Basic Structures
What is a structure?

The **structure** of a building is the part which is responsible for maintaining the original shape of the building under the influence of the forces, loads and other environmental factors to which is subjected.

Examples of structural components include:
- Steel beams, columns, roof trusses and space frames
- Reinforced concrete beams, columns, retaining walls and foundations

Below picture shows the Lower Manhattan skyline in New York, one of the greatest concentrations of high-rise buildings in the world. Space limitations on the island meant building construction had to proceed upwards rather than outwards, and the presence of solid rock made foundations for these soaring structures feasible.

[Image below: Lower Manhattan skyline in New York, USA]
Structural understanding

The basic function of a structure is to transmit loads from the position of application of the load to the point of support and thus to the foundations in the ground.

Any structure must satisfy the following criteria:

01/ Aesthetics (it must look nice).
02/ Ease of maintenance.
03/ Durability. This means that the materials used must be resistant to corrosion, spalling (pieces falling off), chemical attack, rot.
04/ Fire resistance. While few materials can completely resist the effects of fire, it is important for a building to resist fire long enough for its occupants to be safely evacuated.
Safety and serviceability

There are two main requirements of any structure: it must be safe and it must be serviceable.

**Safe** means that the structure should not collapse

**Serviceability** means that the structure should not deform unduly under the effects of deflection, cracking or vibration.

[Image below: Cartier Foundation by Jean Nouvel, Paris, France, Detail of Glass Wall.]
Composition of a structure

A building structure contains various elements, the adequacy of each of which is the responsibility of the structural engineer. A roof protects people and equipment in a building from weather. An example of a roof structure is shown in the picture below [Roof structure of Reichstag Dome by Norman Foster, Berlin, Germany.]

It is essential to realise that all parts of the building need to be supported. Always ask yourself the question: ‘How will my building stand up?’ Remember – if you have difficulty in getting your model to stand up, it is unlikely that the real thing will stand up either!
Post and Lintel system

Post-and-lintel system, in building construction a system in which two upright members, the posts, hold up a third member, the lintel, laid horizontally across their top surfaces. This form is commonly used to support the weight of the structure located above the openings in a bearing wall created by windows and doors. Stonehenge is an example of post and lintel construction. [1]

Disvantage:
The biggest disadvantage to a post and lintel construction is the limited weight that can be held up, and the small distances required between the posts. Roman developments of the arch allowed for much larger structures to be constructed. There are two main force vectors acting upon the post and lintel system: weight carrying compression at the joint between lintel and post, and tension induced by deformation of self-weight and the load above between the posts. The two posts are under compression from the weight of the lintel (or beam) above. The lintel will deform by sagging in the middle because the underside is under tension and the topside is under compression. [1] www.wikipedia.org/wiki/Post_and_lintel

[© Images: Stonehenge is an example of post and lintel construction]

(a) Simply supported beam

(b) Cantilever beam
Cantilever

A cantilever is a beam supported on only one end. The beam carries the load to the support where it is resisted by moment and shear stress. Cantilever construction allows for overhanging structures without external bracing. Cantilevers can also be constructed with trusses or slabs. This is in contrast to a simply supported beam such as those found in a post and lintel system. A simply supported beam is supported at both ends with loads applied between the supports. [1]

Framing

Structure supported mainly by a skeleton, or frame, of wood, steel, or reinforced concrete rather than by load-bearing walls. Rigid frames have fixed joints that enable the frames to resist lateral forces; other frames require diagonal bracing or shear walls and diaphragms for lateral stability.
Arches and Vaults

The arch, developed by the Romans, is more versatile structure system than the post-and-lintel system. Arches are semicircular in shape, and the compression that is required for structural stability is perfect for the use of stone as its building material. Arches are built over a wooden scaffolding, or centering, system, which is then taken down once the center stone, the keystone, is locked into place.

