

Historic Masonry Structures part 1



Pantheon in Rome
142 ft. diameter
125 AD

Ziggurat

Mesopotamian

The Great Ziggurat of Ur

- In southern Iraq
- 2000 BC
- 210ft x 150ft x 100ft high
(64m x 46m x 30m high)
- Clay brick core
with fired brick skin
- Temple of moon god Nanna



Early Egyptian

Mastaba

- kings' burial sites
- Early (3000 BC) mud bricks
- By the 3rd Dynasty they used stone (2670 BC)



Mastabat al-Fir'aun of king Shepseskaf 2510 BC
Red sandstone 325 ft x 250 ft x 30 to 60 ft high

Early Stepped Pyramid

- Netjerikhet
- Made from stone
- 3rd Dynasty



The Step Pyramid of Netjerikhet is the oldest known building to be completely made of stone.

Early Egyptian

Bent Pyramid

- Initially 60° changed to 55°
- 2600 BC
- Cracking in base



Bent Pyramid at Dahshur



Early Egyptian

Bent Pyramid at Dahshur



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Masonry

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Great Pyramid

Egyptian

Great Pyramid at Giza

- Last remaining “wonder”
- For king Khnum-Khufu
- 2580 – 2560 BC
- Near the capital of Memphis
- 756ft x 756ft x 481ft
(230m x 230m x 147m)
- Slope of 51°



Bent Pyramid at Dahshur

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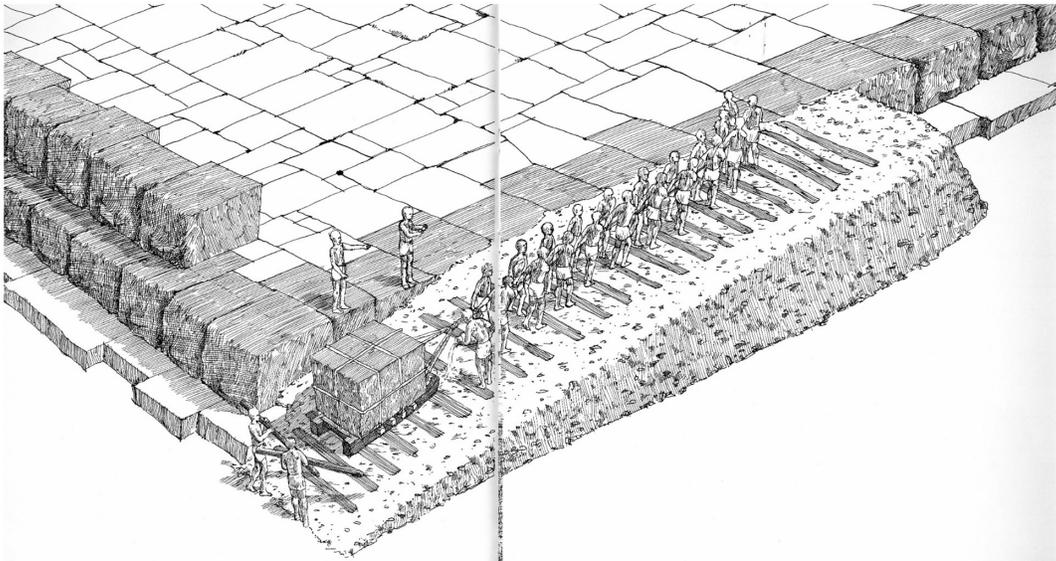
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Great Pyramid

Egyptian

Great Pyramid at Giza

- Construction in stone



From David Macaulay *Pyramid*

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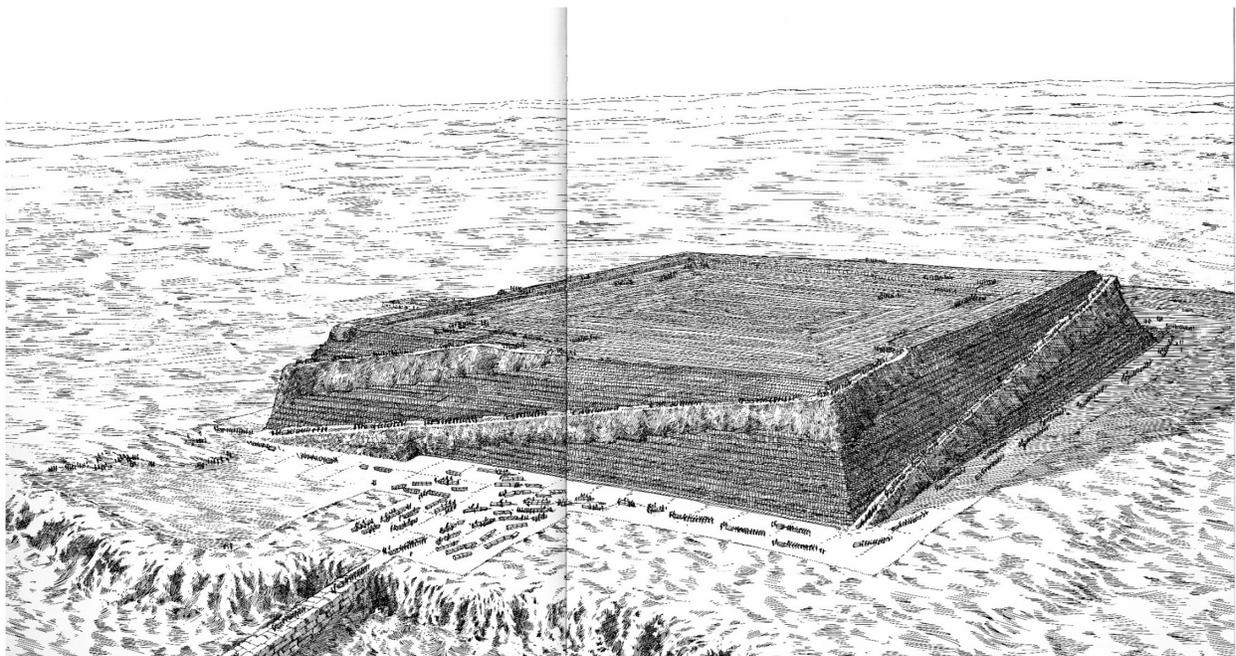
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Great Pyramid

