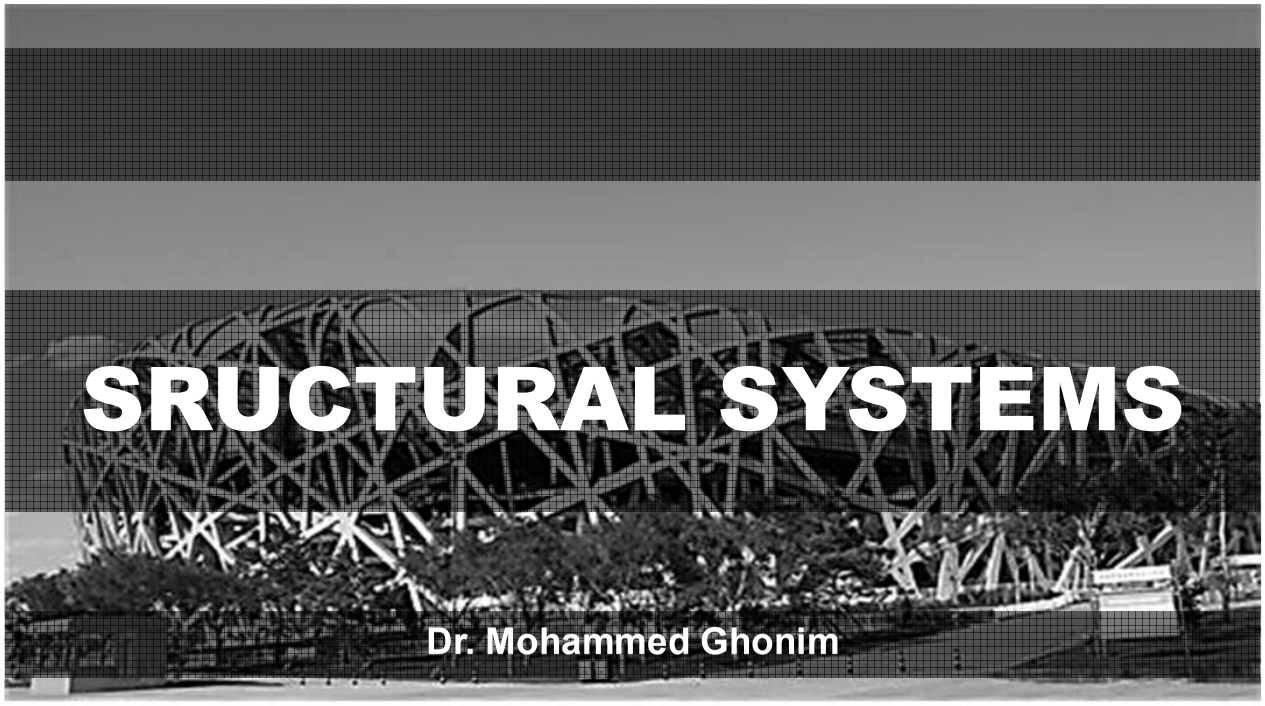
KING SAUD UNIVERSITY

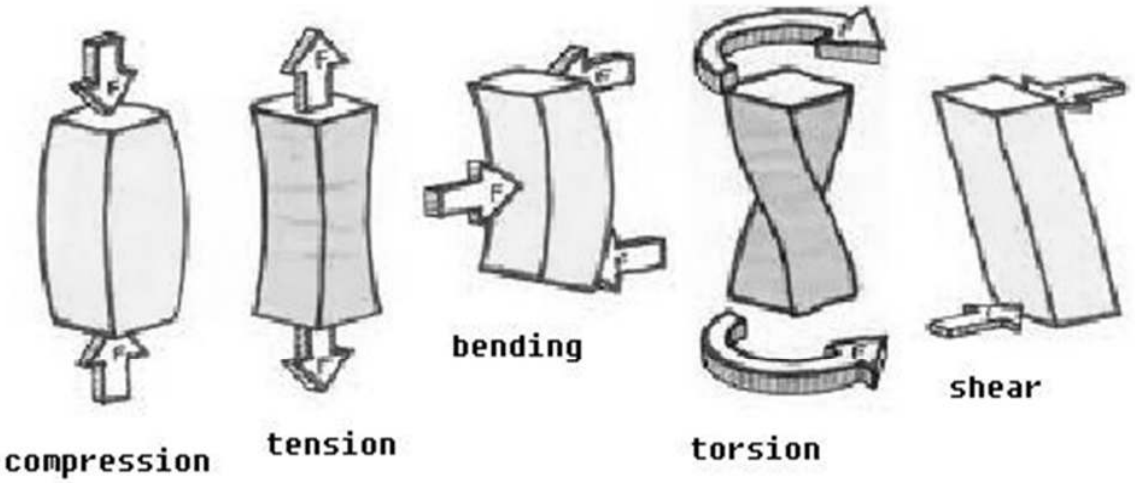
COLLEGE OF ARCHITECTURE AND PLANING



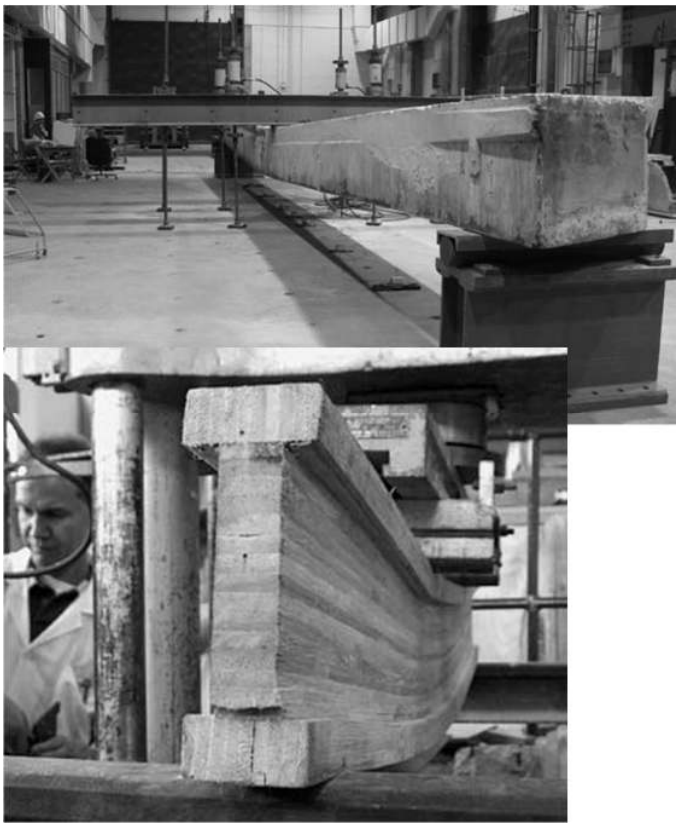
SRUCTURAL SYSTEMS

Dr. Mohammed Ghonim

Forces



Loads & Stresses



