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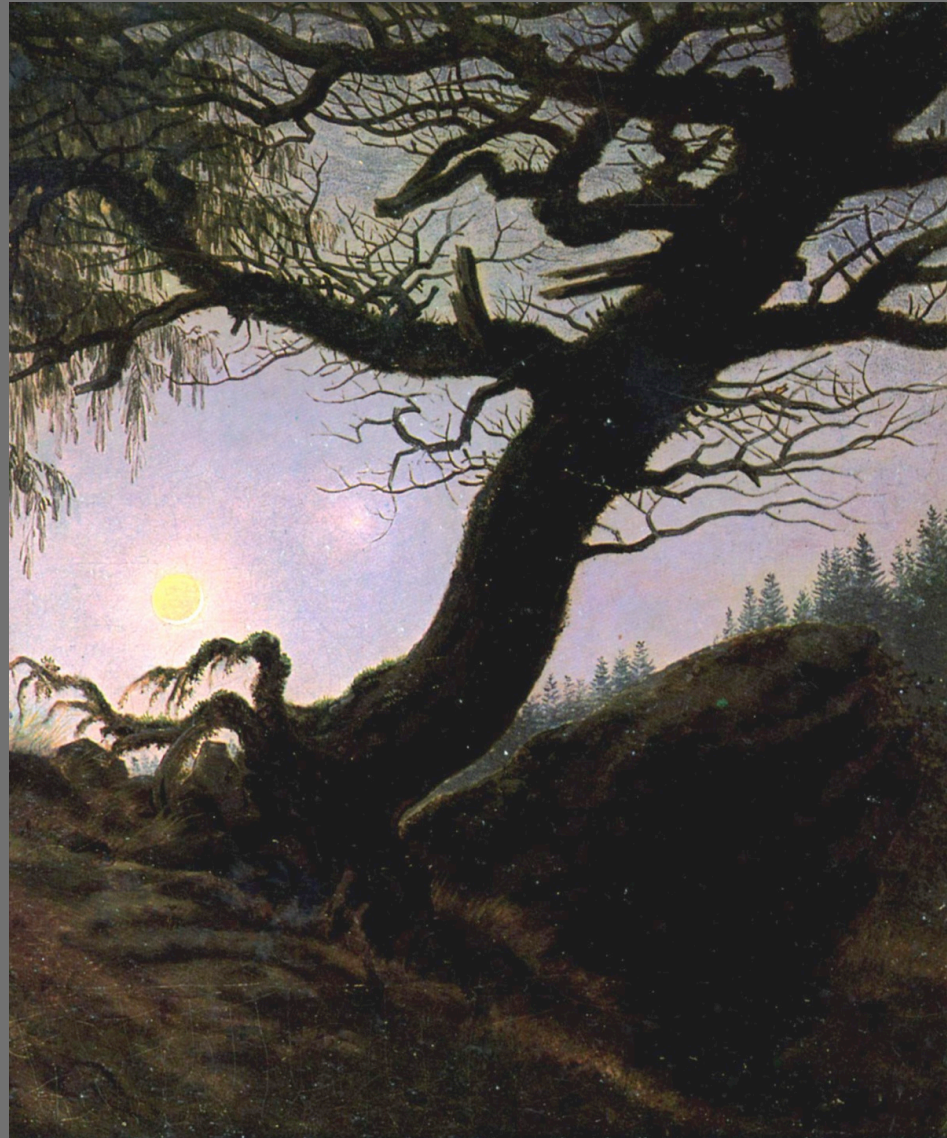
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Combined Stress

