

APPLIED ARCHITECTURAL STRUCTURES:

STRUCTURAL ANALYSIS AND SYSTEMS

ARCH 631

DR. ANNE NICHOLS

FALL 2013

lecture
SIX

cables & arches

Cables & Arches 1
Lecture 6



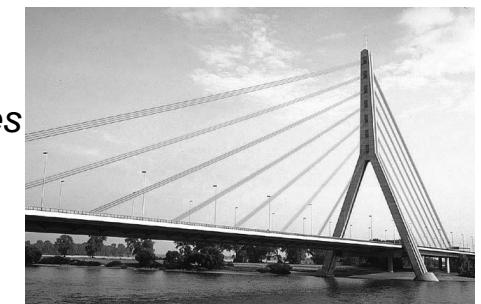
Millennium Bridge in Newcastle, UK

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Cables

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



<http://nisee.berkeley.edu/godden>

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Cables

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



<http://nisee.berkeley.edu/godden>

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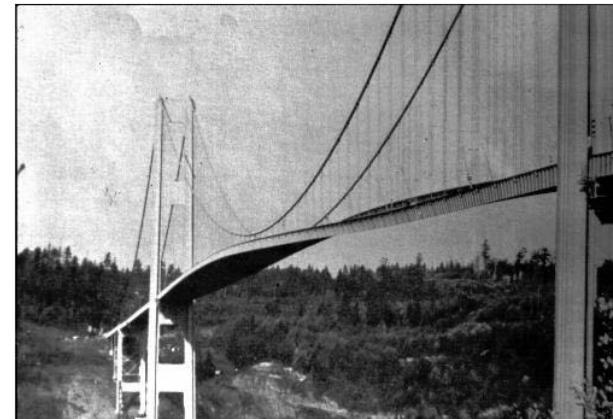
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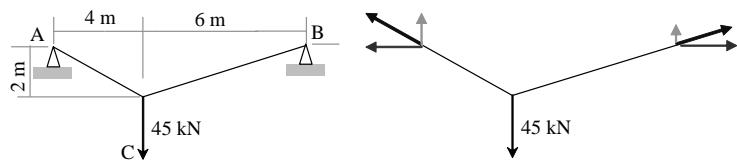
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Cables

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



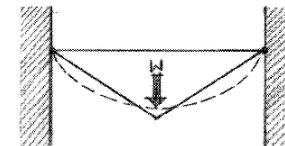
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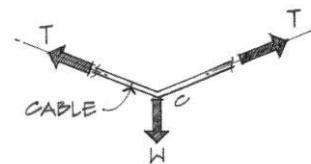
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Cable Loads

- straight line between forces



(a) Simple concentrated load—triangle.



(b) Several concentrated loads—polygon.

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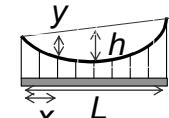
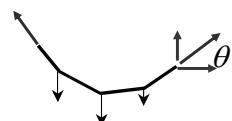
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Cable Loads

- trig: $T_x = T \cos \theta$
 $T_y = T \sin \theta$
- parabolic (catenary)
 - distributed uniform load

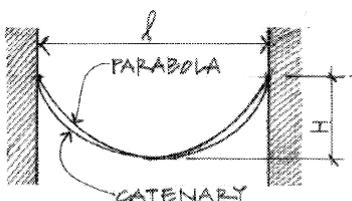
$$y = 4h(Lx - x^2) / L^2$$

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

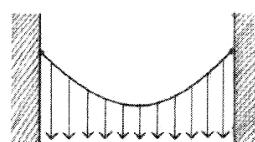


Cable Loads

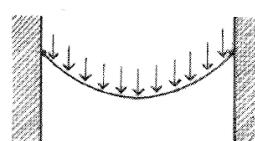
- shape directly related to the distributed load



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



(c) Uniform loads (horizontally)—parabola.



