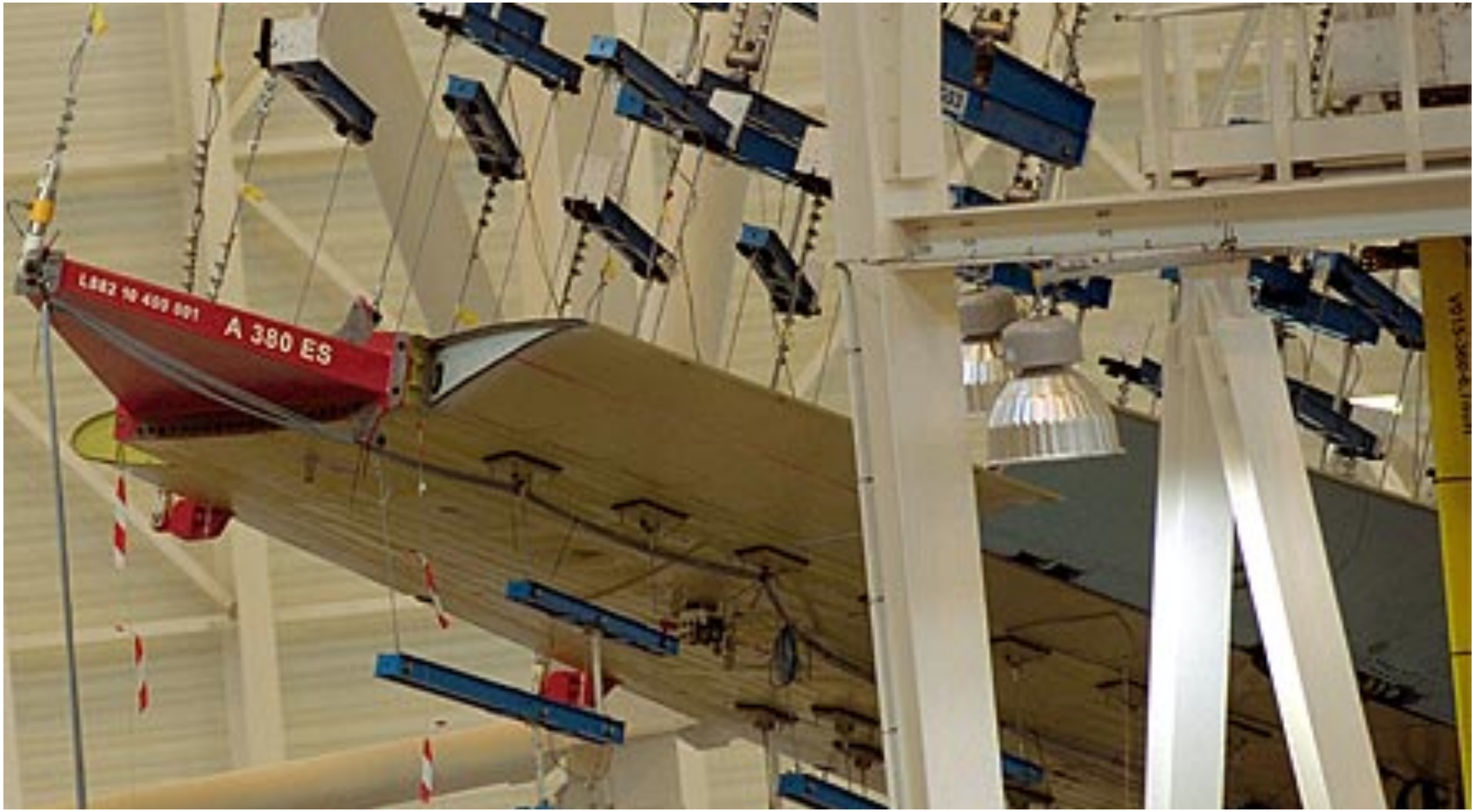
Composite Beam Bending

ASEN 2001 Lab 3
Fall 2016

Boeing 787 – Bending test

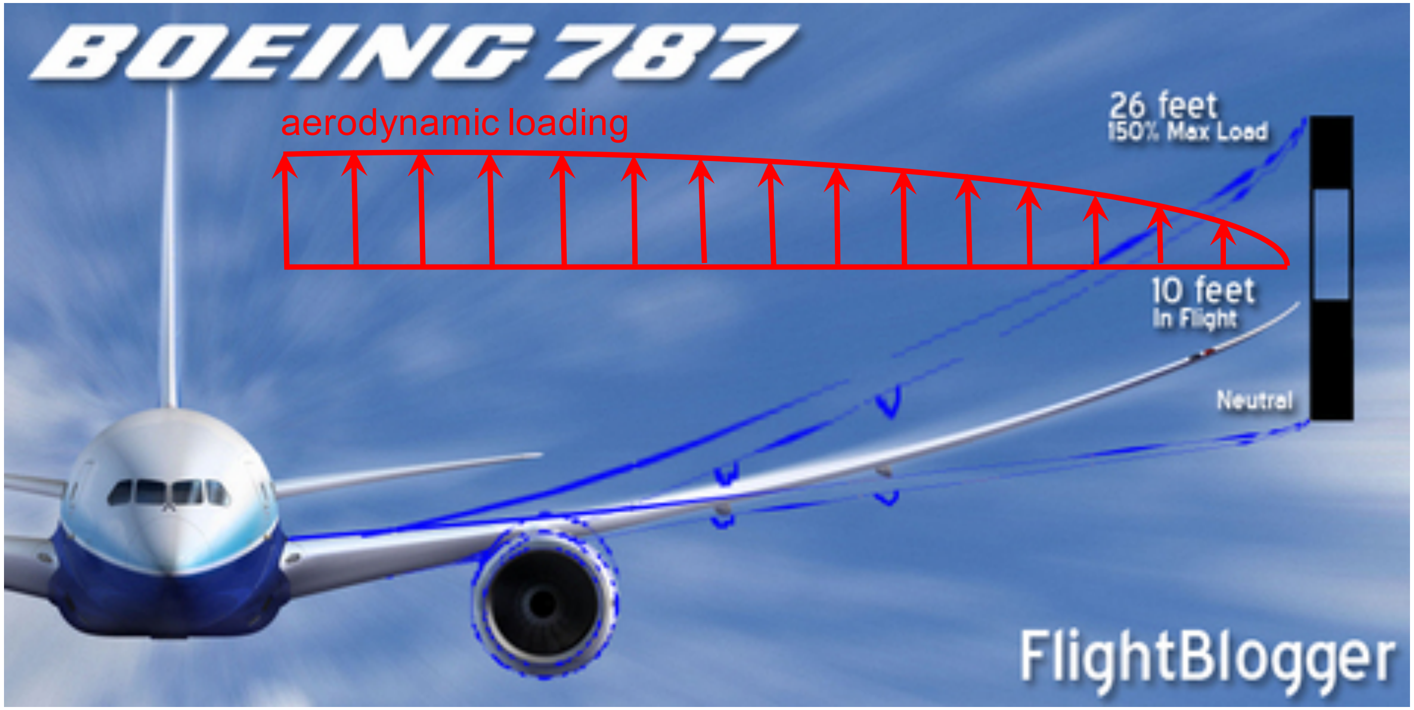
Airbus A380 wing test



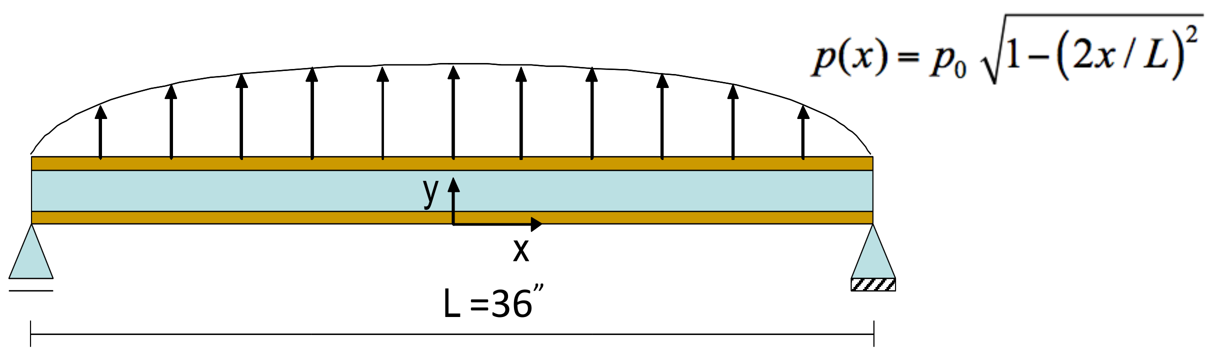
Glider wing test

Lab 3 Goals

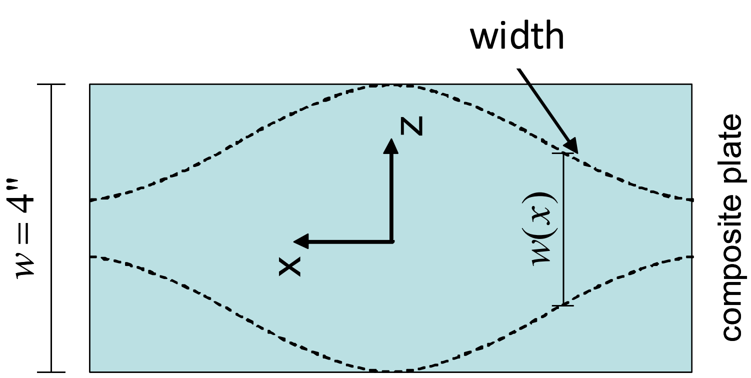
Analyze, design, manufacture, and test a composite wing with maximum strength while having minimum weight subject to aerodynamic loading.