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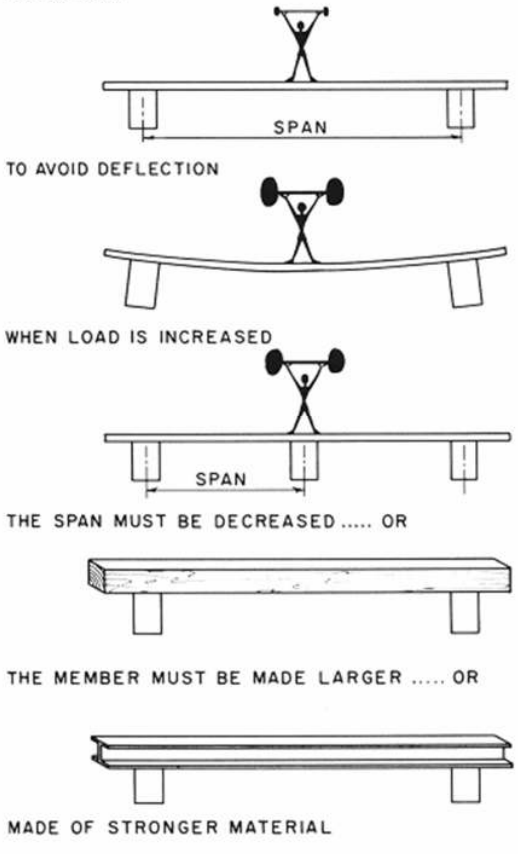

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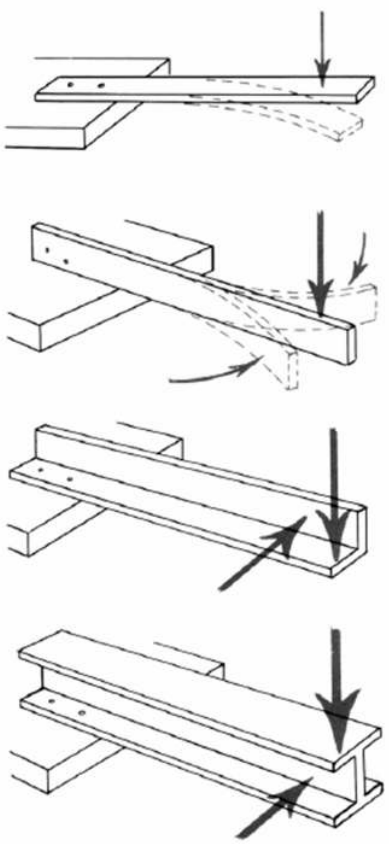
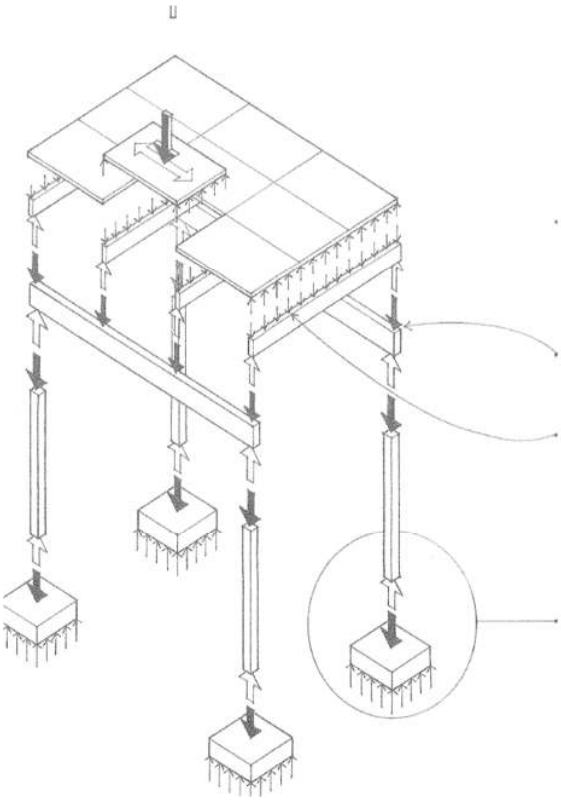


Fig. 52–10. Deflections can be eliminated by combining members.

