Domes: Structure, construction and materials

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Material and Methods of Construction I ARCH-230

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Introduction:
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- Revolution of domes

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5. Geodesic dome
6. Hemispherical dome
7. Onion dome
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9. Parabolic dome
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11. Saucer dome
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- Stability of domes
- Dome failure

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1. Tube and hub
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3. Beam and hub
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5. Panelized timber
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7. Space framing
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Building envelop system :- material assemblies
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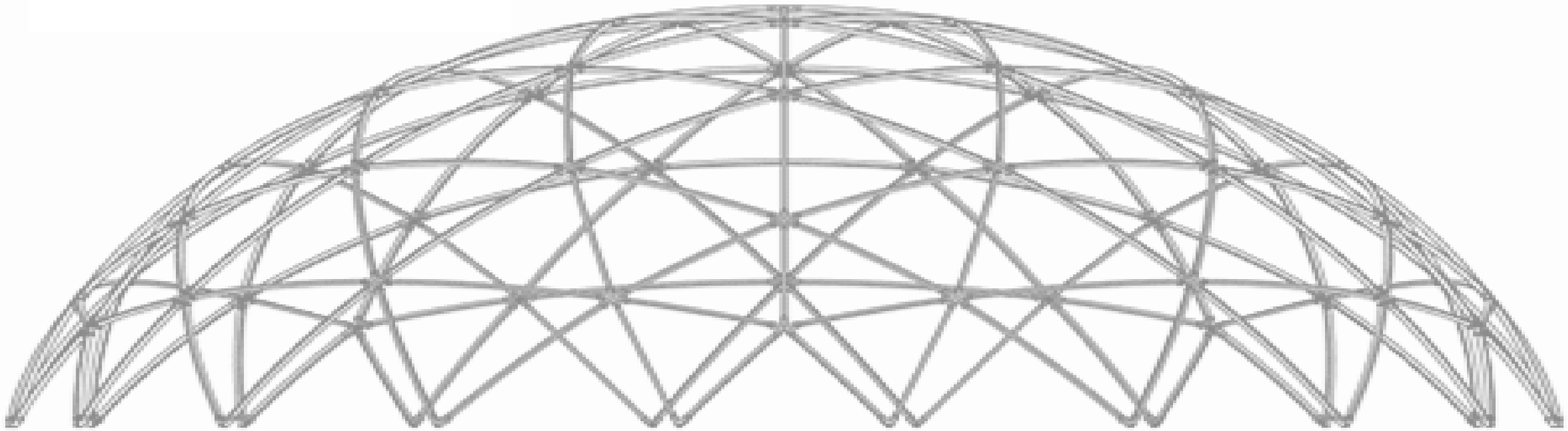
- STEP 2 :- technical drawing
- STEP 3 :- fabrication
- STEP 4 :- installation

Local case study:-
- Alhazm
- Aspire dome
- Abdulwahab mosque
- Kempiniski hotel- doha

INTRODUCTION:

INTRODUCTION: Domes

- Are Strong, Stiff, curved structures.
- Have no angles and no corners.
- Enclose an enormous amount of space without the help of a single column.
- Heavy in weight, making it difficult to lift it off its base.



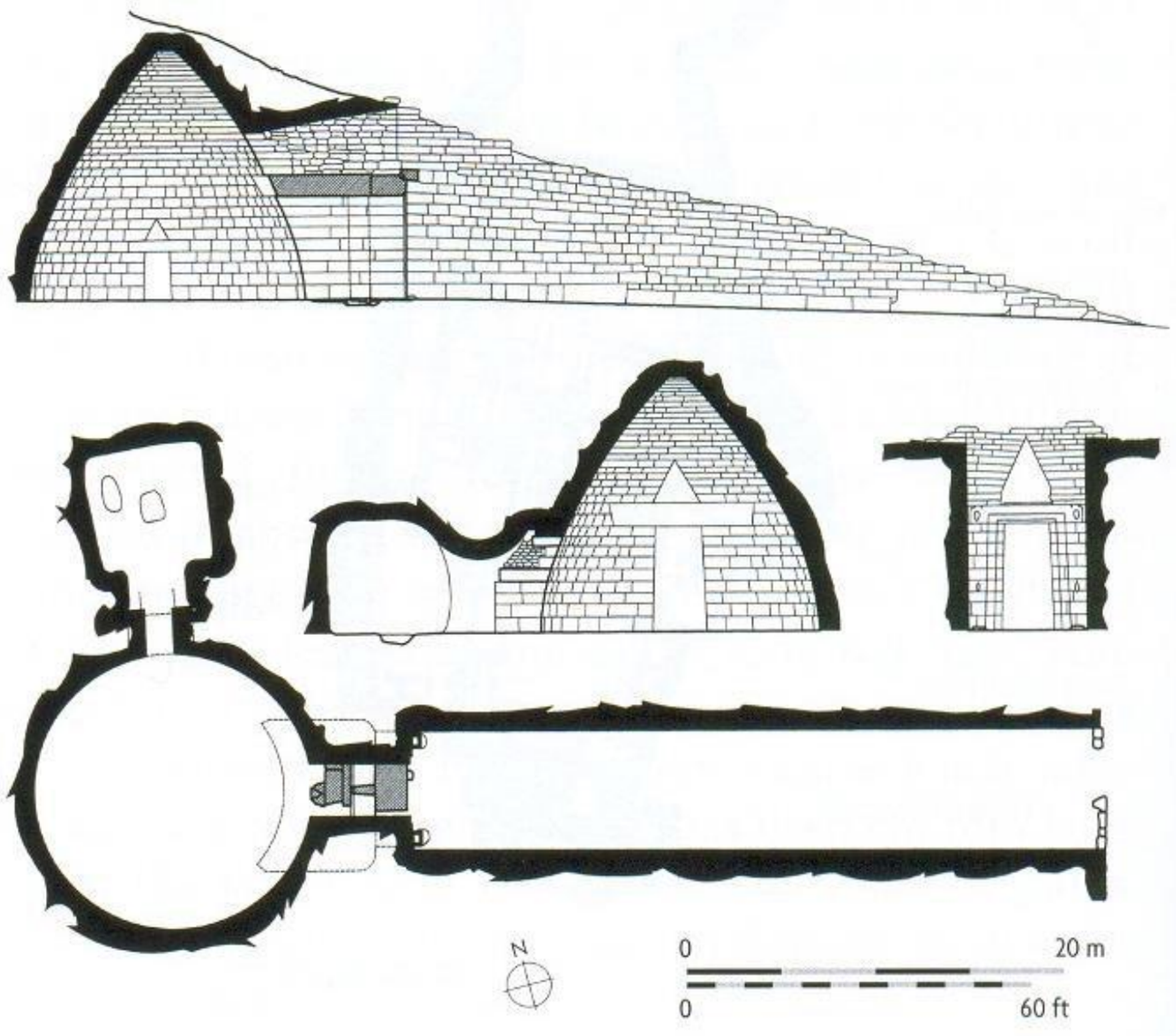
REVOLUTION OF DOMES

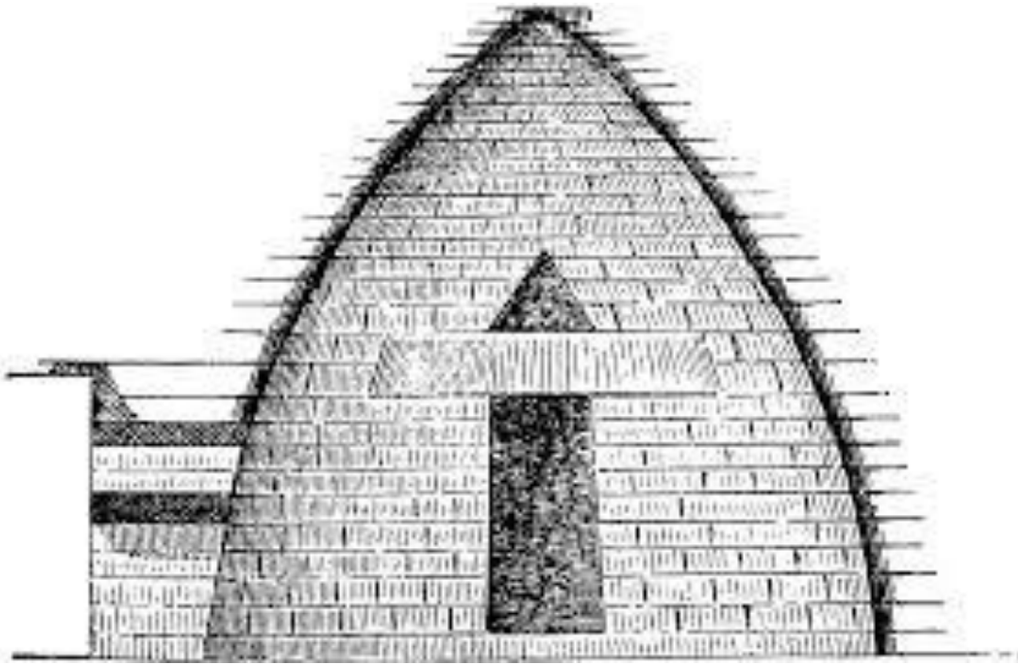
REVOLUTION OF DOMES: Mesopotamian

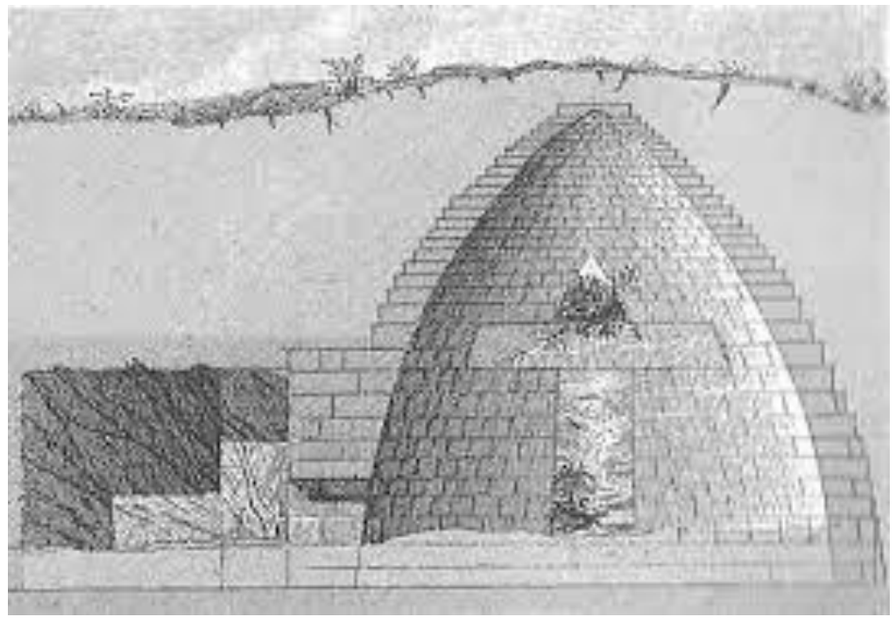
- It developed as roofing for circular mud-brick huts in ancient Mesopotamia about 6000 years ago.

REVOLUTION OF DOMES: Greek

- Built tombs roofed with steep corbeled domes in the shape of pointed beehives in the 14th century

