

lecture
SIX

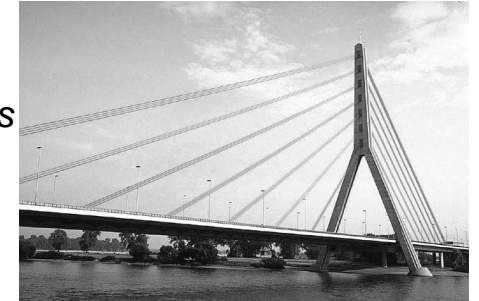
cables & arches



Millennium Bridge in Newcastle, UK

Cables

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



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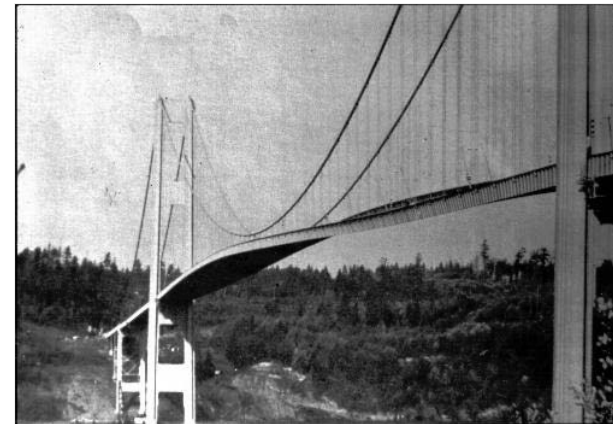
Cables

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



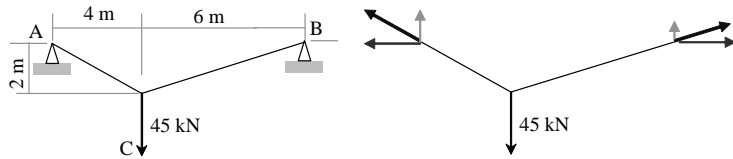
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Cables



Cables

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



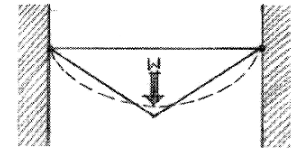
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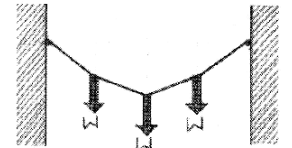
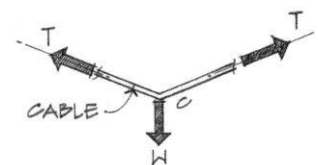
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Cable Loads

- **straight line between forces**



(a) Simple concentrated load—triangle.



(b) Several concentrated loads—polygon.

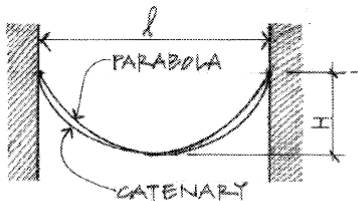
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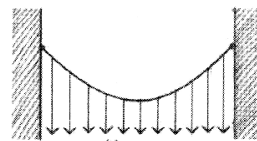
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Cable Loads

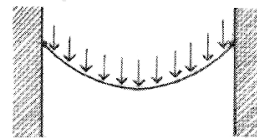
- **shape directly related to the distributed load**



(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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Cable Loads

- **trig:**

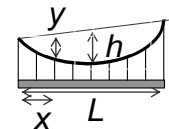
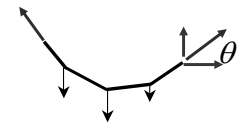
$$T_x = T \cos \theta$$

$$T_y = T \sin \theta$$

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

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

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



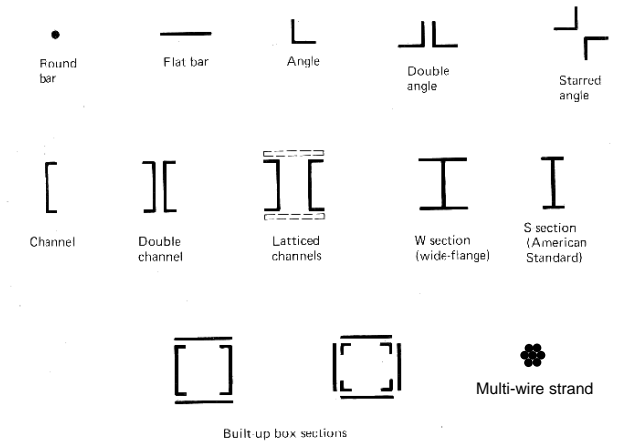
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Cables & Tension Elements

