STRUCTURES AND FORCES!

Adapted from online version
http://extranet.redeemer.ab.ca/sites/Schools/hcc/slyons/Lists/Announcements/Attachments/40/Structures%20and%20Forces%20Notes.ppt

STRUCTURES!

- **Structures =** Things with a definite size and shape, which serve a definite purpose or function.

- To perform its function, every part of the structure must resist **forces** (stresses such as pushes or pulls) that could change its shape or size.
- The structure must also be able to support a **load**.
  - The weight of the structure itself is called the **Dead Load** and the load it carries or forces working on the structure are known as **Live Load** (the books in our first tower and the golf ball in our second tower.

TYPES OF STRUCTURES…

- **Natural Structures:** Structures not made by people.

- Examples: feathers, sand dunes, shells, coral, skeletons trees…

- **Manufactured Structures**: Structures that have been built by people.

- Examples: buildings, umbrellas, jigsaw puzzle…

CLASSIFYING STRUCTURES BY DESIGN…

- **Design** = How a structure is put together, how it is shaped and the materials used in the structure.

- **1) Mass Structure**

  A mass structure can be made by piling up or forming similar materials into a particular shape or design.

None of our towers were Mass structures – what material could we use to make a Mass structure?

MASS STRUCTURES…

- **Natural Mass Structures**

- **Manufactured Mass Structures**

TYPES OF STRUCTURES CONTINUED…

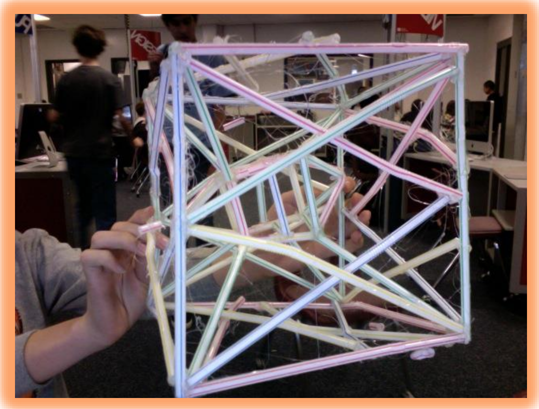
- **2) Frame Structures**

  Frame structures have a skeleton of very strong materials, which supports the weight of the roof and covering materials.

  - Some frame structures are simple and consist only of a frame. Examples: ladders, spider webs…

  - Some frame structures are more complex with added parts. Examples: bicycles, umbrellas…

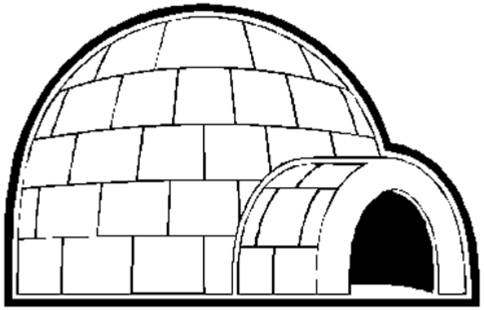
FRAME STRUCTURES…



TYPES OF STRUCTURES CONTINUED…

- **Shell Structures**

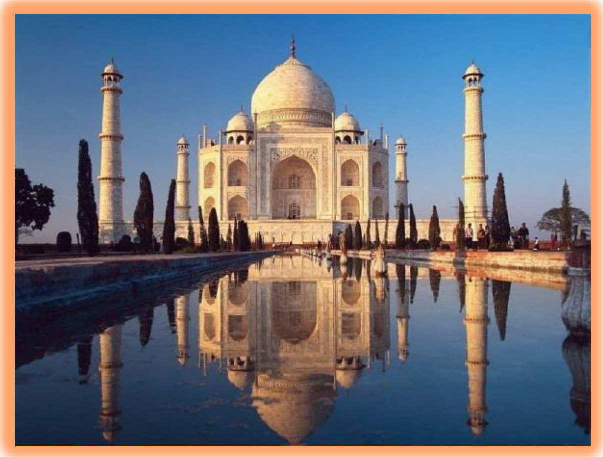
Shell Structures are objects that use a thin, carefully shaped outer layer of material to provide their strength and rigidity.