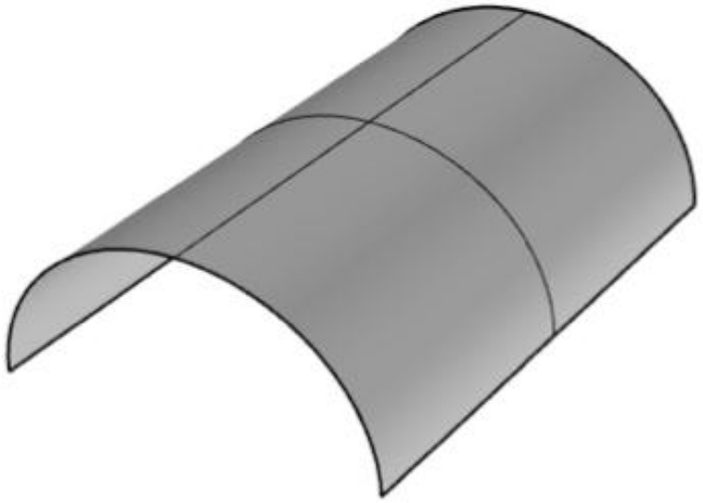


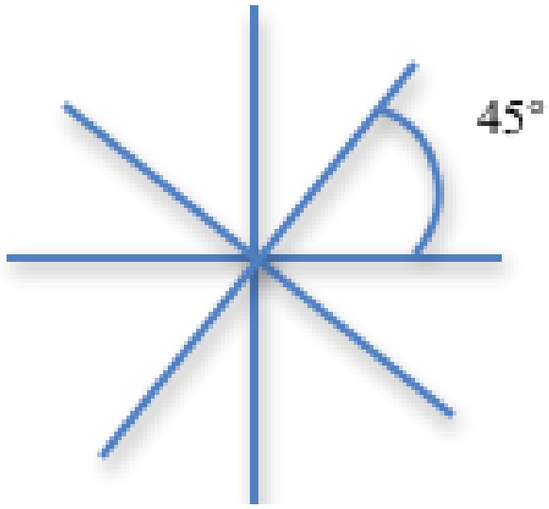


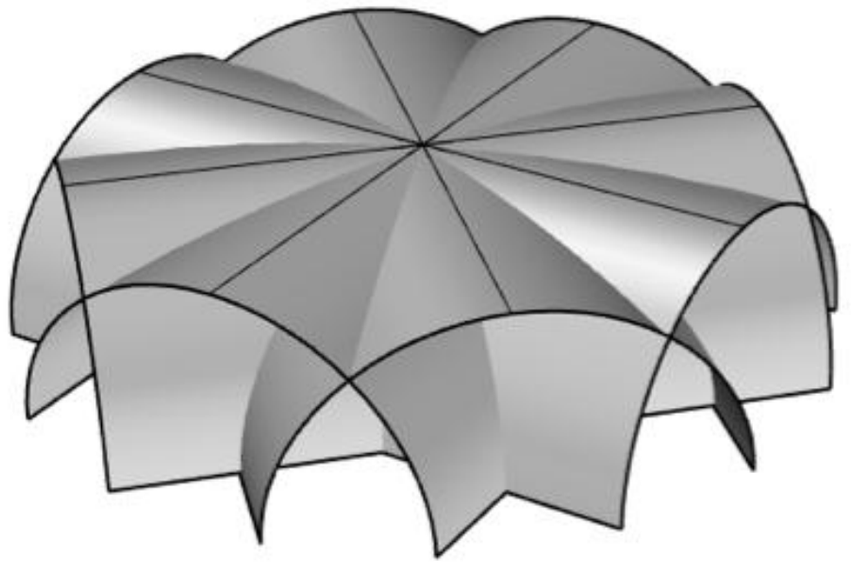


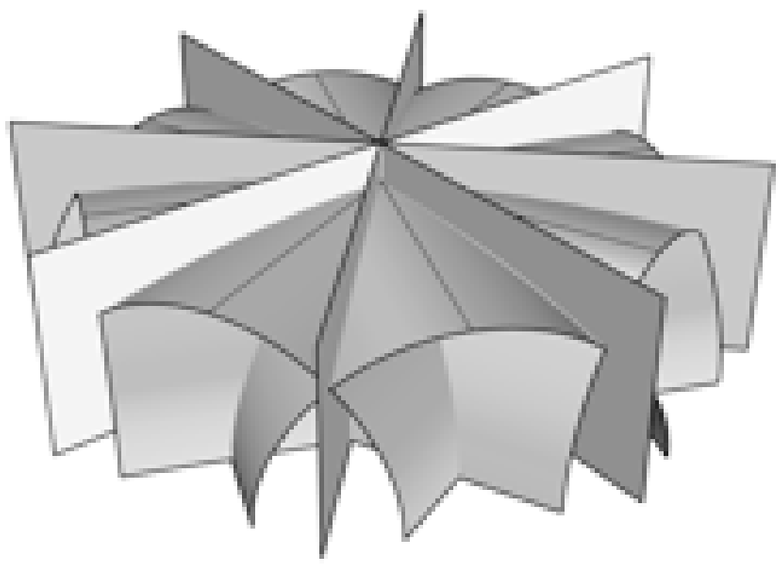
DERIVATION OF DOMES FROM ARCHES

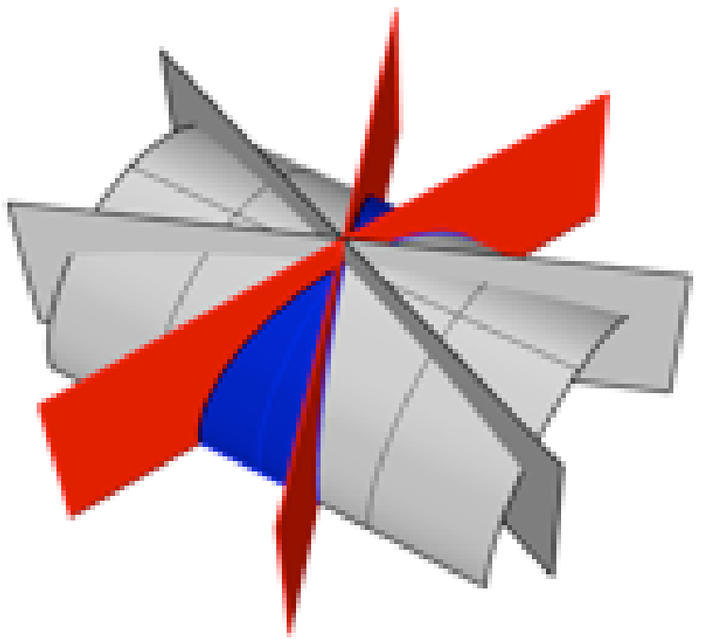
- 4 cylindrical barrels sliced longitudinally
- Placing the barrels such that the axes of the barrels make a 45° angle by placing them by of with each other
- Take a section of the intersected barrels.
- By repeating the same portion, An entire dome structure will be obtained.







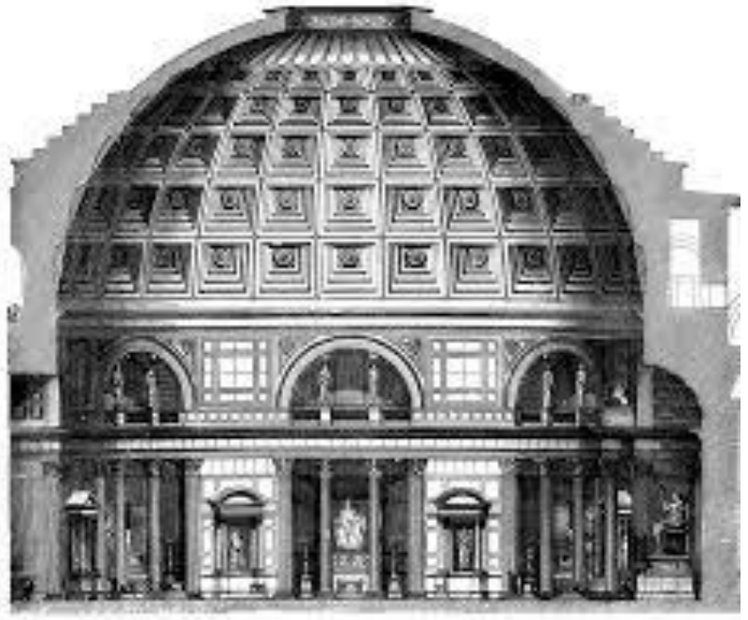


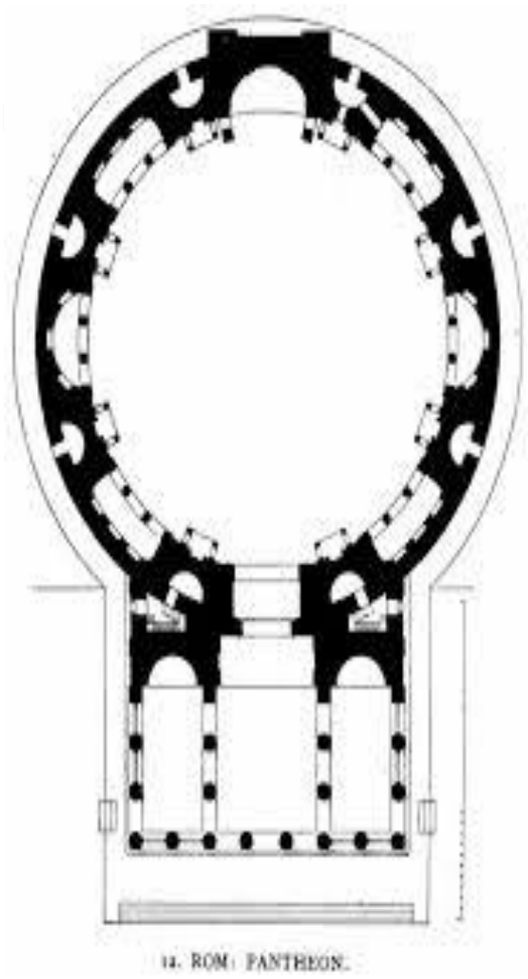


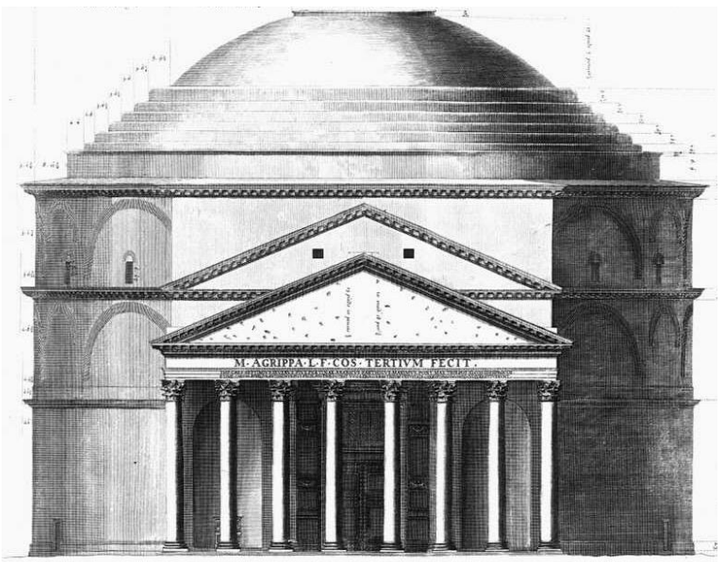
REVOLUTION OF DOMES: Roman

- They developed the masonry dome.

- Example; the Pantheon, a temple built by the emperor Hadrian.
  - The coffered dome rises 43 m
  - Hemispherical dome in the interior.
  - Saucer shaped in the exterior.
  - Set on a massive circular drum 6m (20 ft) thick
  - Has a large oculus (eye) in its ce admit light.



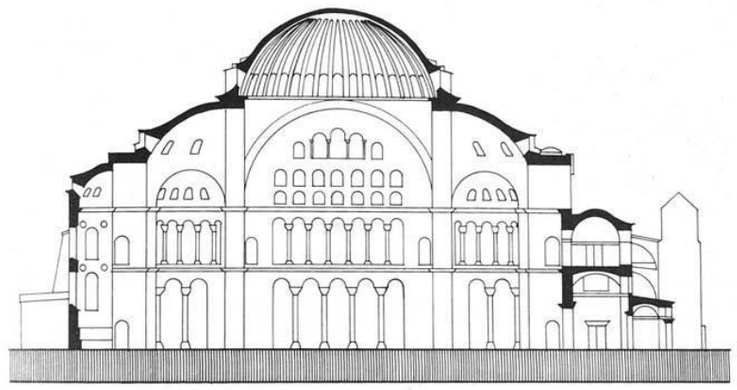


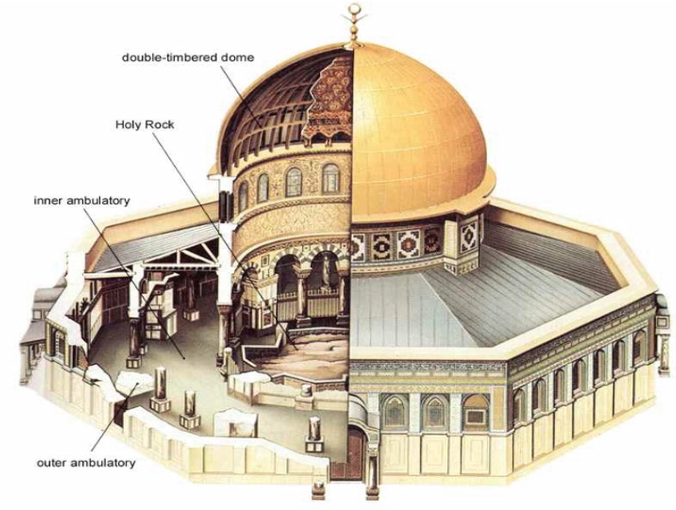


REVOLUTION OF DOMES: Constantinople

Hagia Sophia in Turkey, Istanbul

- was converted to a mosque in the Ottoman Empire
- Umbrella dome



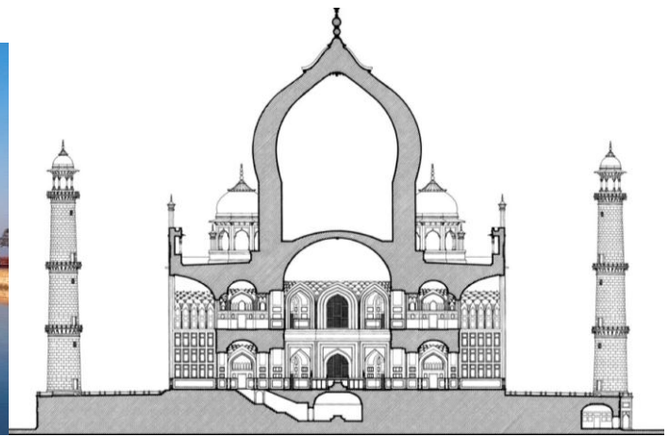


The Dome of the Rock (691) in Palestine

- Set on a pillared arcade, its double dome is of timber construction.
- Hemispherical dome

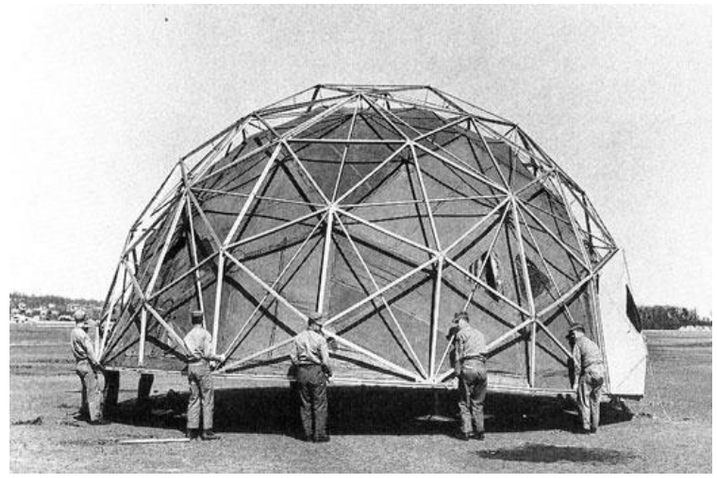
The Taj Mahal in Agra, India

- Its slightly bulbous white marble dome rises on a tall drum over a spacious equilateral building.
- Onion shaped dome



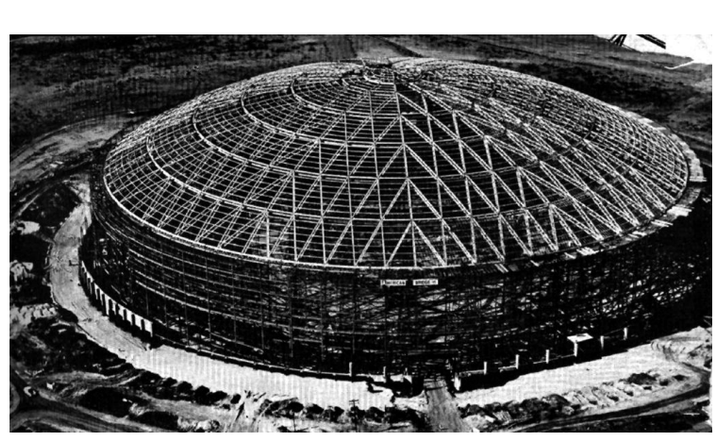
REVOLUTION OF DOMES: 20th century

The technology have radically changed the concept and construction of the dome.



