Architecture 314

Structures I

Catenary Arches

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

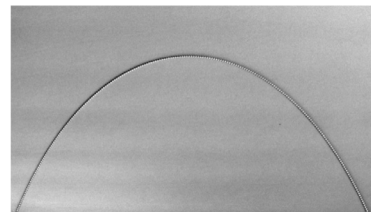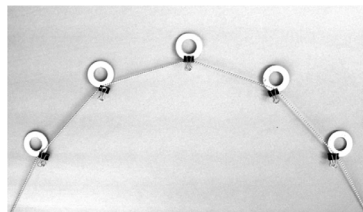

Santiago Calatrava
Valencia, Spain

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.
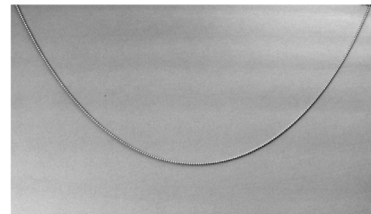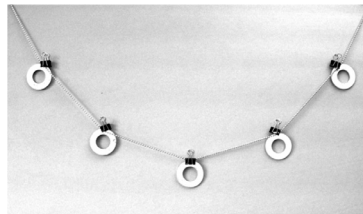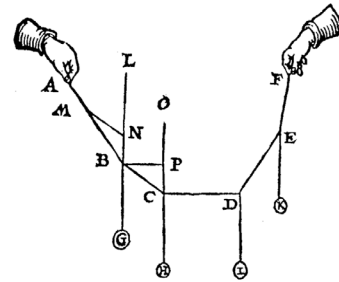

Tension only shapes

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.
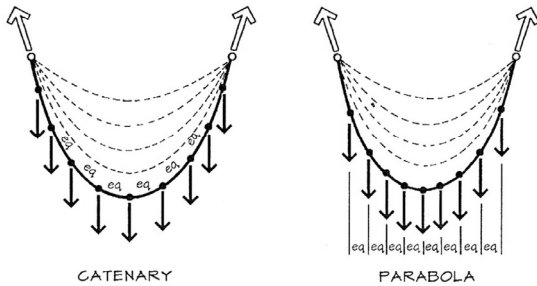
CATENARY

PARABOLA

a) Selfweight
funicular curve

b) Uniform load
parabolic curve
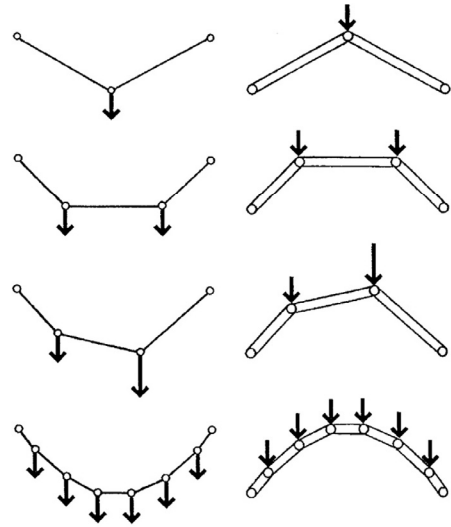
Funicular suspension cables and corresponding arches.