Structural Equilibrium



- Newton's third law of motion, the law of action and reaction, states that for every force acting on a body, the body exerts a force having equal magnitude and the opposite direction along the same line of action as the original force.

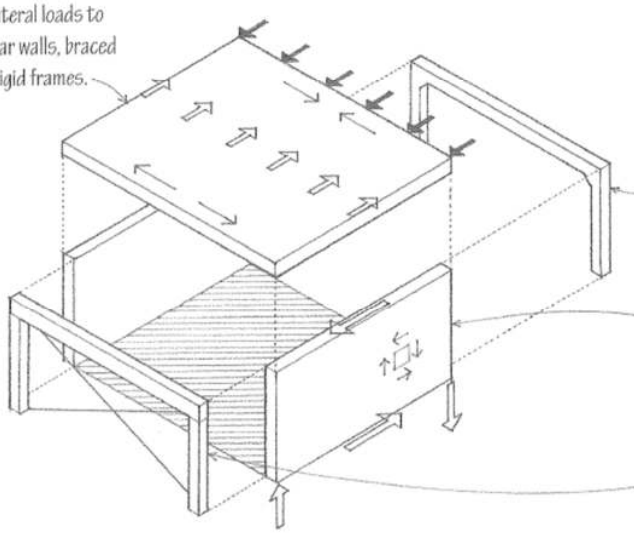
- A concentrated load acts on a very small area or particular point of a supporting structural element, as when a beam bears on a post or a column bears on its footing.
- A uniformly distributed load is a load of uniform magnitude extending over the length or area of the supporting structural element, as in the case of the live load on a floor deck or joist, or a wind load on a wall.

- A free-body diagram is a graphic representation of the complete system of applied and reactive forces acting on a body or an isolated part of a structure. Every elementary part of a structural system has reactions that are necessary for the equilibrium of the part, just as the larger system has reactions at its supports that serve to maintain the equilibrium of the whole.

Lateral Stability

Horizontal diaphragm

- A rigid floor structure, acting as a flat, deep beam, transfers lateral loads to vertical shear walls, braced frames, or rigid frames.



The structural elements of a building must be sized, configured, and joined to form a stable structure under any possible load conditions. Therefore, a structural system must be designed to not only carry vertical gravity loads, but also withstand lateral wind and seismic forces from any direction. The following are the basic mechanisms for ensuring lateral stability.

Rigid frame
- A steel or reinforced concrete frame with rigid joints capable of resisting changes in angular relationships

Shear wall
- A wood, concrete, or masonry wall capable of resisting changes in shape and transferring lateral loads to the ground foundation

Braced Frame
- A timber or steel frame braced with diagonal members

Plate Structures

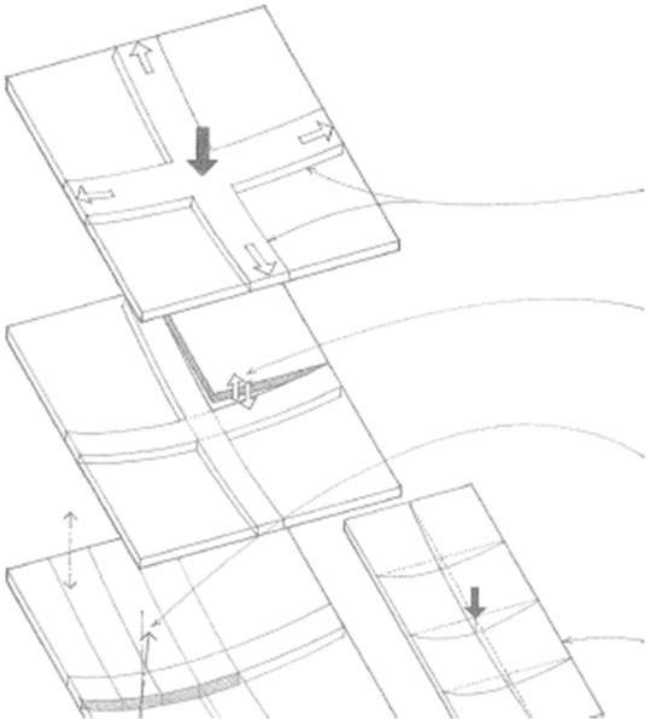
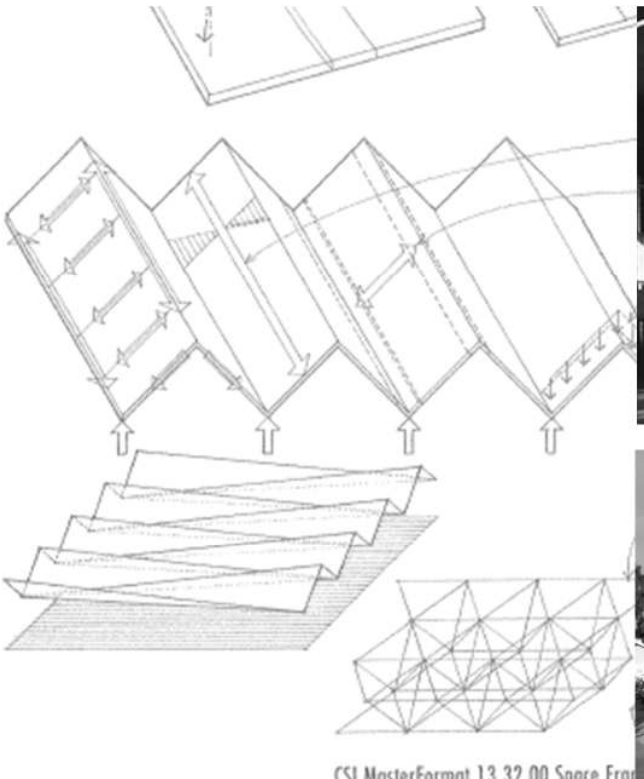


