Architecture 314

Structures I

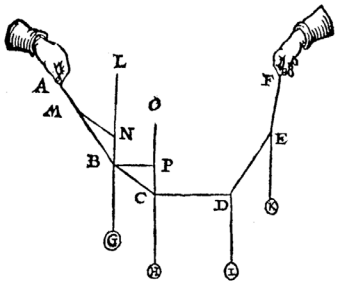
Catenary Arches

- Catenary Arches
- Compression Thrust Lines
- Ideal Compression Arches
- Compression Shells
- Masonry Arches and Vaults

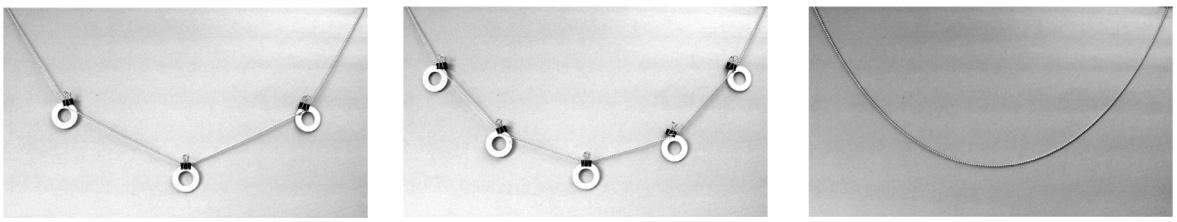
Santiago Calatrava
Valencia, Spain

Catenary Shapes

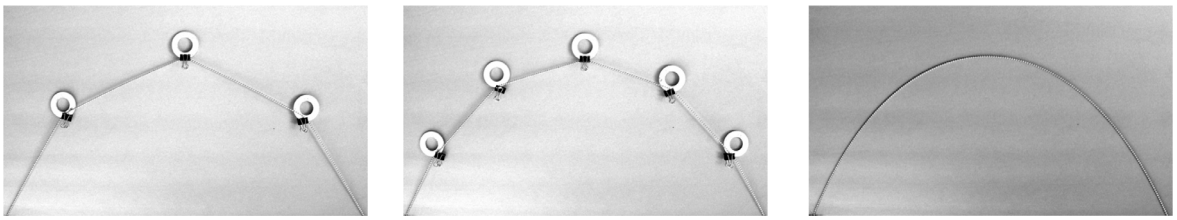
The shape of the catenary depends on the loading. Simon Stevin showed this vector analysis and experimentally in 1585 with a weighted cord.



Because the cord has no resistance to bending, it hangs in pure tension. The reverse shape (flipped over) will be in compression only.



Tension only shapes

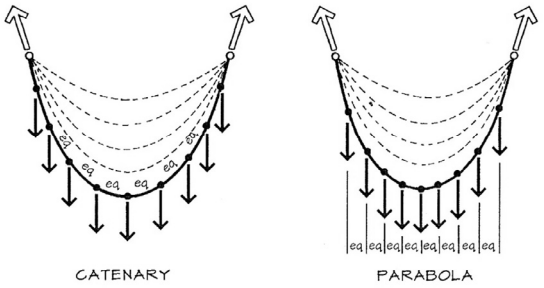


Compression only shapes

Catenary Shapes

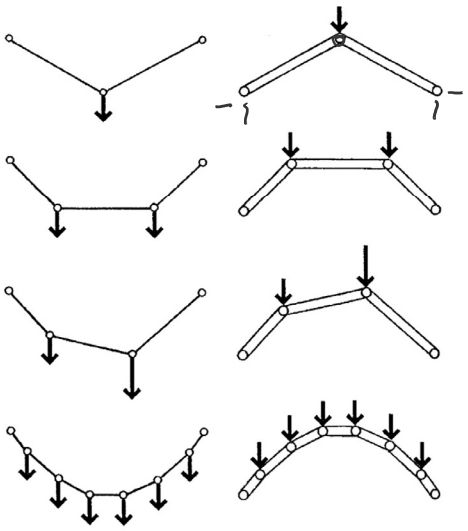
The shape of the catenary depends on the loading. Because the cord has no resistance to bending, it hangs in pure tension. The reverse shape (flipped over) will be in compression only.

Selfweight loading produces a funicular curve. Uniformly applied load (e.g. horizontal PLF load) results in a parabolic curve.