- Axial vs. Eccentric Load
- Combined Stress
- Interaction Formulas

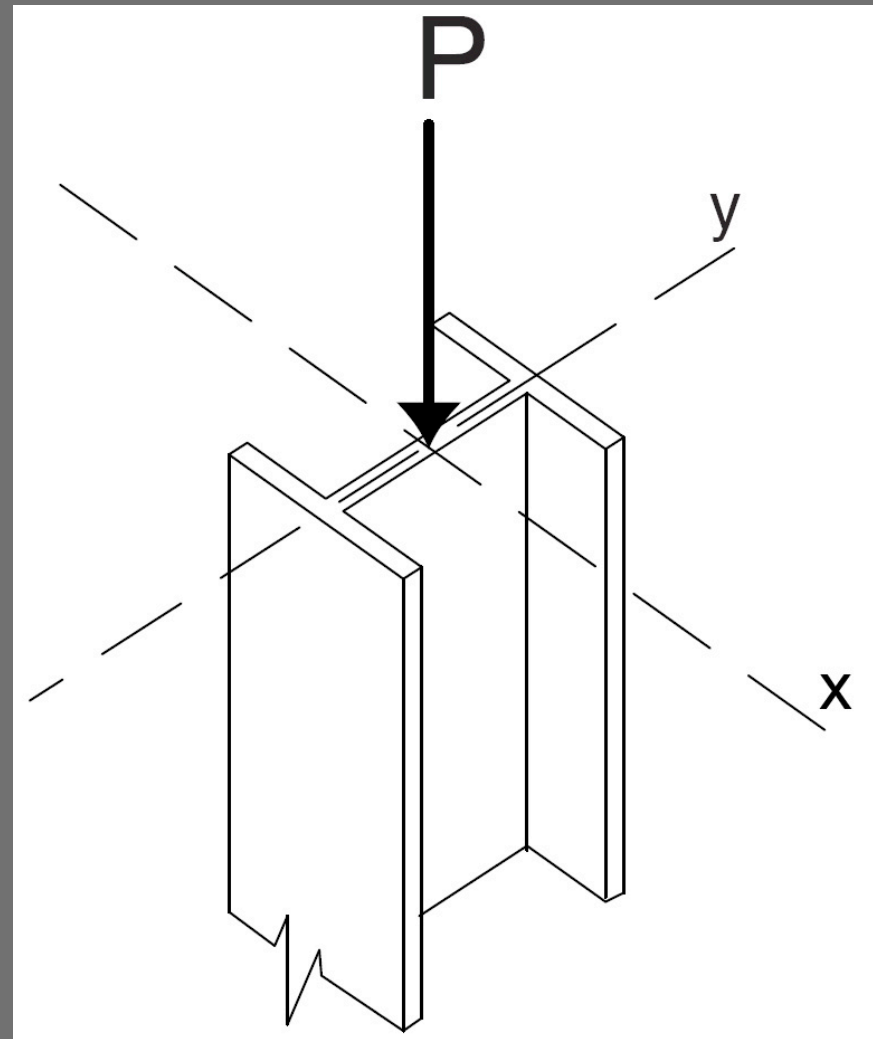


Source: Caspar David Friedrich from "Man und Frau den Mond betrachtend" 1830-35
Alte Nationalgalerie, Berlin

Axial Stress

- Loads pass through the centroid of the section
- Member is straight
- Load less than buckling load