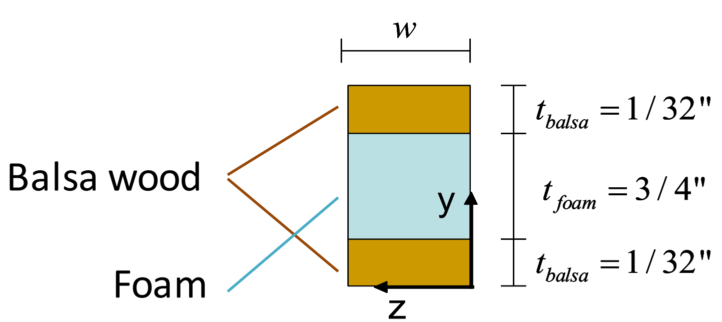
Lab 3 – A simpler set up



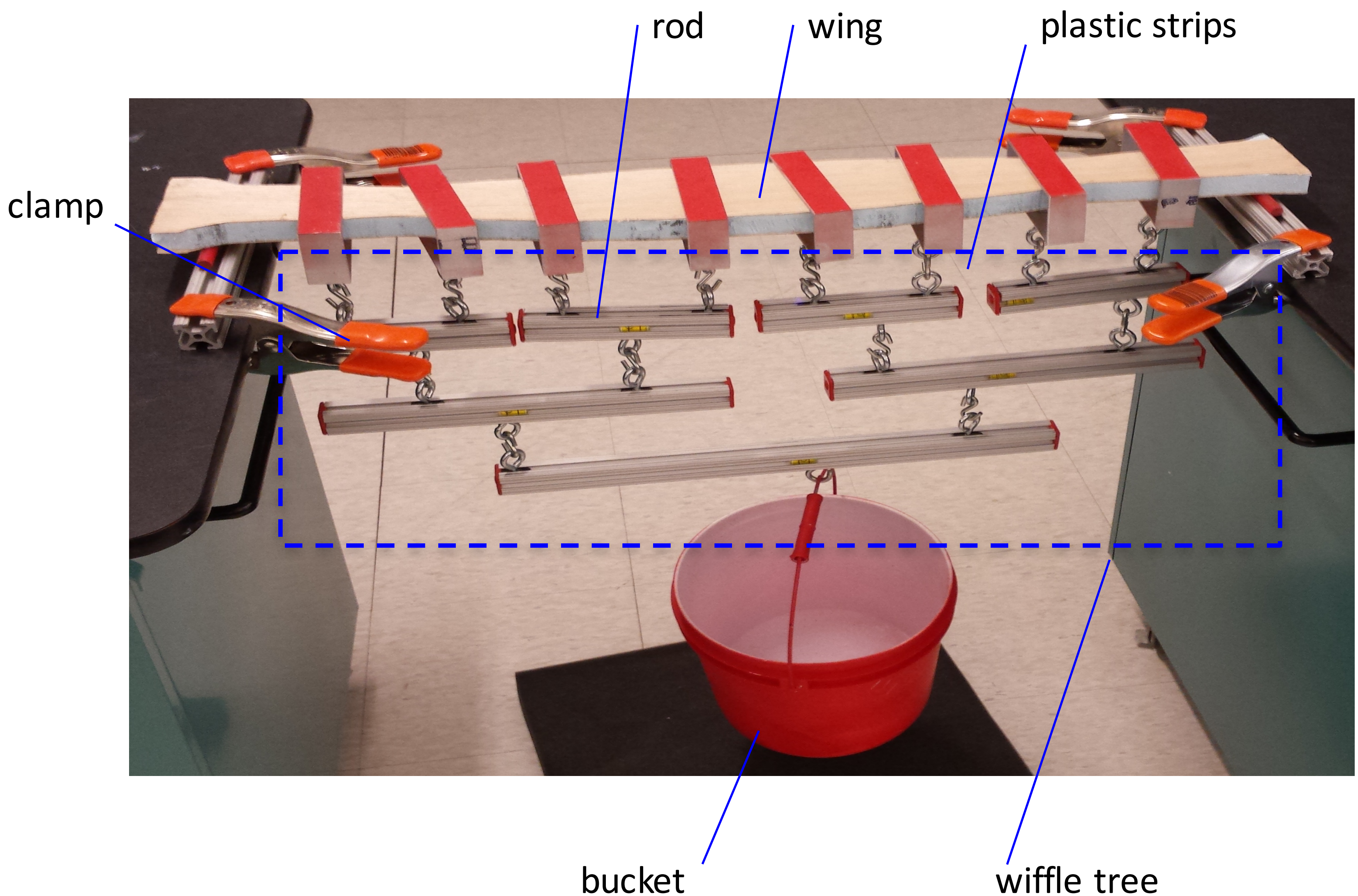
Plan view:



Cross section:



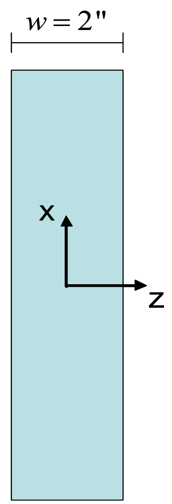
Lab 3 – How will it look like?



Lab 3 – First identify beam strength

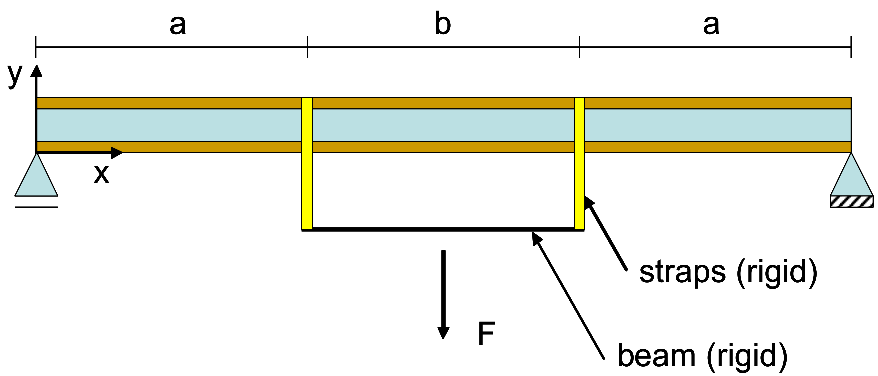
- What is σ_{fail} ?
- What is τ_{fail} ?

