APPLIED ARCHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS
ARCH 631
DR. ANNE NICHOLS
FALL 2012

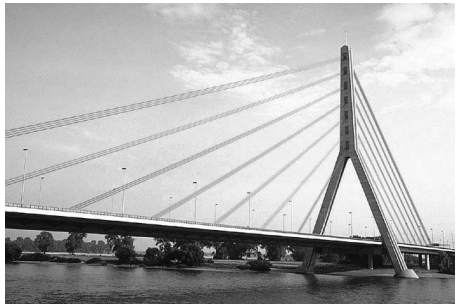
lecture
SIX

cables & arches

Millennium Bridge in Newcastle, UK

Cables

- simple
- uses
  - suspension bridges
  - roof structures
  - transmission lines
  - guy wires, etc.

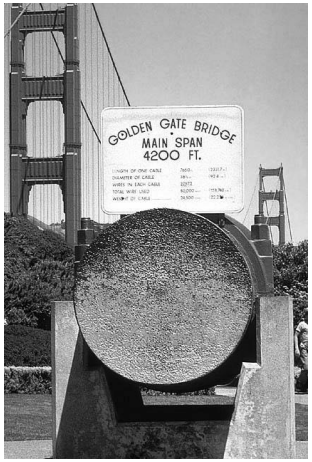


http:// nisee.berkeley.edu/godden

- 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



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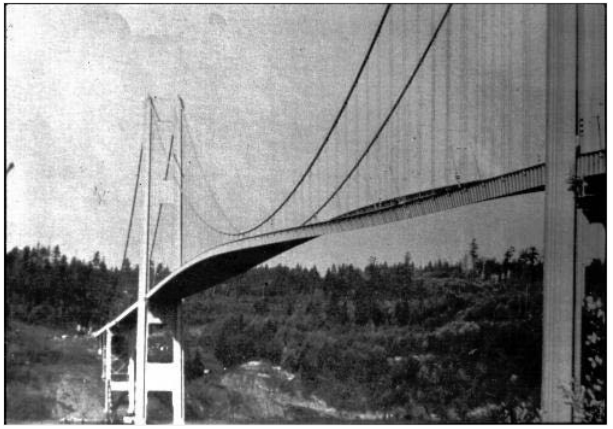
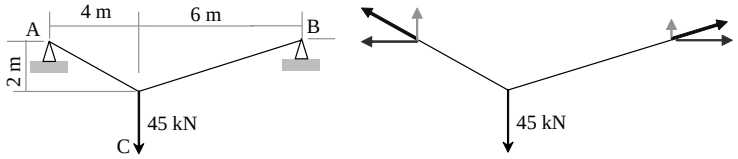
Cables



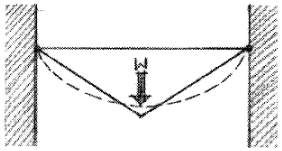
Cables

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

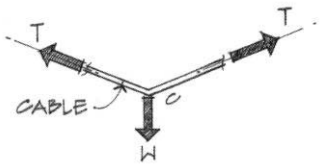


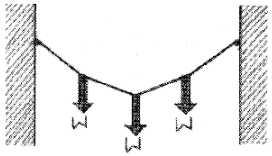
Cable Loads

- *straight line between forces*



(a) Simple concentrated load—triangle.

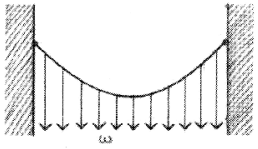




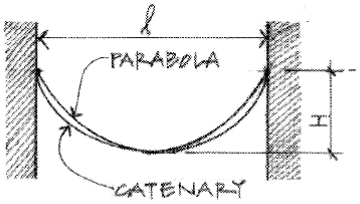
(b) Several concentrated loads—polygon.