- $f = P/A$



Source: University of Michigan, Department of Architecture

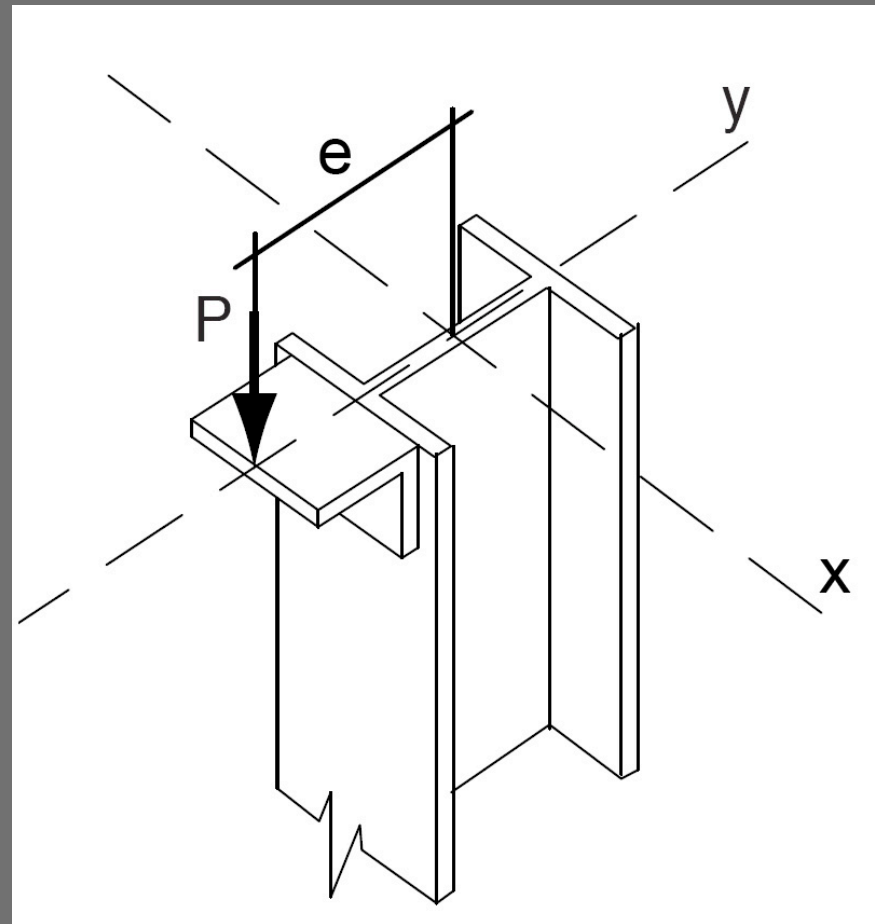
Eccentric Loads

- Load offset from centroid
- $M = P e$
- Total load = $P + M$

Interaction formula

$$f = \frac{P}{A} \pm \frac{Mc}{I}$$

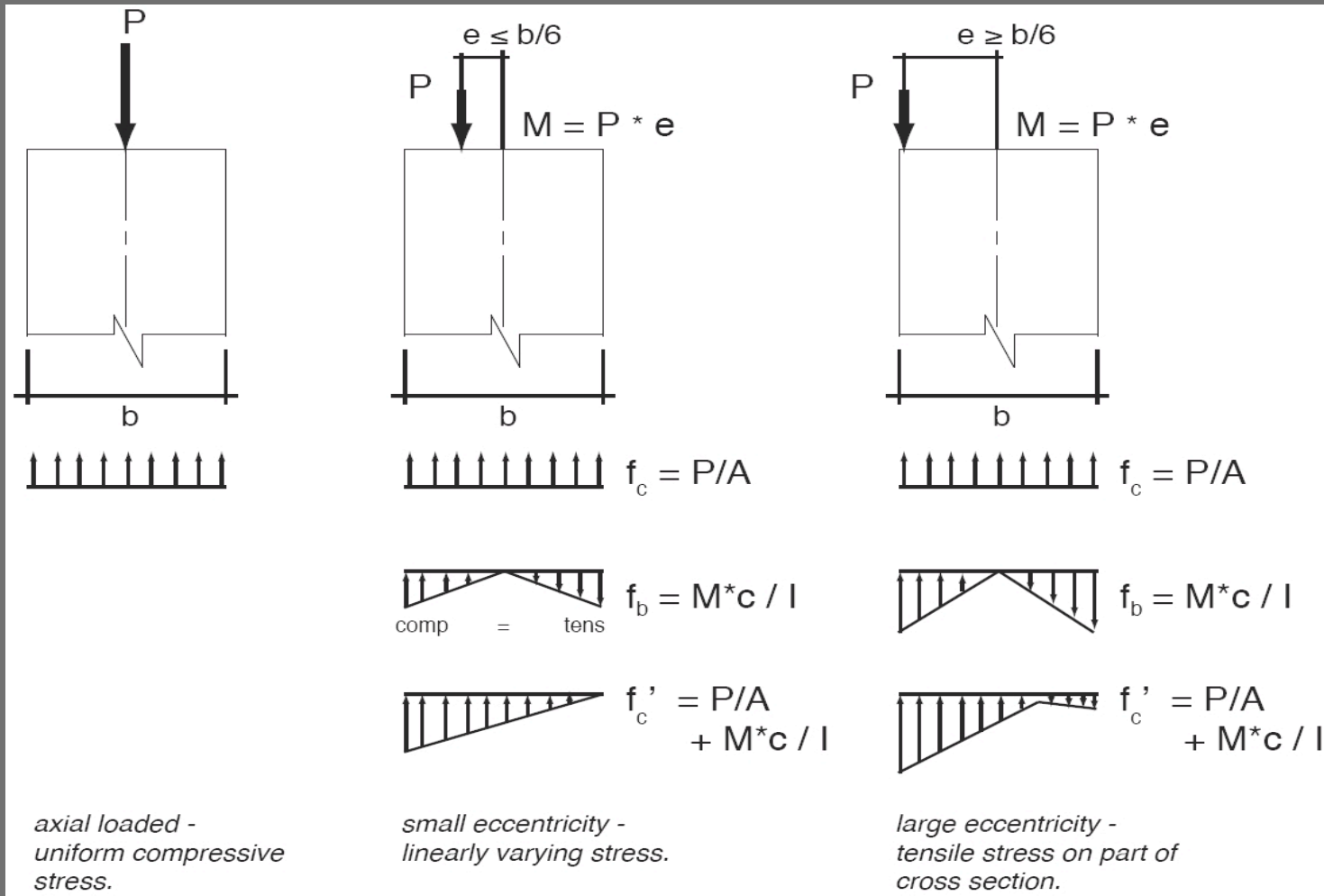
$$\frac{f_a}{F_a} \pm \frac{f_b}{F_b} \leq 1.0$$