- typical cross sections



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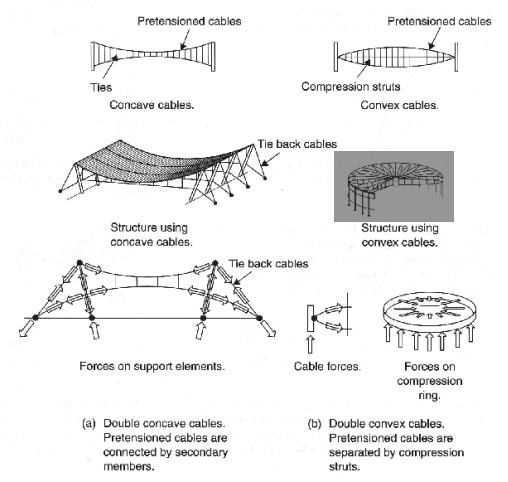
Cable Structures

- 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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Brooklyn Bridge, Roebling 1883



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Dulles Terminal, Saarinen 1962

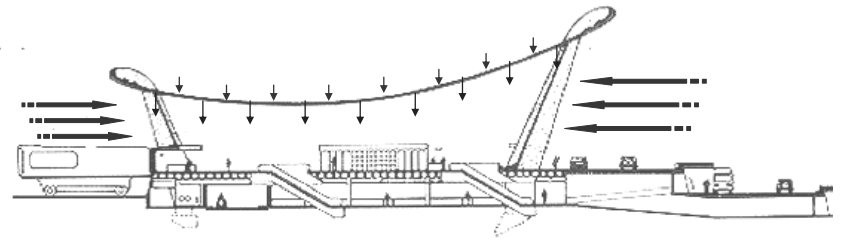


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Dulles Terminal, Saarinen 1962



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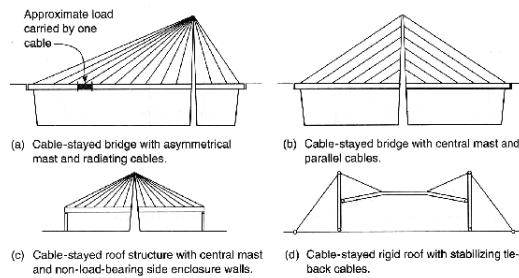
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Cable-Stayed Structures

- diagonal cables support horizontal spans
- typically symmetrical
- cases

- Patcenter
- Alamillo Bridge



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Patcenter, Rogers 1986



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Patcenter, Rogers 1986



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Patcenter, Rogers 1986

- dashes – cables pulling

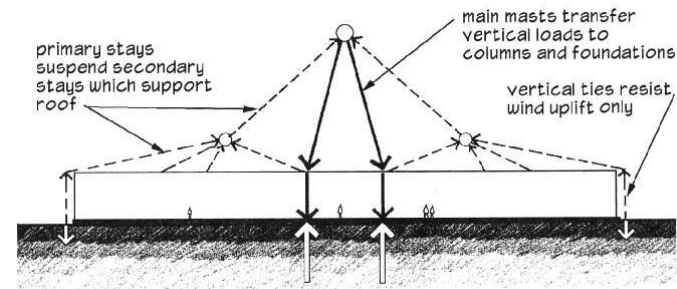


Figure 3.5: Patcenter, load path diagram.

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Alamillo Bridge, Calatrava 1992



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Alamillo Bridge, Calatrava 1992

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

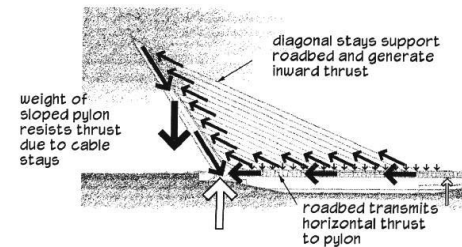


Figure 3.12: Alamillo bridge, load path diagram.