Cable Loads

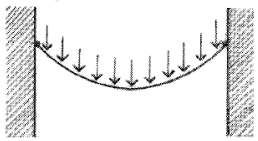
- *shape directly related to the distributed load*



(c) Uniform loads (horizontally)—parabola.



(e) Comparison of a parabolic and a catenary curve.

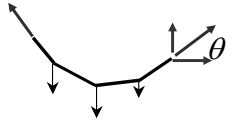


(d) Uniform loads (along the cable length)—catenary.

Cable Loads

- *trig:* $T_x = T\cos\theta$

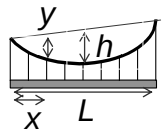
$T_y = T\sin\theta$



- *parabolic (catenary)*
  - *– distributed uniform load*

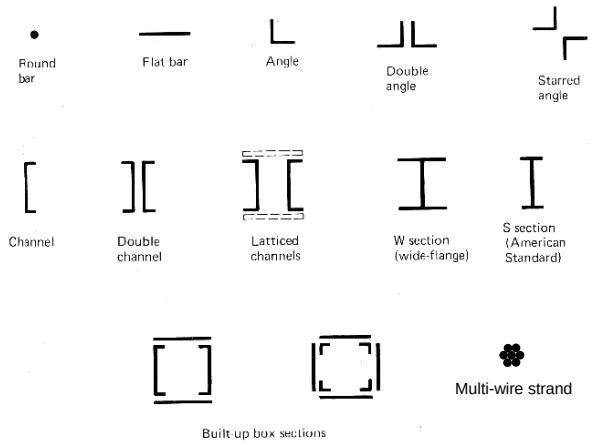
$$y = 4h(Lx - x^2)/L^2$$

$$L_{total} = L(1 + \tfrac{8}{3}h^2/L^2 - \tfrac{32}{5}h^4/L^4)$$



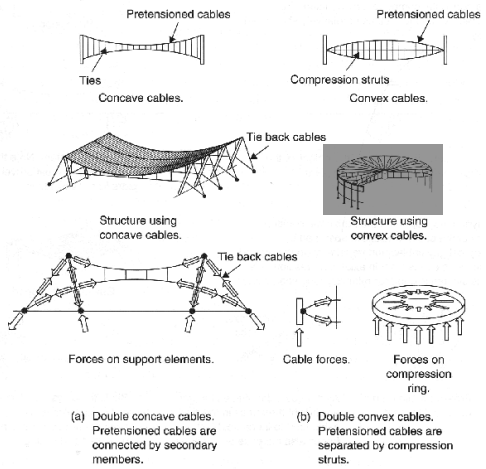
Cables & Tension Elements

- *typical cross sections*



Cable Structures

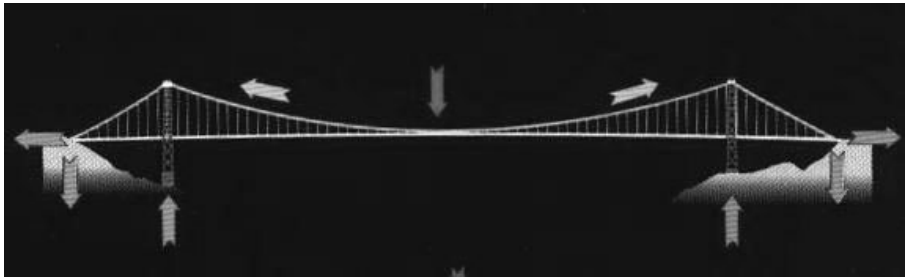
- *categories*
  - *single drape*
  - *double*
    - *different curvature*
    - *same plane or different*
- *cases*
  - *Brooklyn Bridge*
  - *Dulles Terminal*



