Architecture 324
Structures II

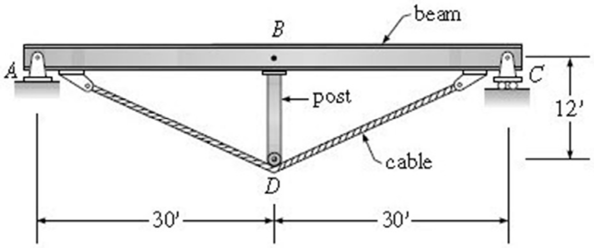
Pre- and Post-Tensioning

- Cable Trusses
- Concrete Beams
- Stressed Membranes

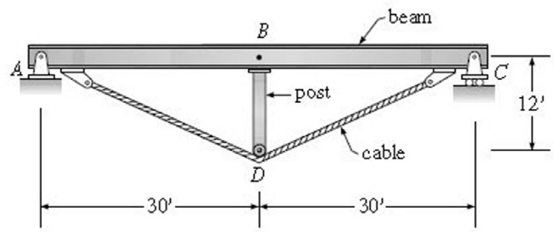
Cable Trusses

- Reduce flexure stress
- Reduce deflection
- Produces stiffer section with less material
- Lighter weight
- Longer spans possible
- Analysis by combined stress

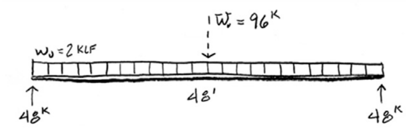
$$f = -\frac{P}{A} \pm \frac{M}{S} \pm \left[\frac{Pe}{S}\right]$$

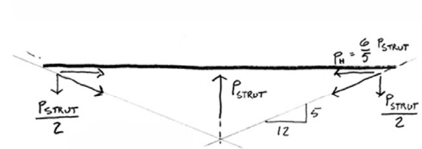


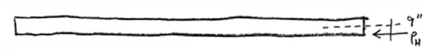
Cable Truss – stress analysis
determine cable prestress



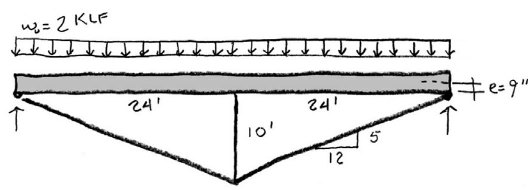
1. Break beam load into 3 FBDs.
   1. applied load
   2. cable + strut
   3. eccentric load (if any)
2. Solve moment for beam at the center line (C.L.) for applied load
3. Solve C.L. moments for other 2 FBDs in terms of strut force, Ps
4. Equate the moments from the three moment equations to cancel at the CL
5. Solve for the strut and cable forces.
6. Construct moment diagram for the beam with all loadings combined: applied load + cable at ends + struts.
7. Solve combined stress in beam using interaction equation.





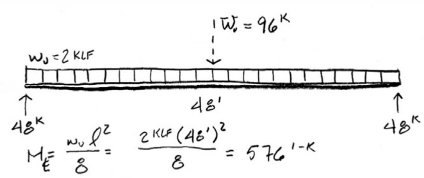


Cable Truss Analysis
Example

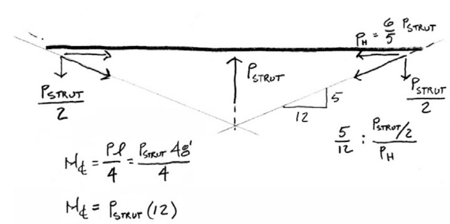


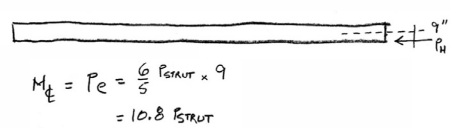
Given: truss configuration with applied load

Required: force in the cable which will result in zero moment at the center line, C.L.



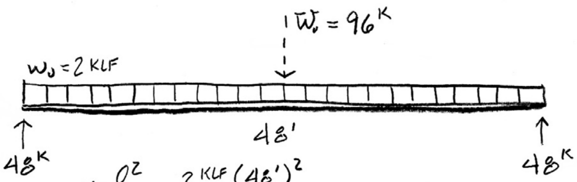
1. Divide the truss into 3 Free Body Diagrams:
   1. applied load
   2. cable + strut
   3. eccentric load (if any)