a) Selfweight funicular curve

b) Uniform load parabolic curve

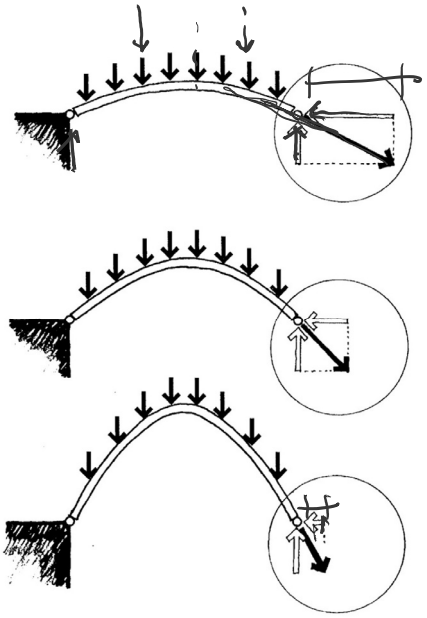


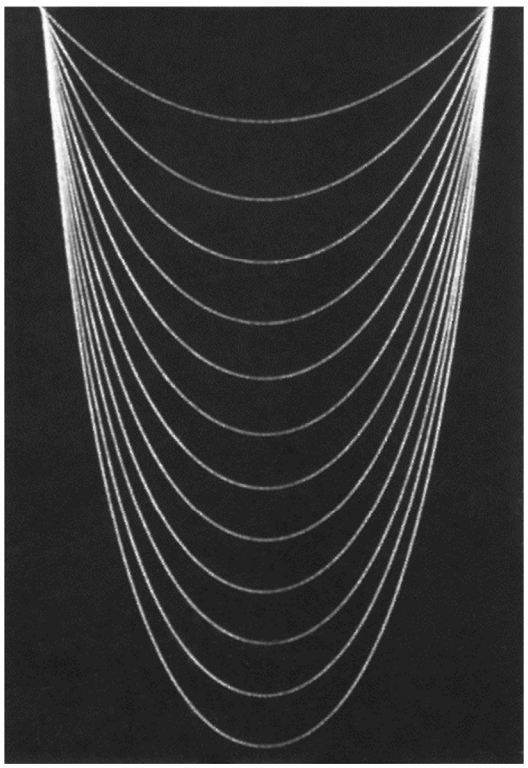
Funicular suspension cables and corresponding arches.

Catenary Shapes

The shape of the catenary also depends on the length of the cord. For any give load and span there are an array of solutions based on the amount of sag.

The greater the sag the less horizontal force will be present at the reaction. The same is true for pure compression arches.

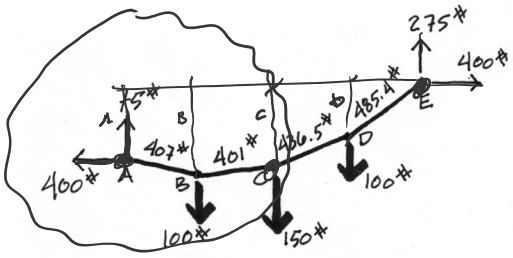


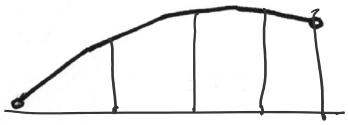


Methods to Determine Ideal Compression Arches

Method 1: FBDs to find forces and dimensions

1. Choose loading
2. Set 3 points (reactions + sag)
3. Solve reactions
4. Calculate funicular shape (as a cable)
5. Invert the shape

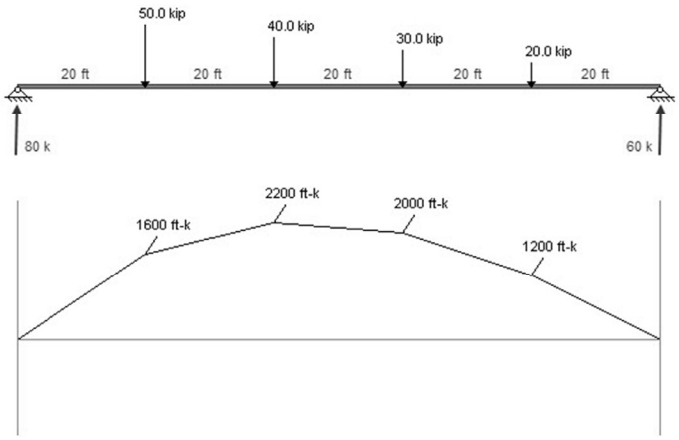




Methods to Determine Ideal Compression Arches

Method 2: Moment Diagram for Even Supports

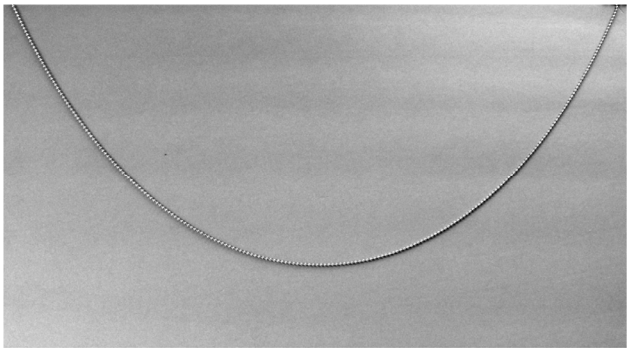
1. Choose loading
2. Draw moment diagram
3. Scale

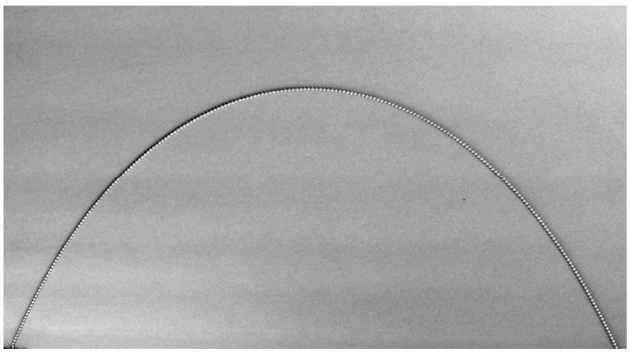


Methods to Determine Ideal Compression Arches

Method 3: Physical model

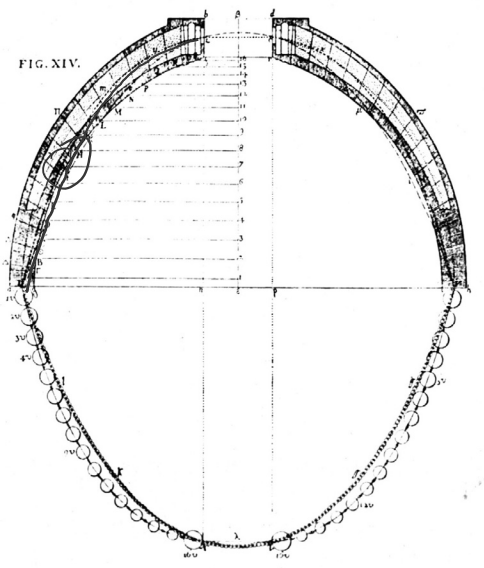
1. Choose loading
2. Hang catenary
3. Scale
4. Invert the shape