Source: University of Michigan, Department of Architecture

Combined Stress

- Stresses combine by superposition
- Values add or subtract by sign

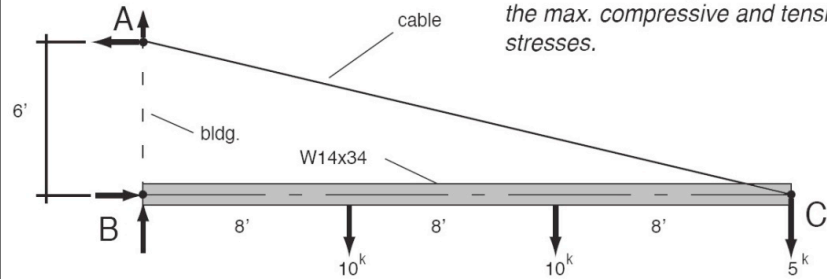


Source: University of Michigan, Department of Architecture

Example

CANOPY CONSTRUCTION PROJECTING FROM FACE OF BUILDING.
The supporting cable is pin-connected on the centroidal axis of the steel beam.

Reactions at face of building.



FOR THE W14x34:
Determine the magnitude and location of the max. compressive and tensile unit stresses.

Source: University of Michigan, Department of Architecture

Determine external reactions

$$\sum M_A = 0 = -B_H(6') + 10^k(8') + 10^k(16') + 5^k(24')$$

$$B_H = 60^k$$

$$\sum M_B = 0 = -A_H(6') + 10^k(8') + 10^k(16') + 5^k(24')$$

$$A_H = 60^k$$

$$\text{CHECK } \sum F_H = 0 = 60^k - 60^k \quad \checkmark$$

FBID @ A



$$\frac{60}{4} = \frac{A_v}{1}$$

$$A_v = 15^k$$

$$\sum F_v = 0 = 15^k - 10^k - 10^k - 5^k + B_v$$

$$B_v = 10^k$$

Example

Determine internal member forces: Axial and Flexural

Determine axial and flexural stresses

Use interaction formula to determine combined stresses at key locations (e.g. extreme fibers)

$$W14 \times 34 \quad A = 10.0 \text{ in}^2 \\ S_x = 48.6 \text{ in}^3$$

FORCE :

$$\text{AXIAL} = 60 \text{ K}$$

$$\text{FLEXURAL} = M = PL/3 = 10 \text{ K}(8') = 80 \text{ K-ft}$$

STRESS :

$$\text{AXIAL} = f_a = \frac{P}{A} = \frac{60 \text{ K}}{10 \text{ in}^2} = 6.0 \text{ KSI}$$

$$\text{FLEXURAL} = f_b = \frac{M}{S} = \frac{80 \text{ K-ft}(12)}{48.6 \text{ in}^3} = 19.75 \text{ KSI}$$