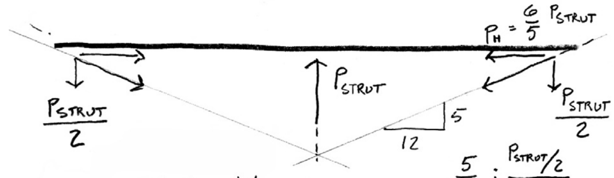
Cable Truss Analysis

2. Find the C.L. moment based on applied load alone.



$$M_{℄} = \frac{w_u l^2}{8} = \frac{2^{KLF}(48')^2}{8} = 576^{1\text{-}K}$$

3. Find the C.L. moment for the cable and strut in terms of the strut force, P_{strut}. Write the components of the cable force in terms of P_{strut}

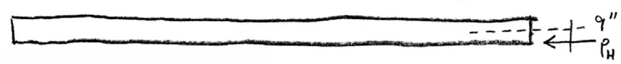


$$\frac{5}{12} : \frac{P_{STRUT}/2}{P_H}$$

$$M_{℄} = \frac{Pl}{4} = \frac{P_{STRUT}\,48'}{4}$$

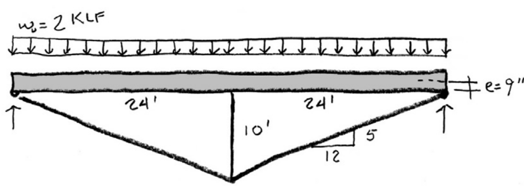
$$M_{℄} = P_{STRUT}(12)$$

4. Find the C.L. moment for the eccentric cable load in terms of P_{strut}



$$M_{℄} = Pe = \frac{6}{5} P_{STRUT} \times 9$$
$$= 10.8\, P_{STRUT}$$

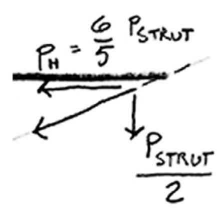
Cable Truss Analysis



5. Set the sum of the C.L. moments equal to zero and solve for the strut force, P_{strut}

$$+M_U - M_{STRUT} - M_e = 0$$
$$576 - 12\,P_{STRUT} - 10.8\,P_{STRUT} = 0$$
$$22.8\,P_{STRUT} = -576 \text{ K-FT}$$
$$P_{STRUT} = 25.26^K$$

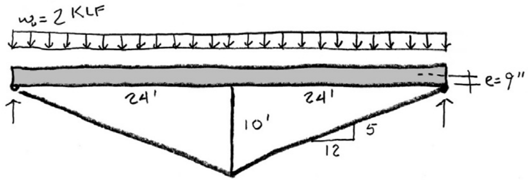
6. Sum the cable components to find the total cable force.



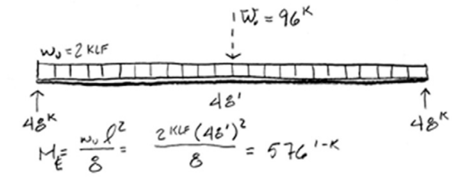
CABLE FORCE

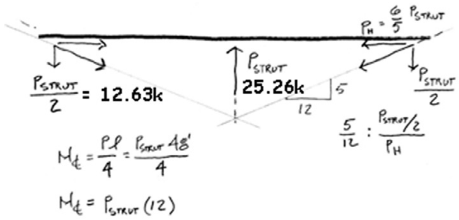
$$\sqrt{\left(\frac{6}{5}(P_{STRUT})\right)^2 + \left(\frac{P_{STRUT}}{2}\right)^2} = 32.84^K$$