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.
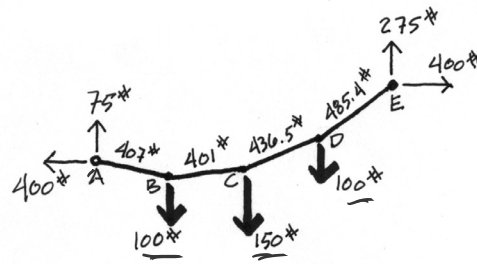
The greater the sag the less horizontal force will be present at the reaction. The same is true for pure compression arches.
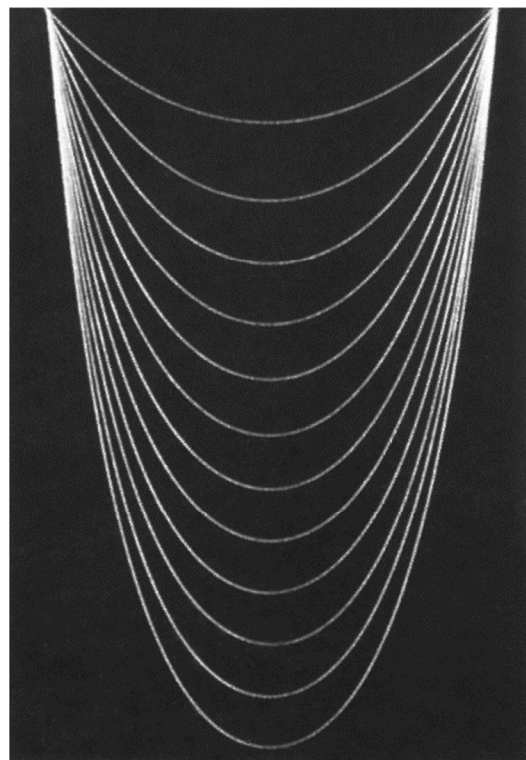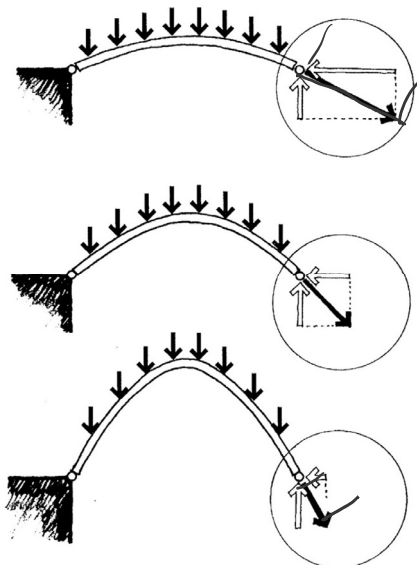
Methods to Determine
Ideal Compression Arches

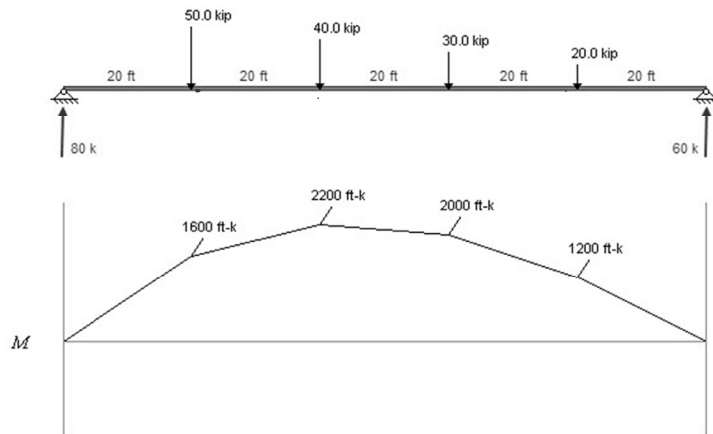**Method 1: FBDs to find forces and dimensions**

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
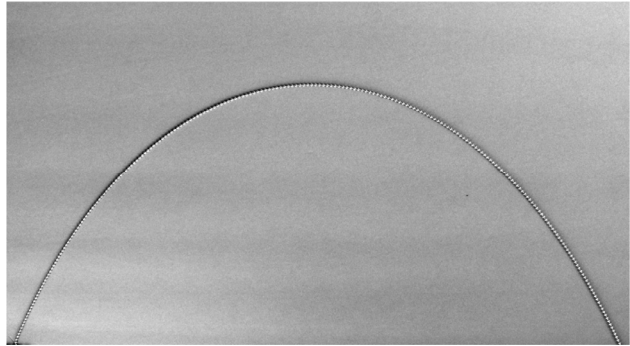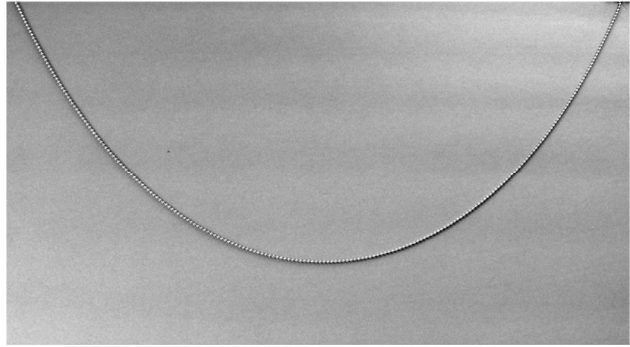
Method 2: Moment Diagram for Even Supports