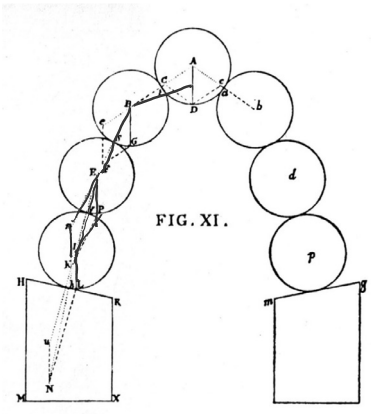
Compression Arches

Ideal Compression Shell or Arch
- All members in compression
- No flexure
- Encloses the catinary line



Giovanni Poleni (1683-1761)
repairs to St. Peter's dome, 1748

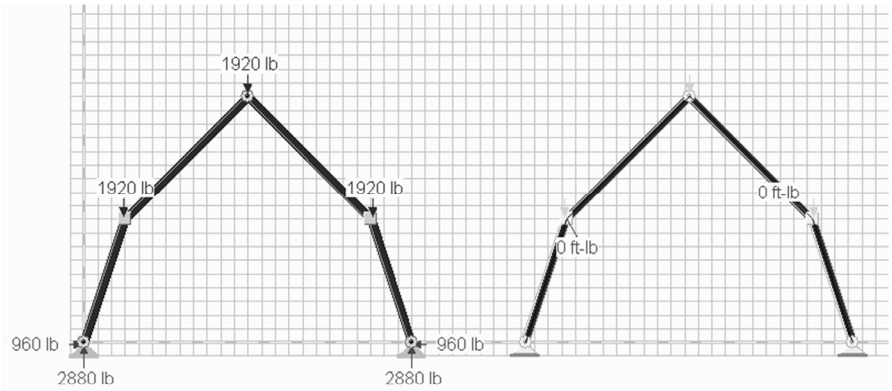
Pont du Gard
Nîmes, France



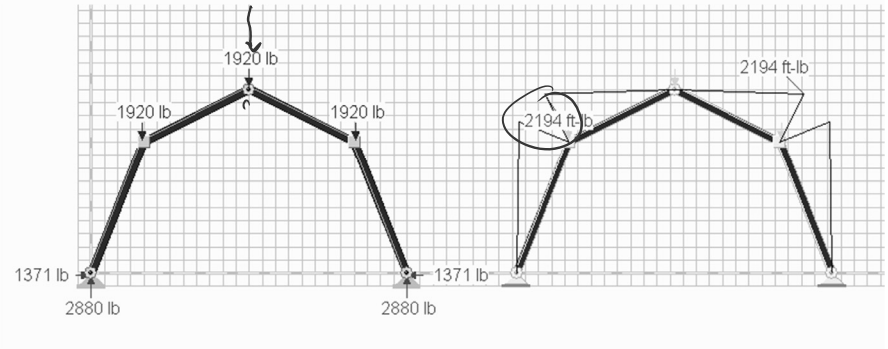
Simon Stevin (1548-1620)