Data (available on D2L) on failure of several wings under four point bending test:



test specimen

Four point bending test:



EXAMPLE 11.1

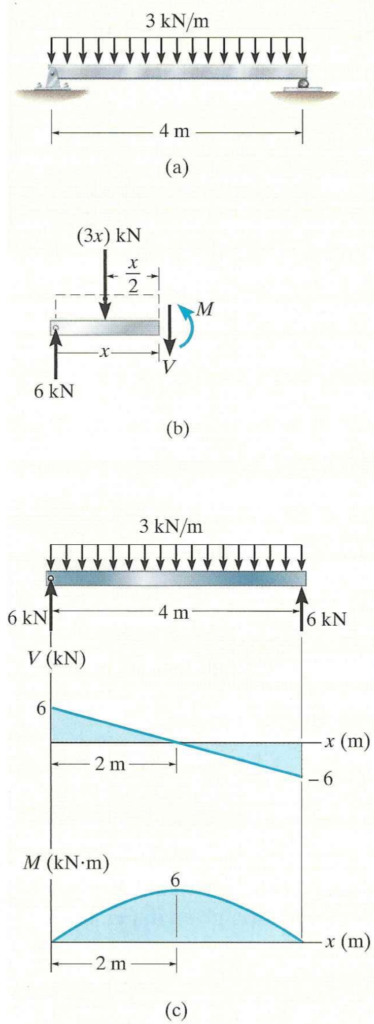


Fig. 11–4

Draw the shear and moment diagrams for the beam shown in Fig. 11–4*a*.

SOLUTION

Support Reactions. The support reactions are shown in Fig. 11–4*c*.

Shear and Moment Functions. A free-body diagram of the left segment of the beam is shown in Fig. 11–4*b*. The distributed loading on this segment is represented by its resultant force $(3x)$ kN, which is found only *after* the segment is isolated as a free-body diagram. This force acts through the centroid of the area under the distributed loading, a distance of $x/2$ from the right end. Applying the two equations of equilibrium yields

$$+\uparrow \Sigma F_y = 0; \qquad 6\text{ kN} - (3x)\text{ kN} - V = 0$$

$$V = (6 - 3x)\text{ kN} \qquad (1)$$

$$\circlearrowleft + \Sigma M = 0; \qquad -6\text{ kN}(x) + (3x)\text{ kN}\left(\tfrac{1}{2}x\right) + M = 0$$

$$M = (6x - 1.5x^2)\text{ kN}\cdot\text{m} \qquad (2)$$

Shear and Moment Diagrams. The shear and moment diagrams shown in Fig. 11–4*c* are obtained by plotting Eqs. 1 and 2. The point of *zero shear* can be found from Eq. 1:

$$V = (6 - 3x)\text{ kN} = 0$$

$$x = 2\text{ m}$$

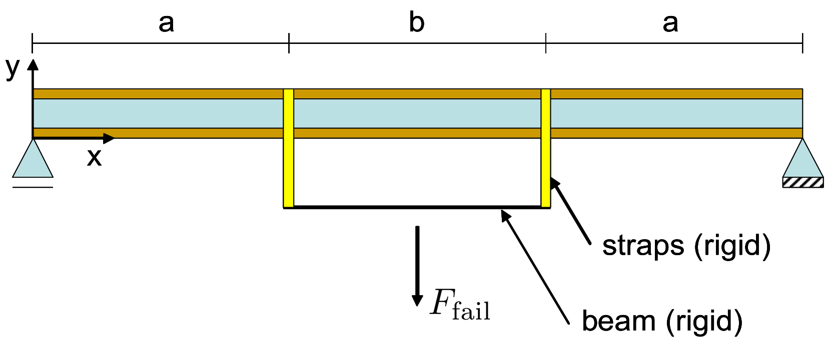
NOTE: From the moment diagram, this value of x represents the point on the beam where the *maximum moment* occurs, since by Eq. 11–2 (see Sec. 11.2) the *slope* $V = dM/dx = 0$. From Eq. 2, we have