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

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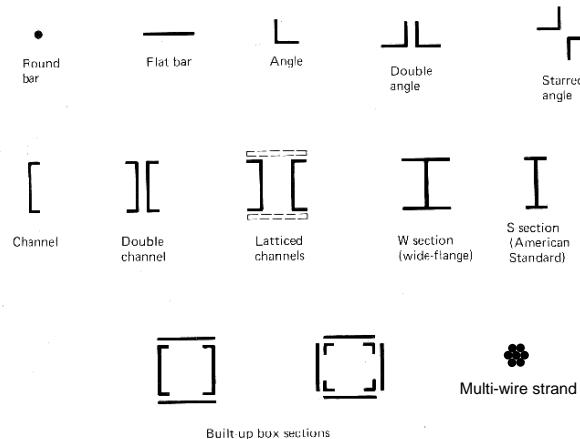
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Cables & Tension Elements

- typical cross sections



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Brooklyn Bridge, Roebling 1883



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Cable Structures

- categories

- single drape

- double

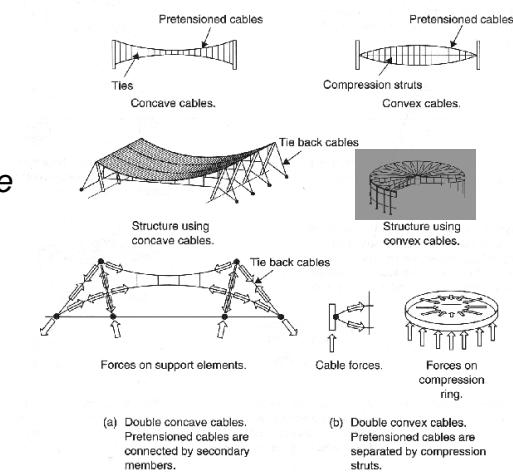
- different curvature

- same plane or different

- cases

- Brooklyn Bridge

- Dulles Terminal



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Brooklyn Bridge, Roebling 1883



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Dulles Terminal, Saarinen 1962

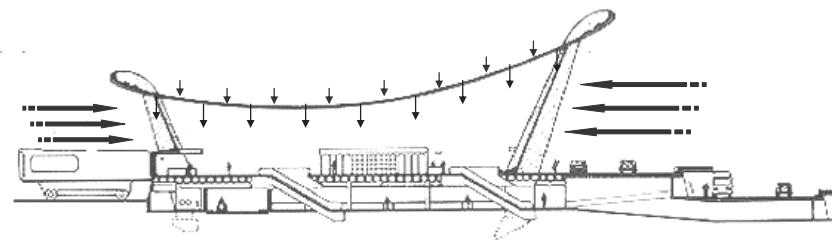


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Dulles Terminal, Saarinen 1962



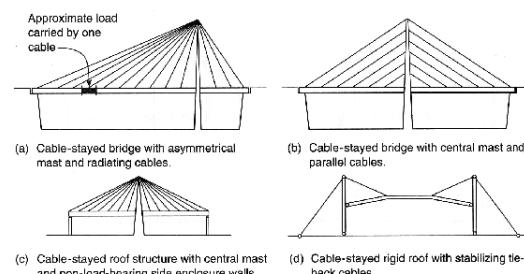
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Cable-Stayed Structures

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



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Patcenter, Rogers 1986

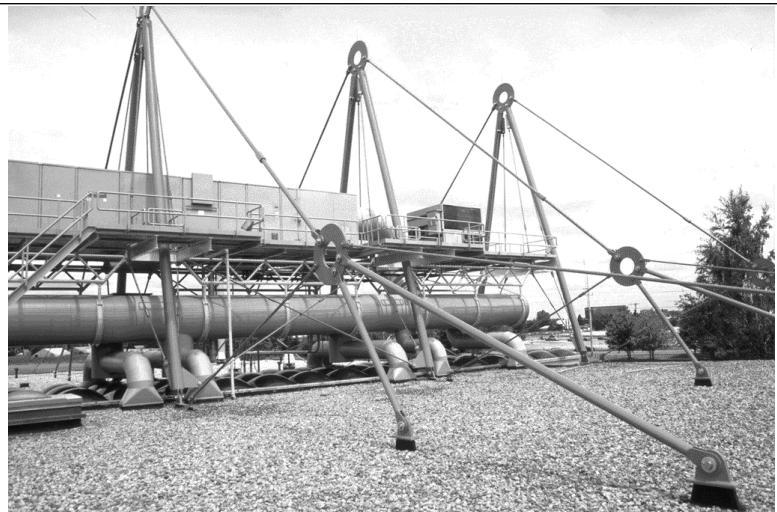


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www.columbia.edu
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Patcenter, Rogers 1986



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Patcenter, Rogers 1986

- dashes – cables pulling

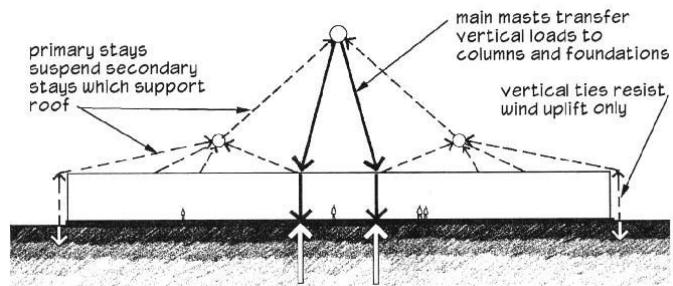


Figure 3.5: Patcenter, load path diagram.