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

Methods to Determine
Ideal Compression Arches
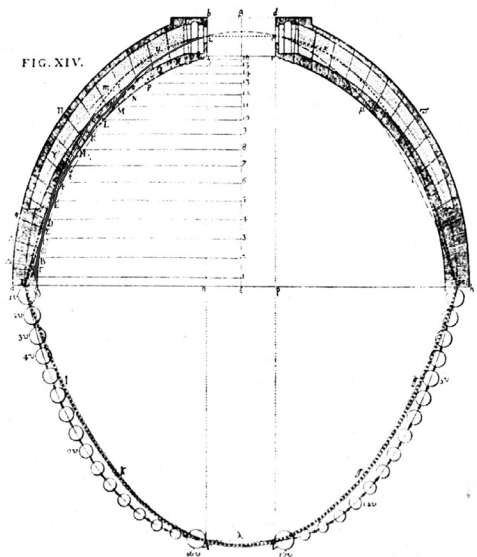
Method 3: Physical model

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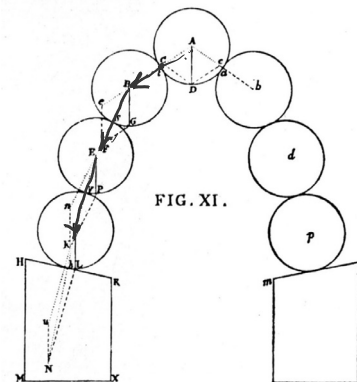

Compression Arches

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

Pont du Gard
Nîmes, France

FIG. XIV.

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

FIG. XI.
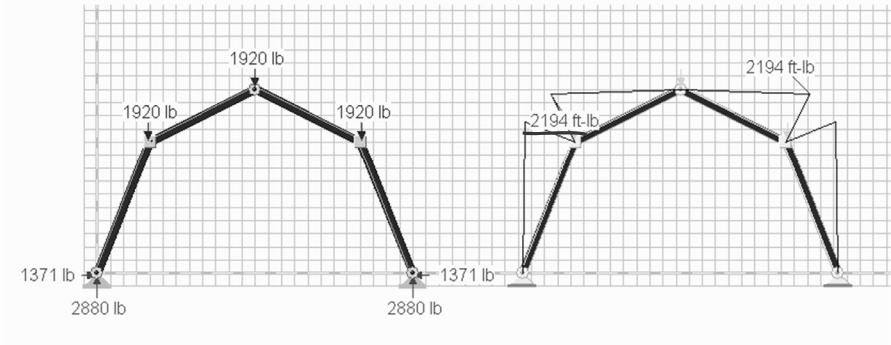
Simon Stevin (1548-1620)