Which of our towers was a shell?

CAN YOU MIX AND MATCH???

What are the following examples?

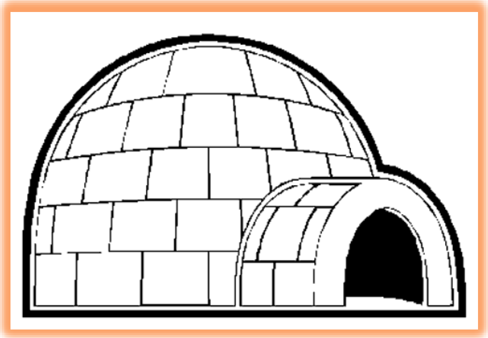


VARIATION IN DESIGN…

- Does the variation in design of structures affect how well it functions?

- How would these roofed structures function differently?

HOW WOULD TIME AND PLACE AFFECT DESIGN??



We have to work with available materials and existing technology.

Describing Structures!! Things to Consider when Building a Structure…

- 1) **Function:** this is the job that the structure is designed to do e.g. 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)

Continued…

- **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.
- **Balancing Cost with Safety**: It is difficult to design safe, well built projects that are not too expensive.
- **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.

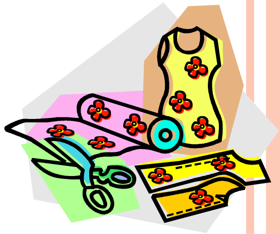
Review

- 1) Function
- 2) Aesthetics
- 3) Safety
- 4) Balancing Cost with Safety
- 5) Materials

Types of Materials

- **Composite Materials:** are made from more than one material
  - e.g. concrete can be reinforced using steel rods.
- **Layered materials**: layers of different materials pressed or glued together often produce useful products.
  - Examples are plywood or juice box material

Materials Continued…



- **Woven and Knit materials**: weaving and knitting are effective ways to make flexible materials.
- E.g. yarn in dishcloths is woven together to be flexible & strong

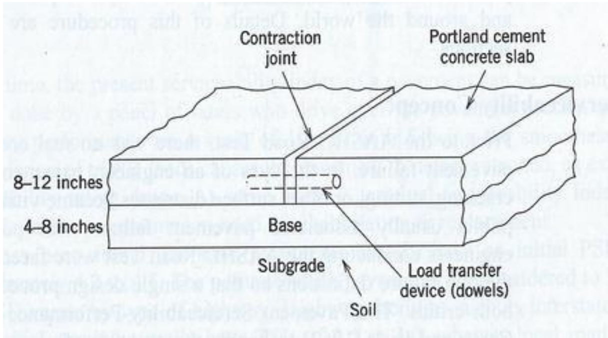
- When engineers choose what materials to use when building structures they must consider:

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

Joints

- **Joints:** Where a structures' parts are joined together

- **<u>Mobile Joints</u>** – allow movement. These hold parts together while still allowing movement
  - e.g. elbows, door hinges, other examples??
- **<u>Rigid Joints</u>** – attach parts of a structure without allowing movement.



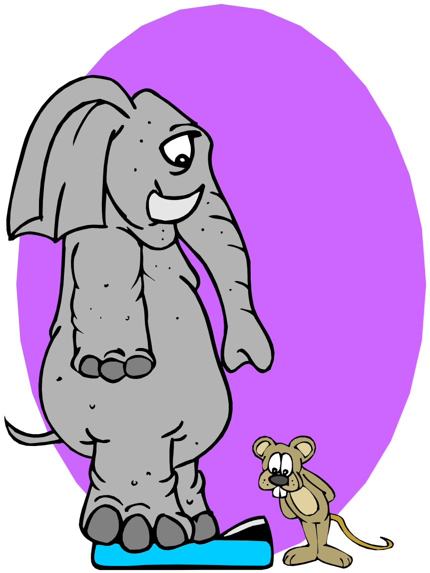
Rigid Joints

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
- **Melting** – welding or soldering materials together

Mass, Forces, Loads and Stresses

- The **mass** of an object is the measurement of the amount of matter in the object.
- Mass is generally measured in grams or kilograms
- Why would an elephant have greater mass than an egg???