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Alamillo Bridge, Calatrava 1992



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<http://en.structurae.de> F2009abn

Alamillo Bridge, Calatrava 1992

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

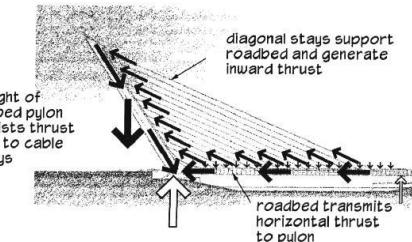


Figure 3.12: Alamillo bridge, load path diagram.

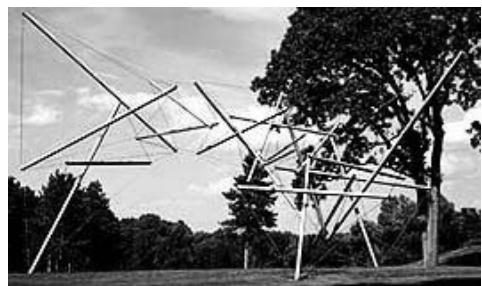
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Tensegrities

- 3D frame
- discontinuous struts
- continuous cables



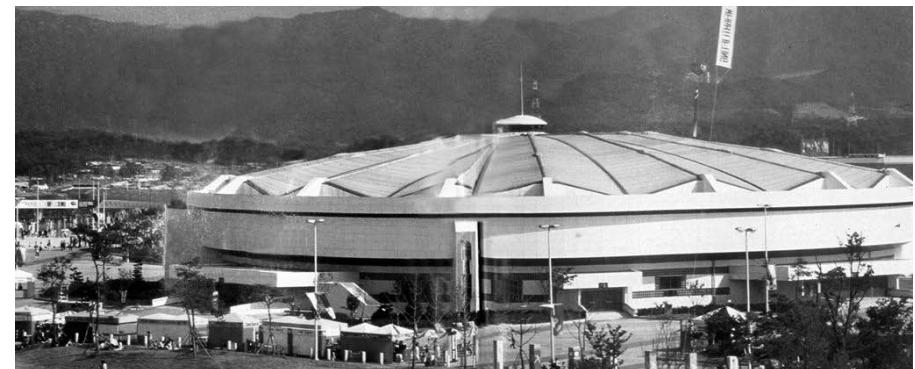
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Olympic Gymnastics Stadium

- Geiger 1988



www.columnbria.edu

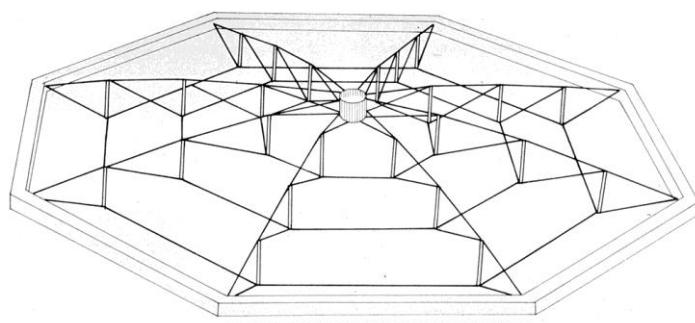
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Olympic Gymnastics Stadium

- Geiger 1988



PERSPECTIVE OF AN 8-SEGMENT CABLE DOME STRUCTURE

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Florida Suncoast Dome, HOK 1989



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Florida Suncoast Dome, HOK 1989

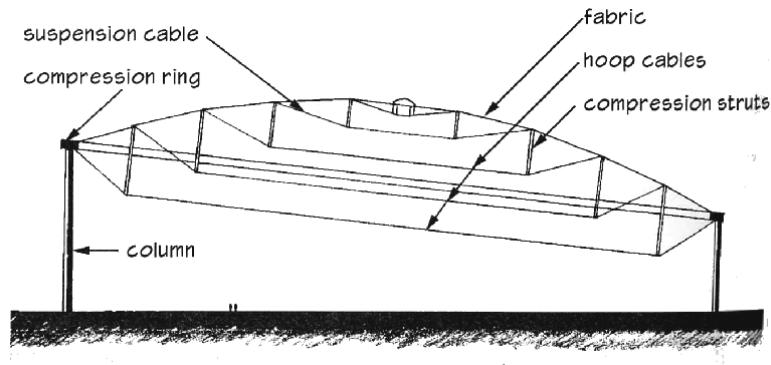


Figure 5.22: Florida Suncoast Dome, section.