Plate structures are rigid, planar, usually monolithic structures that disperse applied loads in a multidirectional pattern, with the loads generally following the shortest and stiffest routes to the supports. A common example of a plate structure is a reinforced concrete slab.

A plate can be envisioned as a series of adjacent beam strips interconnected continuously along their lengths. As an applied load is transmitted to the supports through bending of one beam strip, the load is distributed over the entire plate by vertical shear transmitted from the deflected strip to adjacent strips. The bending of one beam strip also causes twisting of transverse strips, whose torsional resistance increases the overall stiffness of the plate. Therefore, while bending and shear transfer an applied load in the direction of the loaded beam strip, shear and twisting transfer the load at right angles to the loaded strip.

A plate should be square or nearly square to ensure that it behaves as a two-way structure. As a plate becomes more rectangular than square, the two-way action decreases and a one-way system spanning the shorter direction develops because the shorter plate strips are stiffer and carry a greater portion of the load.

Folded Structures



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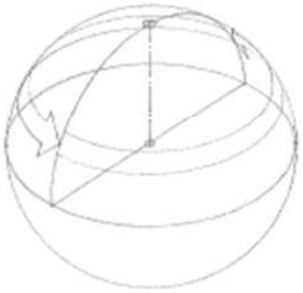
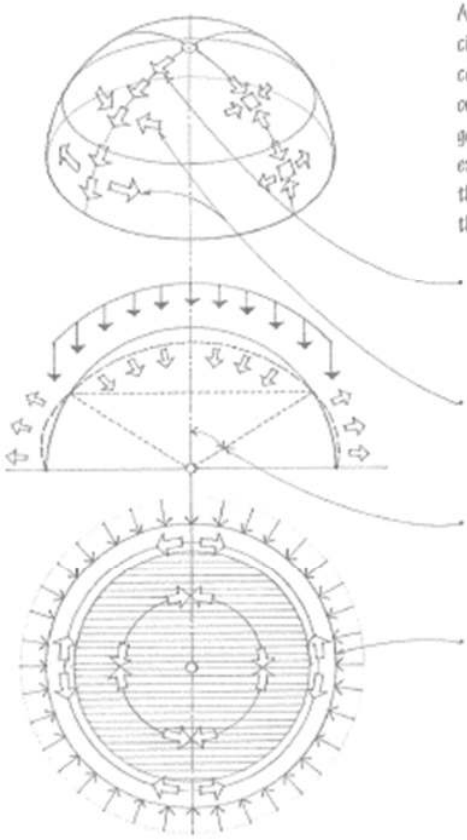
Domes





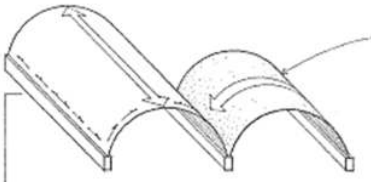
A dome is a spherical surface structure having a circular plan and constructed of stacked blocks, a continuous rigid material like reinforced concrete, or of short, linear elements, as in the case of a geodesic dome. A dome is similar to a rotated arch except that circumferential forces are developed that are compressive near the crown and tensile in the lower portion.

- Meridional forces acting along a vertical section cut through the surface of the dome are always compressive under full vertical loading.
- Hoop forces, restraining the out-of-plane movement of the meridional strips in the shell of a dome, are compressive in the upper zone and tensile in the lower zone.
- The transition from compressive hoop forces to tensile hoop forces occurs at an angle of from 45° to 60° from the vertical axis.
- A tension ring encircles the base of a dome to contain the outward components of the meridional forces. In a concrete dome, this ring is thickened and reinforced to handle the bending stresses caused by the differing elastic deformations of the ring and shell.

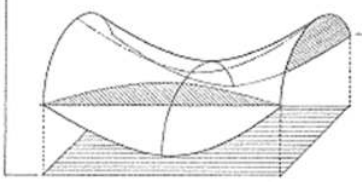
Shell Structures

Shells are thin, curved plate structures typically constructed of reinforced concrete. They are shaped to transmit applied forces by membrane stresses—the compressive, tensile, and shear stresses acting in the plane of their surfaces. A shell can sustain relatively large forces if uniformly applied. Because of its thinness, however, a shell has little bending resistance and is unsuitable for concentrated loads.