COMBINED STRESS

TOP SIDE :

$$f_a + f_b = 6.0 + 19.75 = 25.75 \text{ KSI (COMP)}$$

BOTTOM SIDE :

$$f_a - f_b = 6.0 - 19.75 = -13.75 \text{ KSI (TENS)}$$

Rafters Flexure + Axial

$$f = \frac{P}{A} \pm \frac{Mc}{I}$$

$$P = 22.5 \text{ \#}$$

$$A = 5.25 \text{ in}^2$$

$$f_c = 22.5 / 5.25 = 4.28 \text{ psi}$$

$$M = PL/4 = 39\# \times 96" / 4 = 936 \text{ "- \#}$$

$$c = 1.5" / 2 = 0.75"$$

$$I_y = 3.5(1.5^3)/12 = 0.984 \text{ in}^4$$

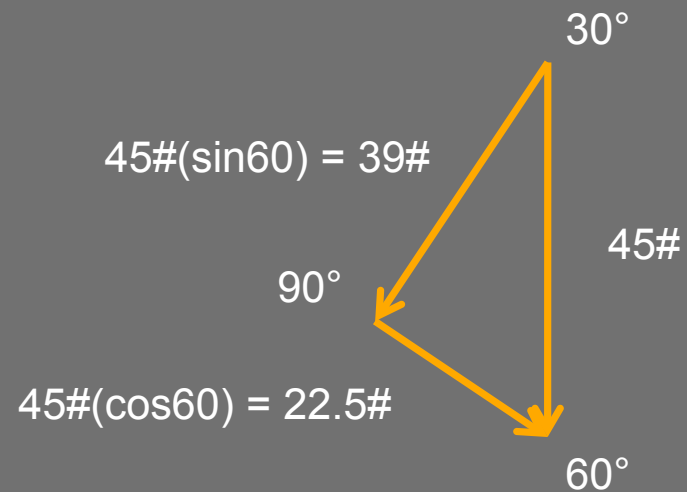
$$f_b = 963 (0.75)/0.984 = 713.14$$

$$f = f_c + f_b = 717.4 \text{ psi}$$

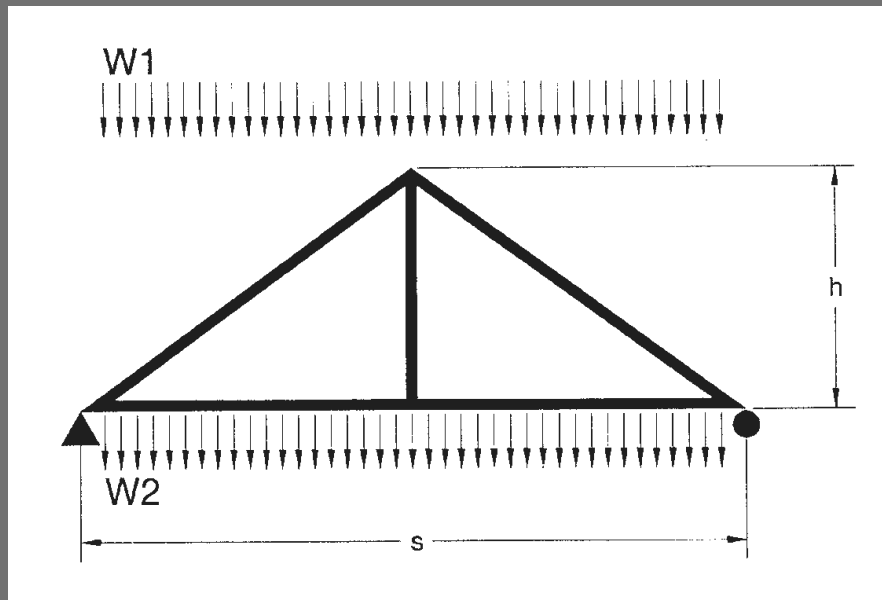
Or