Compression Arches

'Ideal' catenary shape



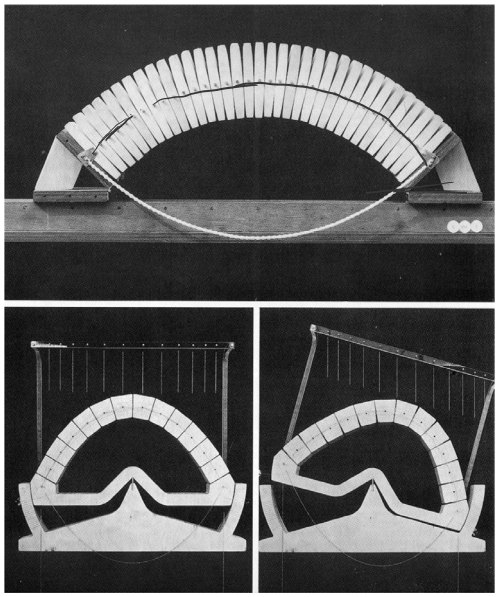
Shape with moments



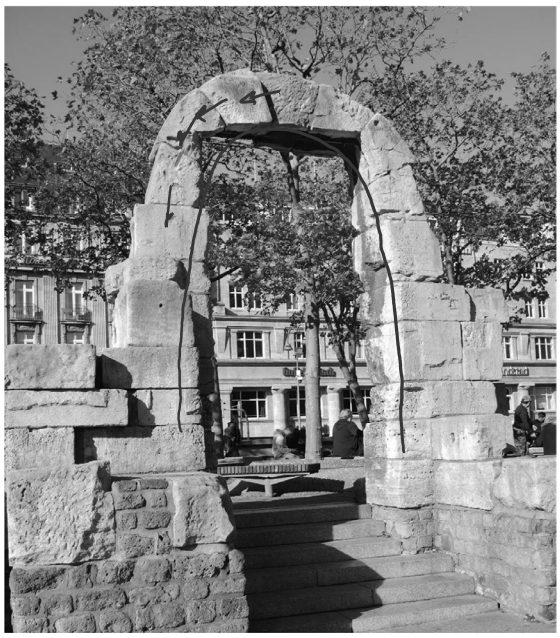
Compression Arches

Ideal Compression arch

- All members in compression
- No flexure
- Encloses the catenary line



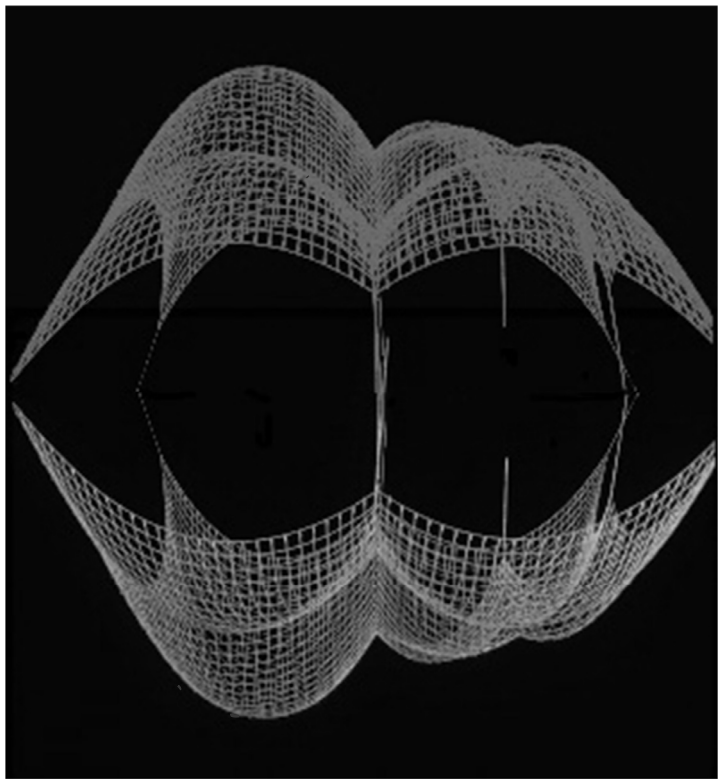
Frei Otto



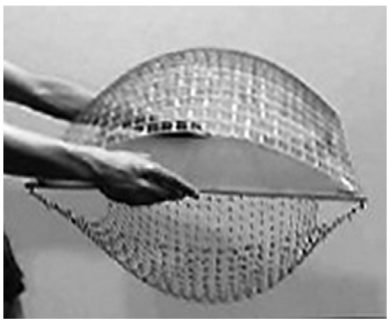
Roman Gate at
Colonia Claudia Ara Agrippinensium
Cologne, Germany