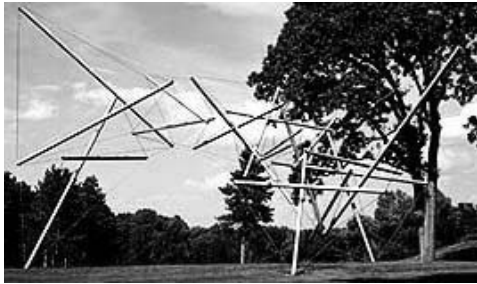
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Tensegrities

- 3D frame
- discontinuous struts
- continuous cables



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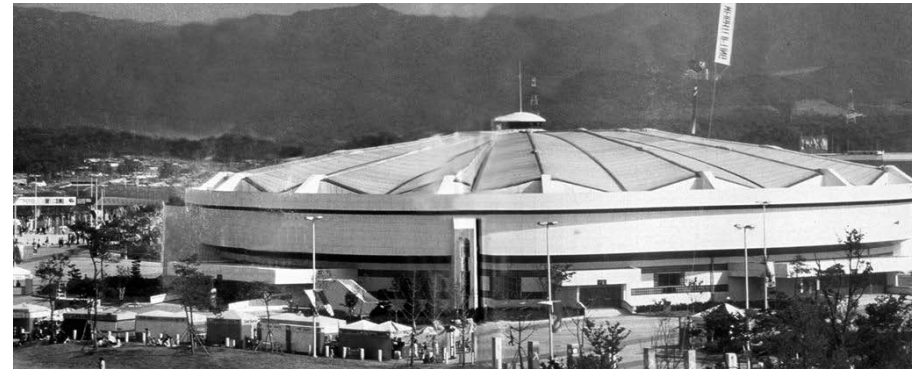
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Olympic Gymnastics Stadium

- Geiger 1988



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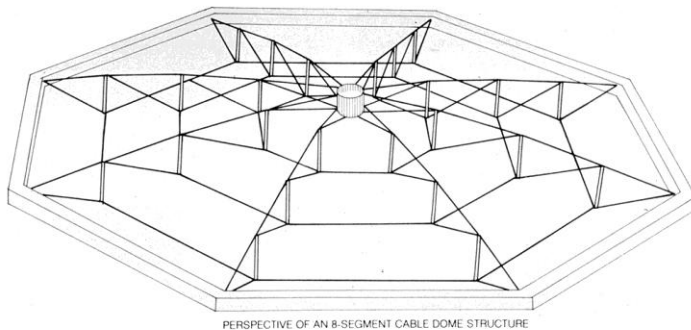
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Olympic Gymnastics Stadium

- 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

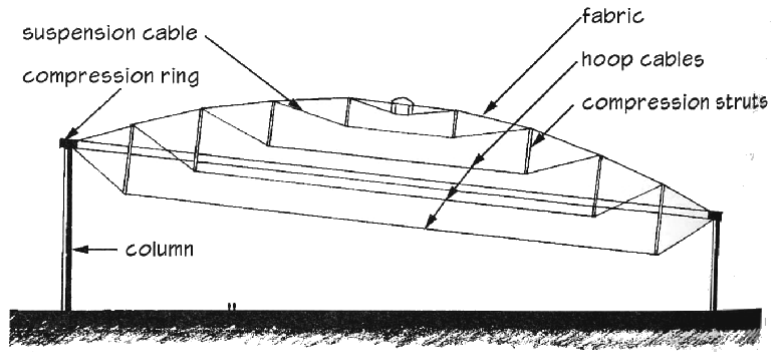


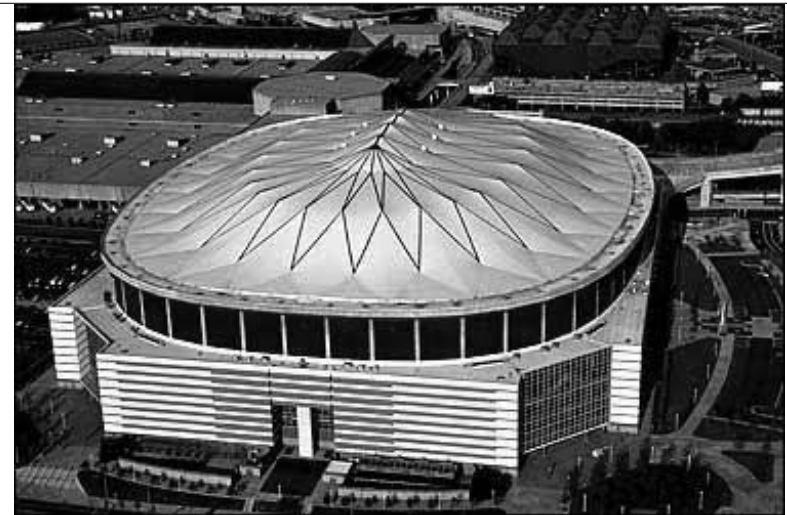
Figure 5.22: Florida Suncoast Dome, section.