Great Pyramid at Giza

- Construction in stone



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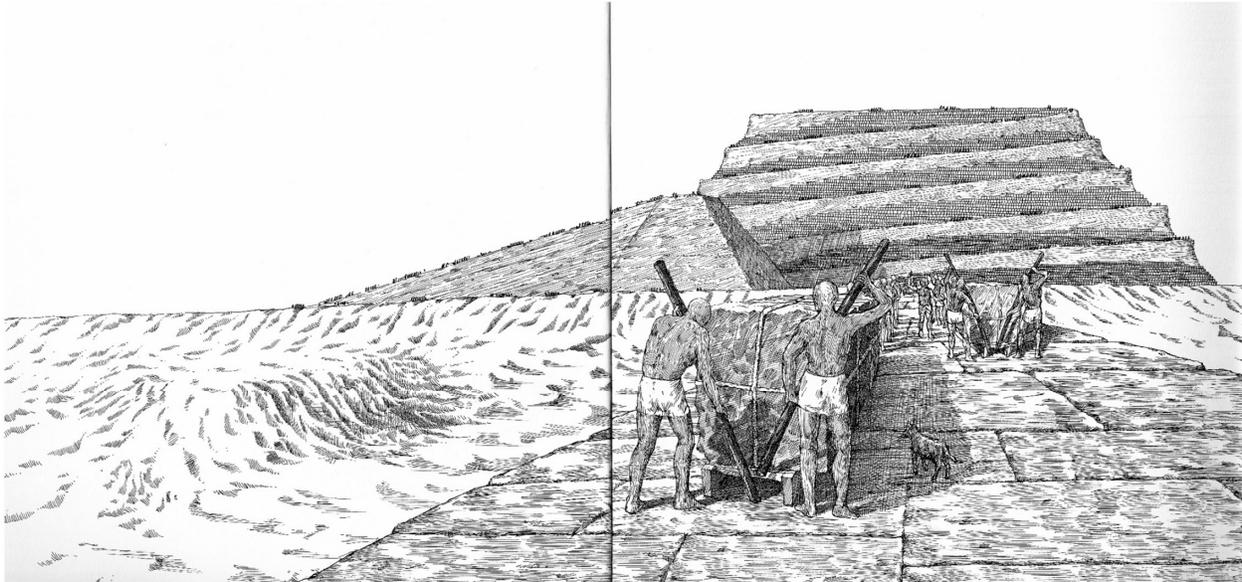
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Great Pyramid

Great Pyramid at Giza

- Construction in stone



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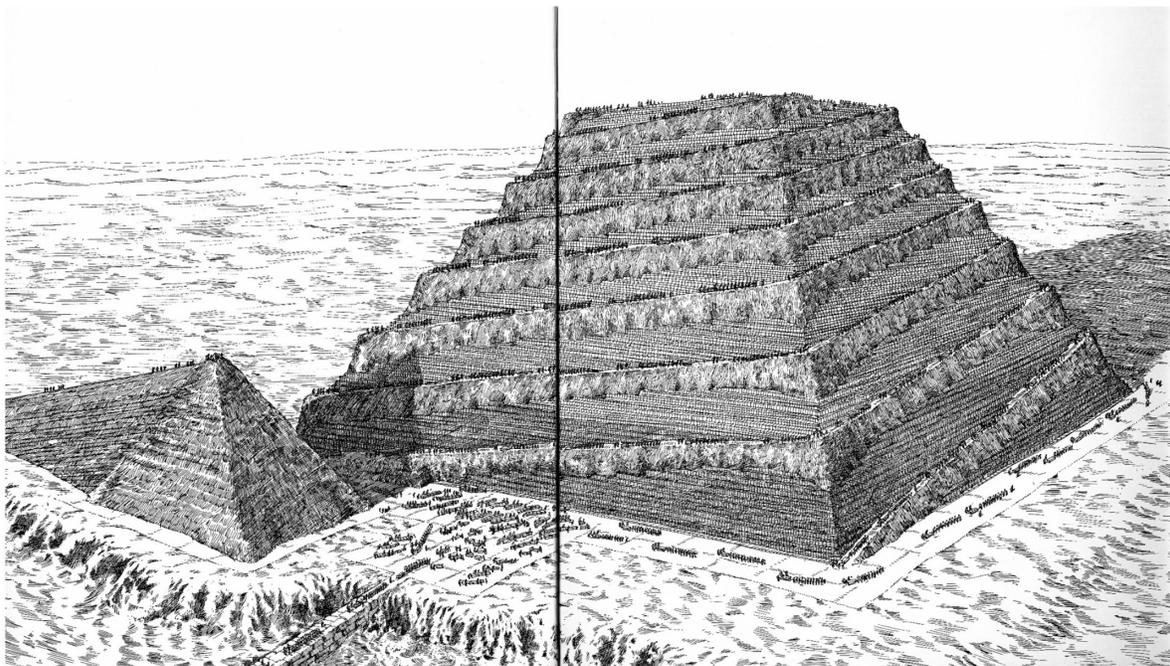
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Great Pyramid