Compression Arches
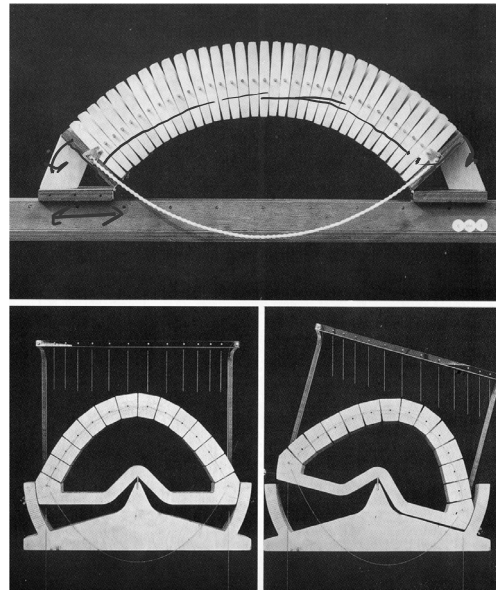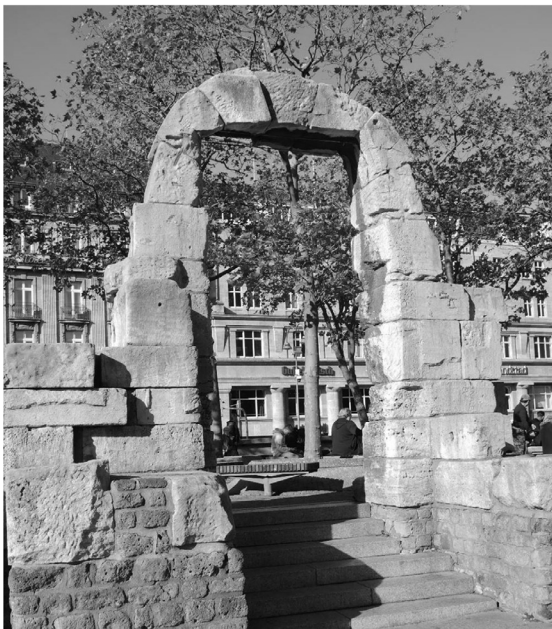
'Ideal' catenary shape
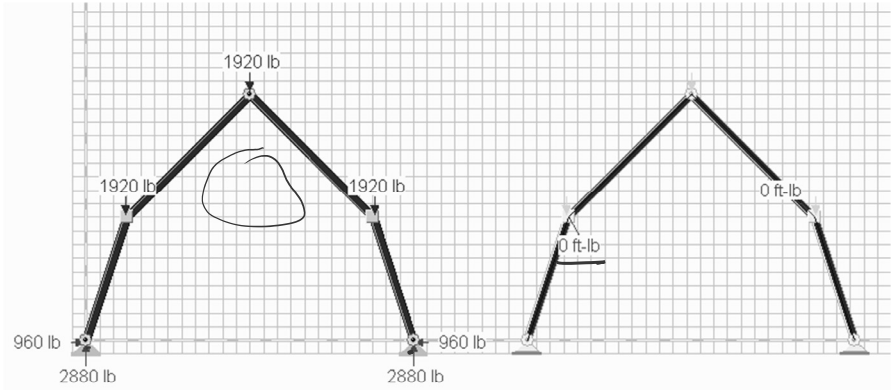
Shape with moments

Compression Arches

Ideal Compression arch
- All members in compression
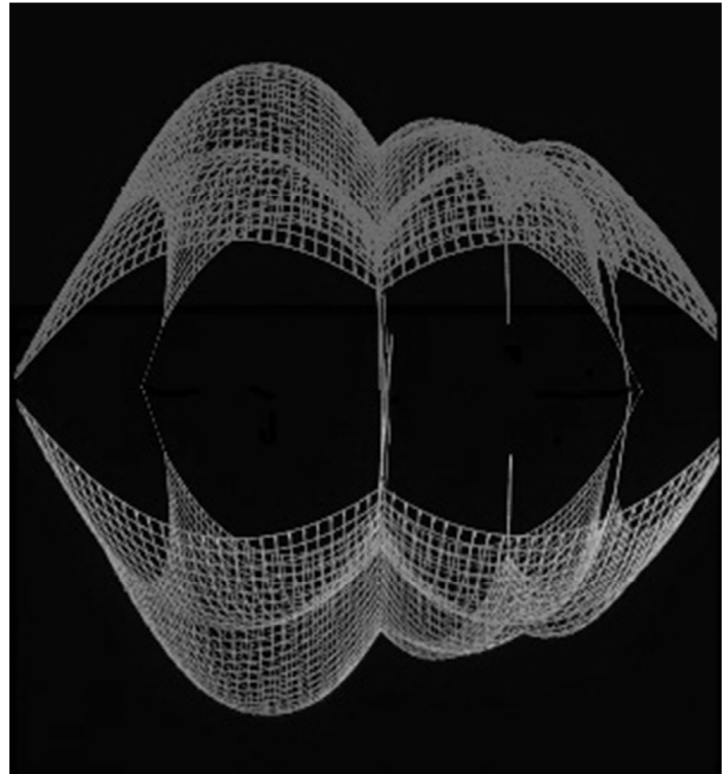- No flexure
- Encloses the catenary line

Frei Otto

Roman Gate at
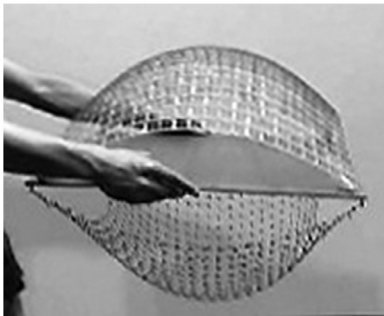Colonia Claudia Ara Agrippinensium
Cologne, Germany