Mass

- A **Balance** is the most common type of measuring instrument for mass.

- Mass is a very useful property to measure because it stays the same no matter where an object is located.

- Why would an elephant have the same mass on Earth as it would on the moon??

Forces

- **Forces** are stresses such as pushes or pulls

- A standard unit of force is called a **Newton (N)**.

E.g.) 1 N is a small force, just enough to stretch a thin rubber band

- To understand and predict how forces affect structures, you need to find the size of the force.

Forces

- **Force meter** = or spring scale, a common laboratory instru for measuring forces.

- Force meters are not very accurate, but they are less expensive and more sturdy than electronic sensors.
- Some forces are very large or otherwise difficult to measure.
- To completely describe a force, you need to determine both its direction and its size.

Force and Weight

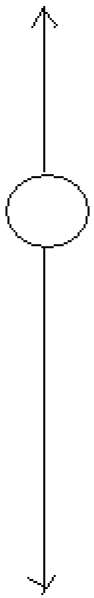
- **Gravitational Force –** The force exerted by gravity on an object; measured in Newtons (N). This is the scientific term for the everyday term “weight”

- 1Kg = 10N

- Would your weight or mass change if you were in the International Space Station farther from the centre of the Earth?

Forces Continued…

- **Force Diagram**: A simple picture that uses arrows to show the strength and direction of one or more forces.



- A circle or a rectangle represents the object on which the forces act.

- Each force is shown by an arrow. The length of the arrow shows the size of the force: a longer arrow represents a larger force. The direction of the arrow shows the direction of the force.

Types of Forces

- **External Forces:** Are stresses that act on a structure from outside it. E.g. kicking a soccer ball. Wind on a tower or bridge, earthquakes and water on a dock are external forces.

- **Internal Forces:** 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 is called **deformation**.

External Forces

- Engineers divide the forces that affect buildings into two groups.
- **Dead Load:** A permanent force acting on a structure. This includes the weight of the structure itself. Over time, this gravitational force can cause the structure to sag, tilt, or pull apart as the ground beneath it shifts or compresses under the load.

The Leaning Tower of Pisa

After the first 3 storeys were built in 1173 the ground beneath the heavy stone building began to sink unevenly.

The tower, even after several attempts to fix it, was supposed to topple in 2001 but engineers reinforced the foundation and it is now much more stable.

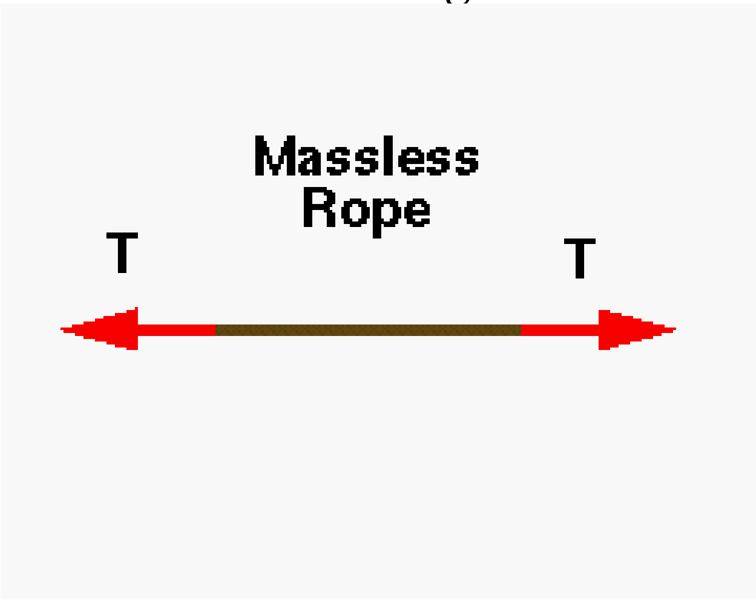
External Forces…

- **Live Load:** A changing or non-permanent force acting on a structure. E.g. snow, weight of vehicles or people