Compression Shells

Tensile Net to Compression Shell
- All members in tension
- No flexure

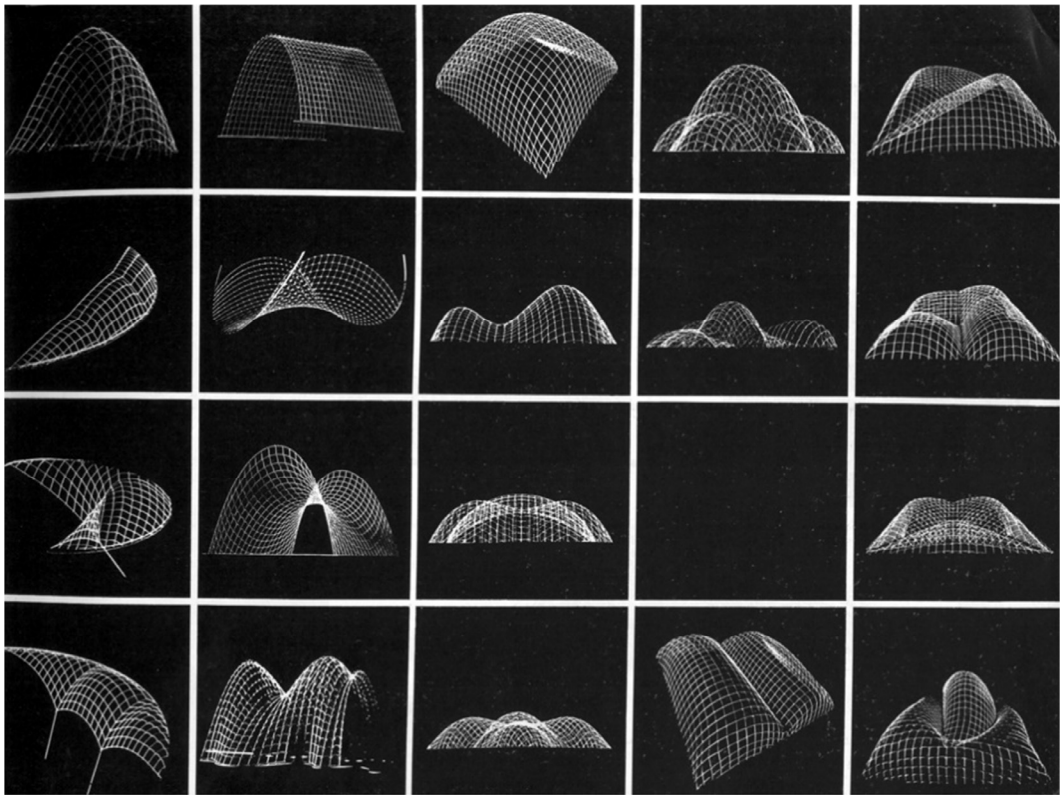


Grid shells based on catenary nets



Compression Shells

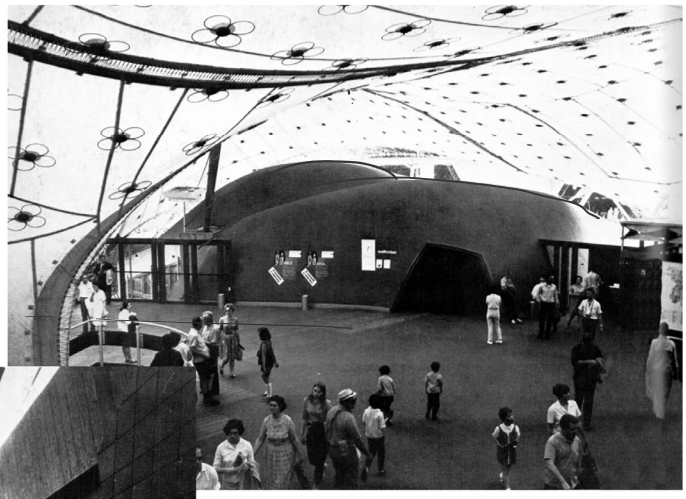
Grid shells based on catenary nets

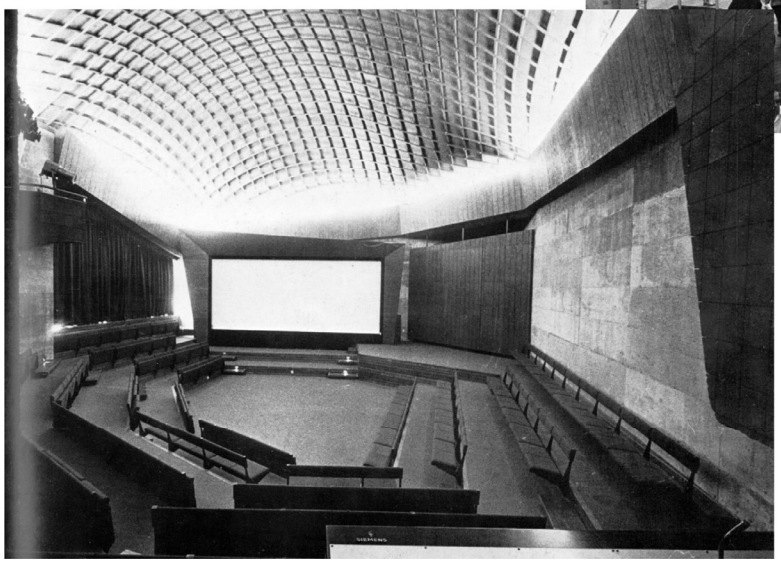


Frei Otto, Grid Shells (IL Series) TA 663 .G58 1974

Compression Shells

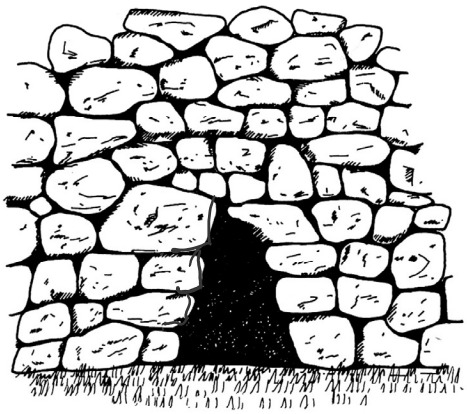
German Pavilion Expo'67 – Frei Otto





Masonry Arches

Corbeled arches and vaults



Corbelled arch in wall, Tiryns, Greece (c. 600 B.C.).

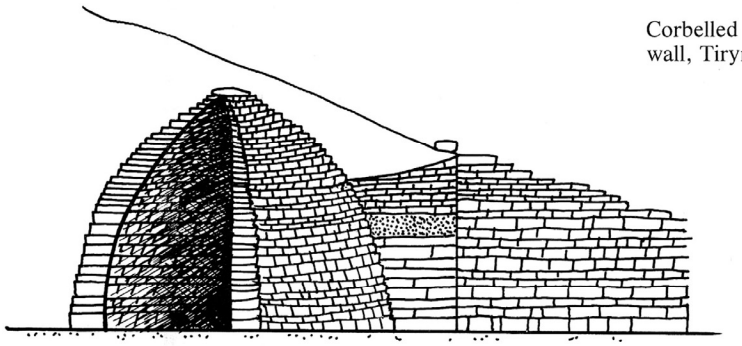


Figure 1.21 Tomb of Agamemnon (c. 1325 B.C.).