Great Pyramid at Giza

- Construction in stone



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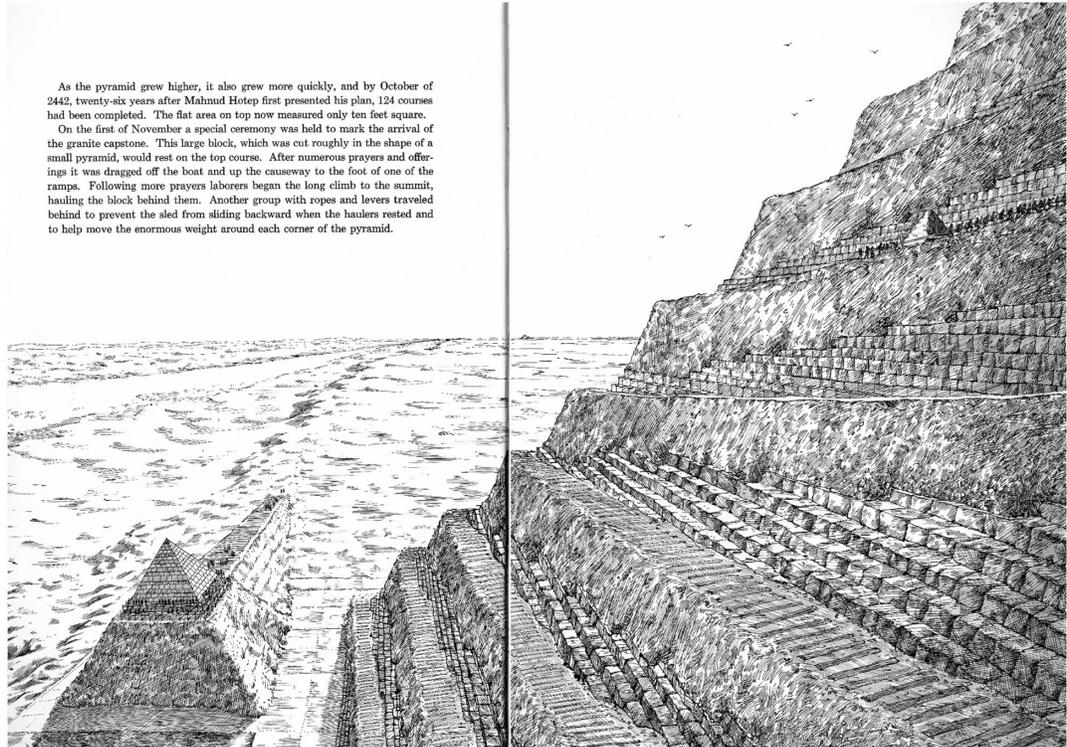
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Great Pyramid

Great Pyramid at Giza

- Construction in stone



From David Macaulay *Pyramid*

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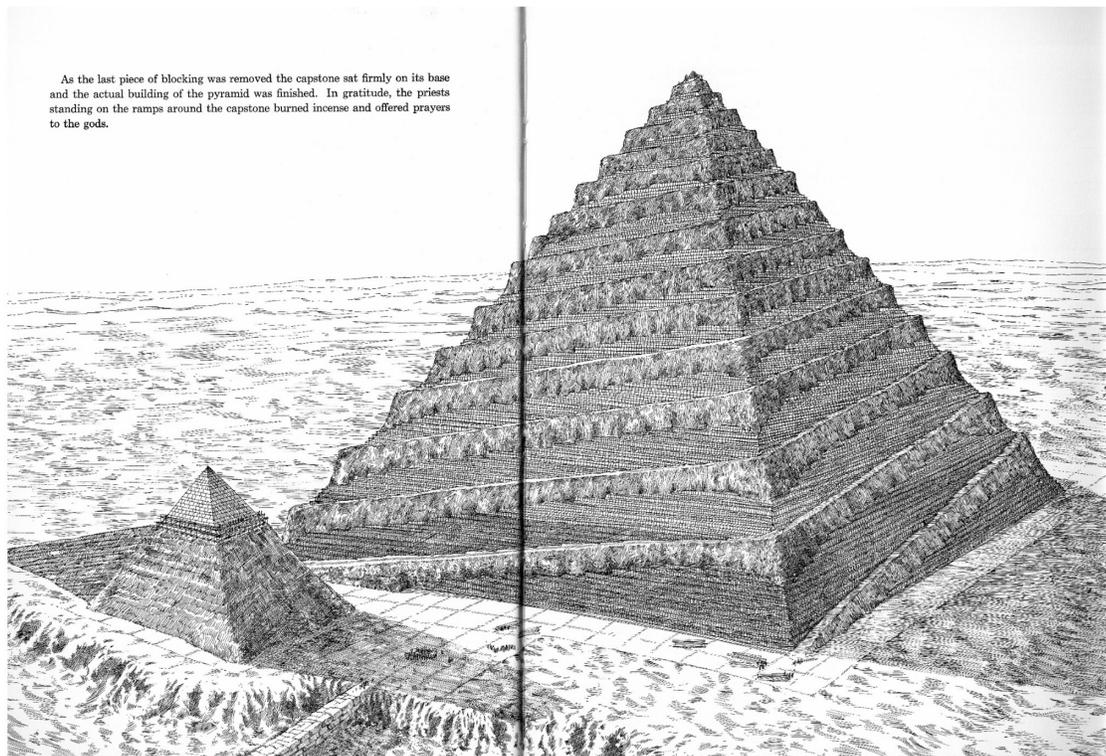
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Great Pyramid