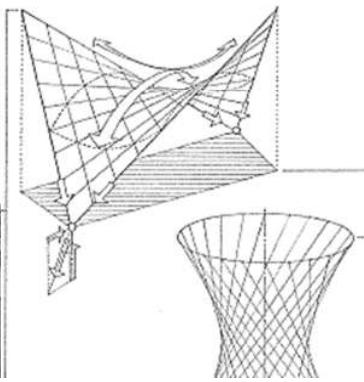
- Translational surfaces are generated by sliding a plane curve along a straight line or over another plane curve.



- Barrel shells are cylindrical shell structures. If the length of a barrel shell is three or more times its transverse span, it behaves as a deep beam with a curved section spanning in the longitudinal direction. If it is relatively short, it exhibits archlike action. Tie rods or transverse rigid frames are required to counteract the outward thrusts of the arching action.



- A hyperbolic paraboloid is a surface generated by sliding a parabola with downward curvature along a parabola with upward curvature, or by sliding a straight line segment with its ends on two skew lines. It can be considered to be both a translational and a ruled surface.

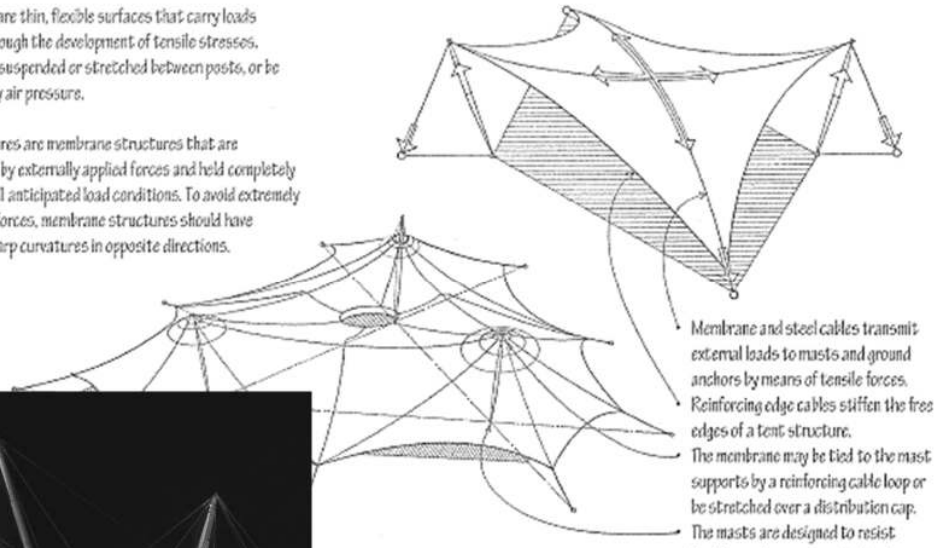


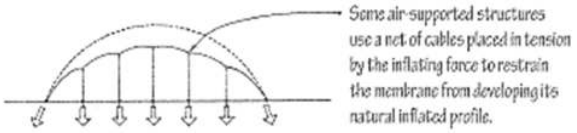
- Saddle surfaces have an upward curvature in one direction and a downward curvature in the perpendicular direction. In a saddle-surfaced shell structure, regions of downward curvature exhibit archlike action, while regions of upward curvature behave as a cable structure. If the edges of the surface are not supported, beam behavior may also be present.

Membrane Structures

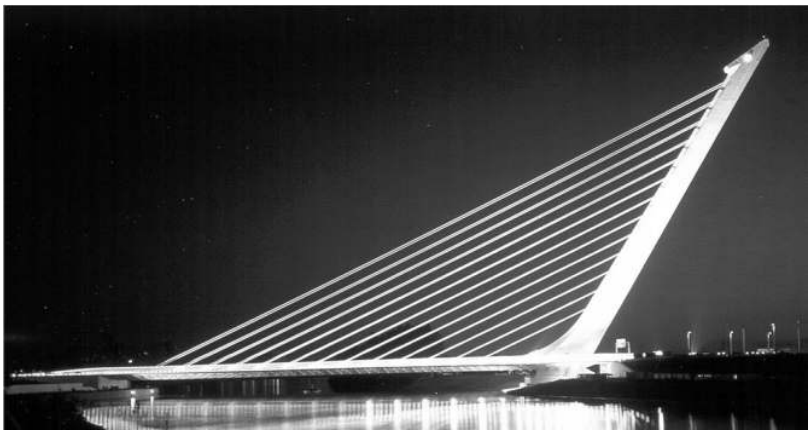
Membranes are thin, flexible surfaces that carry loads primarily through the development of tensile stresses. They may be suspended or stretched between posts, or be supported by air pressure.

Tent structures are membrane structures that are prestressed by externally applied forces and held completely taut under all anticipated load conditions. To avoid extremely high tensile forces, membrane structures should have relatively sharp curvatures in opposite directions.