Compression Shells

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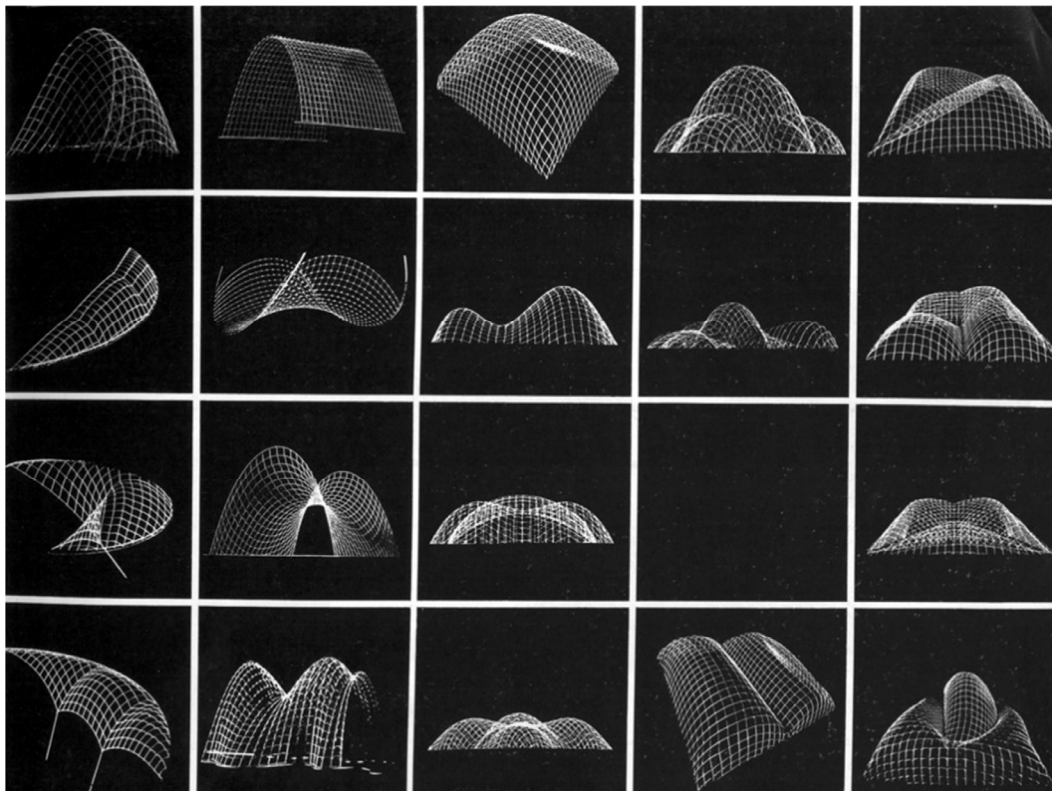- All members in tension
- No flexure

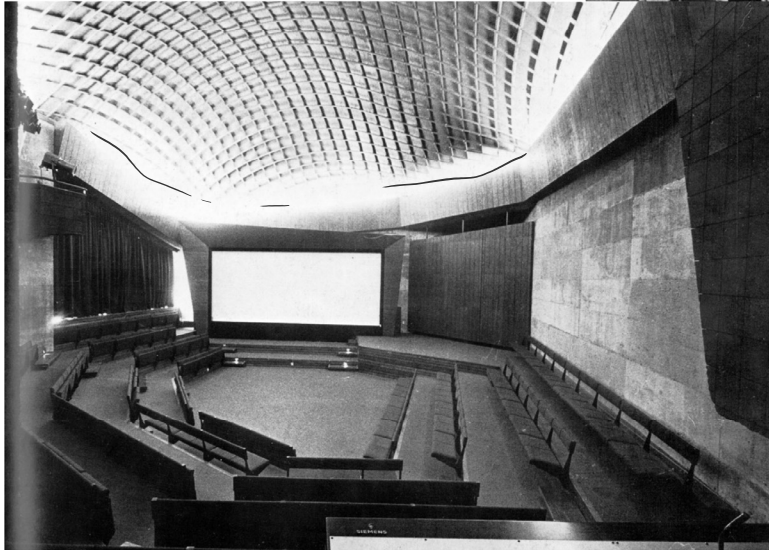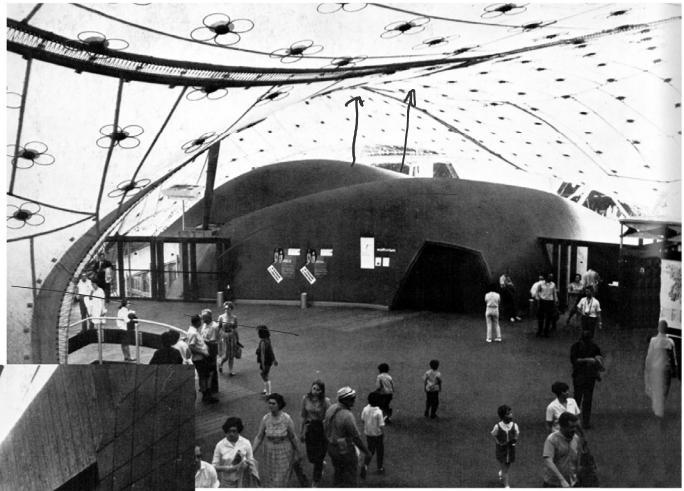Grid shells based on catenary nets