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Georgia Dome, Stainback 1992



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Georgia Dome, Stainback 1992

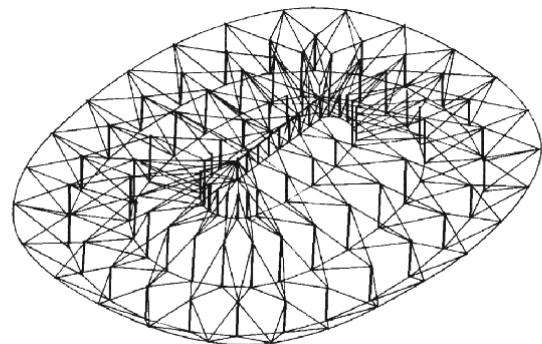


Figure 5.24: Georgia Dome, isometric drawing of cable and strut configuration.

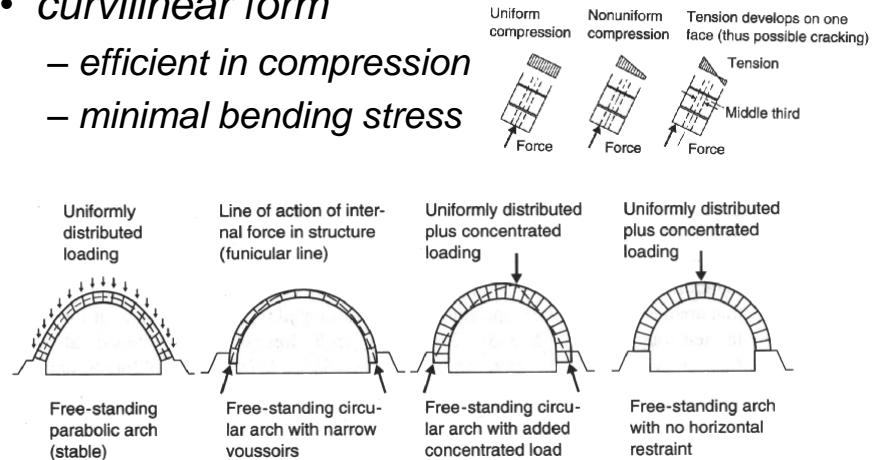
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Arches

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



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Arches

- *ancient*
 - stone
 - masonry



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Rainbow Bridge National Monument

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Arches

- *ancient*
 - stone
 - masonry



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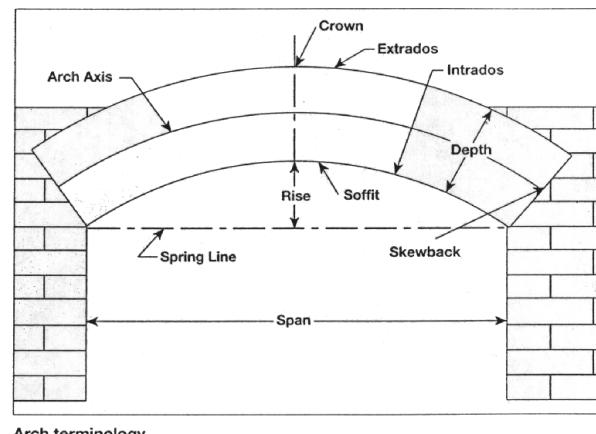
Packhorse Bridge, UK

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Roman Aqueducts

Arches

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



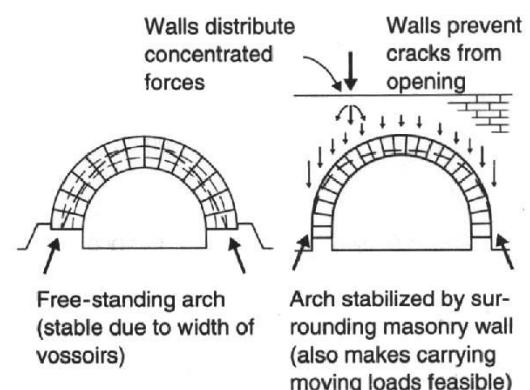
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Arches