Great Pyramid at Giza

- Construction in stone



From David Macaulay *Pyramid*

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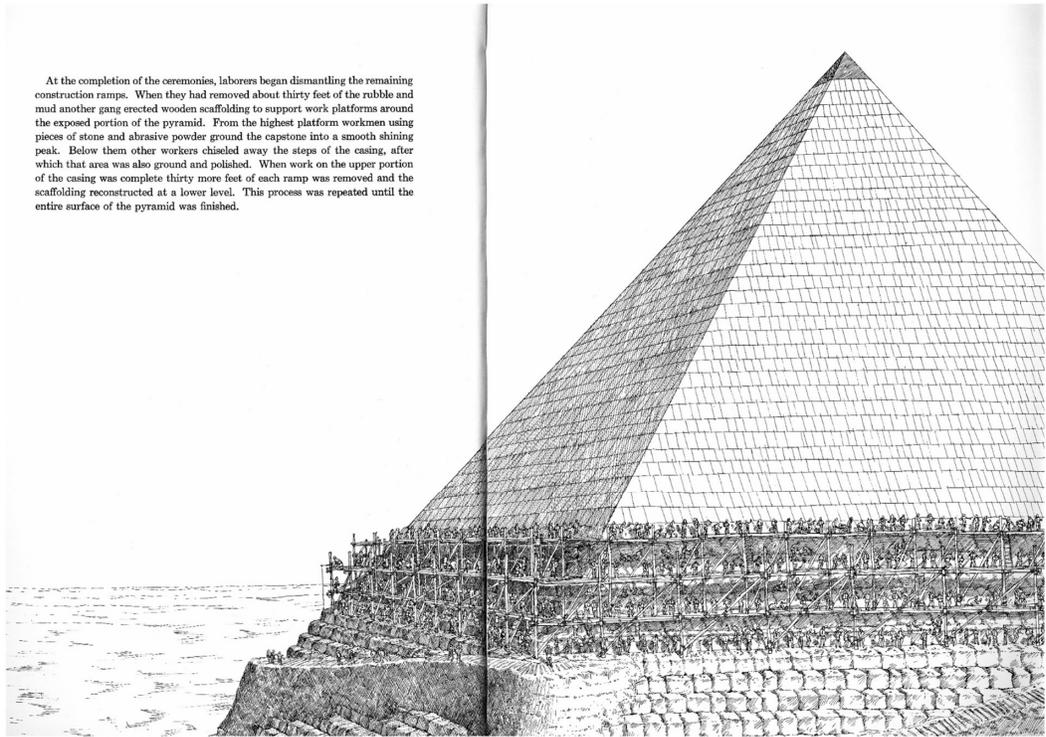
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Great Pyramid

Great Pyramid at Giza

- Construction in stone

At the completion of the ceremonies, laborers began dismantling the remaining construction ramps. When they had removed about thirty feet of the rubble and mud another gang erected wooden scaffolding to support work platforms around the exposed portion of the pyramid. From the highest platform workmen using pieces of stone and abrasive powder ground the capstone into a smooth shining peak. Below them other workers chiseled away the steps of the casing, after which that area was also ground and polished. When work on the upper portion of the casing was complete thirty more feet of each ramp was removed and the scaffolding reconstructed at a lower level. This process was repeated until the entire surface of the pyramid was finished.



From David Macaulay *Pyramid*

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Masonry

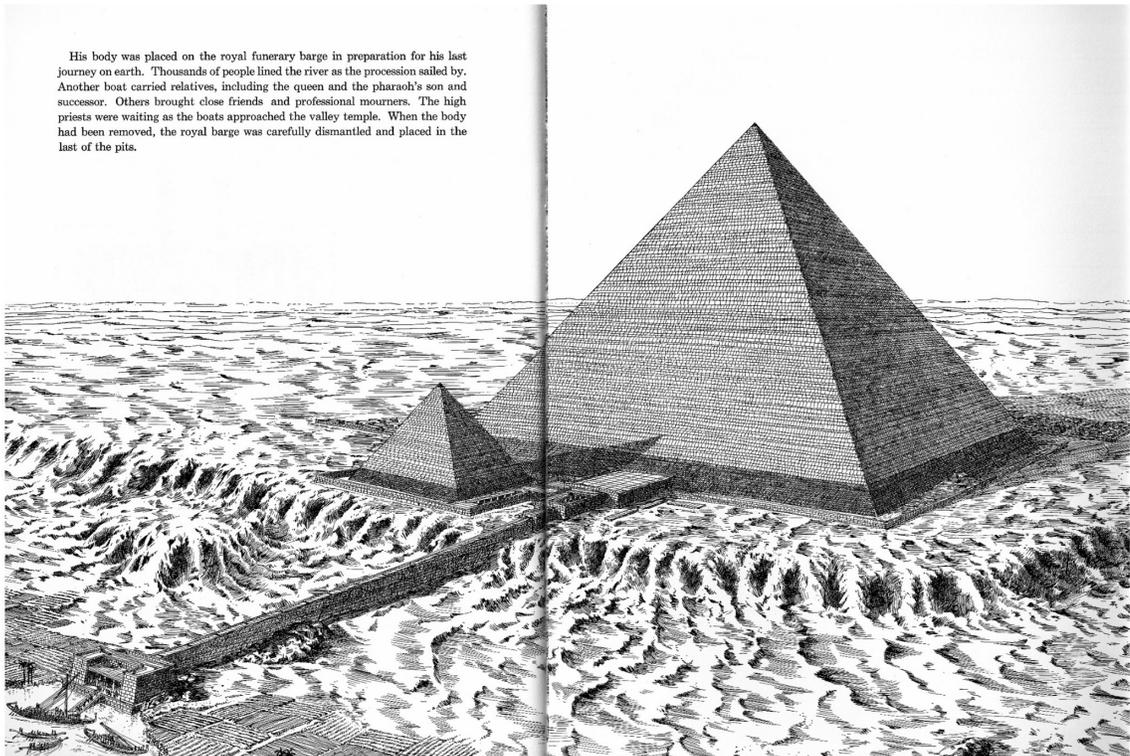
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Great Pyramid

Great Pyramid at Giza

- Construction in stone

His body was placed on the royal funerary barge in preparation for his last journey on earth. Thousands of people lined the river as the procession sailed by. Another boat carried relatives, including the queen and the pharaoh's son and successor. Others brought close friends and professional mourners. The high priests were waiting as the boats approached the valley temple. When the body had been removed, the royal barge was carefully dismantled and placed in the last of the pits.