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Georgia Dome, Stainback 1992



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Georgia Dome, Stainback 1992

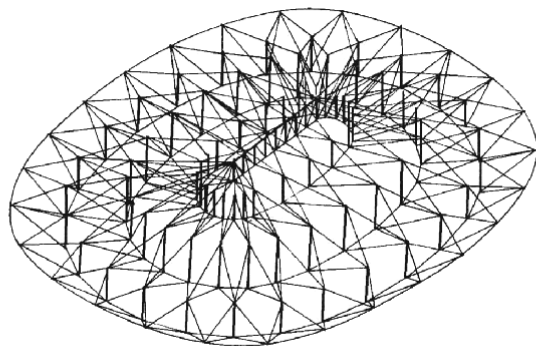


Figure 5.24: Georgia Dome, isometric drawing of cable and strut configuration.

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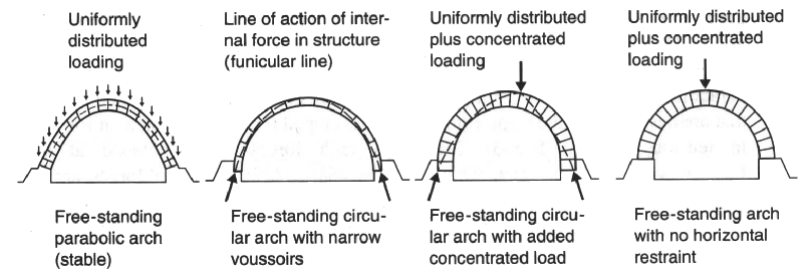
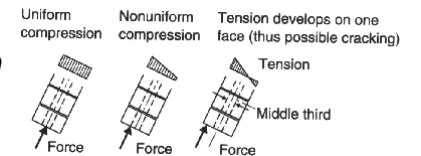
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Arches

- *curvilinear form*

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



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Arches

- ancient
 - stone
 - masonry



www.greatbuildings.com



Rainbow Bridge National Monument

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Arches

- ancient
 - stone
 - masonry

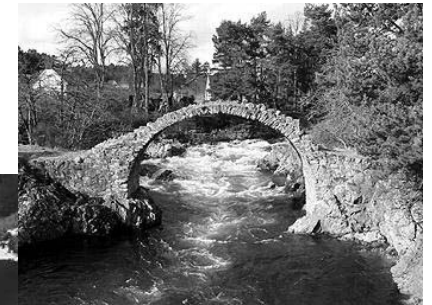


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Roman Aquaducts

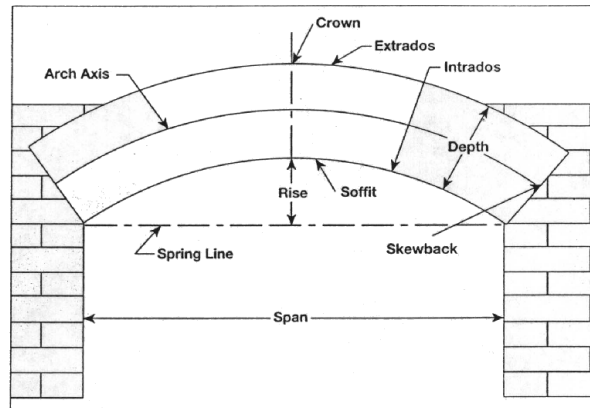
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Packhorse Bridge, UK