Brooklyn Bridge, Roebling 1883

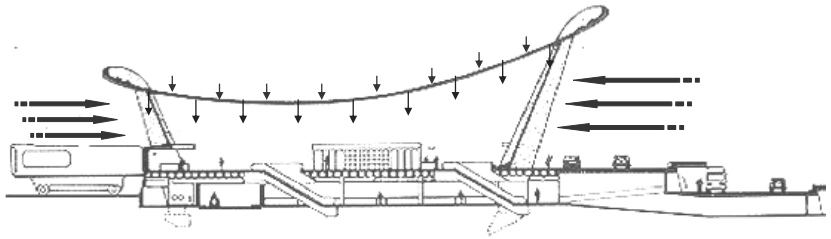
http:// nisee.berkeley.edu/godden

Brooklyn Bridge, Roebling 1883



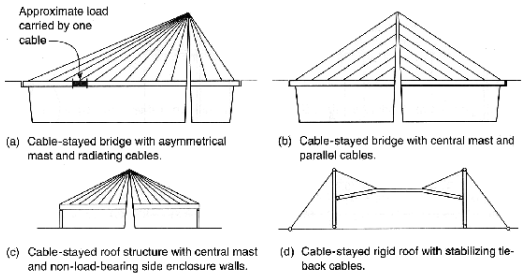
Dulles Terminal, Saarinen 1962

Dulles Terminal, Saarinen 1962



Cable-Stayed Structures

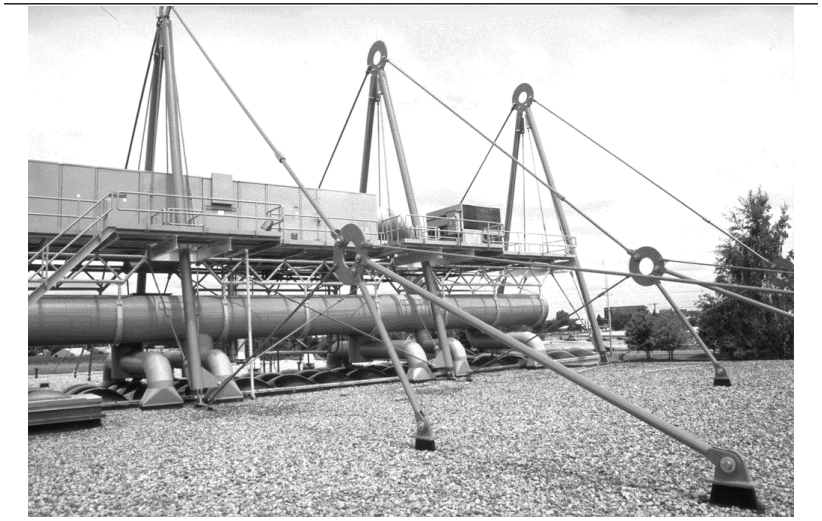
- *diagonal cables support horizontal spans*
- *typically symmetrical*
- *cases*
  - *Patcenter*
  - *Alamillo Bridge*



Patcenter, Rogers 1986

www.columbnbia.edu

Patcenter, Rogers 1986



www.columnbia.edu

Patcenter, Rogers 1986

- *dashes – cables pulling*

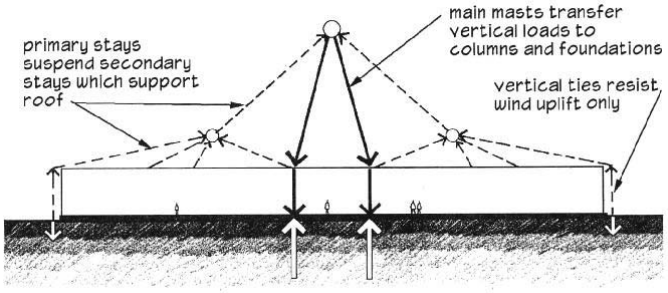


Figure 3.5: Patcenter, load path diagram.

