Structures and Forces Unit Study Notes

Topic 1 – Types of Structures

Structures – things with a definite size and shape, which serve a definite function.

Natural Structures – are not made by people – e.g. feathers, sand dunes.

Manufactured Structures – things that are build by people – e.g. Calgary Tower, spoon.

Forces – a push or pull, or anything that causes a change in the motion of an object.

Load – the weight carried or supported by a structure.

Structures can be classified according to how they are built. Three kinds of designs for structures exist. These are:

Mass Structures – are made by piling up or forming similar materials into a particular shape – e.g. dams, brick walls, cakes, bread.

Frame Structures – the body of most building have a skeleton of very strong materials, which support the weight of the roof and covering materials – e.g. house frame.

Shell Structures – these objects are strong and hollow and have a thin outer layer that is carefully shaped to provide strength. They keep their shape and support loads without a grame or a solid mass inside – e.g. eggs, igloos, bottle, pipe.

Some manufactures structures are combinations of Frame and Shell structures – e.g. football helmets, airplanes, the Calgary Tower, Golf Dome.

Topic 2 – Describing Structures Study Notes

When designers of engineers plan new projects, they must consider the structures'

1. **Function** – this is the job that the structure is designed to do. For example, a train bridge is designed to support the weight of the train.
2. **Aesthetics** – making a structure look good. The best designs not only serve their purpose but they are also "*aesthetically pleasing"* meaning they look good. (Aesthetics – the study of beauty in art and nature)
3. **Safety** – almost all structures are built with a large "*margin of safety."* This means that structures are designed to withstand much more pressure than they would normally need to deal with (e.g. a bridge can hold much more weight than it ever would have to.)
4. **Balancing Cost with Safety** – it is difficult to design safe, well-built projects that are not too expensive.

5. **Materials** – the properties of the material must match the purpose of the structure (e.g. you would not build a bridge for cars out of rubber.)

Composite materials – are made from more than one material (e.g. concrete can be reinforces using steel rods.)

Layered materials – layers of different materials pressed or glued together often produce useful products. These layers are called **laminations**. (e.g. layers of a juice box container involve paper, plastic and aluminum foil, making it lightweight, waterproof, and airtight.)

Woven and Knit materials – weaving and knitting are effective ways to make flexible materials. For sample yarn in dishcloths is woven together to be flexible and strong.

When engineers choose what materials to use when building structures they must consider:

1. Cost of the material
2. Appearance
3. Environmental Impact
4. Energy Efficiency

Joints – this is where a structure's parts are joined together.

Mobile Joints – joints that allow movement. These hold parts together while still allowing movement (e.g. elbow, door hinge)

Rigid Joints – attach parts of a structure without allowing movement. These types of joints fall into 5 categories

- **Fasteners** – nails, bolts, screws
- **Interlocking Shapes –** Lego bricks, some pavement stones
- **Ties –** thread, string rope
- **Adhesives** – glues (*thermosetting* harden when cooled, *solvent based* – harden when dried)
- **Melting** – welding or soldering materials together

Topic 3 – Mass and Forces Study Notes

- The **mass** of an object is the measure of the amount in it.
- A **balance** is the most common type of measuring instrument for mass.
- **Forces** are stresses such as pushes or pulls.
- Standard unit of force is call **Newton (N).** 1 Newton is a small force, just enough to stretch a thin rubber band.)
- **Force meter (spring scale)** – a common laboratory instrument for measuring forces. However, this scale is not very accurate.

- To describe force, you need to determine both its **direction** and its **size.**
- **Gravitational Force** – the force exerted by gravity on an object; measured in Newtons (N). This is the scientific term for the everyday term "weight."
- **Force Diagram** – a simple picture that uses arrows to show the strength and direction of one or more forces.

Topic 4 – Forces, Loads, and Stresses

External Forces – are stresses that act on a structure form outside it, for example, your kick when striking a soccer ball. These forces produce:

Internal Forces – which are stresses, put on the materials that make up a structure. Internal forces are the result of external forces.

Internal stresses can change the shape of a structure. This change of shape to a structure is call **Deformation.**

External Forces

Dead load – a permanent force acting on a structure. Over time can cause the structure to sag, tilt, or pull apart.