The Romans used the arch extensively in their architecture, as seen in the aqueduct in Segovia, Spain (15). If the arch is extended, a barrel or tunnel vault is formed, illustrated in the three barrel vaults of the Basilica of Constantine. If two barrel vaults intersect perpendicularly, a groin or cross vault is formed. The height of an arch is determined by the radius of the semicircle between the posts. Medieval architecture, more specifically Gothic architecture, uses the pointed arch instead so the arch’s height is not limited, and buttressing counteracts the lateral pressure.

www.wikipedia.org/wiki/Arch
www.wikipedia.org/wiki/Vault_(architecture)
Dome

A dome is an arch rotated 360 degrees on its axis. Structurally, a dome is similar to the arch but is even more stable due to compression from all sides. The dome can be seen in the architecture of the Romans such as the Pantheon (image below), the churches of the Renaissance, and in state capitol buildings in the U.S. today. In order for a circular shaped dome to fit on an angular square base, pendentives, or triangular areas, need to be placed underneath the dome to transition to the quadrilateral base. The Byzantine church Hagia Sophia, built by Anthemius of Tralles and Isidorus of Miletus, effectively uses pendentives. The lower circumference of the dome is punctuated by a series of arched windows, making the dome appear to float above its squared base.

www.structuremag.org/article.aspx?articleID=306

[Images from left to right: Pantheon in Rome, Italy // The Hagia Sophia, Istanbul, Turkey // Dome of St. Peter’s Basilica in Rome]
A truss is a structure comprising one or more triangular units constructed with straight members whose ends are connected at joints referred to as nodes. A truss is composed of triangles because of the structural stability of that shape and design. A triangle is the simplest geometric figure that will not change shape when the lengths of the sides are fixed. In comparison, both the angles and the lengths of a four-sided figure must be fixed for it to retain its shape. The simplest form of a truss is one single triangle.

www.wikipedia.org/wiki/Truss
Shell structure

Thin-shell structures are light weight constructions using shell elements. These elements are typically curved and are assembled to large structure. A thin shell is defined as a shell with a thickness which is small compared to its other dimensions and in which deformations are not large compared to thickness. A difference between a shell structure and a plate structure is that, in the unstressed state, the shell structure has curvature as opposed to plates structures which are flat.

www.wikipedia.org/wiki/Thin-shell_structure
A suspension bridge is a type of bridge in which the deck (the load-bearing portion) is hung below suspension cables on vertical suspenders. The main forces in a suspension bridge of any type are tension in the cables and compression in the pillars. Since almost all the force on the pillars is vertically downwards and they are also stabilized by the main cables, the pillars can be made quite slender. In a suspended deck bridge, cables suspended via towers hold up the road deck. The weight is transferred by the cables to the towers, which in turn transfer the weight to the ground.
Advantages over other bridge types:
01// Longer main spans are achievable than with any other type of bridge.
02// Less material may be required than other bridge types, even at spans they can achieve, leading to a reduced construction cost.
03// Except for installation of the initial temporary cables, little or no access from below is required during construction, for example allowing a waterway to remain open while the bridge is built above.
04// May be better to withstand earthquake movements than heavier and more rigid bridges.
Disadvantages compared with other bridge types

01// Considerable stiffness or aerodynamic profiling may be required to prevent the bridge deck vibrating under high winds.
02// The relatively low deck stiffness compared to other (non-suspension) types of bridges makes it more difficult to carry heavy rail traffic where high concentrated live loads occur.
03// Some access below may be required during construction, to lift the initial cables or to lift deck units. This access can often be avoided in cable-stayed bridge construction.
Membrane

Structure with a thin, flexible surface (membrane) that carries loads primarily through tensile stresses. There are two main types: tent structures and pneumatic structures. The Denver International Airport (1995) features a terminal building roofed by a white membrane stretched from steel masts. Another such structure is London’s The Millennium Dome, which has a tensioned membrane structure with a diameter of 320 metres (1,050 feet), one of the largest in the world.
Tent Structure

A membrane structure pre-stressed by externally applied forces so that it is held completely taut under all anticipated load conditions. To avoid extremely high tensile forces, a membrane structure should have relatively sharp curvatures in opposite direction (Reference: The Visual Dictionary of Architecture, Ching).

The purpose of a tent structure is to provide a means of shelter that is lightweight, portable, and quick to install.
Inflatable structures

Inflatable structures are structures made of a flexible outer membrane or fabric that is filled with gas, such as air or helium. The gas gives shape and strength to the structure.