Alamillo Bridge, Calatrava 1992

http://en.structurae.de

Alamillo Bridge, Calatrava 1992

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

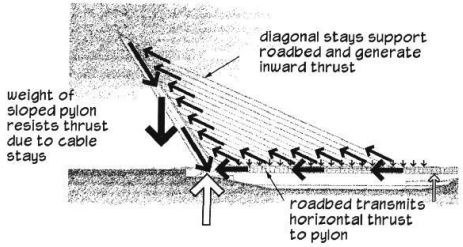
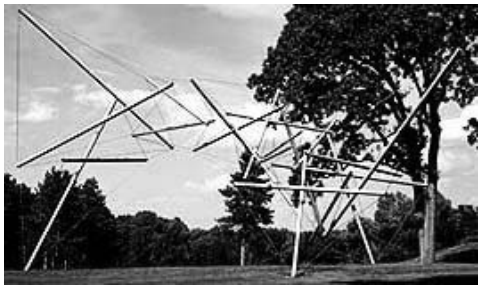


Figure 3.12: Alamillo bridge, load path diagram.

Tensegrities

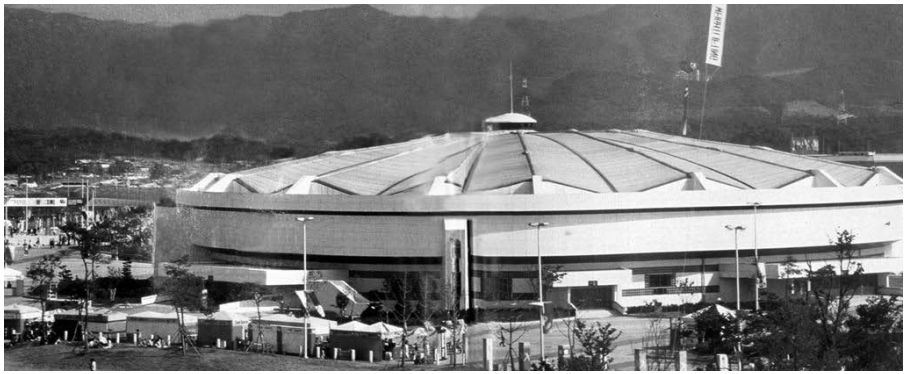
- 3D frame
- discontinuous struts
- continuous cables