Ostia

Masonry Arches

Ostia, Italy

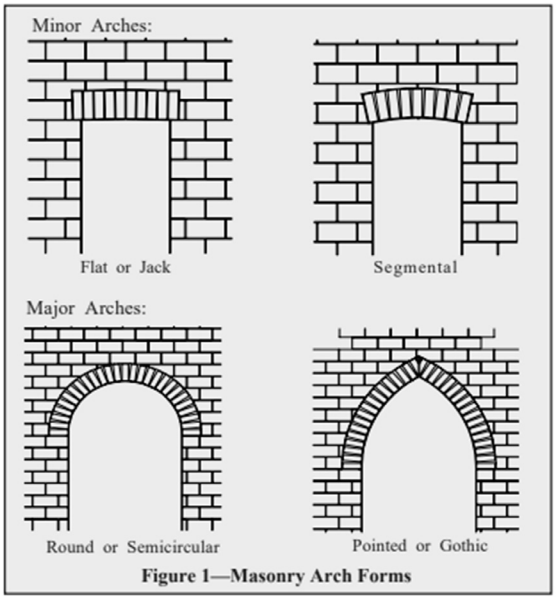


Figure 1—Masonry Arch Forms

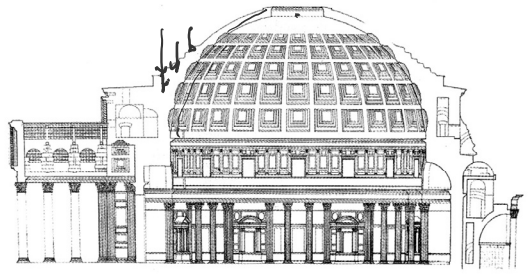
Pont du Gard
Nîmes, France

Masonry Arches

Masonry Arches

Thrust lines

Institute for Lightweight Structures (IL)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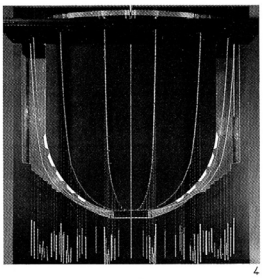
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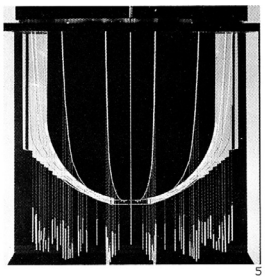
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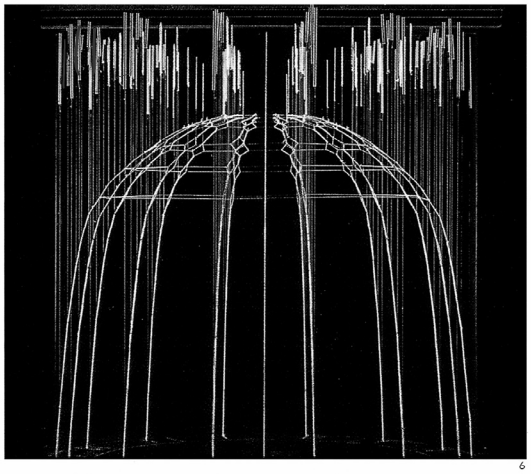
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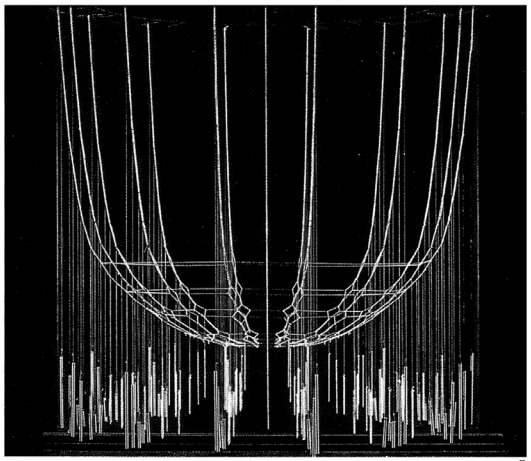
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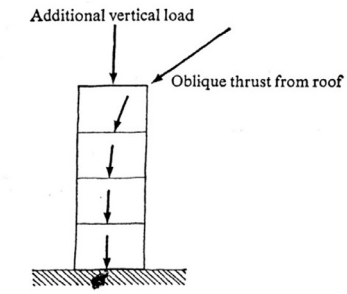
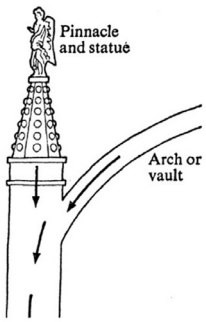
Gothic Masonry

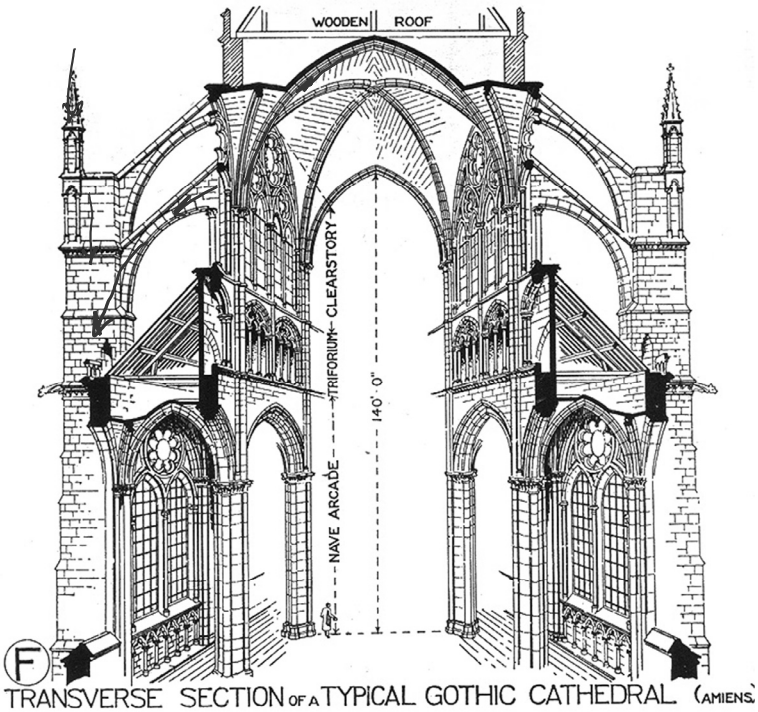
Gothic vaults

- Amiens
- 1220-1225



The effect of an additional load at the top of the wall is to *reduce* the eccentricity of the thrust line.



