Cables
• simple
• uses
  – suspension bridges
  – roof structures
  – transmission lines
  – guy wires, etc.
• have same tension all along
• can’t stand compression – struts do

Cables
• use high-strength steel
• need
  – towers
  – anchors
  – stiffeners (hangers)
• have spans & sag
• don’t want movement
  – dynamic effects of wind
  – resonance
Cables

• equilibrium:
  – not enough to solve, we have slopes
  – X component the same everywhere

Cable Loads

• straight line between forces

Cable Loads

• shape directly related to the distributed load

Cable Loads

• trig:
  \[ T_x = T \cos \theta \]
  \[ T_y = T \sin \theta \]

• parabolic (catenary)
  – distributed uniform load
  \[
  y = 4h(Lx - x^2) / L^2
  \]
  \[
  L_{total} = L(1 + \frac{8}{3}h^2/L^2 - \frac{32}{75}h^4/L^4)
  \]
Cables & Tension Elements

- typical cross sections

  - Round bar
  - Flat bar
  - Angle
  - Double angle
  - Channel
  - Double channel
  - Laminated channels
  - H section (wax-open)
  - S section (American Standard)
  - Multi-wire strand

Cable Structures

- categories
  - single drape
  - double
    - different curvature
    - same plane or different

- cases
  - Brooklyn Bridge
  - Dulles Terminal

Brooklyn Bridge, Roebling 1883
Cable-Stayed Structures

- diagonal cables support horizontal spans
- typically symmetrical
- cases
  - Patcenter
  - Alamillo Bridge

Patcenter, Rogers 1986
Patcenter, Rogers 1986

- dashes – cables pulling

![Patcenter, Rogers 1986](image)

Figure 3.5: Patcenter, load path diagram.

Alamillo Bridge, Calatrava 1992

- concrete “mast”
- parallel cable stays
- steel box beam spine in deck

![Alamillo Bridge, Calatrava 1992](image)

Figure 3.12: Alamillo bridge, load path diagram.
Tensegrities

- 3D frame
- discontinuous struts
- continuous cables

Olympic Gymnastics Stadium

- Geiger 1988

Olympic Gymnastics Stadium

- Geiger 1988

Florida Suncoast Dome, HOK 1989
**Florida Suncoast Dome, HOK 1989**

![Diagram of Florida Suncoast Dome](image1)

Figure 5.22: Florida Suncoast Dome, section.

**Georgia Dome, Stainback 1992**

![Image of Georgia Dome](image2)

Figure 5.24: Georgia Dome, isometric drawing of cable and strut configuration.

**Arches**

- **curvilinear form**
  - efficient in compression
  - minimal bending stress

![Diagram of Arches](image3)
Arches

• ancient
  – stone
  – masonry

Rainbow Bridge National Monument

Packhorse Bridge, UK

Arches

• terminology
  – arch axis
  – crown
  – rise
  – extrados
  – intrados
  – depth
  – spring line
  – span
  – skewback
  – soffit

Arch terminology

Arches

• behavior
  – stabilization
  – resist thrust

• materials
  – stone
  – masonry
  – concrete
  – laminated wood
  – steel

Free-standing arch (stable due to width of vossoirs)

Arch stabilized by surrounding masonry wall (also makes carrying moving loads feasible)
Arches

• behavior
  – thrust related to height to width

Arches

• common forms
  – Arch in Compression
  – Parabolic Arch
  – Semicircular Arch

Arches

• common variations
  – two hinged
  – three hinged – statically determinate

Arches

• requires lateral bracing
  – lateral ties
  – diagonal ties
Arches

- ... bracing
  - lamellas

(d) Lamella (diagonal)
truss barrel vault

Vaults

- Crypt of the Colonia Güell - Gaudi

Domes

- arch of revolutionary design
- resists
  compressive
  forces
Domes

• materials & forms
  – concrete
  – masonry
  – steel

• stresses and displacements

Domes

• materials & forms
  – concrete
  – masonry
  – steel

Domes

• Palazzetto dello Sport -Nervi