Free Ride Home – Kenneth Snelson

Olympic Gymnastics Stadium

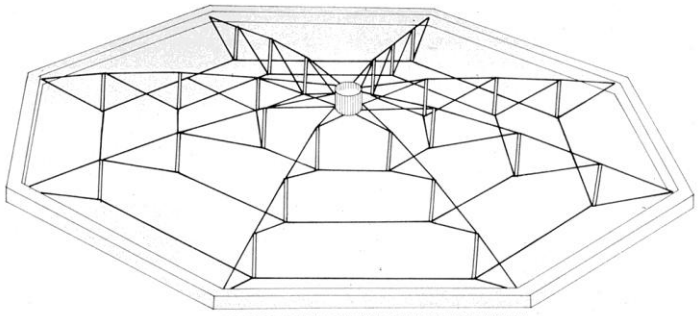
- Geiger 1988



www.columnbia.edu

Olympic Gymnastics Stadium

- Geiger 1988



Florida Suncoast Dome, HOK 1989

Florida Suncoast Dome, HOK 1989

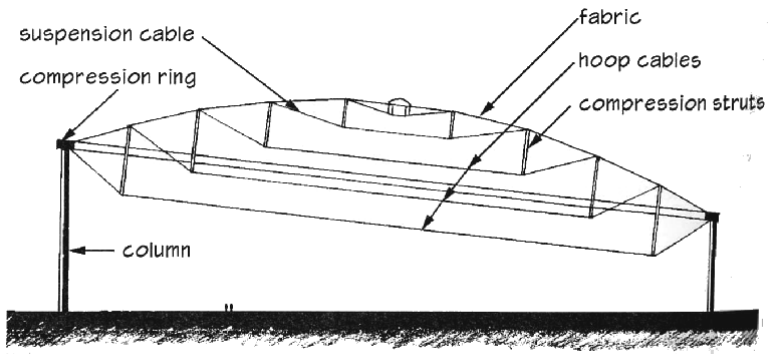
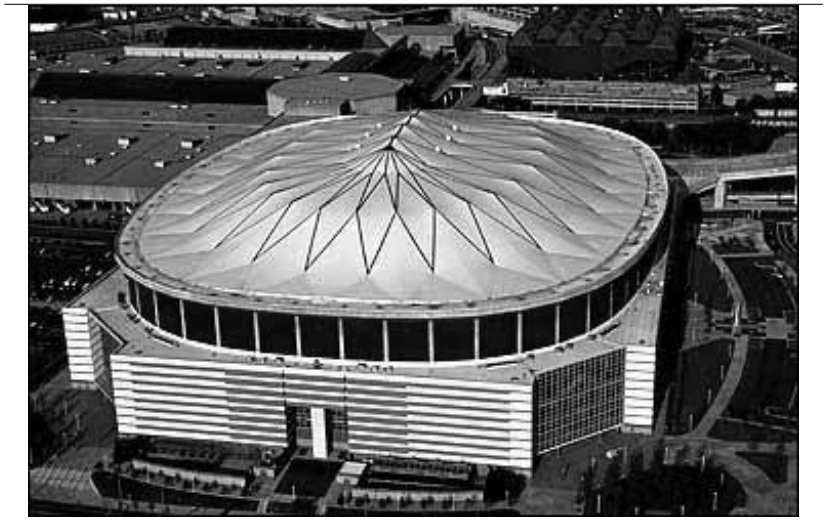


Figure 5.22: Florida Suncoast Dome, section.

Georgia Dome, Stainback 1992



Georgia Dome, Stainback 1992

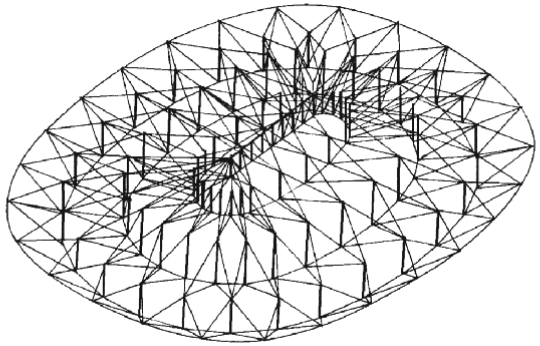
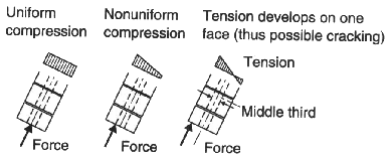
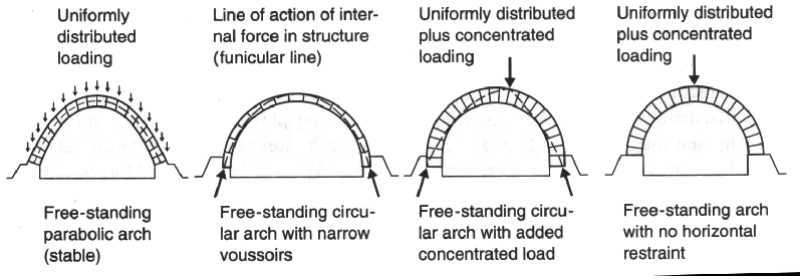


Figure 5.24: Georgia Dome, isometric drawing of cable and strut configuration.