From David Macaulay *Pyramid*

University of Michigan, TCAUP

Masonry

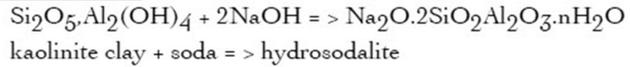
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Great Pyramid

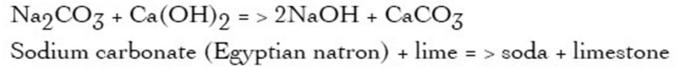
Great Pyramid at Giza

- cast “stone” ?

Chemical reaction 1:



Chemical reaction 2:



References:

Summary of the re-agglomerated stone binder chemical formula:

clay + natron + lime => feldspathoids + limestone (i.e. a natural stone)

pro

Joseph Davidovits, *Why the pharaohs built the Pyramids with fake stones*, 2009

<https://www.geopolymer.org/archaeology/pyramids/are-pyramids-made-out-of-concrete-1/>

or

con

Donald Campbell and Robert Folk, “Ancient Egyptian Pyramids – Concrete or Rock?”, *Concrete International*, Vol 13 Issue 8, August 1991

Great Pyramid

Great Pyramid at Giza

- Or cast “stone”

From Joseph Davidovits' book

Joseph DAVIDOVITS

Why the Pharaohs built
THE PYRAMIDS
with fake stones

The ULTIMATE scientific proofs
The rise and decline of a technology

GEOPOLYMER

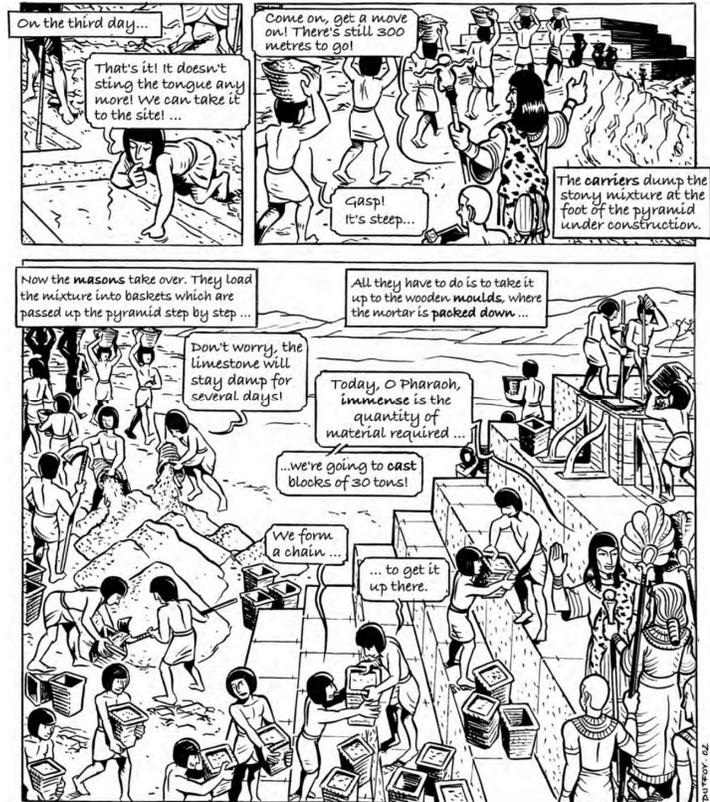


(1) Wadi : a desert watercourse that dries up periodically

Great Pyramid

Great Pyramid at Giza

- Or cast "stone"



From Joseph Davidovits

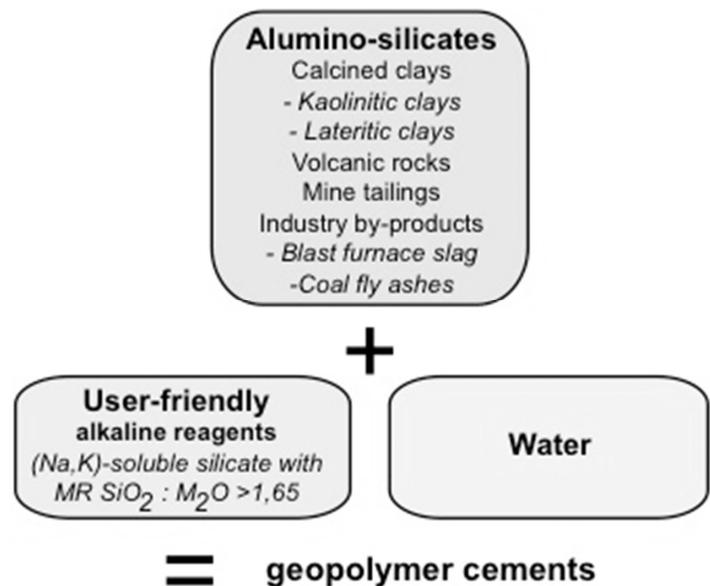
Pyrament

Pyrament from Lone Star

- Geopolymer cement
- Cures faster
- High strength

Used in bridge decks in Kentucky ~ 1995

https://uknowledge.uky.edu/ktc_researchreports/846/



Corbeled Arch

Greek

Lion Gate

- Mycenae
- 1250 BC
- Corbeled “arch”