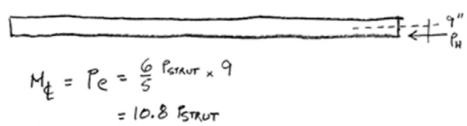
Cable Truss Analysis

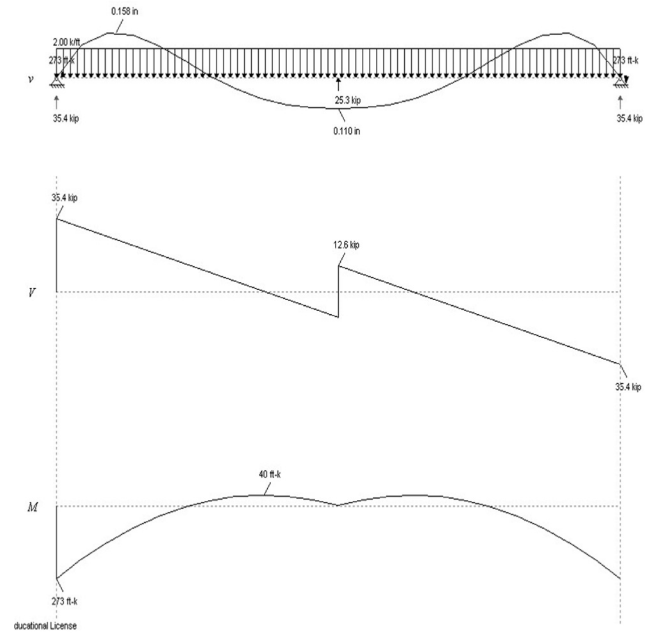


7.find end reactions and calculate shear & moment

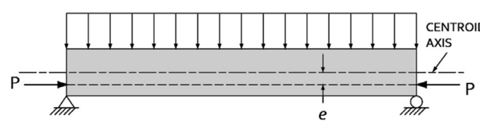




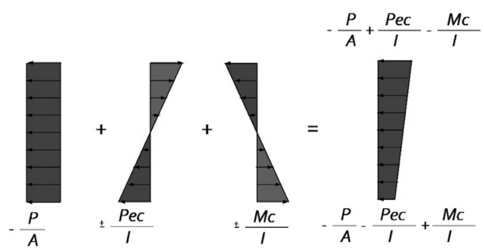




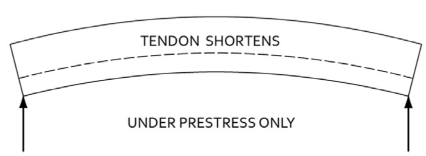
Pre-stressed Concrete

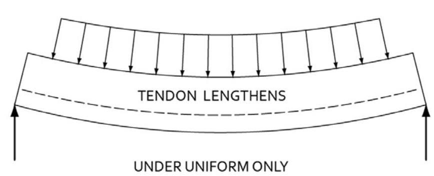


- More concrete active in resisting moment
- Produces stiffer section with less material
- Lighter weight
- Longer spans possible
- Analysis by combined stress



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





Pre-stressed Concrete

Steel:

high strength wires 250 or 270 ksi
wire diameter 0.105 – 0.276
used in strands of bundled wire
most common is 7 wire strand

Concrete:

higher strength 5 – 10 ksi
to reduce creep and strain
reduced cracking
stiffer sections

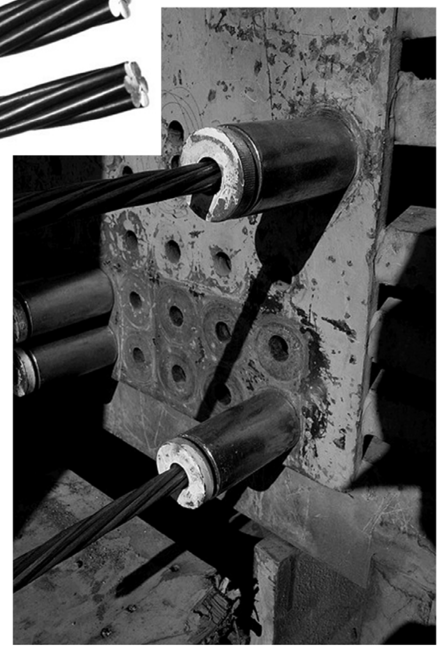


Photo by Angelo Marasco

Pre-stressed Concrete

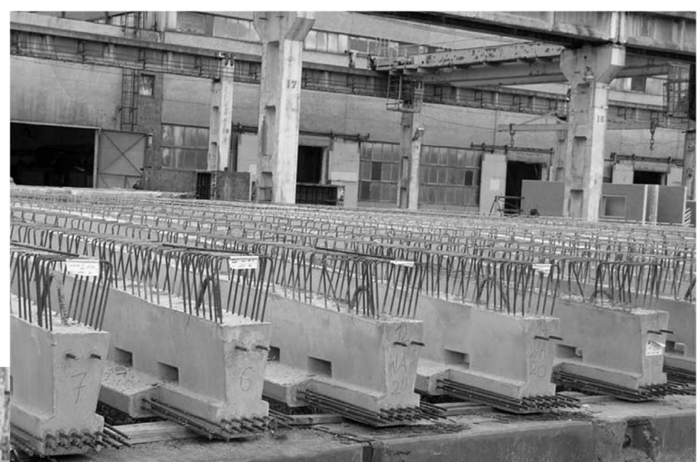
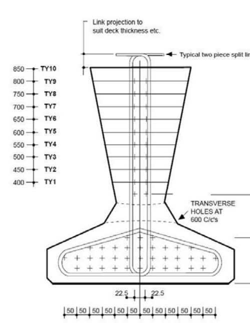