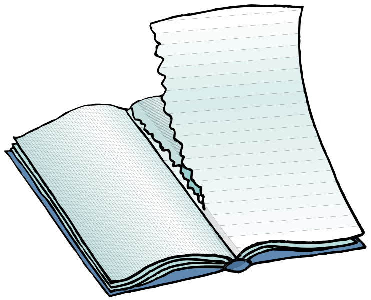
- The structure must be built for a reason and that is usually to contain or support a particular material that has mass.

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.

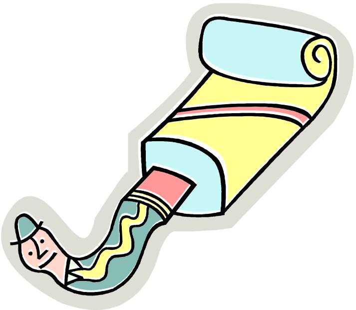


Internal Forces…



- **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 a material by squeezing it together.
- **Compressive Strength:** Measures the largest compression force the material can stand before losing its shape or breaking into pieces.



Internal Forces…

- **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.

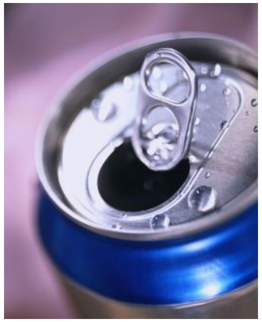
- **Bending forces:** Are a combination of tension and compression forces.

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

How Structures Fail

- If a great enough force is applied to a structure, it will begin to fail or fail catastrophically. Some structures are removed through controlled demolition by removing the supports with explosives.

- **<u>Levers create large forces</u>** – 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)



Continued…

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

- **Shear** (weight of building causes soil to shear and the building to collapse)

- **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)

Good Use of Forces

- 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 car 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.

Continued…

- **Shear**- in a boats outboard motor, the propeller is held to the engine with a shear pin. This pin breaks if the propeller gets tangled in weeds. This is done to save the engine.

- **Twist** – spinning cotton or wool fibers very tightly together can make very strong fabric. Controlled twisting can turn string into ropes

- Other Examples???

Things to Know

- **Metal Fatigue** – this is when metal weakens due to stress. This process often results in the metal cracking and breaking.
- Can you think of examples of Metal Fatigue in everyday life??

- <u>**Friction**</u> – a force that resists, or works against the movement of two surfaces rubbing together
- ex. 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.
- We want friction when stopping a car or the car will skid or not stop. Tires 'grip' the road and brakes are designed to slow or stop a car through friction.

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.

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

Stable Structures

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

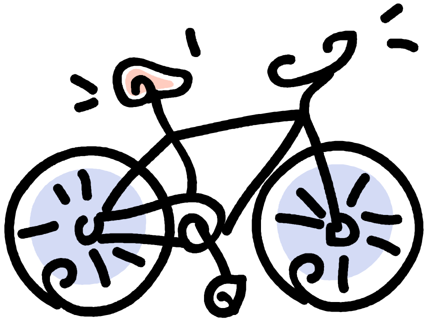
Building on Shifting Ground

- **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.
- **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).
- **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 ex. This is why footings (concrete foundations beneath houses) are wider than the walls themselves.

Stable Structures

- **Spin Stabilization** – the tendency of an object that is spinning on its axis to move in a predictable manner

- ex. The faster a bicycle wheel spins the more stable it is. A Beyblade is stable when it spins fast.



Key Questions or Learnings

- Over this entire PowerPoint, what did you find most interesting? Do you have any questions?