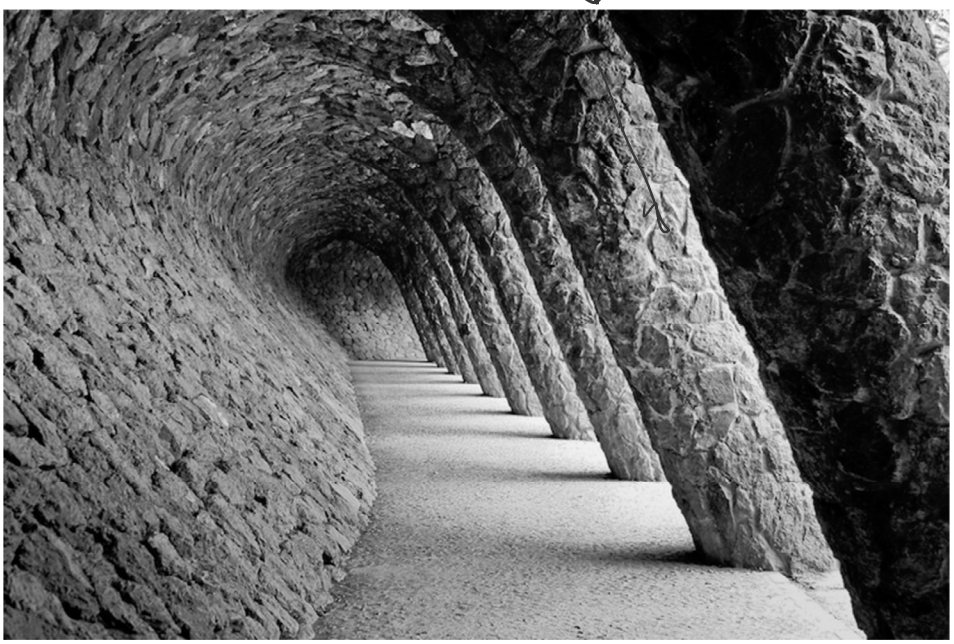


F TRANSVERSE SECTION OF A TYPICAL GOTHIC CATHEDRAL (AMIENS)

Catenary Masonry

Catalonian

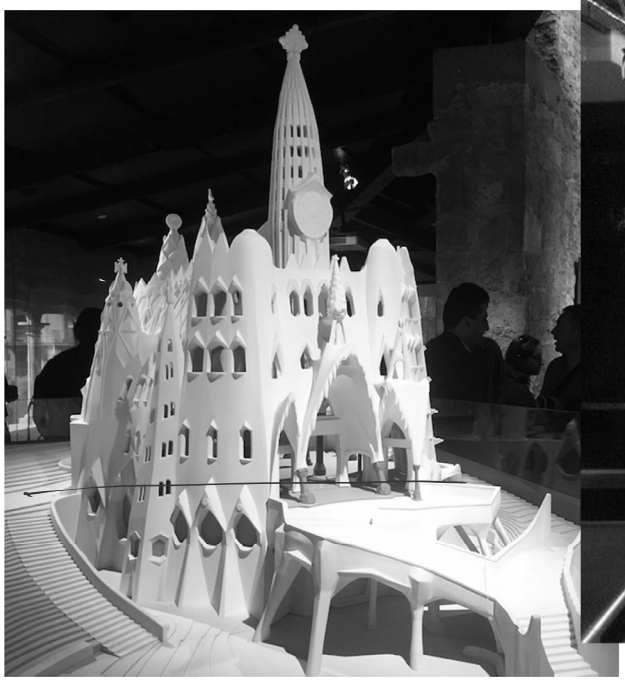
- Antonio Gaudi 1852 - 1926
- Catalonian Art Nouveau
- Park Guell



