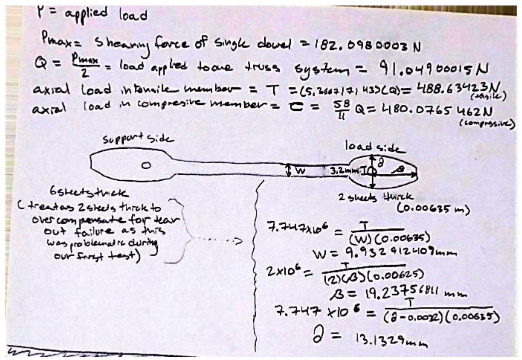
Failure Analysis: Members

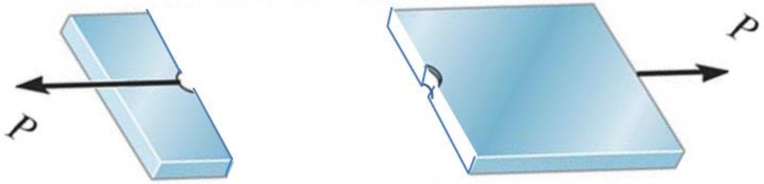
- The constraining member was the loaded dowel pin which was under 3pt bending, all other elements were designed to fail at the same load
- Due to the high compressive load in the bottom member, a box beam design was implemented to compensate for failure due to buckling

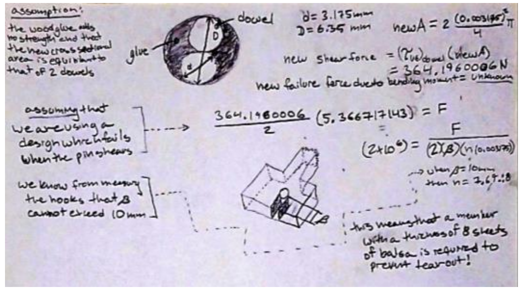


Failure Analysis: Holes









Tested PV

- Calculated PV ~ 504
- Tested PV ~ 250