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Compression Shells
Grid shells based on catenary nets

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

Compression Shells
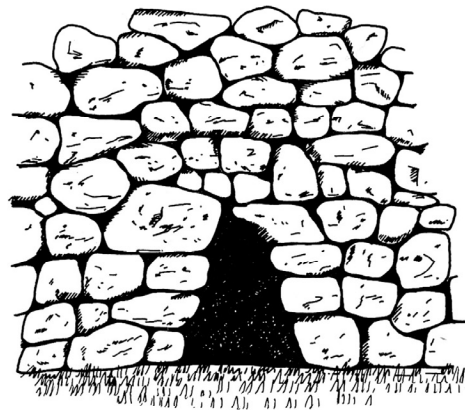German Pavilion Expo'67 – Frei Otto

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Masonry Arches

Corbeled arches and vaults

Corbelled arch in
wall, Tiryns, Greece (c. 600 B.C.).
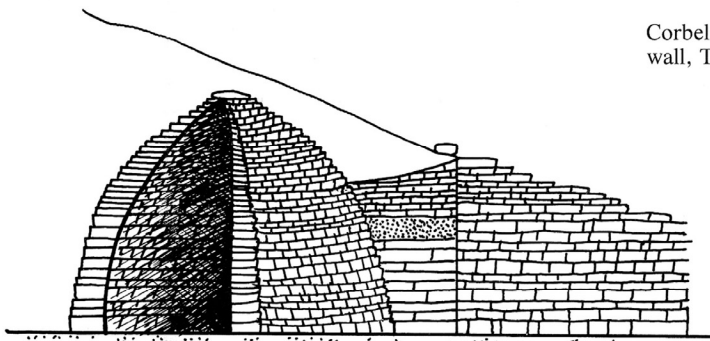
Figure 1.21 Tomb of Agamemnon (c. 1325 B.C.).