- Stone lintel
- 3 ft thick
- 30 ton



Corbeled Arch

Greece

Treasury of Atreus at Mycenae

- 1250 BC



Syria

Royal Palace of Ugarit

- 1400 - 1200 BC



Corbeled Arch

India

Billbee-ubud



Maya

Cahal Pech
• 250 AD



Trabeate Arch – New Delhi

Post & Lintel

Greek

Temple form

- Derived from wood construction
- “architecton” is master carpenter
- Stone replaced wood by 700 BC

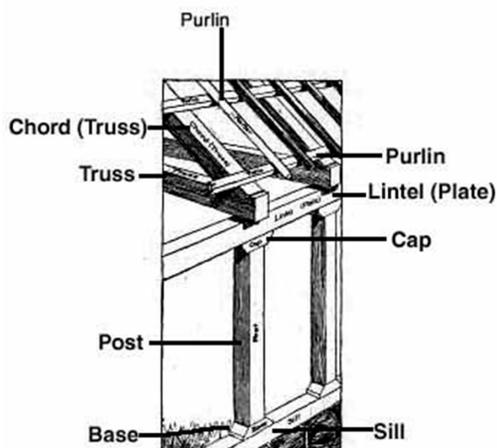


FIG. 7—NEW HAMPSHIRE BARN FRAME

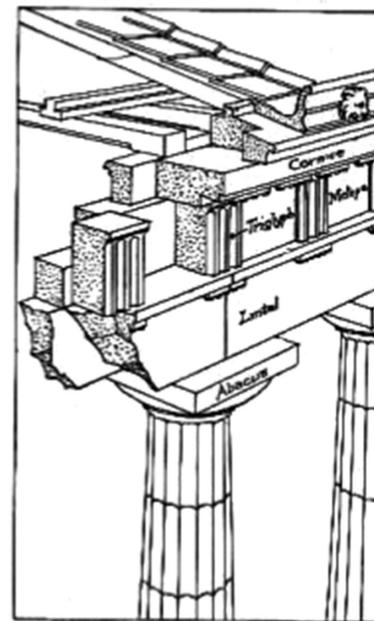


FIG. 8—GREEK STONE CONSTRUCTION

Post & Lintel

Greek

Parthenon

- 447- 438 BC



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Post & Lintel

Nashville

Parthenon

- Original in wood 1897
- 1925 exterior
- 1931 interior
- 1990 statue



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Masonry

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Wall Construction

Roman

Fired brick used in walls

- Solid masonry
- Infill with concrete (pozzolanic)

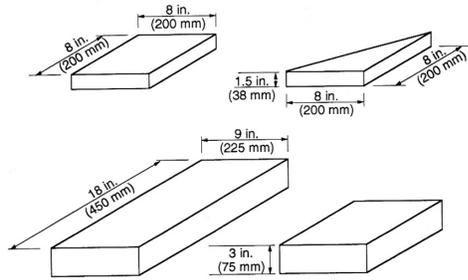
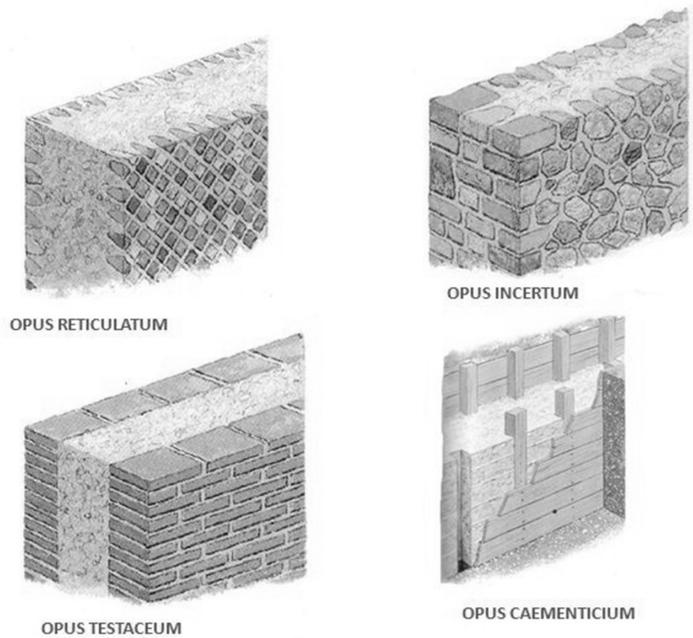


Figure 1.3 Roman bricks made in a mold.

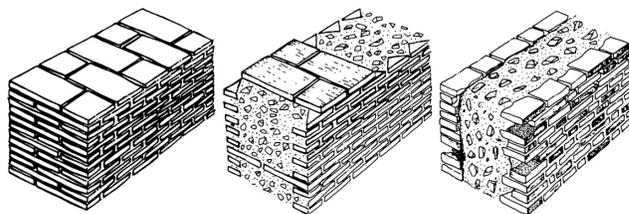


Wall Construction

Roman

Fired brick used in walls

- Solid masonry
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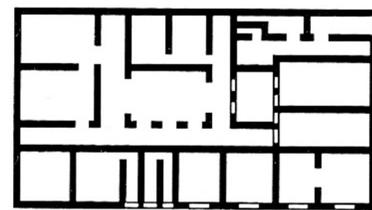


(a) Bonded Brick Wall (b) Brick Faced Wall with Header Courses (c) Brick Faced Wall

Figure 1.7 Roman masonry walls.