Geodesic dome:

- composed of a lattice of interlocking tetrahedrons and octahedrons made of lightweight materials,
- The interior free of structural supports.



Sports arena use in the Houston Astrodome, Texas:

- Steel-dome construction
- Its plastic roof is 195 m (642 ft) wide

The Palazetto dello Sport Rome for the 1960 Olympic Games:

- Reinforced concrete ribs

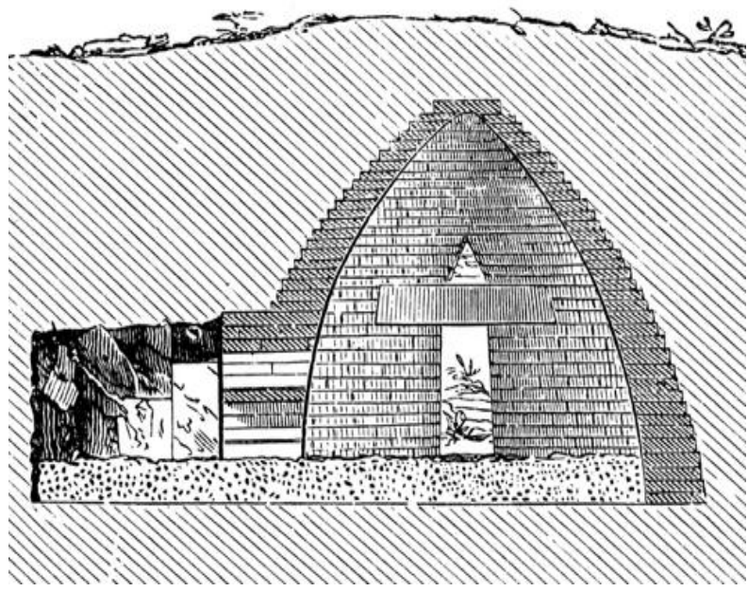
TYPES OF DOMES

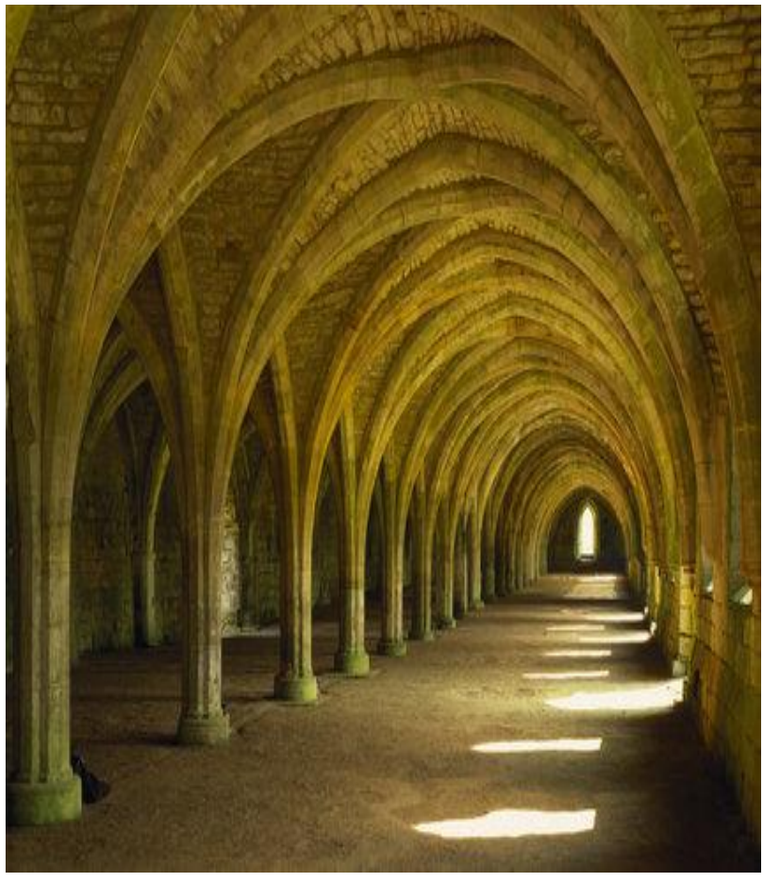
TYPES OF DOMES

Beehive dome (corbelled dome)

- They consist of horizontal layers.
- Each is slightly corbelled toward the center as the layers get higher until they meet in the center.
- EX:

Mycenaean Treasury of Atreus from the late Bronze Age.





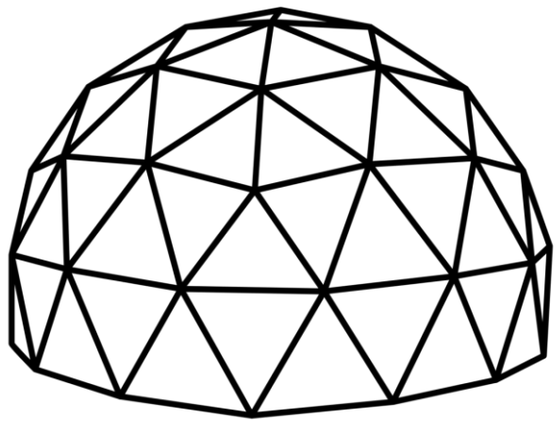
Cloister vault (domical vaults)

- The horizontal cross section is a polygonal
- EX:

The Renaissance octagonal dome of Filippo Brunelleschi over the Florence Cathedral.

TYPES OF DOMES

Geodesic dome

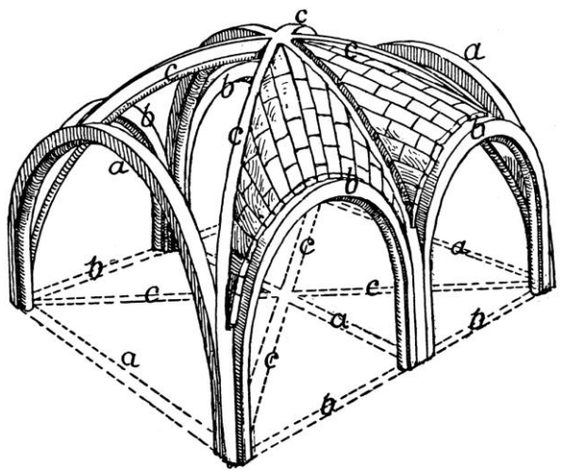


- *Geodesic domes* are the upper portion of geodesic spheres.
- They are composed of a framework of triangles in a polyhedron pattern.
- The structures are based upon octahedrons or tetrahedrons.
- Such domes can be created using a limited number of simple elements and joints and efficiently resolve a domes internal forces.

Crossed-arch dome (ribbed vault)

- Rather than meeting in the center of the dome, the ribs characteristically intersect one another off-center, forming an empty polygonal space in the center.
- EX:

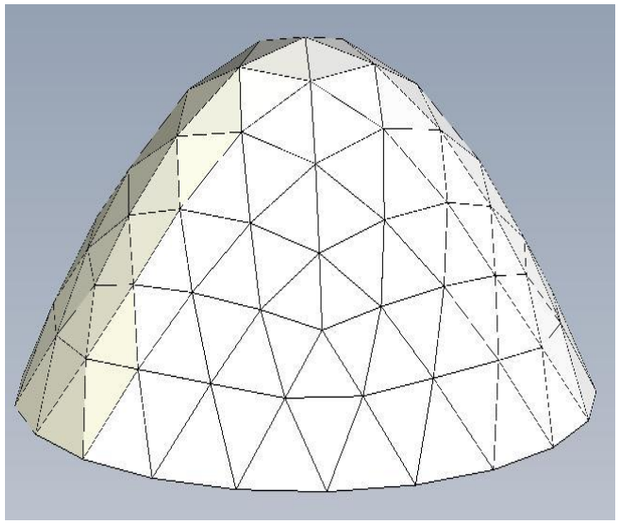
The Great Mosque of Córdoba

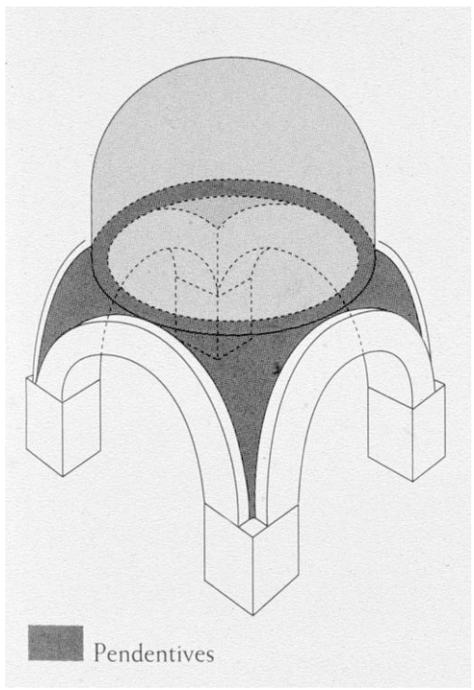


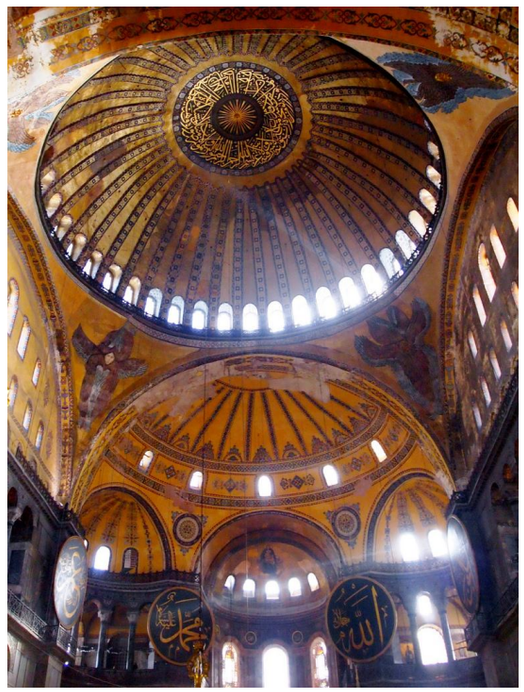
TYPES OF DOMES

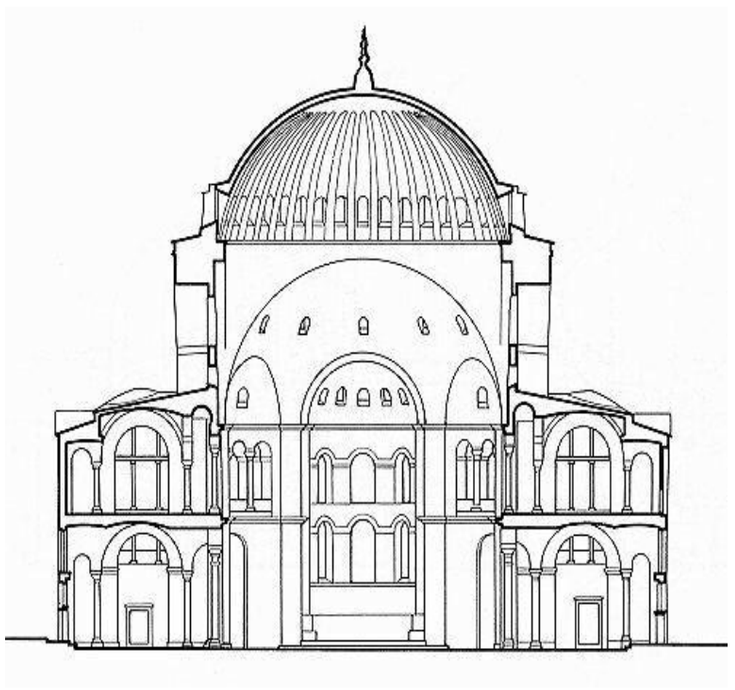
Parabolic dome

- Its bending stress due to the uniformly distributed load of its dead load is zero.
- It was widely used in buildings in ancient times, before the advent of composite structures.