$$M = PL/4 = 45\# \times 83.14" / 4 = 936 \text{ "- \#}$$

$$f_b = 963 (0.75)/0.984 = 713.14$$

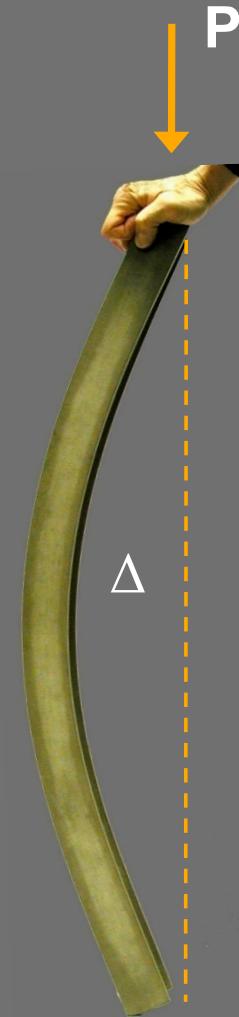


Other Examples



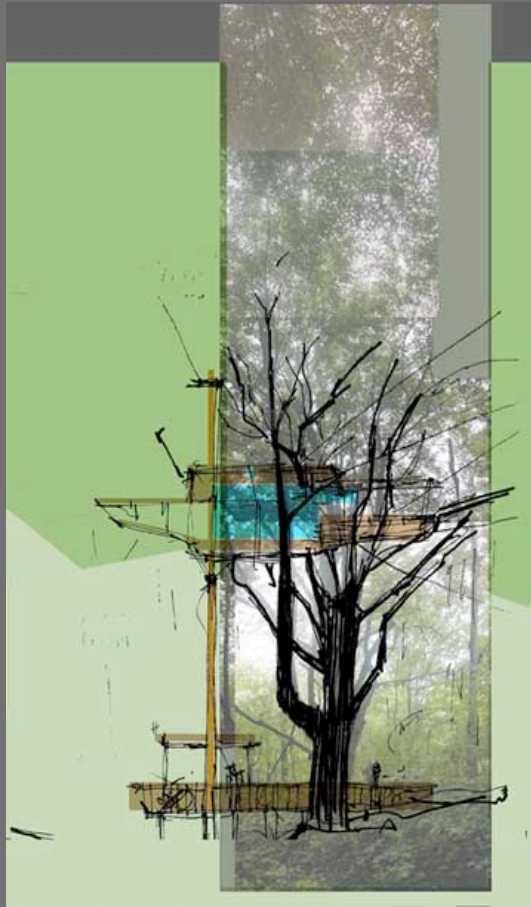
Second Order Stress “P Delta Effect”

1. Eccentric load causes bending moment
2. Bending moment causes deflection, Δ
3. $P \times \Delta$ causes additional moment
4. The additional $P\Delta$ moment causes additional deflection, Δ_1



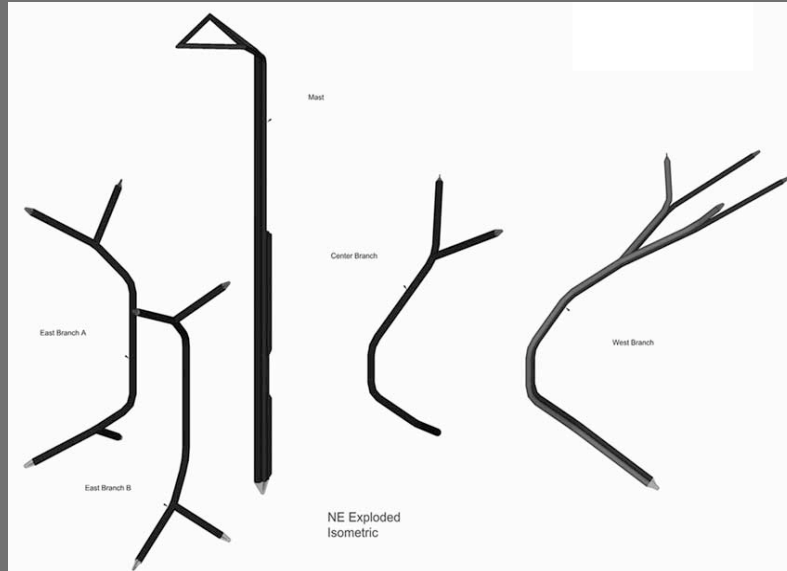
Treehouse

- Form Exploration



Treehouse

- Details
 - Pinned at ends
 - Radius bent at joints
 - ‘Continuous’ sections
 - Welded seams