Elevation



Plan

Apartments in Ostia

Arches

Roman

The arch

- First to use
- Circular form
- Braced sides

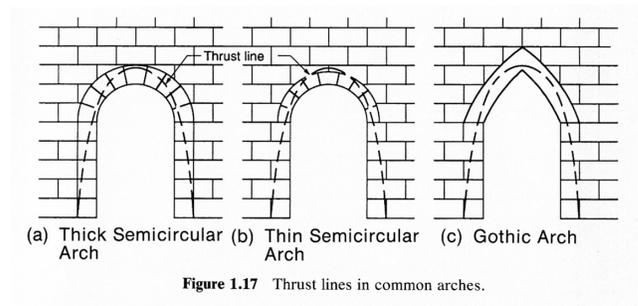
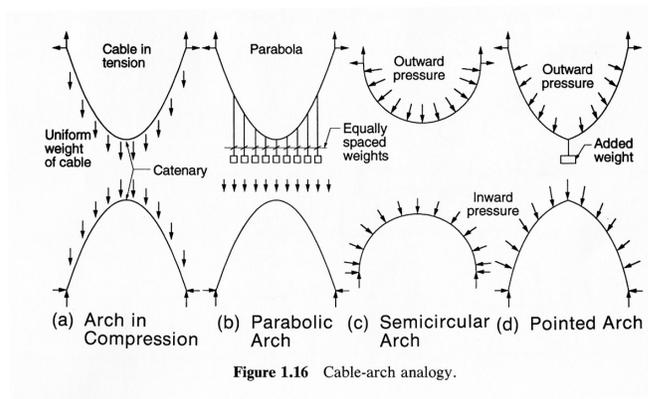
Ostia



Arches

Arch forms

- catenary
- parabolic
- circular



Arches

Arch forms

- catenary
- parabolic
- circular

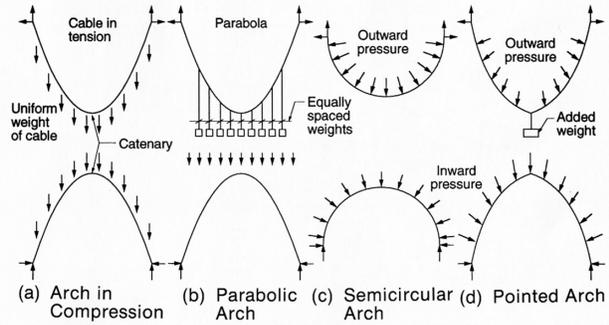


Figure 1.16 Cable-arch analogy.

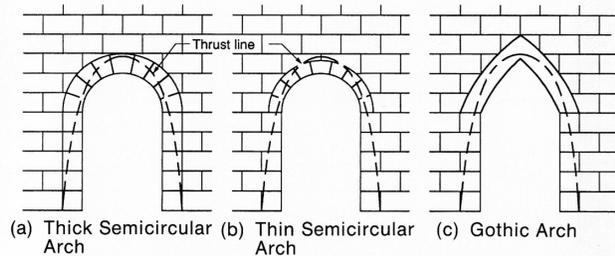
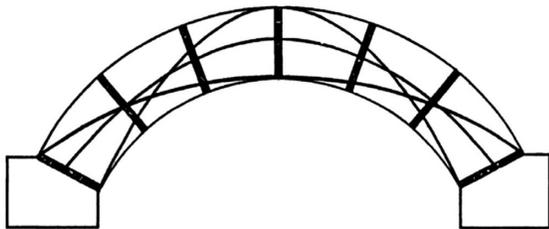


Figure 1.17 Thrust lines in common arches.

Arches

Arches – thrust line calculation

- Sum moments at section

TWO COUPLES ARE EQUAL

$$W \times \frac{L}{4} = R \times h$$

$$R = \frac{WL}{4h}$$

TRACE THE THRUST LINE BY CUTTING A SECTION.

ΣM TO FIND a

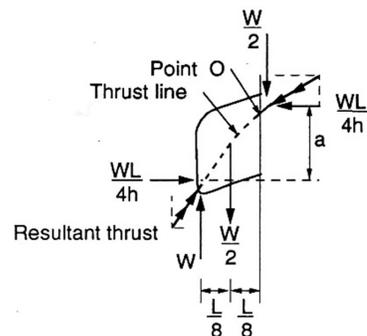
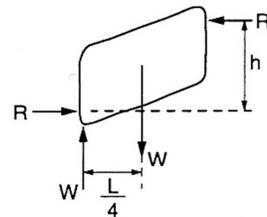
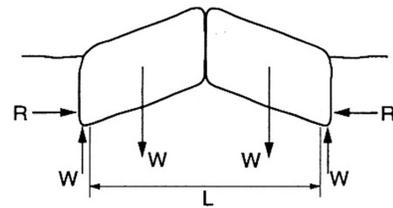
$$\Sigma M_{O_0} = 0$$

$$-\frac{WL}{4h} a + \frac{WL}{4} - \frac{WL}{2} \frac{L}{8} = 0$$

$$\frac{WL}{4h} a + \frac{WL}{4} = \frac{WL}{4}$$

$$a = \frac{3}{4} \frac{WL}{WL} \cdot \frac{h}{WL}$$

$$a = \frac{3}{4} h$$



Arches

Arches – thrust line calculation

- Sum moments at section

Two examples with different contact bearing points

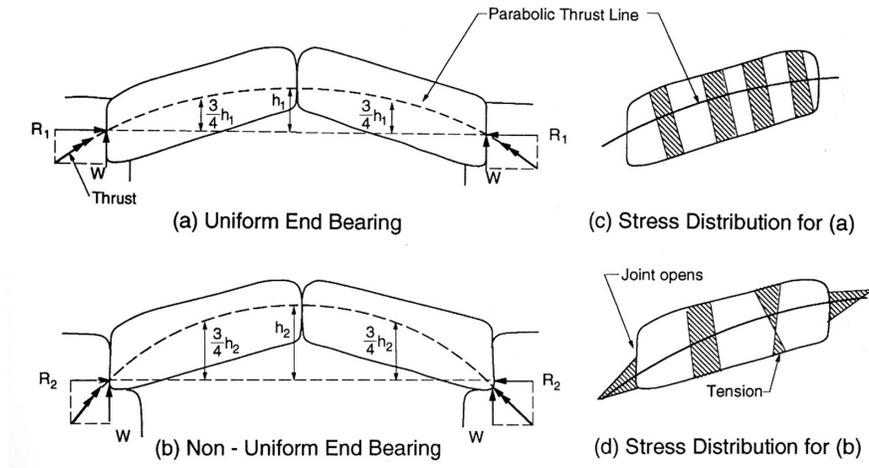


Figure 1.14 Thrust lines and stresses in inclined lintels (primitive arches).