Compound dome

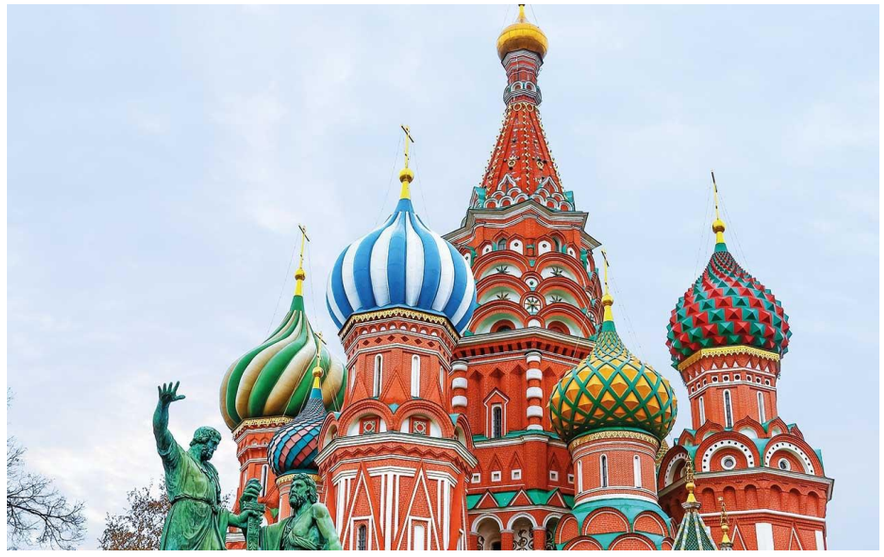
they have pendentives that support a smaller diameter dome above them.

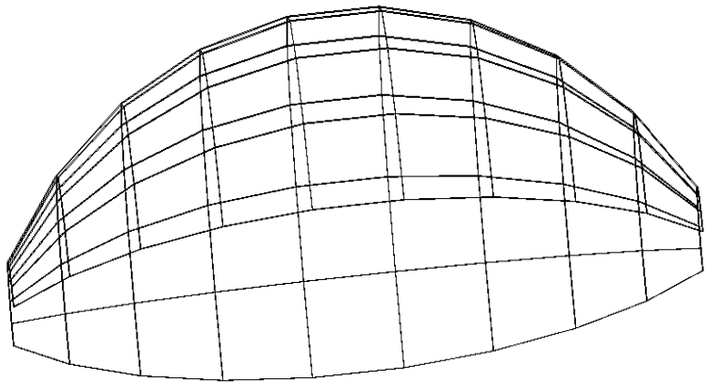
TYPES OF DOMES

Onion dome (Bulbous domes)

- The profile is greater than the hemisphere
- An onion dome is a greater than hemispherical dome with a pointed top in an ogee profile.
- EX:

Saint Basil's Cathedral





Oval dome

- Oval shape in plan, profile, or both.
- The earliest oval domes were used in corbelled stone huts as rounded but geometrically undefined coverings
- The first examples in Asia Minor to around 4000 B.C.T

TYPES OF DOMESc

Umbrella dome

- The bases are divided into curved segments, which follow the curve of the elevation.
- Exteriorly Fluted, such as was common in Mamluk Egypt.
- The "ribs" of a dome are the radial lines of masonry that extend from the crown down to the springing.
- The central dome of the Hagia Sophia uses the ribbed method, which accommodates a ring of windows between the ribs at the base of the dome.

Saucer dome (segmental domes)

- These have profiles of less than a half circle.
- very shallow.
- Its radius of curvature of the dome is very large compared with its rise.

Hemispherical dome

- Half of a sphere
- EX:

DOME OF THE ROCK

BUILDING STRUCTURE PRINCIPLES

BUILDING STRUCTURE PRINCIPLES

The structural system is mainly transferring the loads through interconnecting structural components or members.

Generally:

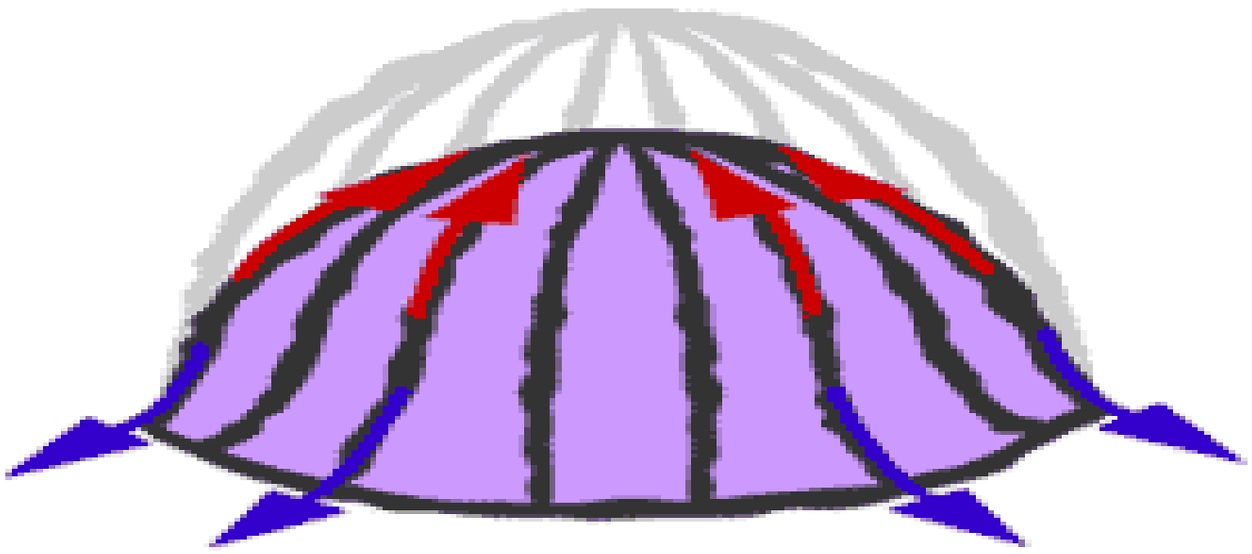
- a dome is composed of a series of rings, resting on each other
- a dome is characterised by a thrust, with pushes on the walls

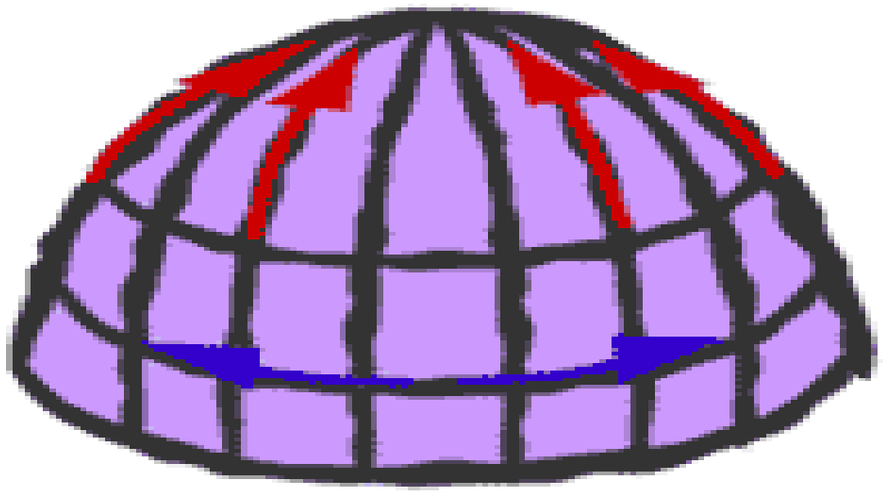
2 forces are acting in a dome:

- The thrust which pushes down with an angle on the walls
- a concentric thrust which acts in every ring and compresses it

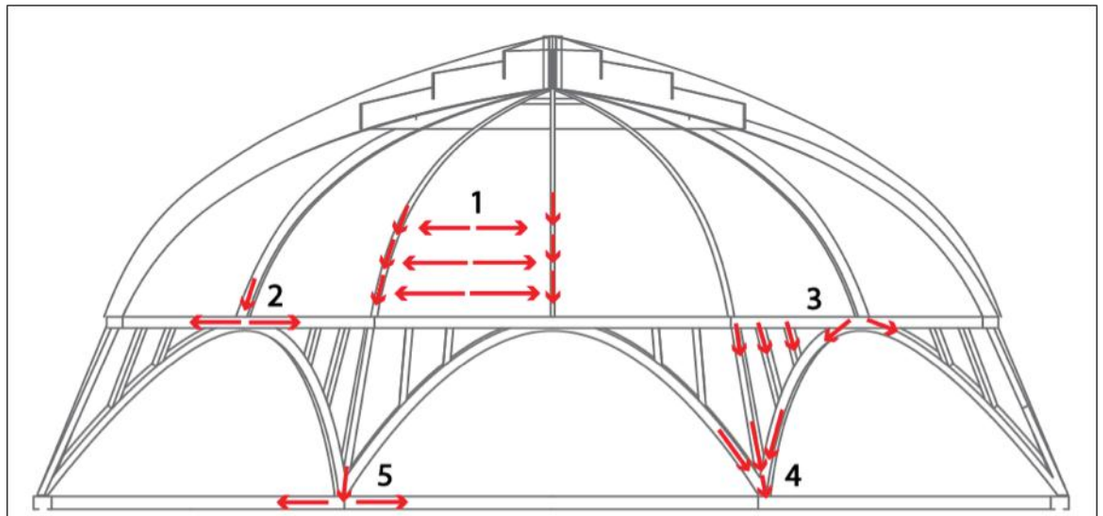
the thrust is composed of 2 forces:

- a horizontal force, which tends to push the walls apart
- the weight, which is the weight of the masonry

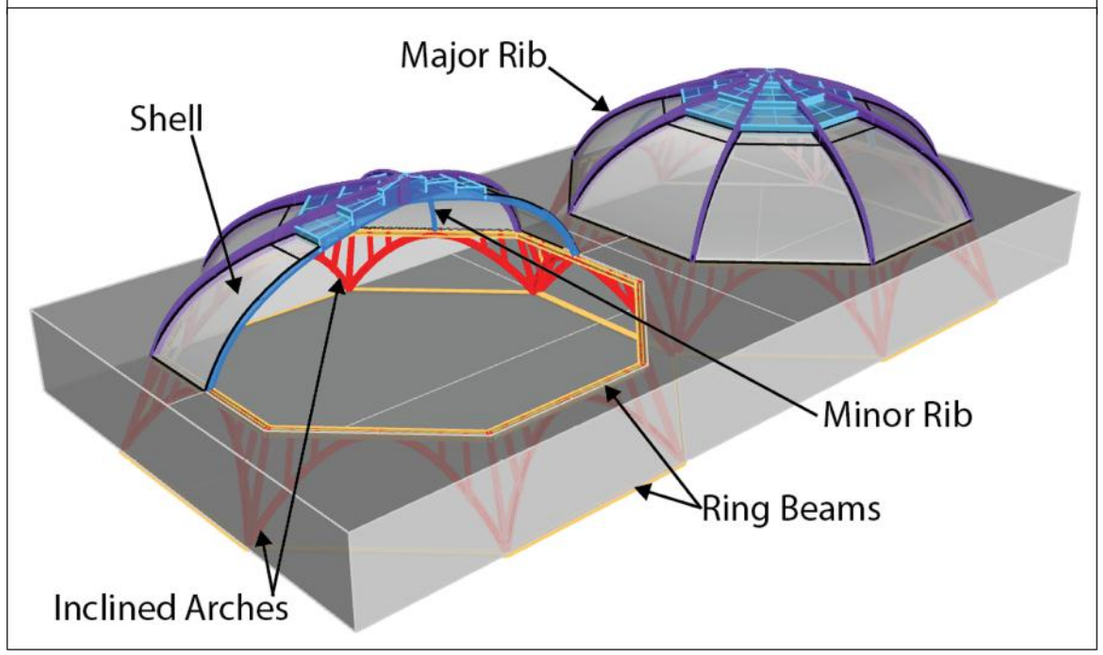


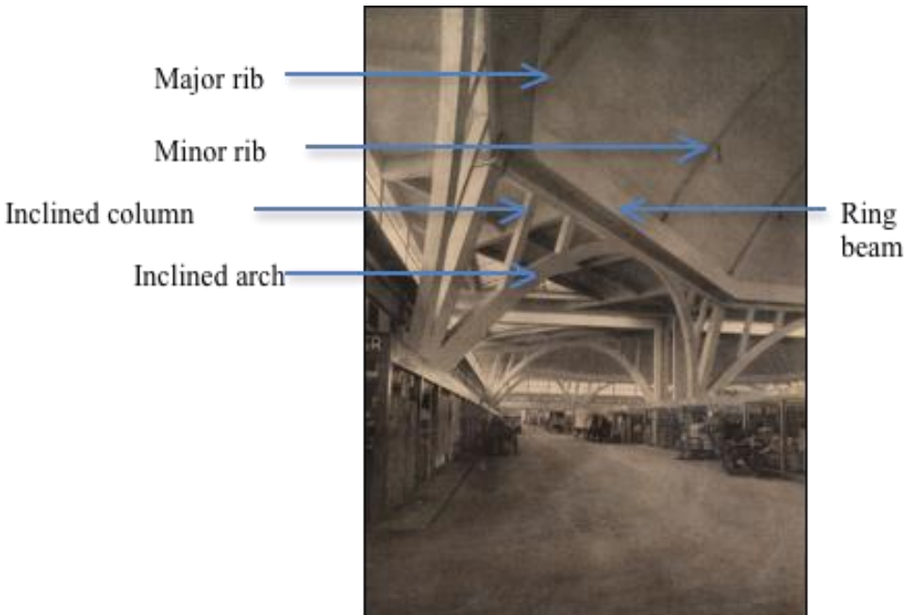


- The loads on the shells, including self-weight, snow, and wind loads, are transferred to the main and minor ribs.
- Beams at the roof level take some of the self-weight of the shell.
- The main ribs that are visible outside act as arches and exert a horizontal force on the flat roof.
- Some of the horizontal force is contained by the first ring beam which is also located at the flat roof but is not seen from outside.
- The rest of the horizontal forces are transferred to the bottom of the building through the inclined columns and arches where they are constrained by yet another ring beam in the basement and lateral ties.
- The vertical forces from the roof are transferred downwards through the inclined columns and arches.