Treehouse

- Details
 - Pinned at ends
 - Radius bent at joints
 - ‘Continuous’ sections
 - Welded seams



Treehouse

- Erection
 - 3 sections
 - Trucked to site
 - Erected with mobile crane
 - One day process



Treehouse

- Erection
 - 3 sections
 - Trucked to site
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Treehouse

- Finished



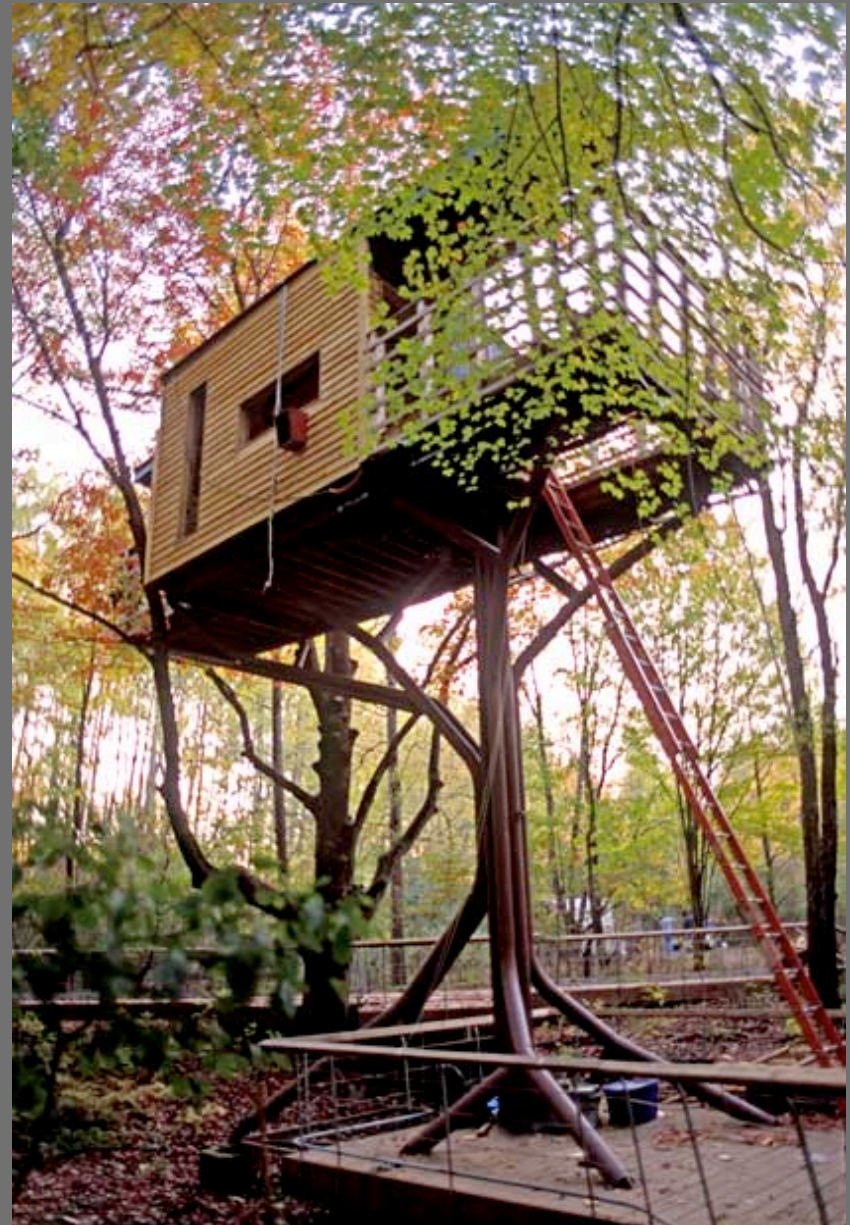
Treehouse

- Finished



Treehouse

- Finished



Treehouse

- Finished