Arches

Roman

The arch

- First to use
- Circular form
- Braced sides





Vaults

Vault forms

- single
- parallel
- cross
- pointed (gothic)

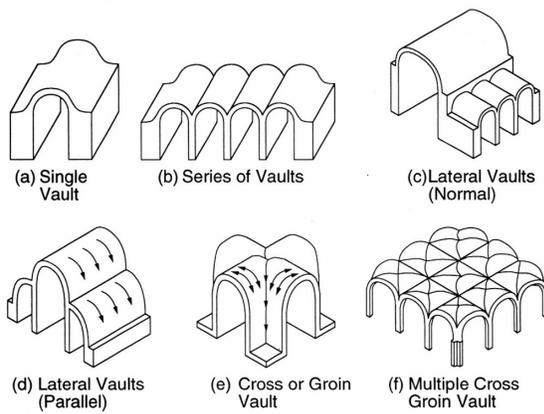


Figure 1.25 Examples of combined barrel vaults.

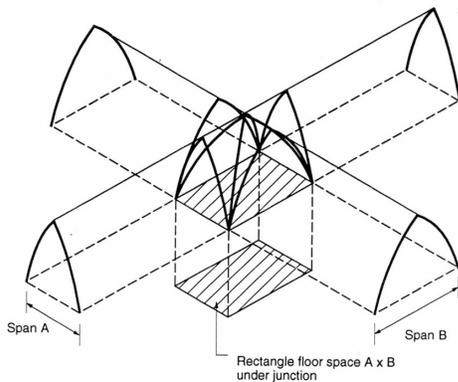
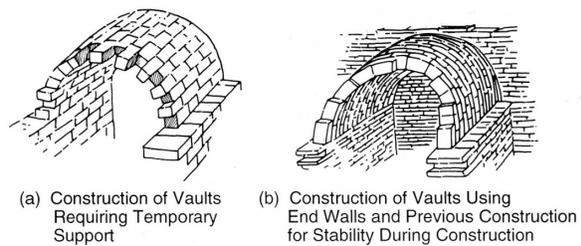


Figure 1.27 Intersection of pointed vaults.



(a) Construction of Vaults Requiring Temporary Support

(b) Construction of Vaults Using End Walls and Previous Construction for Stability During Construction

Domes

Arch forms

- catenary
- parabolic
- circular

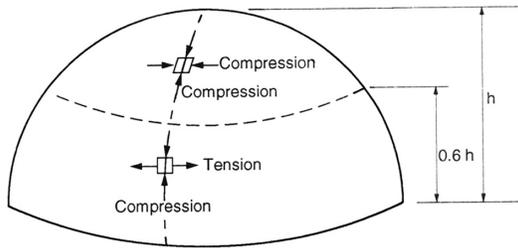


Figure 1.22 Stress in a hemispherical dome under its own weight.

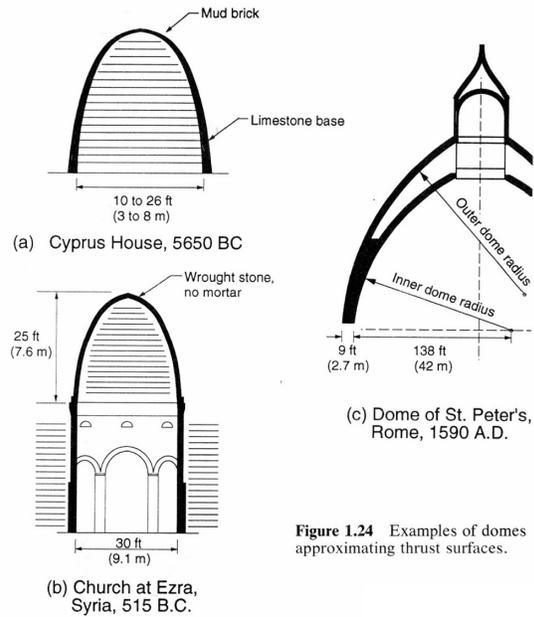


Figure 1.24 Examples of domes approximating thrust surfaces.

Domes

Roman

The masonry dome

- First to use
- Spherical form
- Braced sides



Pantheon 124 AD

Domes

Roman

Pantheon 125 AD

- First to use
- Spherical form
- Braced sides

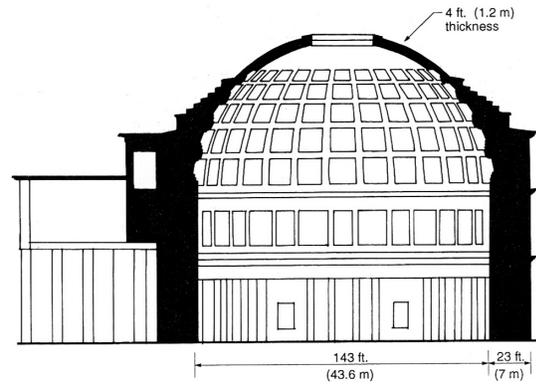


Figure 1.23 The Pantheon in Rome (A.D. 123). (Redrawn from Ref. 1.9)



Domes

Roman

Pantheon

- Thrust line
- Catenary models

Institute for Lightweight Structures (IL)