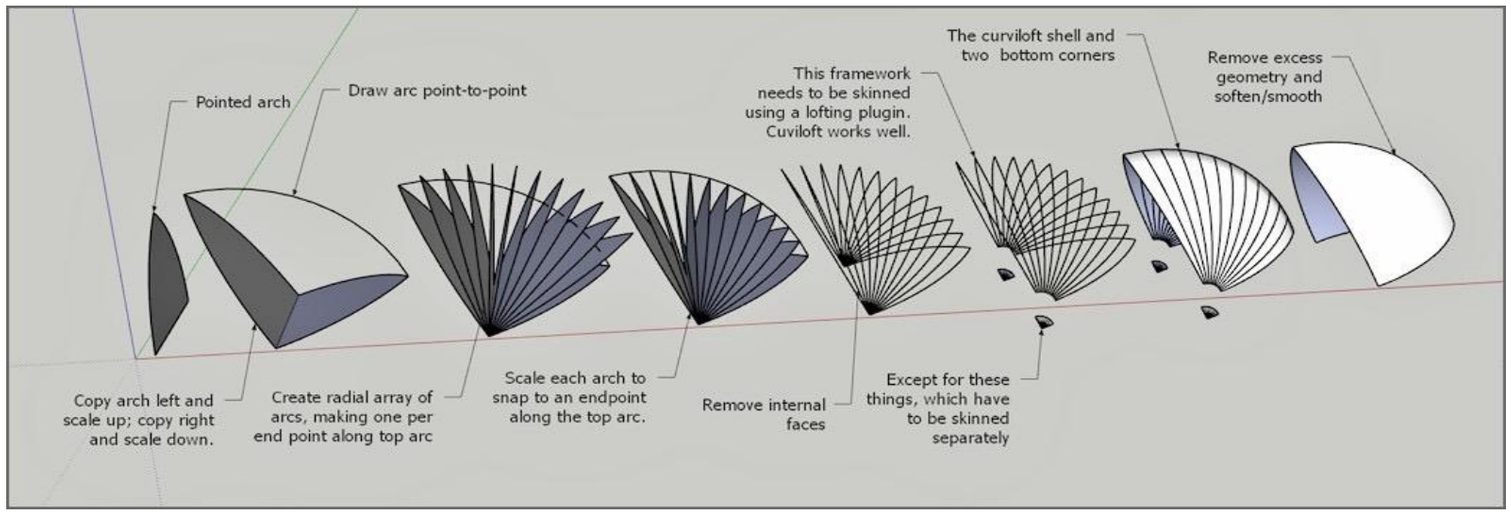
Flow of Forces



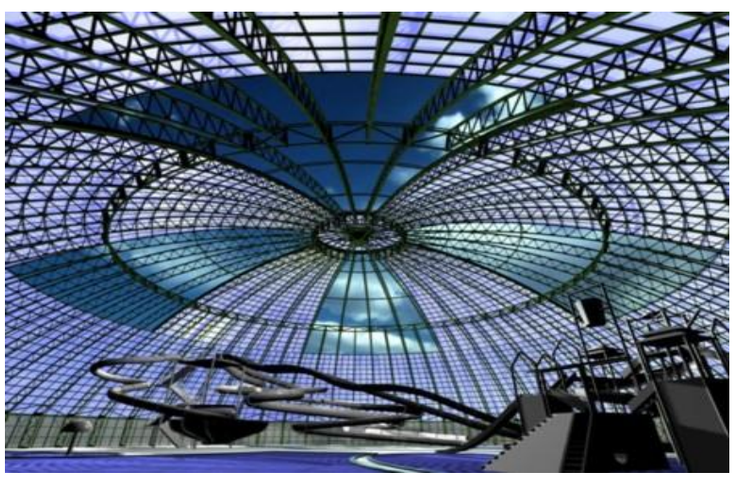


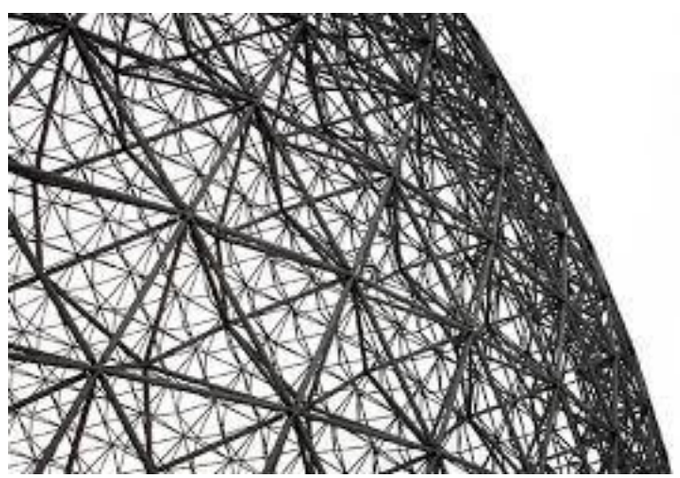
Techniques of load transfer in domes depends on the construction of a dome:

- No frames:
  - Arches: The curve of an arch transfers compression force downward



- Have voids (according to different material use):
  - Trusses: use the strength of triangles to make structures strong. The sides of the triangle distribute forces so the structure can support more weight.





STABILITY OF DOMES

STABILITY OF DOMES

HEMISPHERICAL DOME

- It often needs a tie ring
- the round wall can be a difficulty
- If it is for an exposed roof, the water proofing often cracks

SEGMENTAL CLOISTER ARCH DOME

- it always needs a tie beam
- it does not need arches to support it
- suitable for floors of apartments in multi storey buildings

HEMISPHERICAL DOME ON PENDENTIVES

- its is advised to use a tie beam
- it needs arches
- if the segmental sphere is the roof
- the waterproofing often cracks

POINTED CLOISTER ARCH DOME

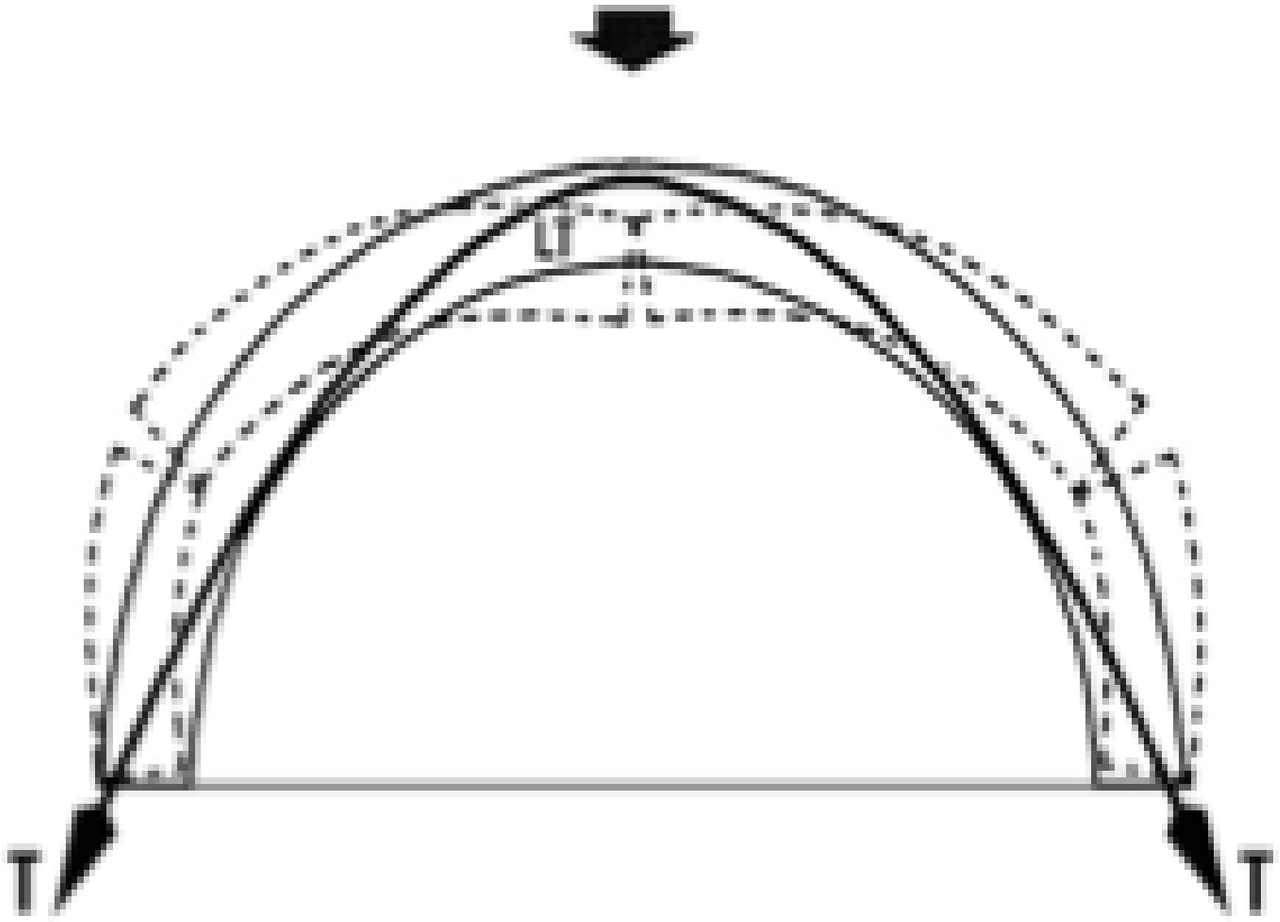
- it always needs a a tie been
- it does not need arches to support it
- it is suitable for roofs with pyramidal shape.
- durable water proofing

DOME FAILURE

CASE 1

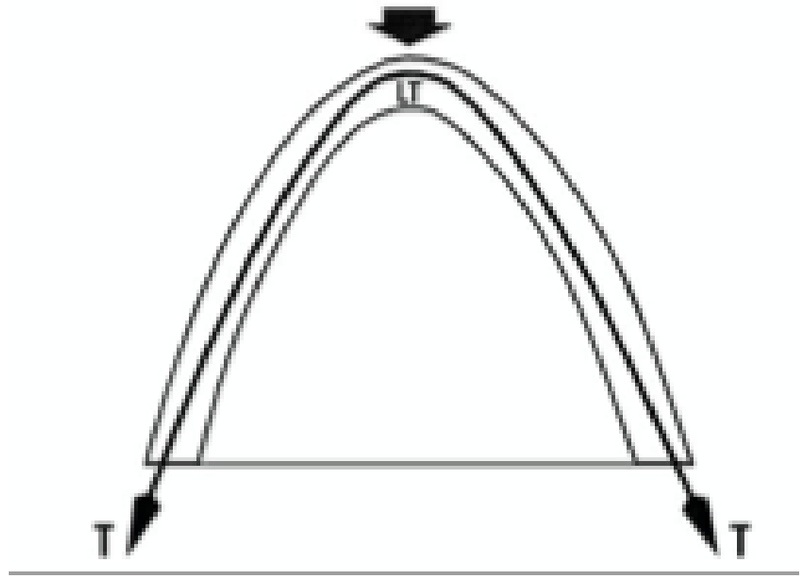
A heavy central load is applied on top of the arch, or the shape is disproportioned.

The line of thrust passes in the intrados third and will cause failure.



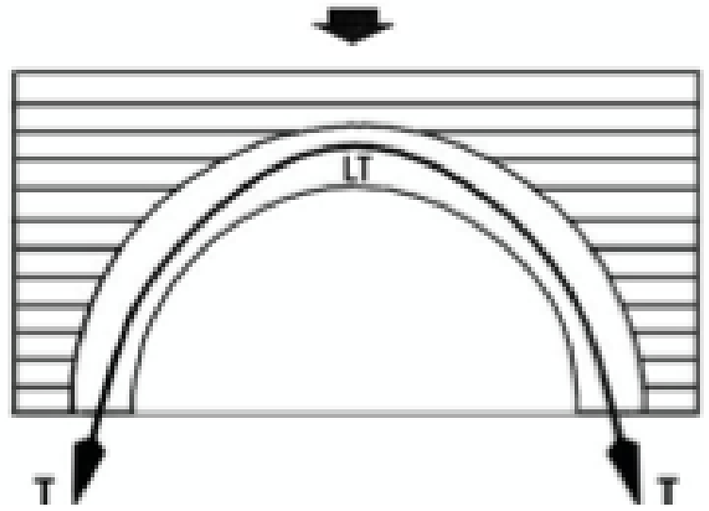
Solution1:

Change the shape of the arch



Solution2:

Keep the shape and the load haunches

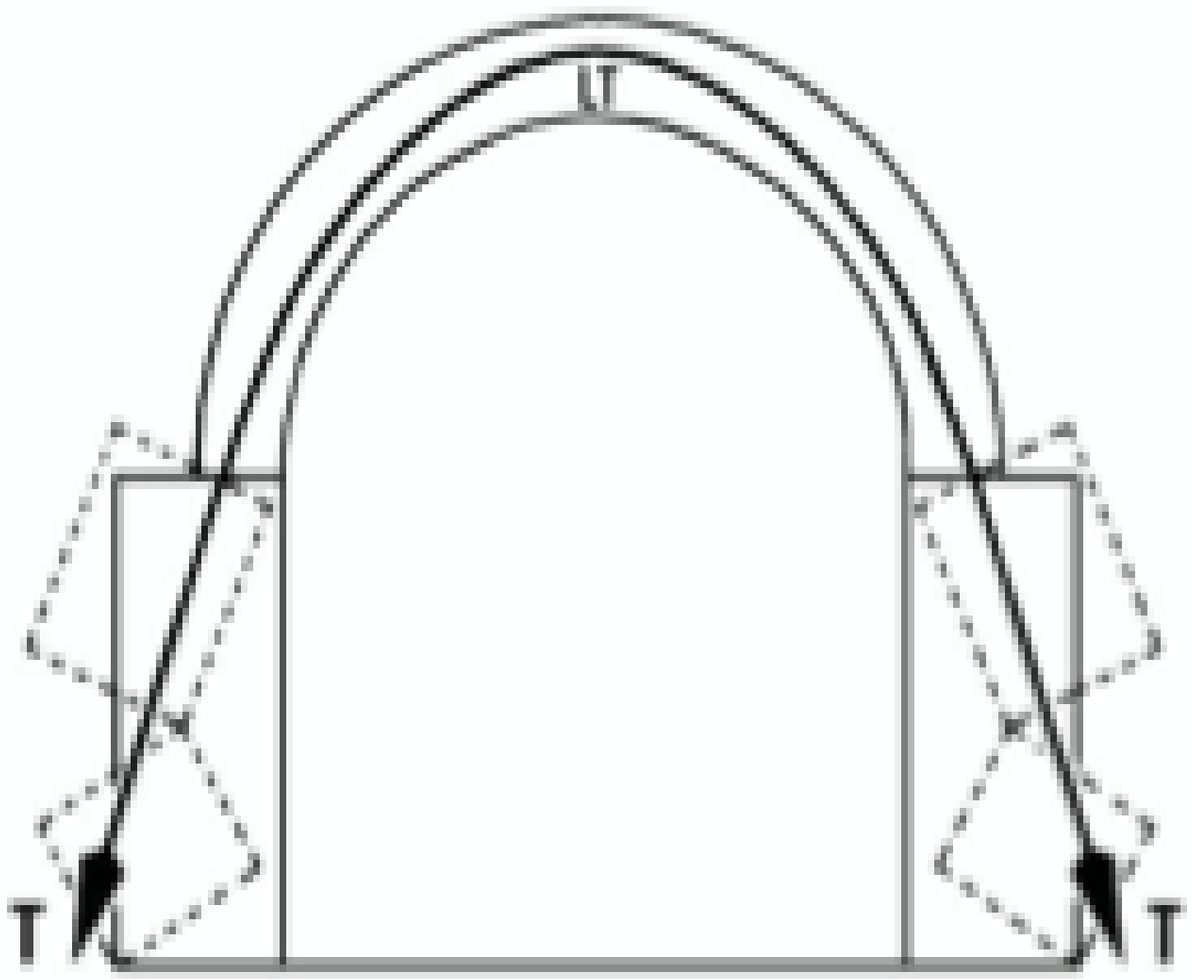


DOME FAILURE

CASE 2

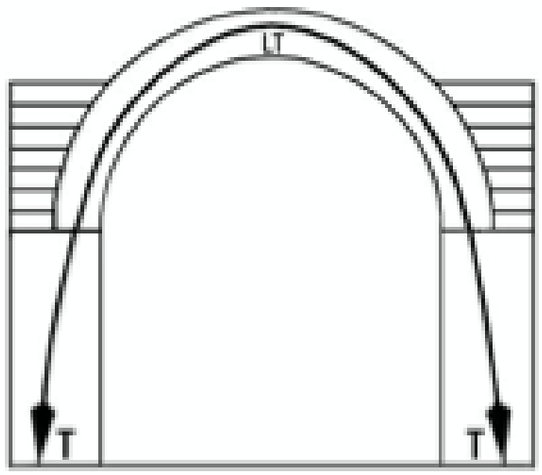
The line of thrust is in the middle third of the arch, but not in the middle third of the pier.

The latter is not wide enough and will collapse.



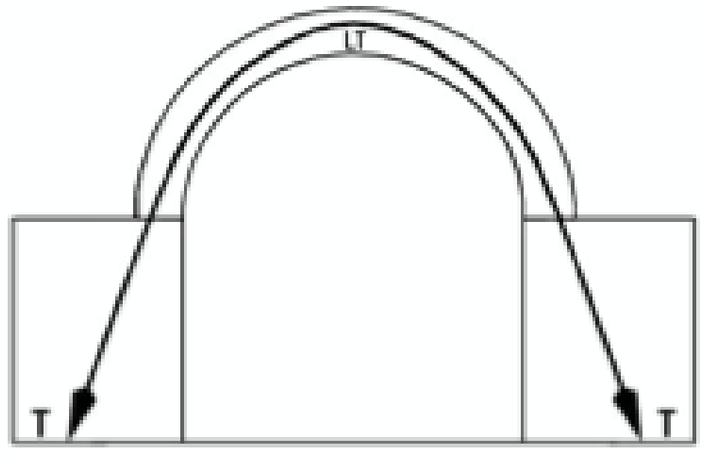
Solution1

Load the haunches of the arch to change the angle of the thrust.



Solution2

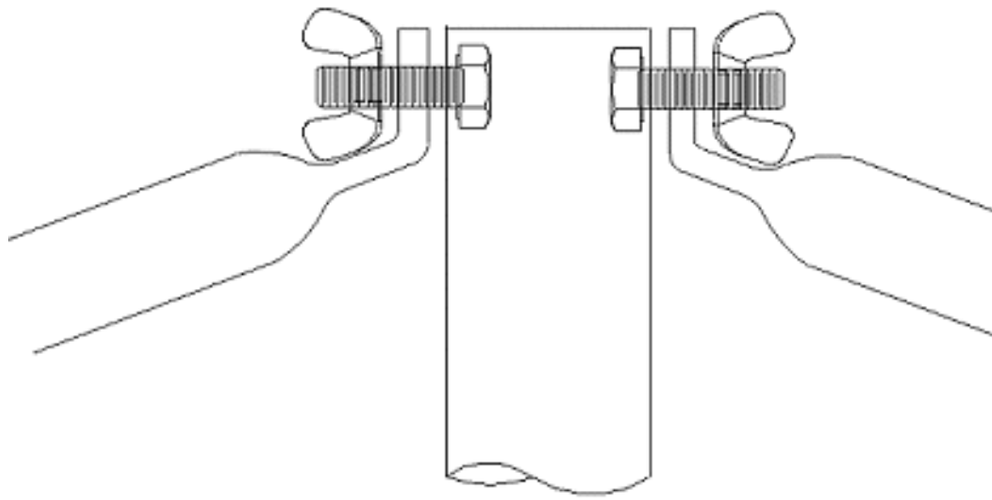
Increase the width of the pier or, if it is a vault, add regular spaced buttresses.



CONSTRUCTION OF DOMES

CONSTRUCTION OF DOMES: Tube & Hub

- Simple construction technique
- A large diameter pipe is used as a hub holes are drilled through the hub and the struts are bolted to it.
- Used for Tubular dome framework.



Advantages:

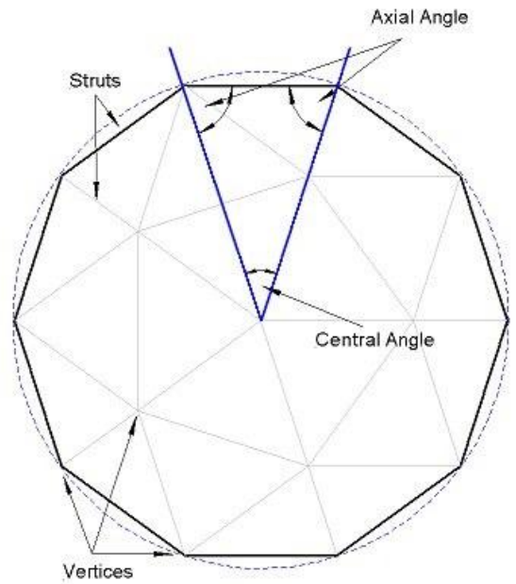
- Neat result
- Cheap
- Easy to build

Disadvantages:

- Great for material covers but there is no easy way to fix a hard covering material.

CONSTRUCTION OF DOMES: Flattened conduit

- The simplest way to build a geodesic dome frame
- Used for burning man, climbing frames and other small projects.



Advantages:

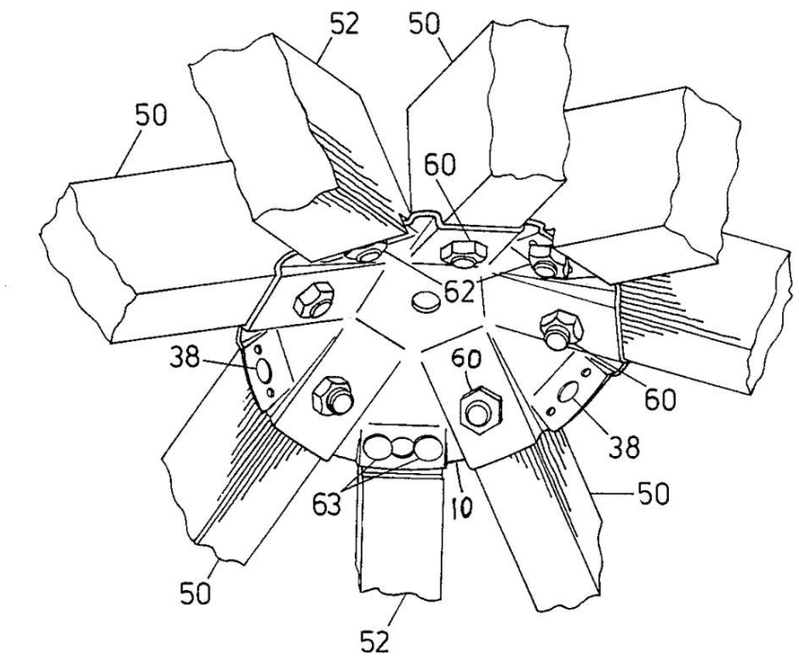
- Really easy to build,
- easily assembled/disassembled,
- no special tools required

Disadvantages:

- Quite crude.

CONSTRUCTION OF DOMES: Beam and hub

- Wooden beams are attached to specially made hubs to form the dome framework.
- Makes a solid permanent dome.
- The angles are taken care of by the hubs so all beams should be cut in the right lengths.



Advantages:

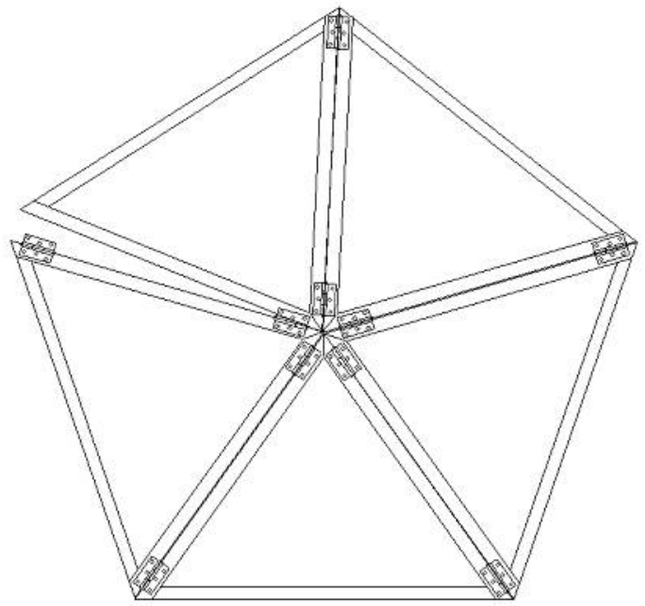
- Simple dome construction system that doesn't require specialist tools or knowledge to build.

Disadvantages:

- The hubs are expensive
- The hubs are hard to find because they have to be specially made.

CONSTRUCTION OF DOMES: Stressed skin

- Metal or fiberglass panels are bolted/riveted together to form the dome, there are no beams, hubs or separate support structure the skin does everything.



Advantages:

- The most effective and efficient way to build a dome.
- Fabrication is required but this can be easily sourced locally.

Disadvantages:

- Metal sweats when it gets cold so some form of insulation has to be glued to the inside of the panels to prevent condensation forming.
- Cutting holes for doors and windows can weaken the dome structure.

CONSTRUCTION OF DOMES: Panelized timber

- This system uses wooden beams (Plywood)
- The panels are factory made so all you have to do is nail them together in the correct order to build a dome.

Advantages:

- Extremely fast way to build a permanent dome structure.

Disadvantages:

- Few variety of designs since the panels are manufactured.
- Ventilation problems can occur when material is fixed to both sides.

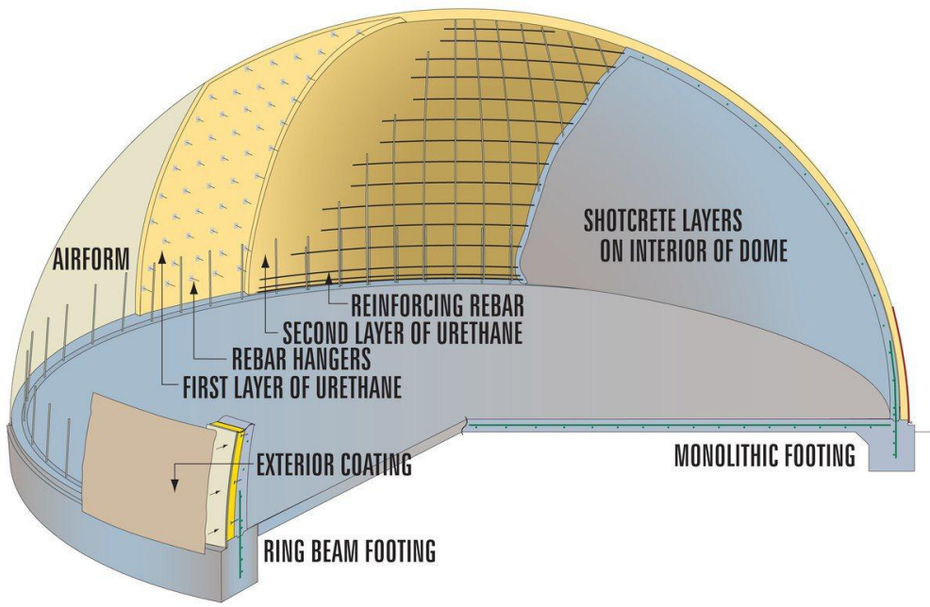
CONSTRUCTION OF DOMES: Monolithic

- 3 stages:

1-First an air form membrane made from PVC is inflated on the site were the dome is to be built; this acts as the out weatherproof skin.