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



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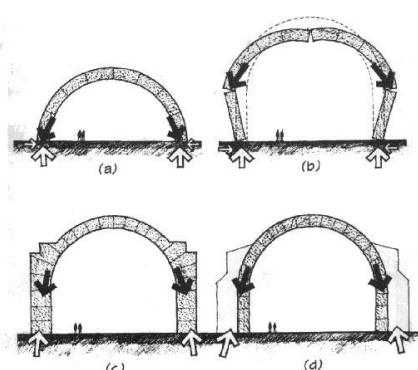
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Arches

- behavior

- thrust related to height to width



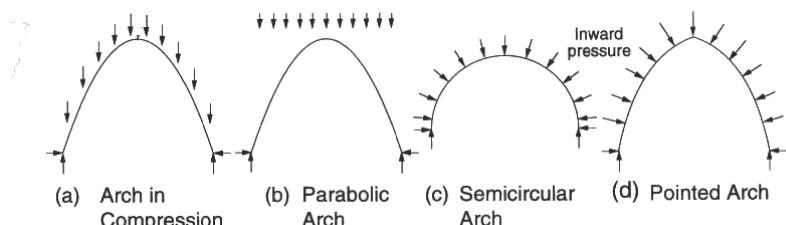
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Arches

- common forms



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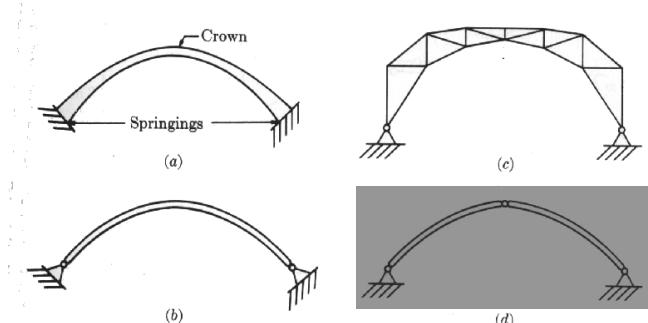
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Arches

- common variations

- two hinged
 - three hinged – statically determinate



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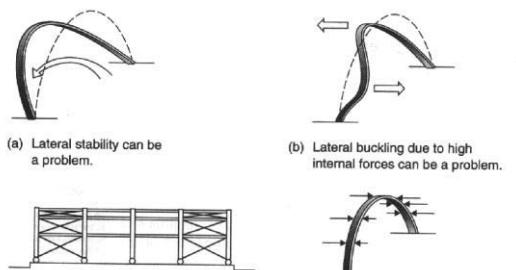
Arches

- requires lateral bracing

- lateral ties
 - diagonal ties



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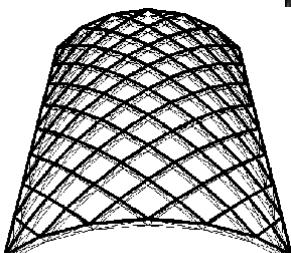


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Arches

- ... bracing
 - lamellas



(d) Lamella (diagonal)
truss barrel vault



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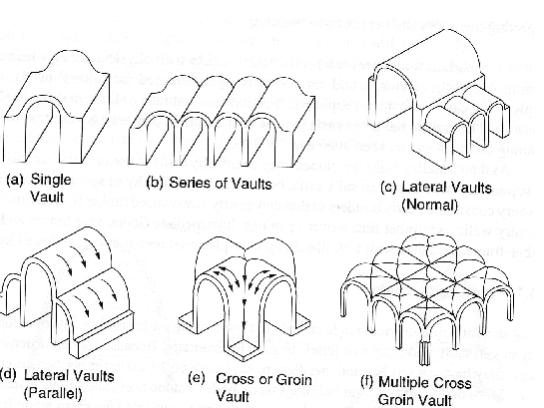
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Vaults



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Vaults

- Crypt of the Colonia Güell - Gaudi



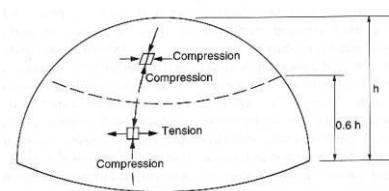
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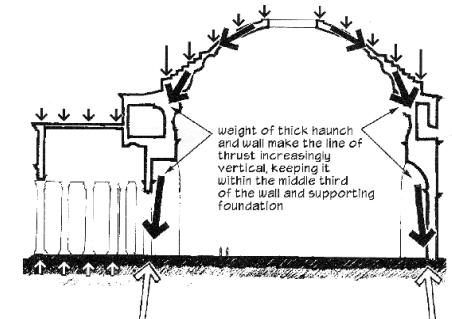
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Domes