Tensile Structures



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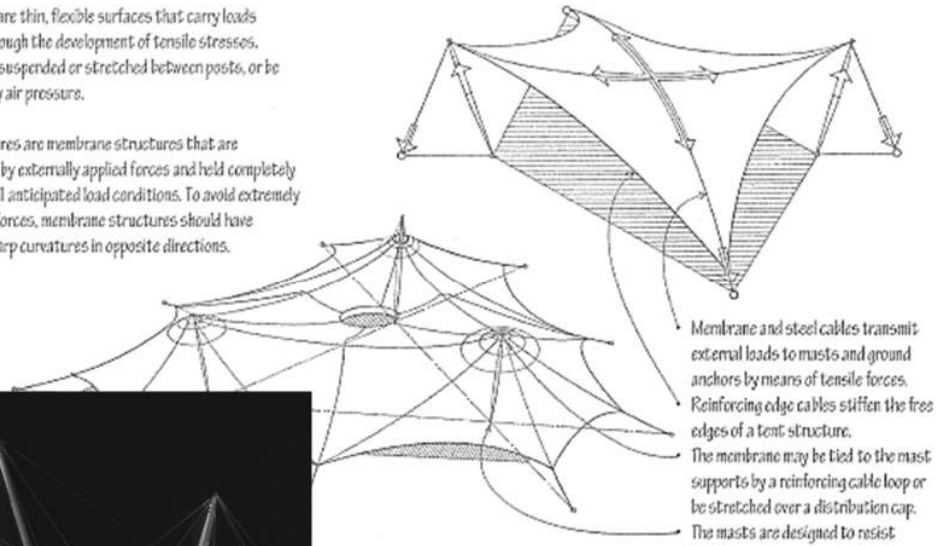
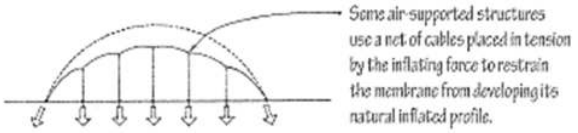
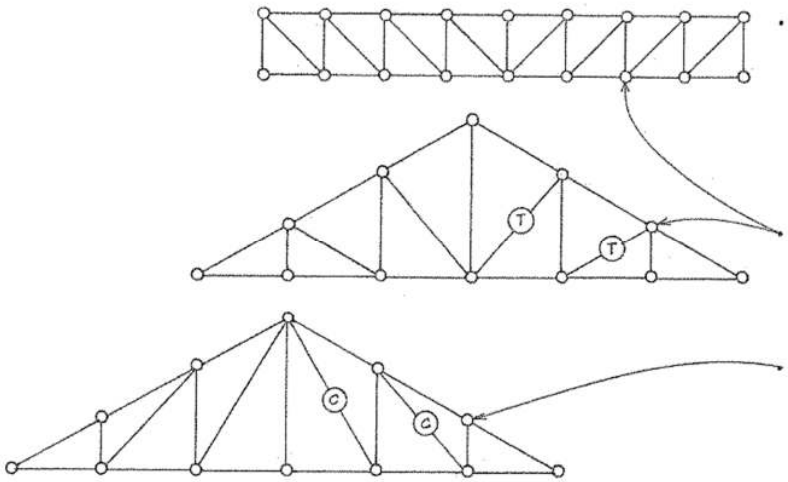




Steel Rigid Frames

Trusses



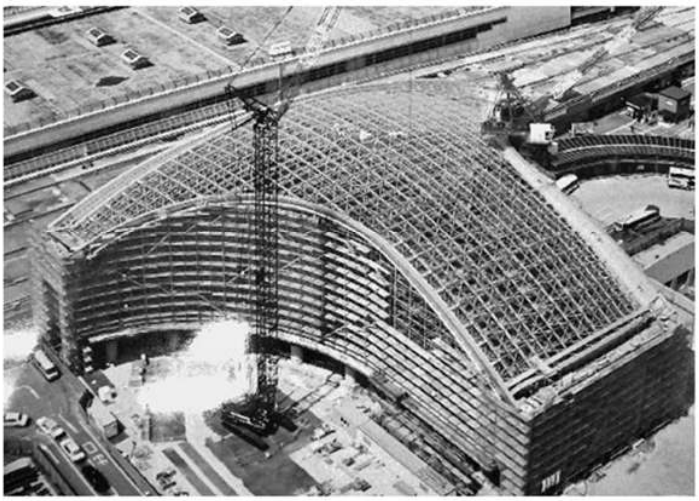
- Flat trusses have parallel top and bottom chords. Flat trusses are generally not as efficient as pitched or bowstring trusses.
- Pratt trusses have vertical web members in compression and diagonal web members in tension. It is generally more efficient to use a truss type in which the longer web members are loaded in tension.
- Howe trusses have vertical web members in tension and diagonal web members in compression.