Live load – a changing or non-permanent force acting on a structure, for example, snow, weight of vehicles or people (Impact forces, such as kicking a soccer ball, are a type of live load.)

Internal Forces

Tension forces – stretch the material by pulling its ends apart.

- *Tensile strength* - measures the largest tension force the material can stand before breaking

Shear forces – bend or tear the material by pressing different parts in opposite directions at the same time

- *Shear strength* – measures the largest shear force the material can stand before breaking

Compression forces – crush the material by squeezing it together.

- *Compressive strength* – measures the largest compression forces the material can stand before losing its shape or breaking.

Torsion forces – twist the material by turning the ends in opposite directions

- *Torsion strength* – measures the largest torsion force the material can stand and still regain its original shape.

Bending forces – are a combination of tension and compression forces.

The strength of a material is dependent on the forces between its particles. For example, steel has high tensile strength while rubber has high torsion strength.

Topic 5 – How Structures Fail

- If a great enough force is applied to a structure, it will begin to fail.

Levers create large forces – a **lever** is a device that can change the amount of force needed to move an object (e.g. With a crowbar, you can lift very heavy objects. Some levers consist of a long arm that rests on a pivot or **fulcrum**.) The wind can act as a lever to begin pushing over a flagpole.

Materials Fail – external forces can cause internal forces in the structure. These internal forces can cause the following types of damage:

- **Shear** (weight of the building causes soil to shear and the building collapses)
- **Bend or Buckle** (a tin can will bend or fold up when it is compressed)
- **Torsion** (twisting can lead structures to break apart or become tangled).

Materials that snap, break, bend and shear can be put to good use in the following ways:

- *Buckle* – car bumpers and sheet metal used in cars are designed to buckle in a collision. Therefore, the care becomes badly damaged but the people in the car may not be badly injured because the metal crumpled and absorbed the energy of the collision.
- *Shear* – in a boat's outboard motor, the propeller is held to the engine with a shear pin. This pin breaks if the propeller gets tangles in weeds. This is done to save the engine.
- *Twist* – spinning cotton or wool fibres very tightly together can make very strong fabric. Controlled twisting can turn string into ropes.

Metal Fatigue – this is when metal weakens due to stress. This process often results in the metal cracking and breaking.

Topic 6 – Designing with Forces

- Designers often rely on one of three key methods to help structures withstand forces:

1. Distribute the load throughout the structure so that no single part is carrying most of the load.
2. Direct the forces along angled components so that the forces hold pieces together instead of pulling them apart.
3. Shape the parts to withstand the specific type of force they are likely to experience.

(Examine 3 structural problems and their solutions on pgs. 321-322)

- Structures can be strengthened by using materials that are appropriate for their function (e.g. in a swing set – use a rope or chain that has high tensile strength to attach the seat to the frame.)

Friction – a force that resists, or works against the movement of two surfaces rubbing tougher (e.g. brick wall – each layer of bricks rests on the layer below. This "friction" holds the bricks in place.)

Frictional forces are greater between rough surfaces.

Topic 7 – Stable Structures

- A **stable** structure is one that is not likely to tip or fall over.

Centre of Gravity – the point at which all of the gravitational force of an object may be considered to act.

It is important that home builders understand the properties of the ground they are building on. If they do not, then the houses that they are building can be damaged by the shifting soil.

Constructing stable structures on shifty ground

1. **Find something solid** – below the soil lies solid bedrock. Builders can build solid foundations on the bedrock, or they can sink large metal, concrete or wood cylinders into the soil to rest directly on the bedrock.
2. **Make a solid layer** – Road builders always pack loose surface soil before paving to create a solid base for the asphalt or concrete (packed gravel foundations are also useful for road construction).
3. **Spread the load** – If the weight of the structure is spread over a large area, any particular part of the ground supports only a small part of the weight (e.g. – This is why footings, which are concrete foundations beneath houses, are wider than the walls themselves.

Spin Stabilization – the tendency of an object that is spinning on its axis to move in a predictable manner (e.g. – the faster a bicycle wheel spins, the more stable it is. See pg. 340)