Arches

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





Arches

- *ancient*
  - *stone*
  - *masonry*

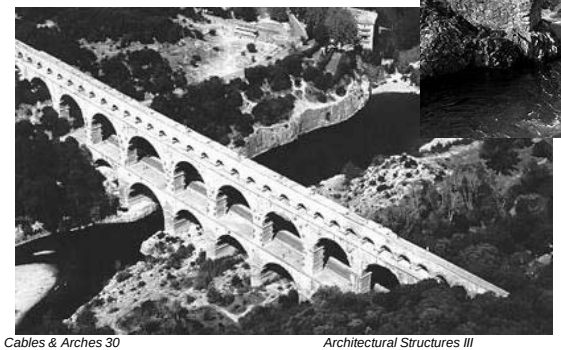
www.greatbuildings.com

Rainbow Bridge National Monument

Arches

- *ancient*
  - *stone*
  - *masonry*

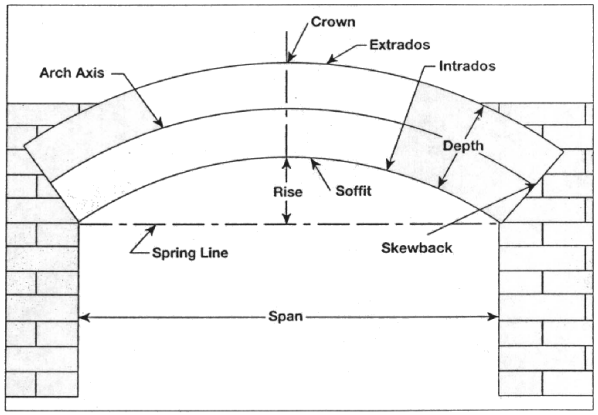
Packhorse Bridge, UK



Roman Aquaducts

Arches

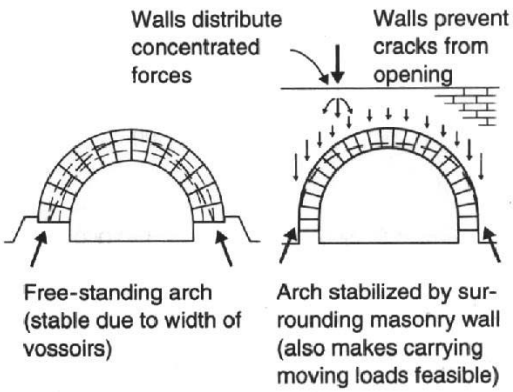
- *terminology*
  - *arch axis*
  - *crown*
  - *rise*
  - *extrados*
  - *intrados*
  - *depth*
  - *spring line*
  - *span*
  - *skewback*
  - *soffit*



Arch terminology

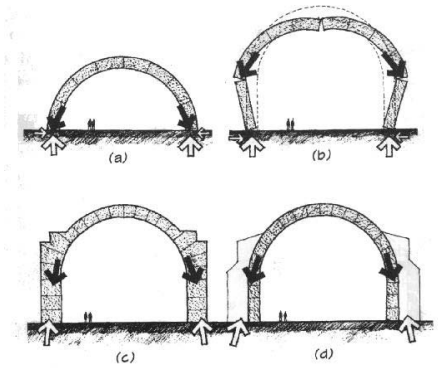
Arches

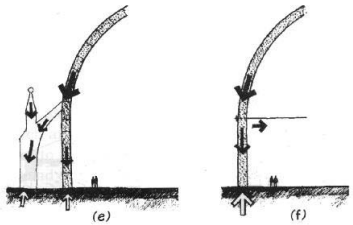
- *behavior*
  - *stabilization*
  - *resist thrust*
- *materials*
  - *stone*
  - *masonry*
  - *concrete*
  - *laminated wood*
  - *steel*



Arches

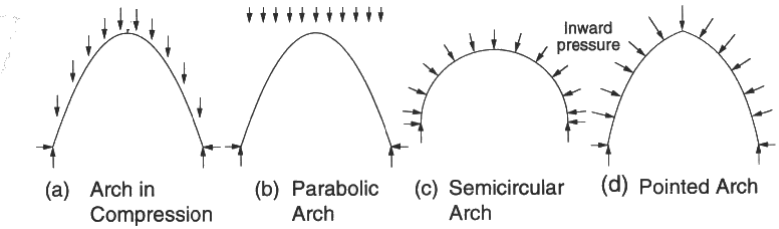
- *behavior*
  - *thrust related to height to width*