- arch of revolutionary design
- resists compressive forces



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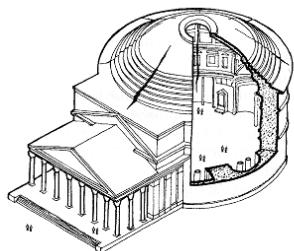


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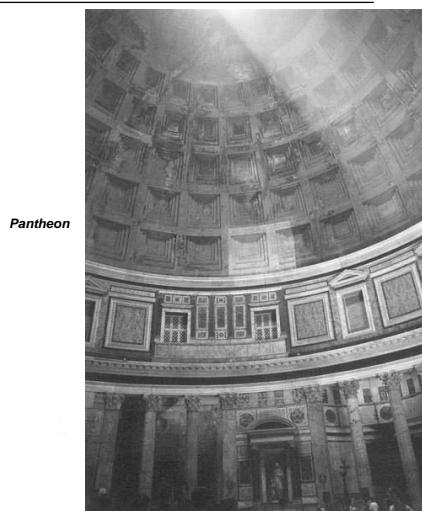
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Domes

- materials & forms
 - concrete
 - masonry
 - steel



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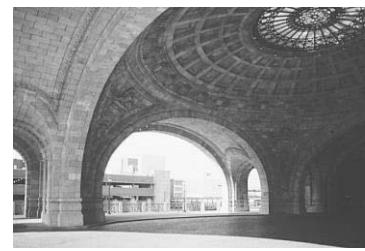
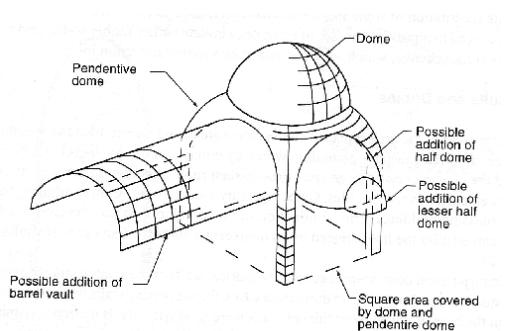
Pantheon

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Domes

- materials & forms
 - concrete
 - masonry
 - steel



Union Station Rotunda, Pittsburgh

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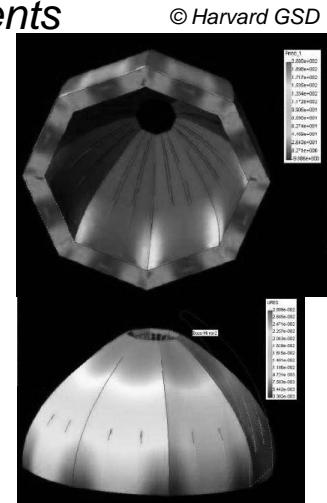
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Domes

- stresses and displacements



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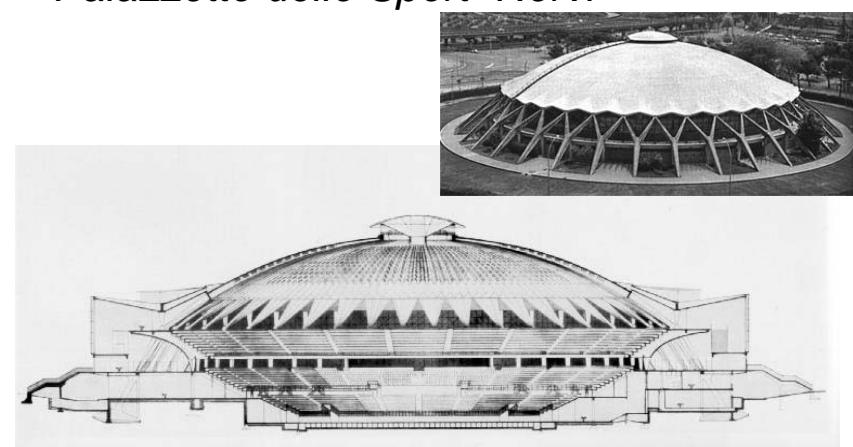


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Domes

- Palazzetto dello Sport -Nervi



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