Ostia

Masonry Arches
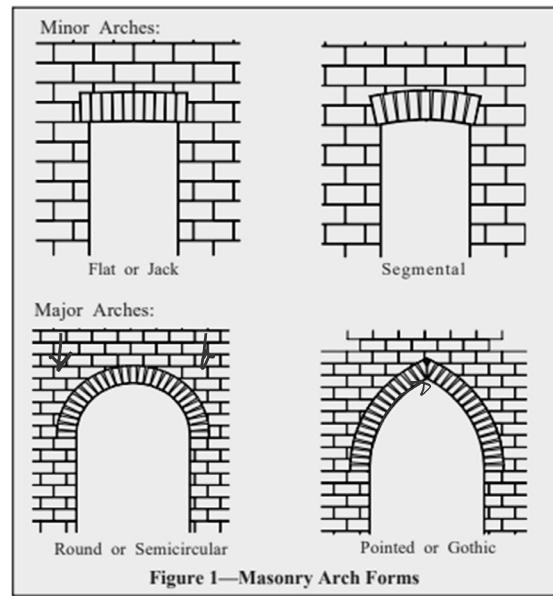

Ostia, Italy

Figure 1—Masonry Arch Forms

Pont du Gard
Nîmes, France

Masonry Arches

Masonry Arches

Thrust lines

Institute for Lightweight
Structures (IL)
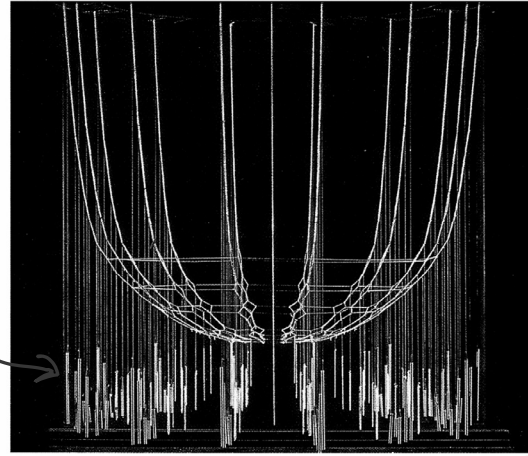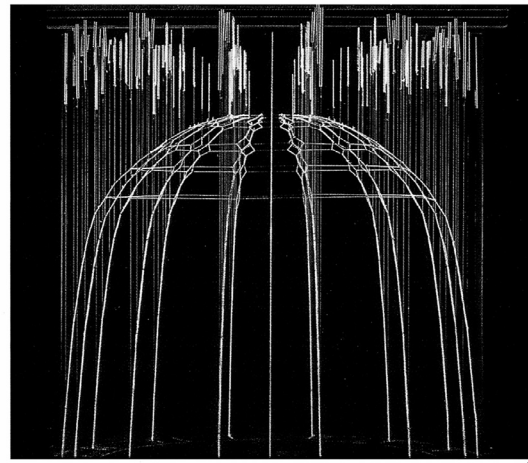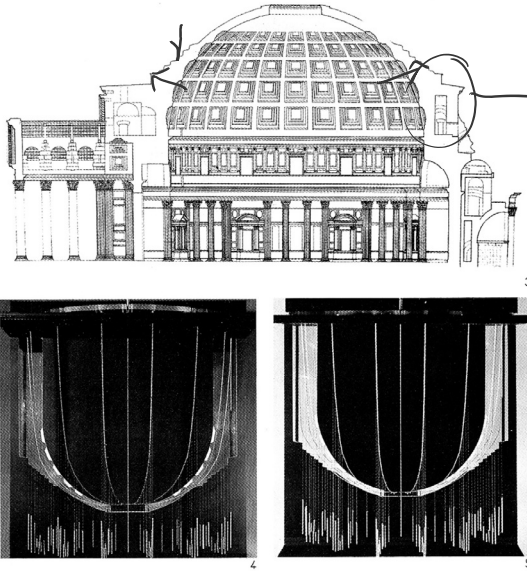
Gothic Masonry

Gothic vaults
*   Amiens
*   1220-1225
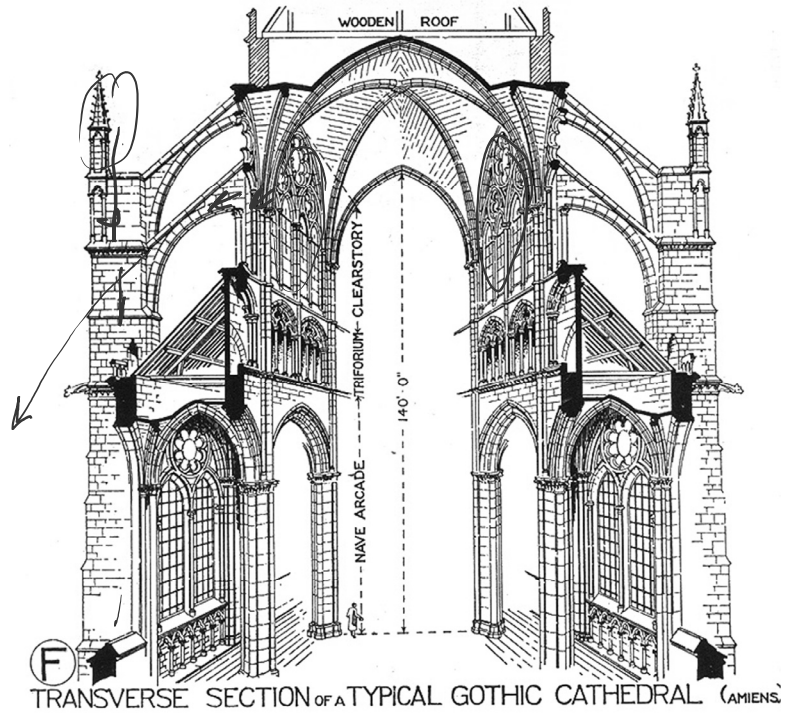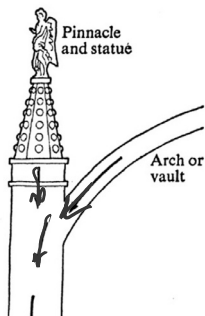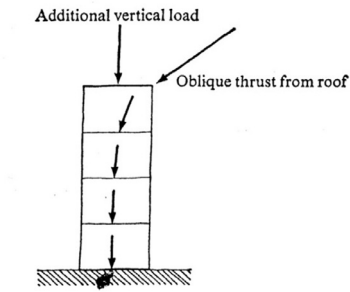
Additional vertical load