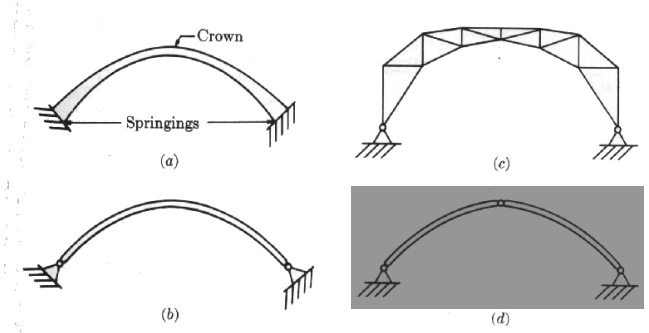
Arches

- *common forms*



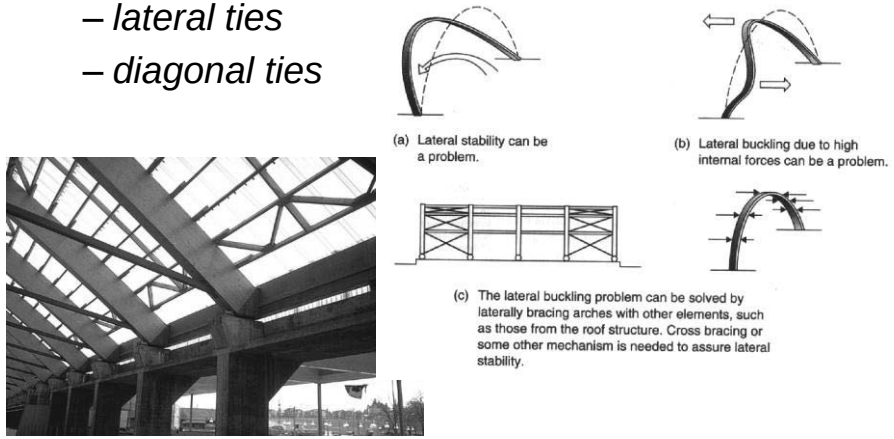
Arches

- *common variations*
  - *two hinged*
  - *three hinged – statically determinate*



Arches

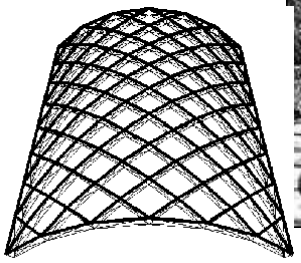
- *requires lateral bracing*
  - *lateral ties*
  - *diagonal ties*