2-Next the inside is sprayed with polyurethane foam to insulate the structure; reinforcing bar is fixed for the next stage.

3-Finally a concrete mix is sprayed on top of the urethane to finish.



Advantages:

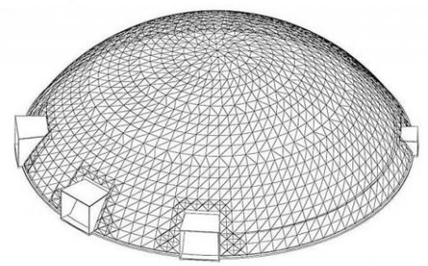
- Very strong efficient structure
- Does not require too much heating and cooling.

Disadvantages:

- The outer air can be damaged easily allowing water into the insulation layer.
- not that environmentally friendly.
- Require dehumidifiers or heat exchange

CONSTRUCTION OF DOMES: Space frame

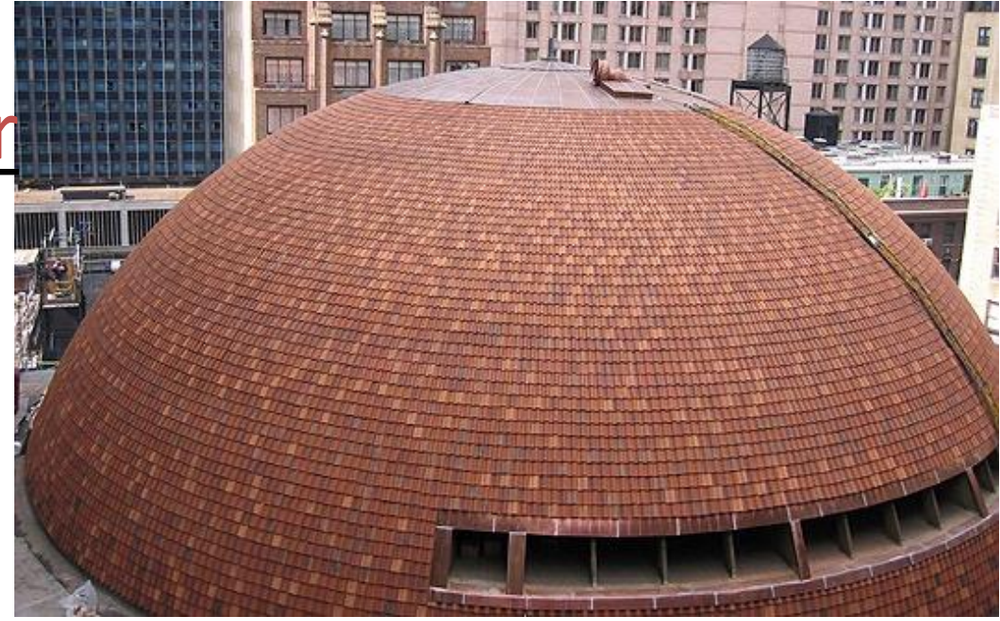
- The struts are made from solid bar and they are connected together with solid balls that have fixing points machined into them.
- Used at airports and exhibition halls.
- Too expensive



CONSTRUCTION OF DOMES: Brick&former

- Very old method
- A wooden former is made to the shape required then stone, brick, or concrete is laid on top of the former to produce the final dome shape.

- Used to build arches



Advantages:

- Makes a very strong long lasting dome that can be built using reclaimed materials.

Disadvantages:

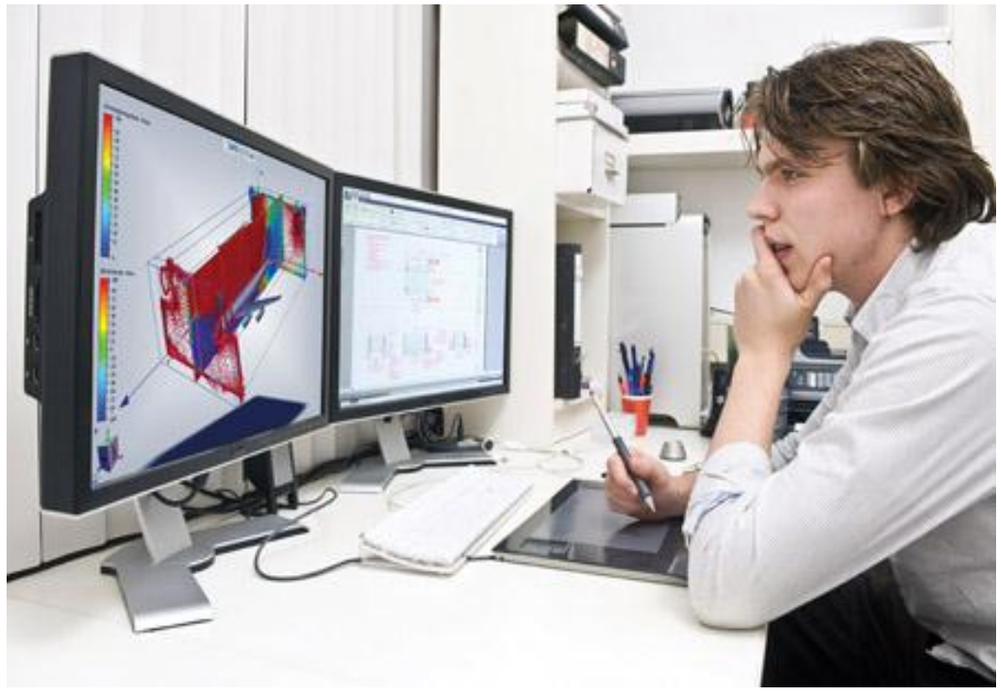
- A lot of expense is involved in making the former that MUST support the whole weight of the dome when the dome is finished the former becomes redundant

ENVELOPE SYSTEM

DOMES BUILDING ENVELOPE

- STEP 1 :-

Designing stage



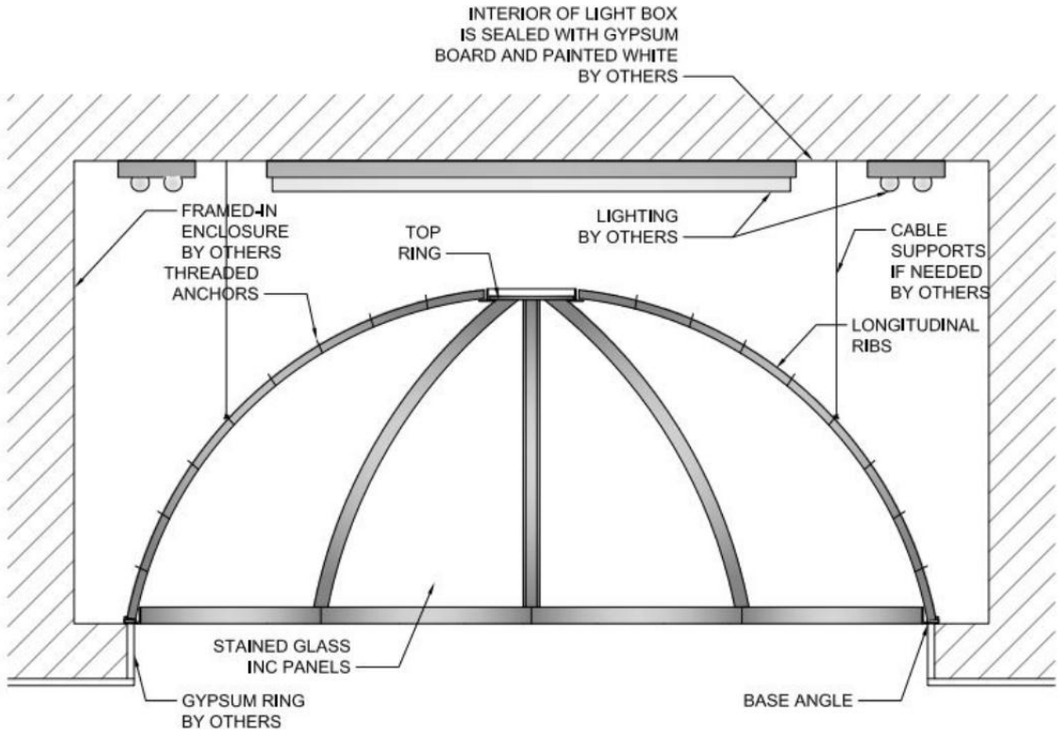
This stage is done by architects

- to develop a design idea into a coherent proposal.
- Ideas and concepts.
- convince clients of the merits of a design.

DOMES BUILDING ENVELOPE

- STEP 2:-

Technical drawing



This stage is mainly a cooperation between structure engineers and architects to enable a building contractor to construct it.

- Architectural drawings which includes particular views, sections, elevations
- Choosing materials
- Confirmation from the client

DOMES BUILDING ENVELOPE

- STEP 3:-

Fabricationc

- The process of manufacturing the dome elements.
- the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located.

DOMES BUILDING ENVELOPE

- STEP 3:-

Installation

The act of installing the dome with all the materials that it needs , and this process contest of installing the :-

- Foundation
- Roofing Systems
- Insulation Systems
- Interior Finishing

DOMES BUILDING ENVELOPE: Installation

A. The substructure (Foundation):

- A foundation is used to support a building or structure and transmits loads directly to the underlying soil or rock.

B. The superstructure (Finishing materials)

A) Dome Roofing Systems

The dome is essentially all roof.
Leaky domes are caused by incorrect roofing applications and poorly designed and installed skylights.

Examples

- Asphalt Shingles
- Elastomeric Liquid Coatings
- Wood Shakes
- Aluminum Shakes

DOMES BUILDING ENVELOPE: Installation

B. Dome Insulation Systems .. some examples :-

- Fiberglass Batt Insulation :- this act as an ultra-super-insulated wall.

- Sprayed-Foam Insulation :- Some foam insulation consists of materials similar to those found in pillows and mattresses.

C. Interior Finishing .. some examples :-

- Wood Interior Triangle Panels :- Wood is a renewable resource only if it is managed as such.

- Plywood Interior Triangle Panels :- special premium grade of plywood with the surface being sanded. can then finish them while they are on the floor.

- Wood Interior Panel :- Batten strips cover the joint between the interior tongue and groove wood triangles. wide enough to cover most gaps and the nail heads on the panels.

Local case studies

LOCAL CASE STUDIES: ALHAZM

- Designed for connoisseurs, those who appreciate the finer things in life. Alhazm offers the world's most exclusive brands and contemporary luxuries in a fashionably refined setting.

- the dome is Diameter 40M and 18M height , which makes it one of the biggest dome in Qatar

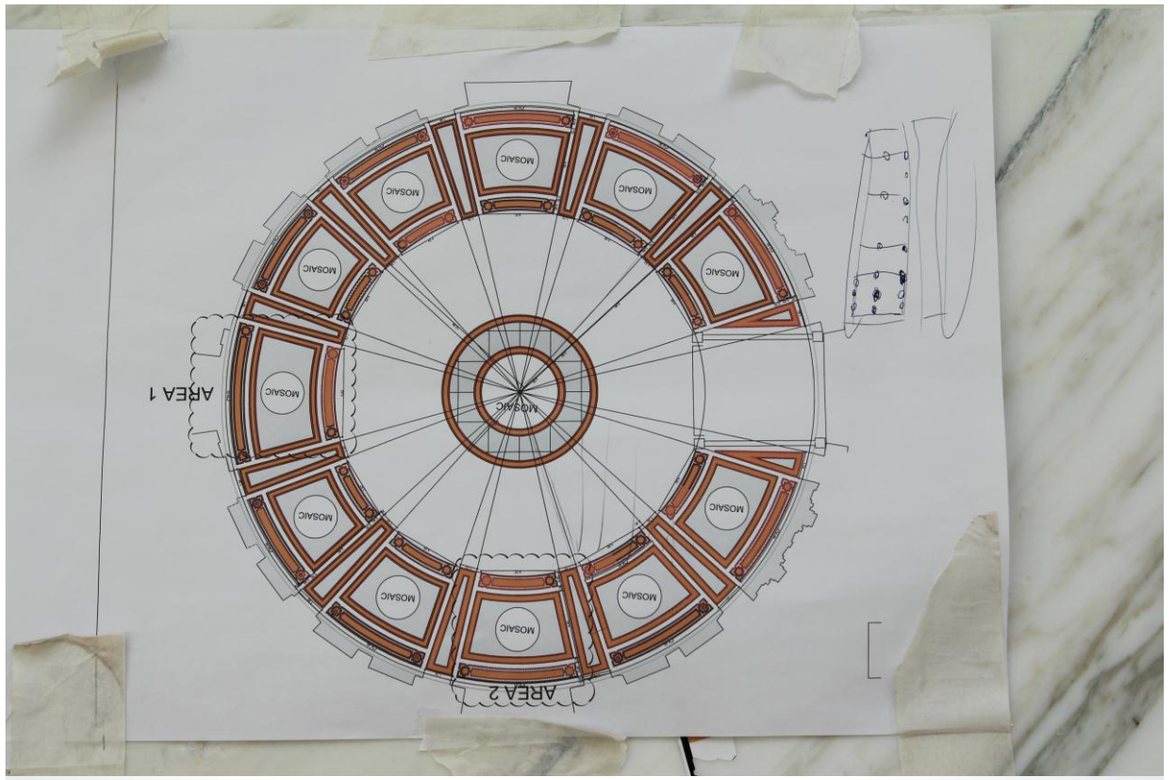
- there are 12 columns and Horizontal beams to hold the structure
- The U-value for the glass is 3 layers is considered to keep the temperature cool inside in the summer seasons