Oblique thrust from roof

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

Pinnacle
and statue

Arch or
vault

WOODEN ROOF

TRIFORIUM — CLEARSTORY

NAVE ARCADE

140' 0"

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
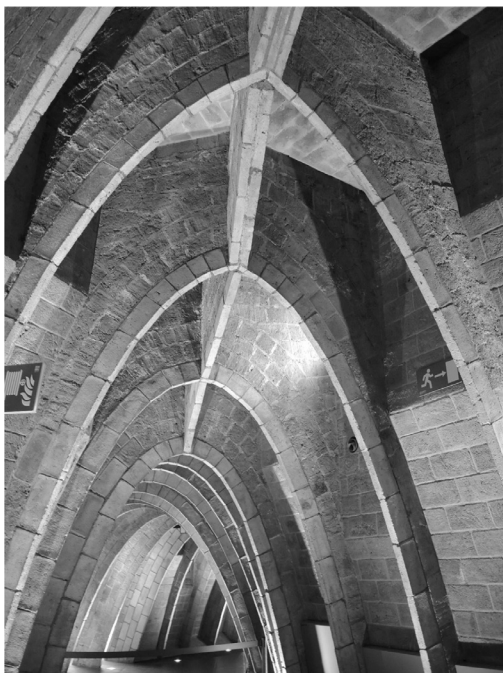- Catalonian Art Nouveau
- Crypt at Colonia Güell

Catenary Masonry

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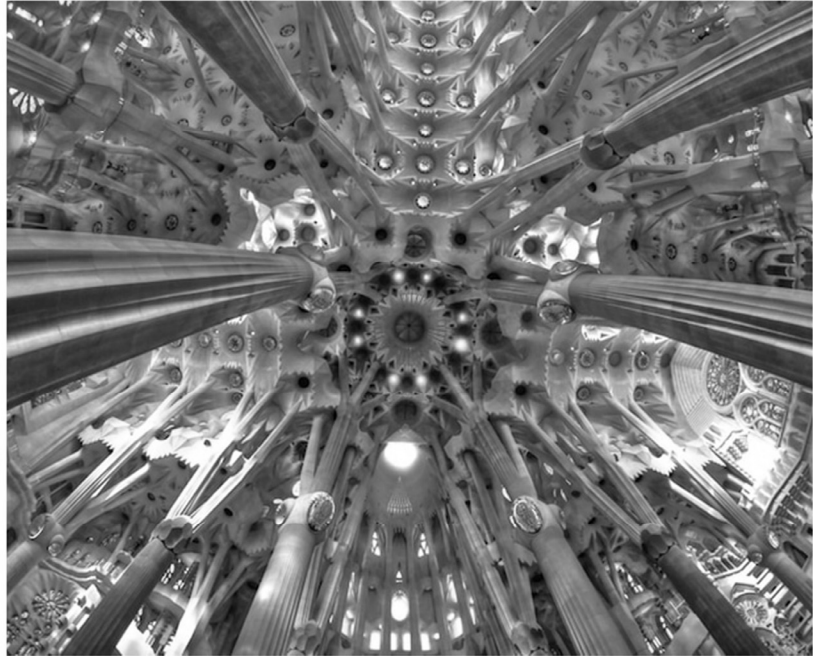
Catenary Masonry

Catalonian

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

Catenary Masonry

Catalonian

- Antonio Gaudi 1852 - 1926
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