Arches

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



Arch terminology

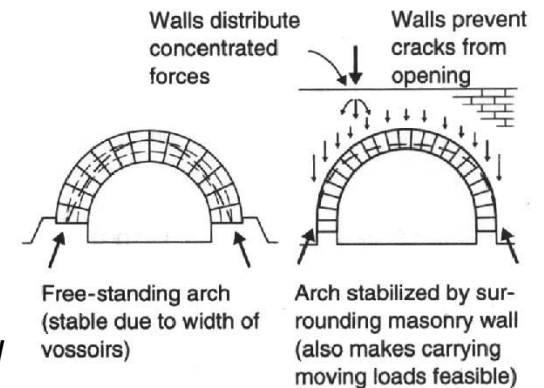
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Arches

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



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

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

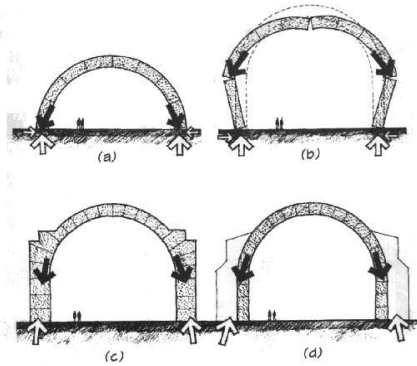
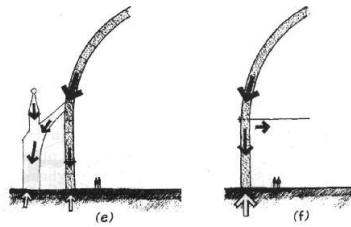
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Arches

- behavior
 - thrust related to height to width



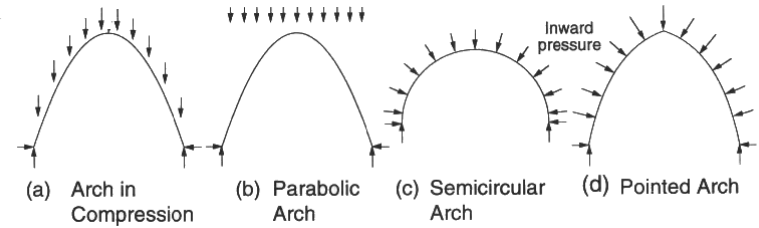
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Arches

- common forms



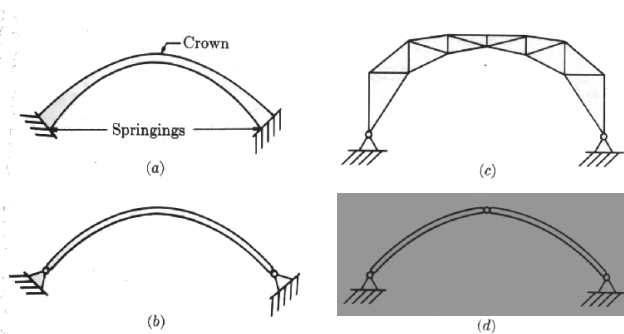
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Arches

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



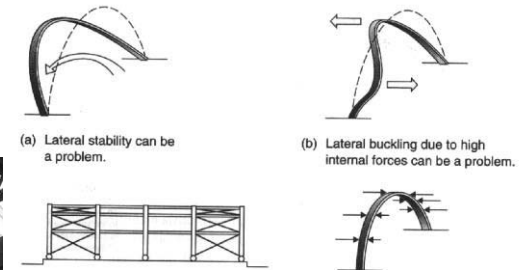
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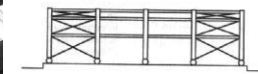
Arches

- requires lateral bracing
 - lateral ties
 - diagonal ties



(a) Lateral stability can be a problem.

(b) Lateral buckling due to high internal forces can be a problem.



(c) The lateral buckling problem can be solved by laterally bracing arches with other elements, such as those from the roof structure. Cross bracing or some other mechanism is needed to assure lateral stability.

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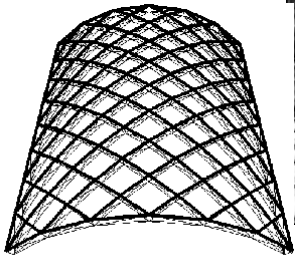
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Arches