Catenary Masonry

Catalonian

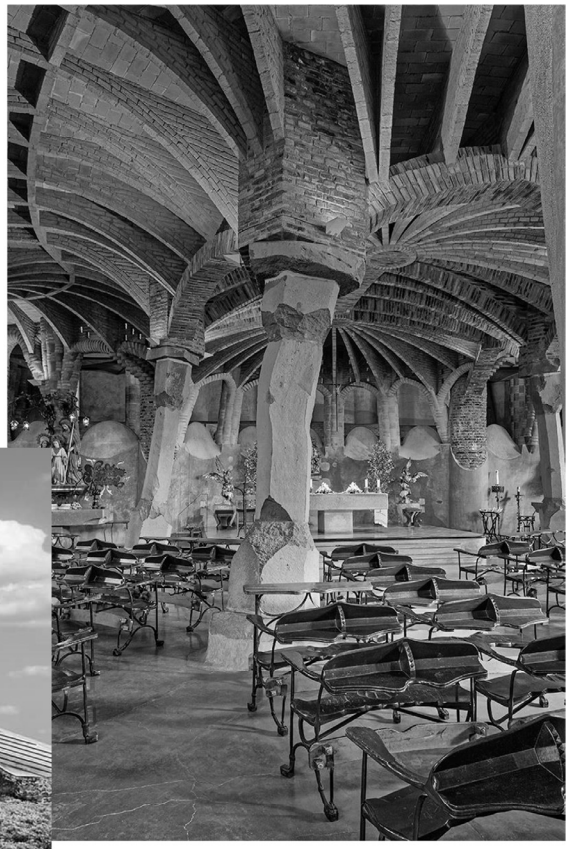
- Antonio Gaudi 1852 - 1926
- Catalonian Art Nouveau
- Church at Colonia Güell



Catenary Masonry

Catalonian

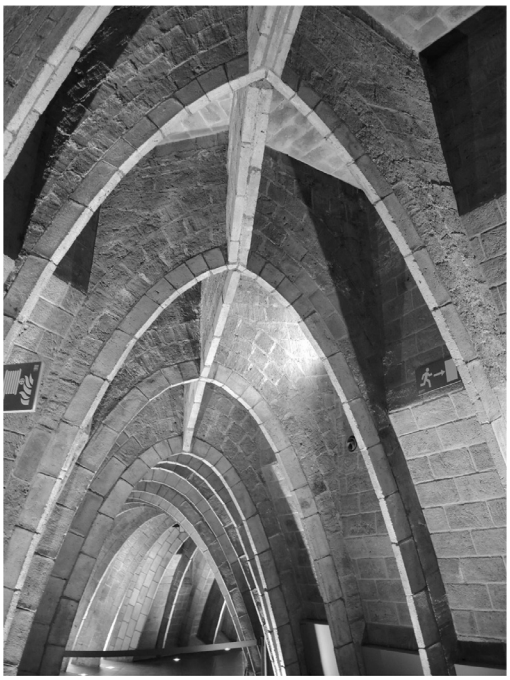
- Antonio Gaudi 1852 - 1926
- Catalonian Art Nouveau
- Crypt at Colonia Güell

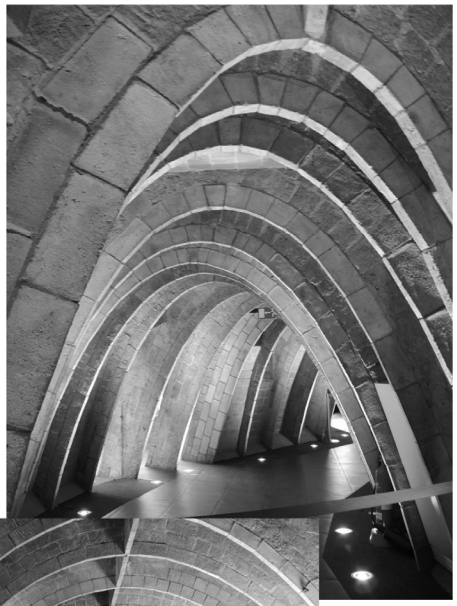


Catenary Masonry

Catalonian

- Antonio Gaudi 1852 - 1926
- Catalonian Art Nouveau
- Casa Mila

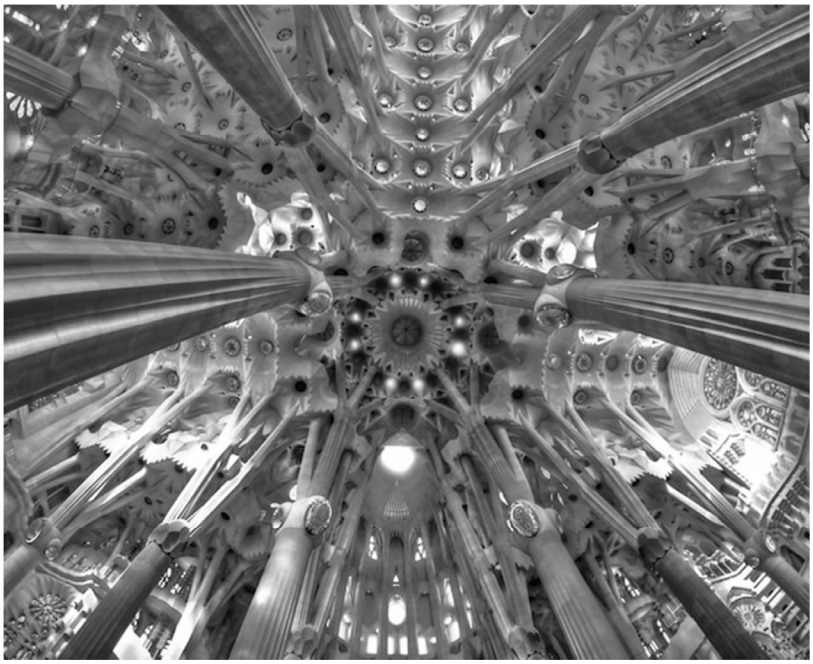




Catenary Masonry

Catalonian

- Antonio Gaudi 1852 - 1926
- Catalonian Art Nouveau
- La Sagrada Familia



Catenary Masonry

Catalonian

- Antonio Gaudi 1852 - 1926
- Catalonian Art Nouveau
- La Sagrada Familia