http:// nisee.berkeley.edu/godden

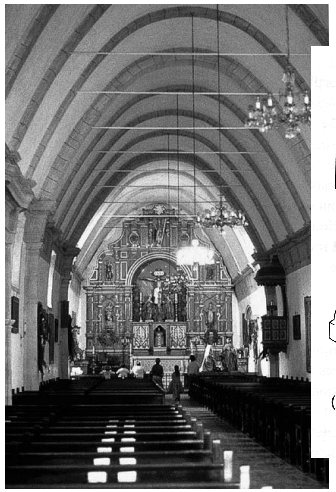
Arches

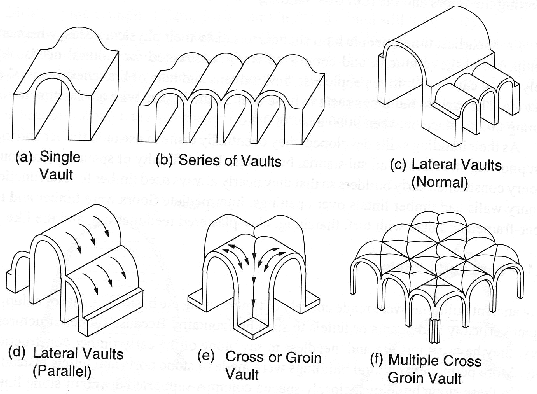
- *... bracing*
  - *– lamellas*



(d) Lamella (diagonal) truss barrel vault

Vaults





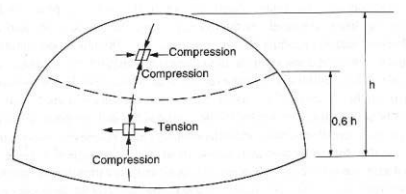
http:// nisee.berkeley.edu/godden

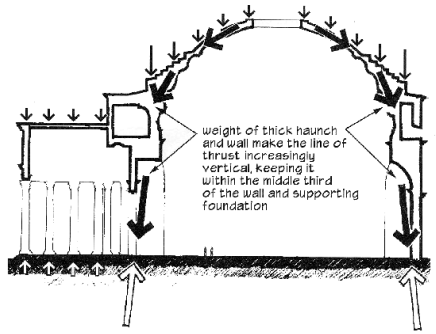
Vaults

- *Crypt of the Colonia Güell - Gaudi*

Domes

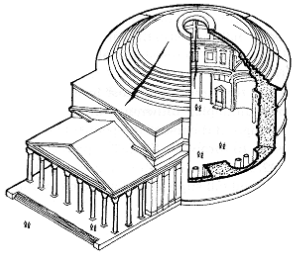
- *arch of revolutionary design*
- *resists compressive forces*

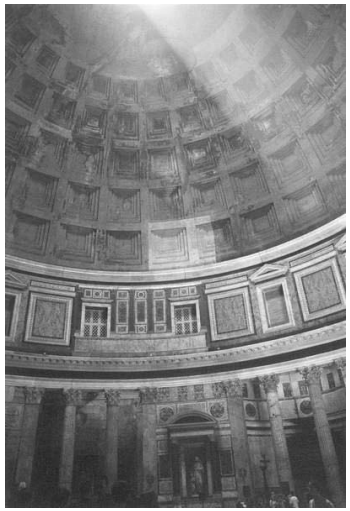




Domes

- *materials & forms*
  - *concrete*
  - *masonry*
  - *steel*

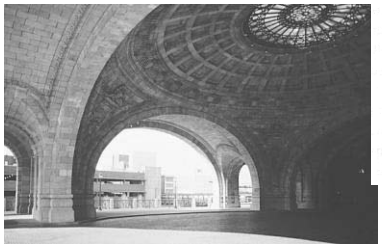




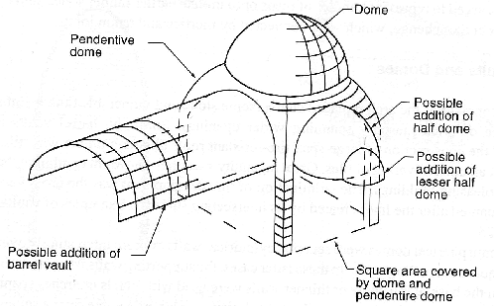
Pantheon

Domes

- *materials & forms*
  - *concrete*
  - *masonry*
  - *steel*



Union Station Rotunda, Pittsburg



Domes

- *stresses and displacements*

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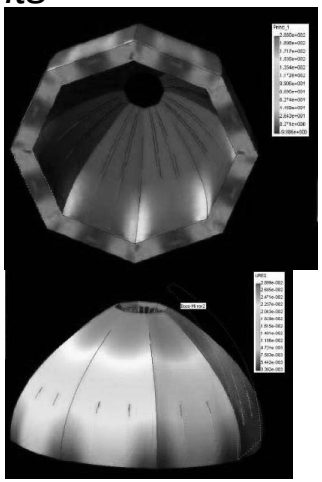

Domes

- *Palazzetto dello Sport -Nervi*