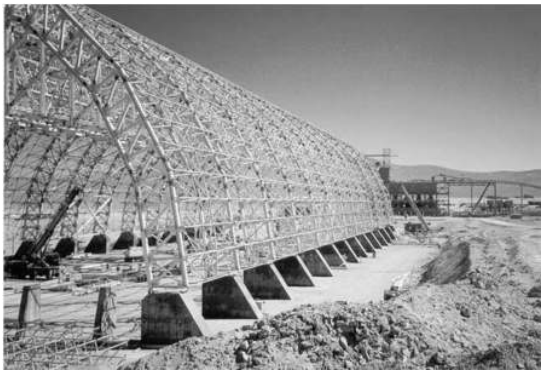
Space Truss

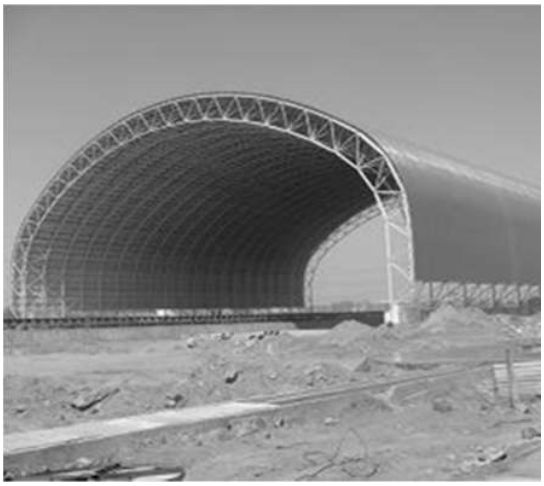
A space frame is a long-spanning three-dimensional plate structure based on the rigidity of the triangle and composed of linear elements subject only to axial tension or compression. The simplest spatial unit of a space frame is a tetrahedron having four joints and six structural members.