- ... bracing
– lamellas



(d) Lamella (diagonal) truss barrel vault



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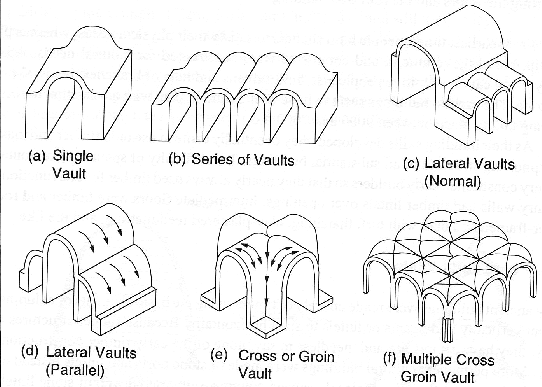
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Vaults



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Vaults

- Crypt of the Colonia Güell - Gaudi



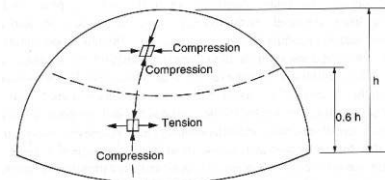
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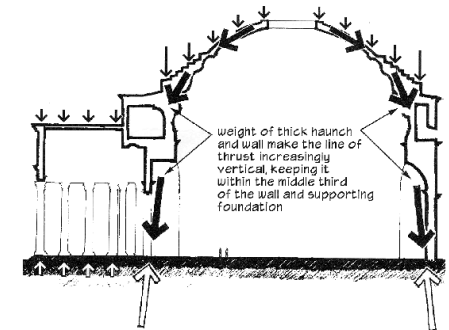
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Domes

- arch of revolutionary design
- resists compressive forces



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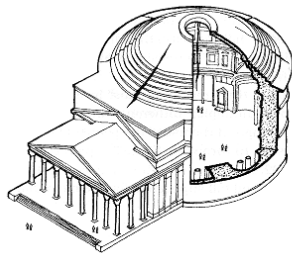


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Domes

- materials & forms
 - concrete
 - masonry
 - steel



Pantheon



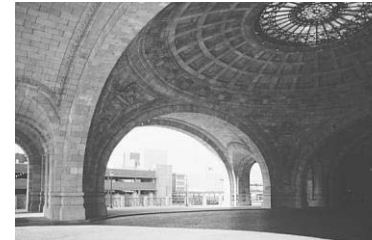
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Domes

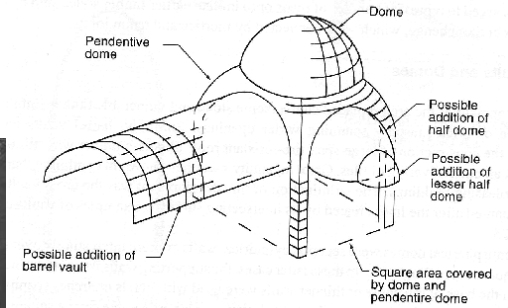
- materials & forms
 - concrete
 - masonry
 - steel



Union Station Rotunda, Pittsburg

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Domes

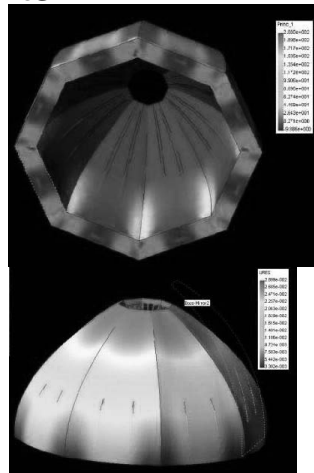
- stresses and displacements

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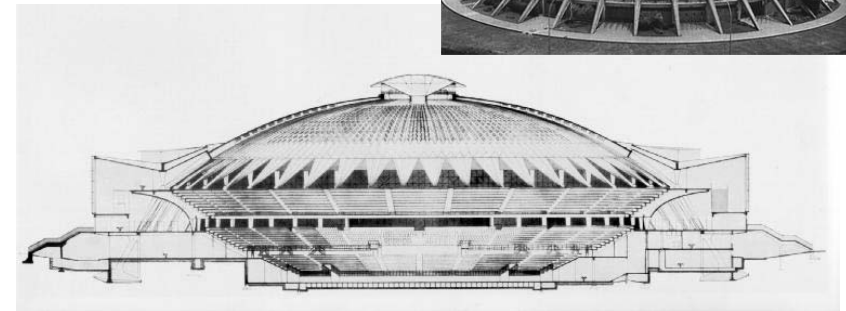
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Domes

- Palazzetto dello Sport -Nervi



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