Photo by MACRETE



Schlaich Bergermann & Partners

Neckarsulm, 1989

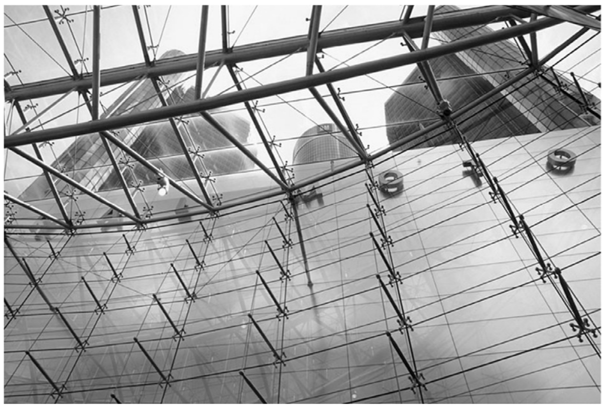
Schlaich Bergermann & Partners

History of Hamburg Museum

Stressed Membrane

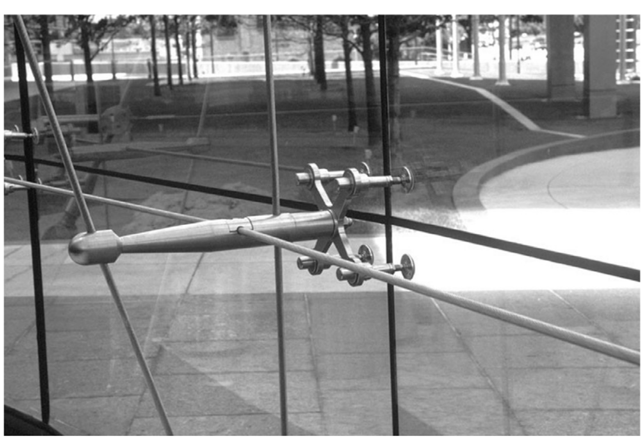
Renaissance Center
Entrance Pavilion
Detroit 2004
SOM

- Point supported glass
- “fish belly” cable truss bacing



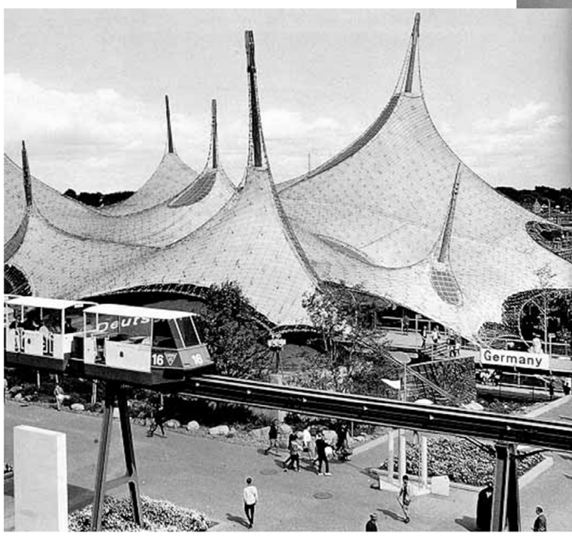
Stressed Membrane

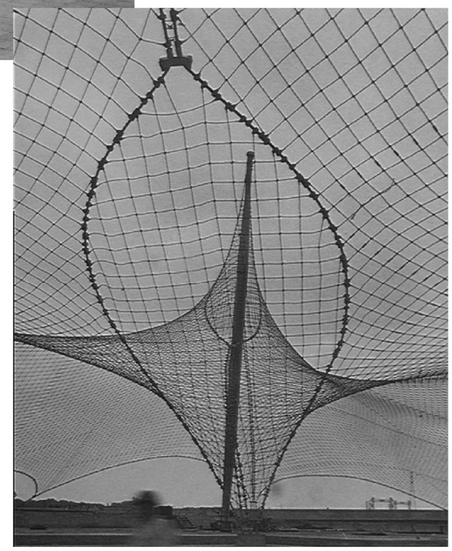
Renaissance Center
Entrance Pavilion
Detroit 2004
SOM



Expo ’67, Montreal

Frei Otto
German Pavilion





Institute for Lightweight Structures – IL (now ILEK)

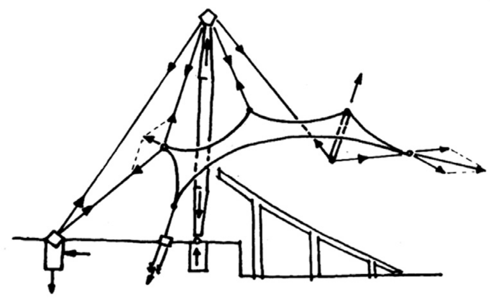
University of Stuttgart

Frei Otto, IL building, University of Stuttgart

Stressed Membrane

Olympic Buildings, Munich 1972
Eng. Otto, Leonhardt, Schlaich
Arch: Behnisch

- Opposing curvature
- Stressed by anchors and masts



Frei Otto, Munich Soccer Stadium (from back)

Stressed Membrane Olympic Stadium, Munich 1972

Bundesgartenschau Köln
Frei Otto