Structures

There are both naturally made and manmade structures. Many manmade structures are based off the design of structures found in nature.

Manmade examples: bridges, umbrella, pillars

Natural examples: spider web, tree, sea arch, cave

Types of structures:

- Frame
- Arch
- Shell
- Beam
- Box

Frame Structure

Frame structures are skeleton-like structures. They may be covered or left open. Closed frame structures are covered and open frame structures are frames with no cladding. Most modern buildings are closed frame structures consisting or steel frames surrounded by outside walls and interior cladding.

E.g. spiders web, human body, most modern buildings

Arch Structure

Arch structures stretch all back to around 2,500BC. They are a curved structure in design that cross a gap and are capable of supporting weight. Arch structures can be seen in doorways, bridges. Arch structures usually consist of a keystone which is a central stone at the apex of the design that locks the rest of the stones into place.

E.g. bridges, doorways, sole of foot, roofs

Shell Structure

Shell structures draw their strength and rigidity from their shape. They are usually lighter than frame structures and not as strong. Ridges and curves can be included in the design to strengthen the overall structure. Cars are an example of shell structures as they consist of exterior sheet metal panels welded together to form the shape of the car.

E.g. cars, egg carton, snail shell, helmets, boats.

Beam Structure

A beam is a long rigid structure generally made out of wood, metal or concrete. Beams are often used to support a load across a gap. Beams can also be used in construction to be incorporated into larger, more complex structures. There are different profiles for beams, different shapes have different attributes such as strength or weight. Hollow beam structures can often be seen in scaffolding as solid structures would be too heavy to use.

E.g. scaffolding, bridges, pillars, columns, cantilevers

Box Structure

A box structure is based off the geometric shape of a box or rectangle. They often gain additional strength by having diagonal or transversal components added to them. Box structures are often used in radio pylons, motor way signs, speaker mounts at concerts and bridge structures.

E.g. motorway signs, concert stage supports, radio pylons

Force

A force is anything that causes something to change its speed or direction. Engines, motors and sails generate a force which results in motion in many everyday vehicles. Gravity (9.81N) is the force which holds us down on planet earth. The mass of an object is constant, however the weight of any object is its weight multiplied by the force acting on it. You will weigh more on Earth than you would on Mars even though you will have the same mass (more or less) because gravity is stronger on Mars.

Force is measured in Newtons (N)

Tension

Tension is a pulling force. If an object is in tension it is being stretched out in opposite directions.

E.g. A suspension bridge

Compression

Compression is a force that results from an object being pressed and flattened into a smaller shape than it naturally is.

E.g. a soft drinks can being crushed, a pillar of a building

Torsion

Bending is a force that twists opposite ends of an object in opposite directions.

E.g. twisting a wrench, wringing out a wet cloth

Bending

Bending of a structure results when one side of the structure is compressed, resulting in the other side being under tension.

Eg: a gymnast swinging on a bar

Shear

Shearing force is a cutting, tearing or ripping force that results from one part of an object being forced in one direction and then an opposite force being applied to the same object just slightly separated.

Eg: scissors cutting through paper, clippers cutting grass

Ties & Struts

A strut is a component of a structure that is under compression. Stuts help keep two separate components of a structure from getting closer together or collapsing.

A tie is a component of a structure that is under tension. Ties keep structural members from separating.

Structures can be reinforced by the addition of struts and ties

Redundant Members

A redundant member is any part of a structure that holds no structural force and can be removed without compromising the existing structure in any way. Well-designed structures will have no redundant members.

Loads

Static loads exert a constant force on whatever structure is supporting them.

E.g. the weight exerted on the supports of a bridge by the bridge structure itself

Dynamic loads vary in the amount of force they exert on a structure at any given time.

E.g. the weight a car exerts on a bridge as it drives across it

Equilibrium

A lever is said to be in equilibrium when it is not turning and remains balanced and still, when clockwise moments equal anticlockwise moments.

A lever is a rigid structure that can pivot or rotate around a fixed point called a fulcrum.

Centre of Gravity

The centre of gravity is where the weight of any body is most concentrated. The lower the centre of gravity the more stable the object. If the centre of gravity lies near to, or outside of the body then it is more likely to eventually topple over.

- The Tesla Model 3 electric car has a very low centre of gravity due to the placement of the battery low in the chassis of the car. This resulted in the car getting a 5 star crash test safety rating.

Triangulation

The triangle is one of the strongest structures that can be created. When a force is applied to a triangulated structure, two of its members stretch out the third member placing it under tension which pulls the other two members towards it and as a result makes the overall structure more rigid as the force is spread out between all three members.

Triangulation is used in structures such as house roofs, bicycle frames, motorway signs, gates and pylons

Factor of Safety [FoS]

The factor of safety of a structure refers to the ratio of its actual load capacity over its required loading expressed as a percentage. It tells us the actual maximum load the structure can support along with the load it is required to carry

$$FoS = Capability / Requirement$$

Over engineering a structure refers to adding components which increase the overall strength and take into account imperfections, flaws, degradation and uncertainty so as to ensure the structure will be able to hold whatever load is presented to it.

A factor of safety of 5 means that the structure is capable of supporting 5 times the load that is usually expected from use.

Structural Testing

Two approaches:

- Non - Destructive Testing
- Destructive Testing

Non-Destructive Testing

This involved testing an object without breaking, damaging or compromising it any way. It can save time and money and is regularly used throughout the design and manufacturing process. Visual inspection can be used to detect external flaws and ultrasonic testing can detect internal flaws.

Destructive Testing

This involves testing a structure until it fails and is destroyed. These tests are generally easier to carry out and will provide a lot more information. They can also be easier to interpret than non-destructive testing.

Destructive testing can be expensive however and as a result is only usually used with objects that will go into mass production, like cars, helmets, electrical equipment.

Simulation software can also be used to test structures by writing computer programmes to digitally test a variety of different scenarios or forces on the object being tested.