- they used a T section to transfer the load , and they used decorative section in the middle to keep the structural system intriguing

- Structurally it was possible to decrease the number of construction materials but according to the architecture design more elements are added only to provide a pleasing look to the dome however the engineers fixed this by using distributing the load

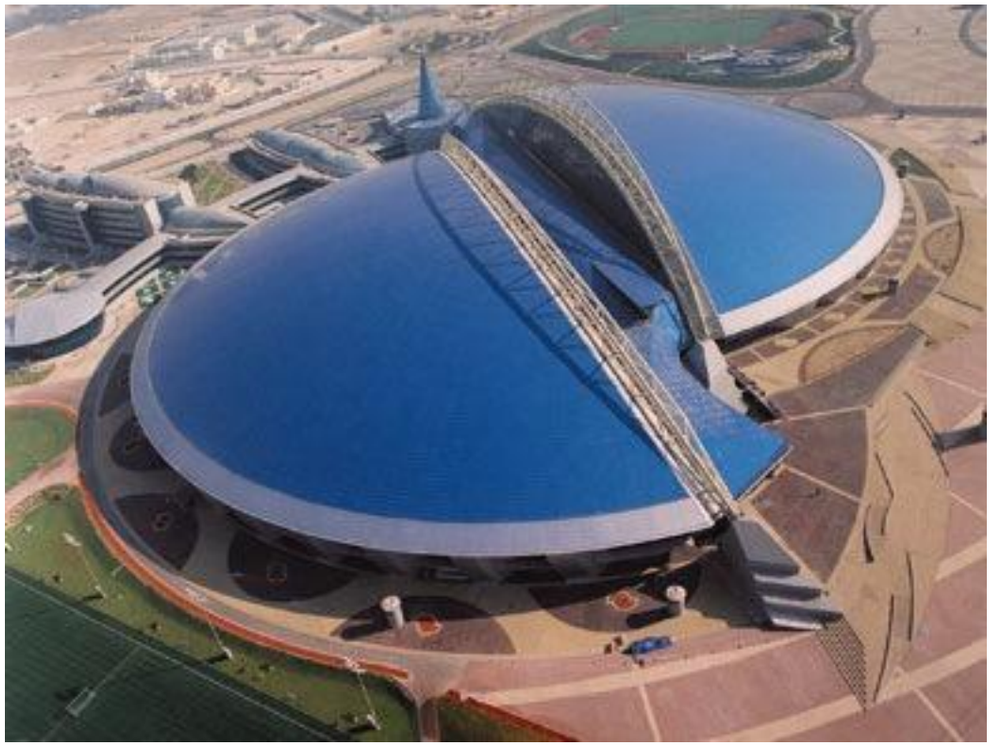
- Under the dome is an opened space for exterior sittings

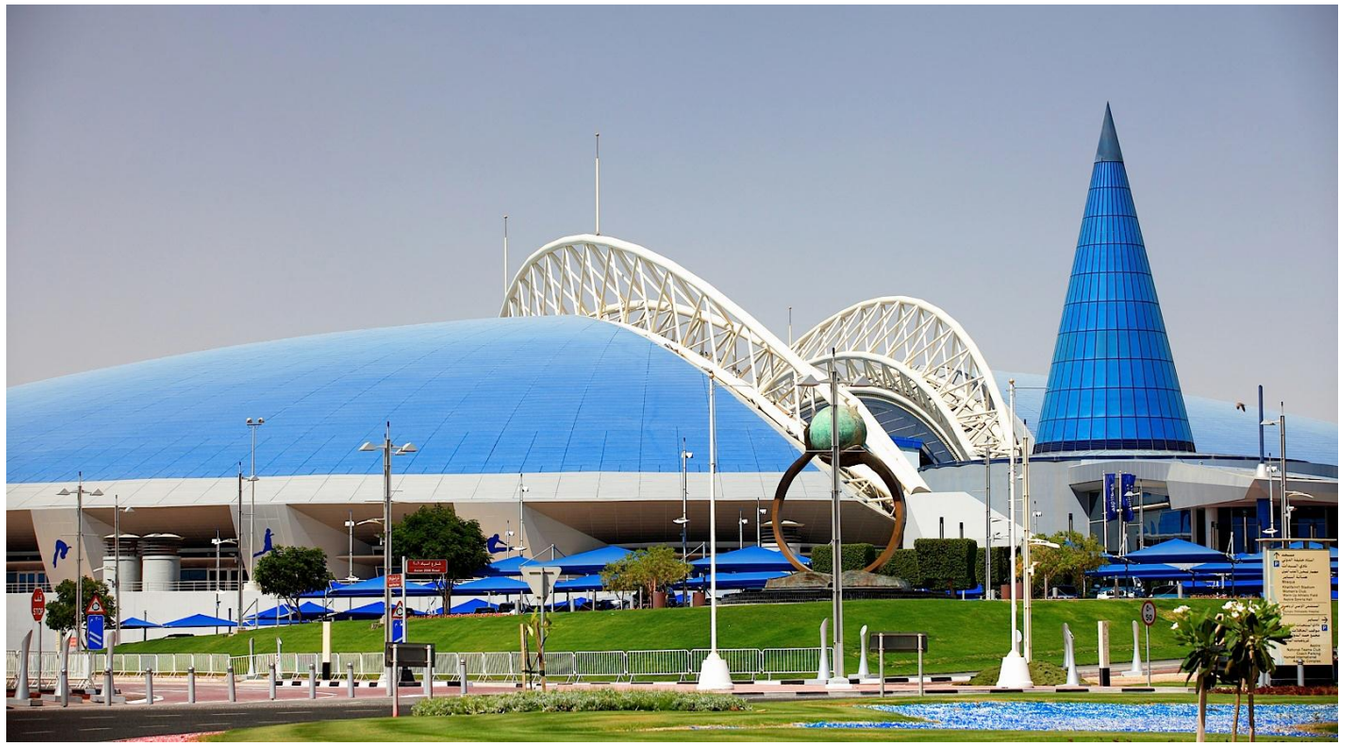
LOCAL CASE STUDIES: ALHAZM



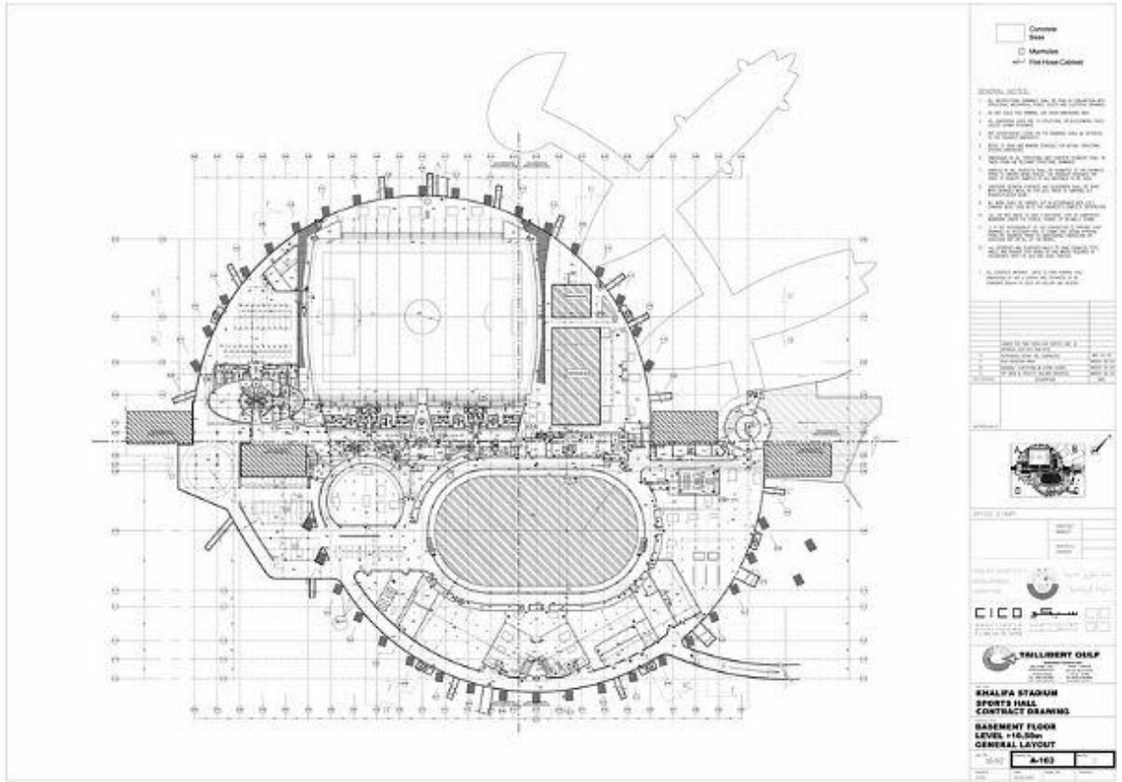
LOCAL CASE STUDIES: ASPIRE DOME

- Originally constructed in Doha, Qatar, to support the 15th Asia Games, the ASPIRE Dome is the world's largest indoor sports facility.
- The free-standing, 46-meter-high dome houses a football stadium, a track-and-field arena, a swimming stadium, eight fencing pistes, two sports halls, three martial arts arenas, 13 table tennis courts and two squash courts.
- Within the various halls, there is space up to 15,000 spectators.
- The roof is clad in Reynobond Architecture aluminum composite panels from Alcoa Architectural Products.
- Underneath the Reynobond Architecture panel, the roof was sealed with a pre-fabricated standing seam system to guard against the penetration of water or, even more importantly, sand.
- For aesthetic reasons, the standing seam system was then completed with the overlaying composite panels from Reynobond Architecture, providing a finish for practically the entire roof



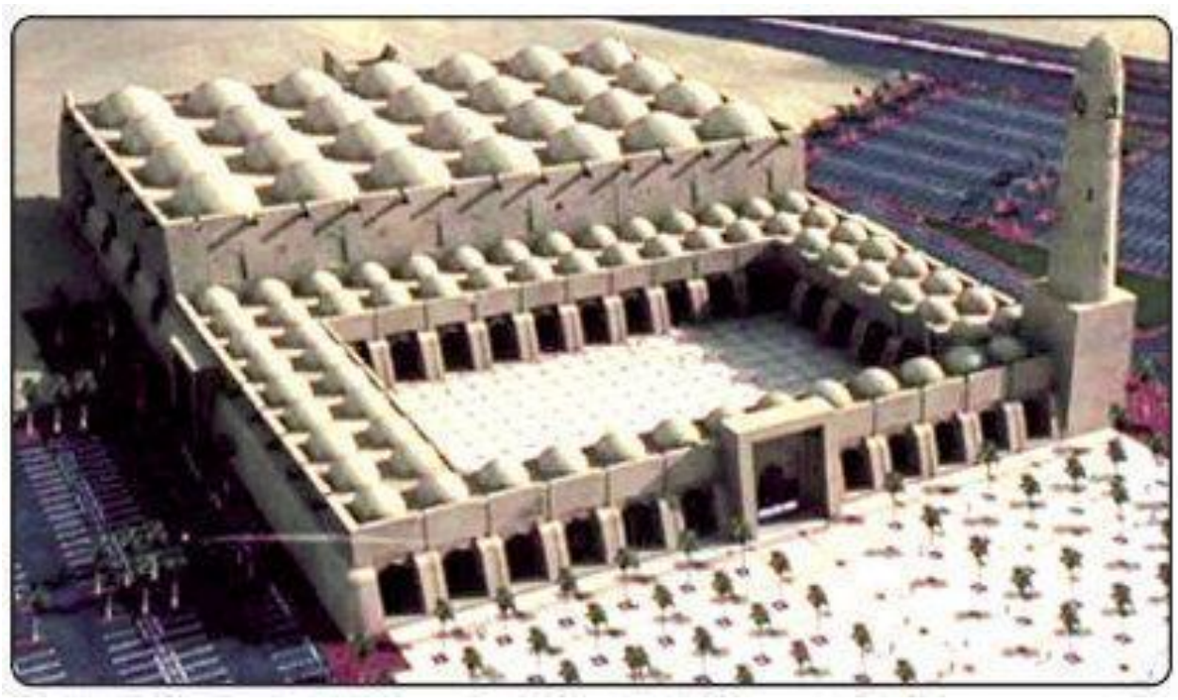


LOCAL CASE STUDIES: ASPIRE DOME



LOCAL CASE STUDIES: Mohammed bin abdulwahab mosque

- the extravagant mosque has a very modern feel with crisp lines and large open outdoor spaces.
- However, the mosque preserves some of the traditional aspects of the gulf region’s past, the sandstone facades.
- The mosque covers a total area of 175,164 sq.m.
- the modest building height and ninety smaller domes mimic the building constraints present when Qatar was in its early years.
- As many as 28 large domes cover the central hall while 65 domes cover the outer quadrangle.



LOCAL CASE STUDIES: Kempinsky Hotel Marsa Malaz

- kempenski hotel domes are used in somebuildings as clerestory to allow the natural sun light in, or to increase the height of the ceiling to give the spot a feeling of a wider space and to add a luxurious design to the building from the outside.
- Kempinsky has 8 domes and 1 main dome.
- Each dome is placed on top of a 7 stories height building
- interiorly it can be seen in the middlle of each square of rooms.

LOCAL CASE STUDIES: Kempinsky Hotel Marsa Malaz

Thank you