$$M_{\max} = [6\,(2) - 1.5\,(2)^2]\text{ kN}\cdot\text{m}$$

$$= 6\text{ kN}\cdot\text{m}$$

Lab 3 – First identify beam strength

1. **Bending failure:**

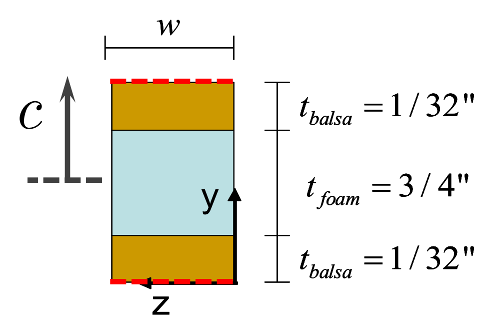


$$F_{\text{fail}} \xrightarrow{\text{moment diagram}} M_{\text{fail}} \xrightarrow{\text{flexture formula}} \sigma_{\text{fail}}$$

Test data

Flexure formula:

$$\sigma_{\text{fail}} = -\frac{M_{\text{fail}}c}{(\underbrace{I_b}_{\text{balsa}} + (\underbrace{E_f}_{\text{foam}}/E_b)I_f)}$$



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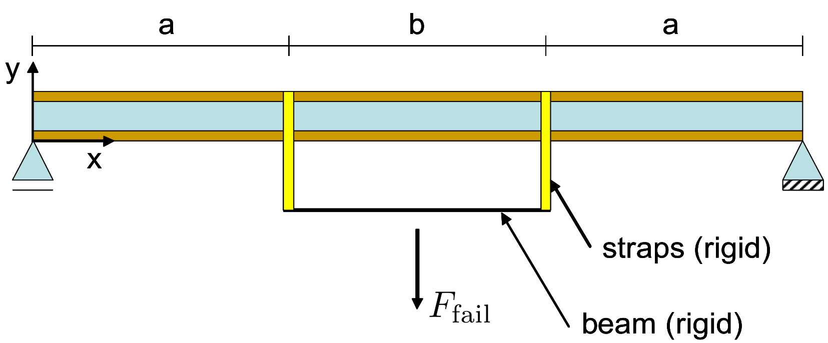
Lab 3 – First identify beam strength

2. Shear failure:



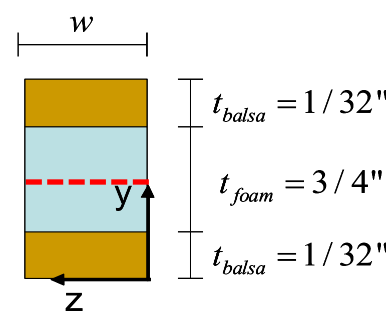
$$F_{\text{fail}} \xrightarrow{\text{shear diagram}} V_{\text{fail}} \xrightarrow{\text{shear formula}} \tau_{\text{fail}}$$

Test data

Shear formula:

$$\tau_{\text{fail}} = \frac{3}{2}\frac{V_{\text{fail}}}{A_f}$$

foam



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Parameter/variable definitions

F_{fail}	Total force on the beam at failure (see data file)
M_{fail}	Bending moment at the failure section (under bending)
V_{fail}	Shear force at the failure section (under shear)
σ_{fail}	Max normal stress at the failure section (under bending)
τ_{fail}	Max shear stress at the failure section (under shear)
I_b, I_f	Moment of inertia of Balsa wood and foam around the axis passing through centroid of section
E_b	Young's modulus of Balsa wood
E_f	Young's modulus of foam
A_f	Area of foam cross section
c	Half of cross section's total height

Data analysis – Tasks for Oct 31st

- Identify E_b and E_f (search online)
- Generate the shear and moment diagrams of the four point test
- For each data entry identify shear or bending failure, and exclude outliers
- For each data entry compute σ_{fail} and τ_{fail} depending on the failure mode
- Pick σ_{fail} and τ_{fail} and a corresponding FOS for your actual design

Writing a MATLAB function to do these is suggested!