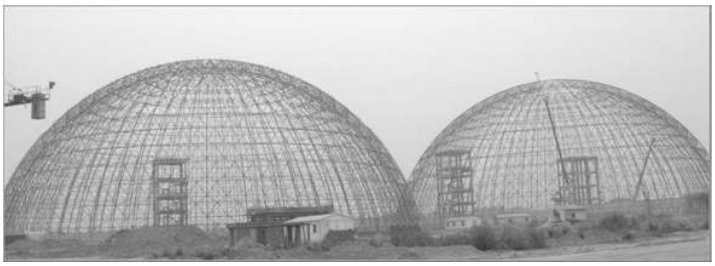
Curved & Spherical Trusses

The huge glass dome of the East square of Kanazawa station

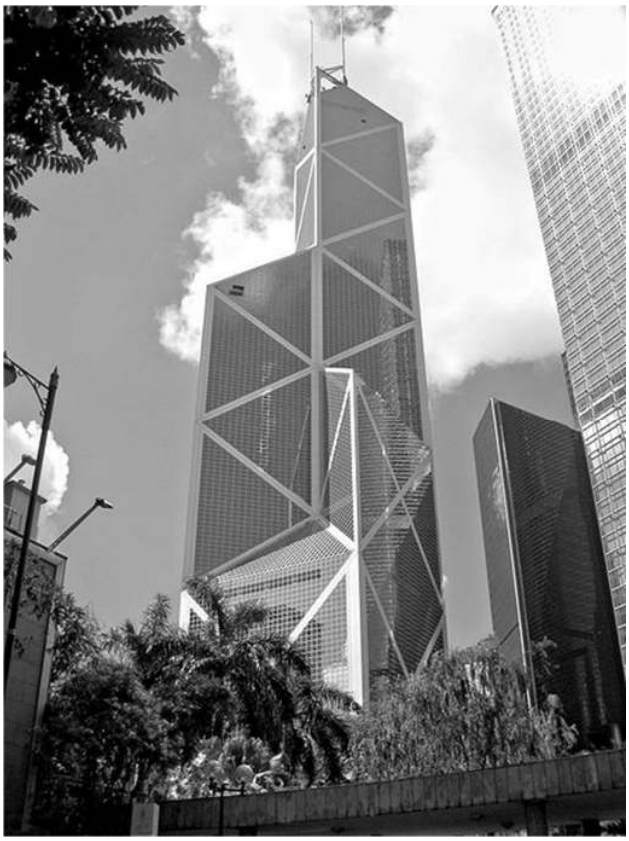


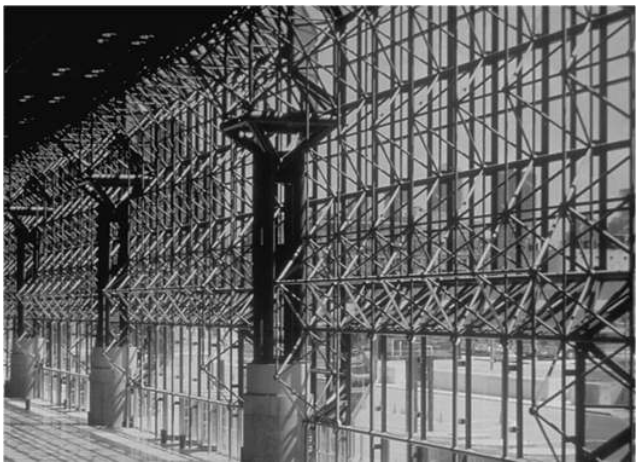






Vertical Trusses

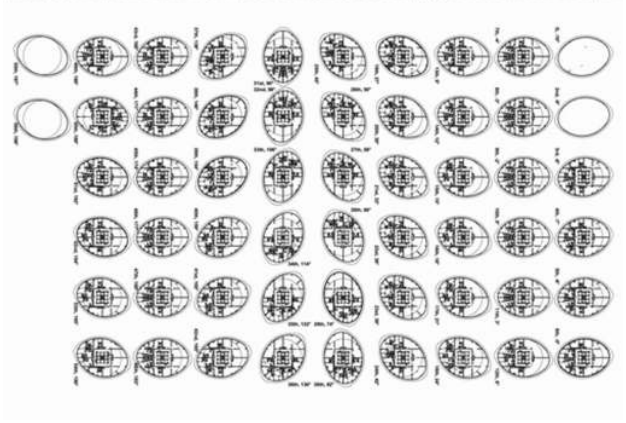




Pneumatic Structures

Case Studies

Absolute Towers

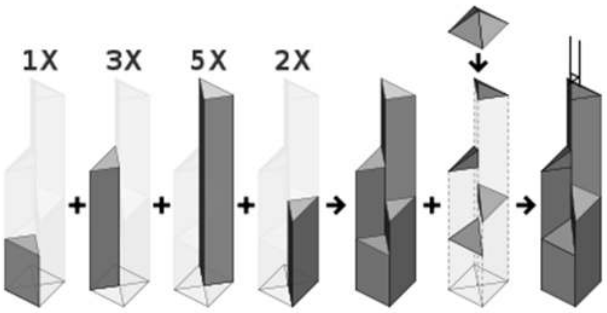


Burj Khalifa

Canton Tower

CTV HQ

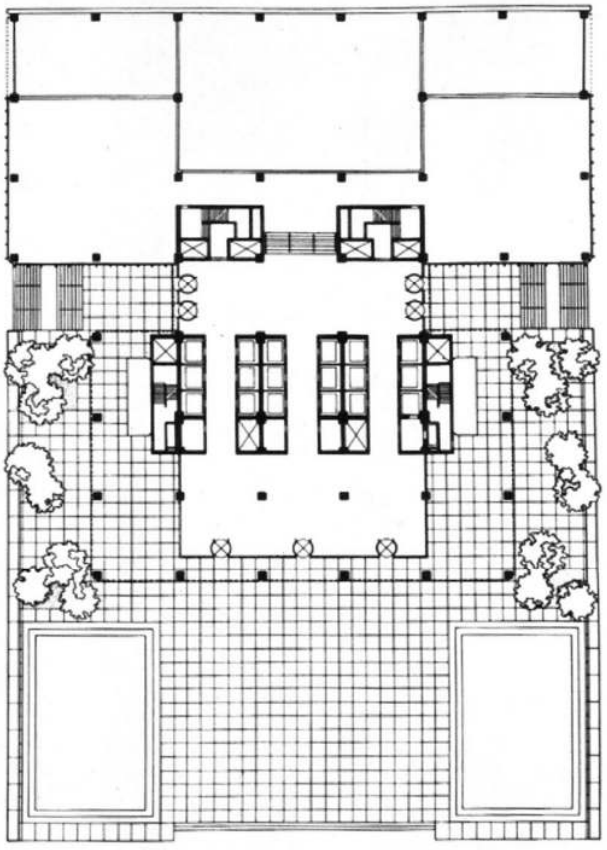
China Bank



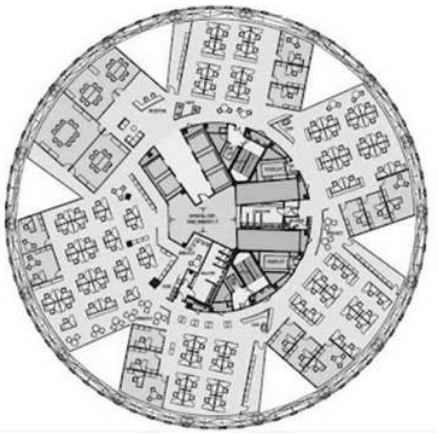
Collserola Tower

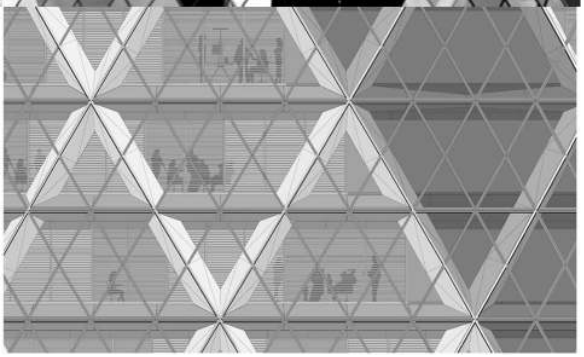
Faisaliah Tower

Seagram Building

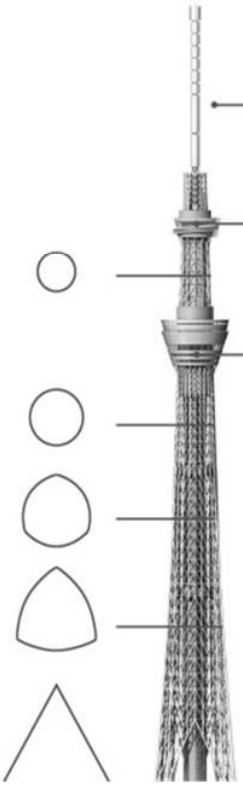


Swiss Re HQ





Tokyo Sky Tree Tower



Triangular to Circular in Plan
The lowest section of the tower is triangular in plan and supported by three legs. The shape is gradually rounded, until at the height of about 300 meters it becomes a perfect circle.

Conclusion