GRADE 7 - STRUCTURES UNIT HANDOUT

STRUCTURES

A structure is something which will support an object or a weight. It can also be described as anything that provides support and is made from one or more parts. When classifying structures by design they can be divided into three groups: frame, solid and shell structures.

SHELL STRUCTURES

In a shell structure the outside layer of the structure holds the whole object together. Tins or cans are shell structures. The weight of the liquid or food inside is supported by the skin of the container.
Examples of shell structures are: ____________________, ______________ ,________________.

Did you know? The Taj Mahal roof in India and the Sky Dome roof in Toronto are examples of shell structures.

FRAME STRUCTURES

Frame structures have a rigid arrangement, or framework, made up of parts fastened together, called structural components. A frame structure can be arranged in 2 dimensions, as in a door frame or fence. A frame structure can also be organized in 3 dimensions, as in the frame for a music stand or the wood framing for a house.
Examples of frame structures are: _________________, _________________ ,_________________.

Did you know? The Greek Parthenon and the Eiffel Tower and the Empire State Building are all examples of frame structures .

SOLID STRUCTURES

Solid structures are sometimes called mass structures and are usually made from one solid piece of a strong material. A solid structure has little or no space inside and relies on its own mass to resist the forces that act upon it.
Examples of solid structures are:_______ _______, ______________ ,________________.

Did you know? The Egyptian pyramids and the CN Tower and the Great Wall of China are all examples of solid structures

NATURAL STRUCTURES

Nature produced the first structure millions of years ago and has been developing them ever since. A leaf is a natural structure. Its veins provide a form of support, rather like a skeleton or umbrella. A spider's web is an extremely strong natural structure in terms of the weight it will support. The threads which go across the web are much stronger than those going around it. Natural structures are those found in nature occurring organically. Is Dow's Lake a natural structure? Is the Rideau Canal a natural structure? The answer to both is NO ..... as they were both made with technology. The Museum of Civilization is a curvilinear organically designed structure representing two distinct Canadian features – can you guess what they are?

Did you know? Australia's Great Barrier Reef extends for more than 2000 km, and it is the largest structure ever built by living creatures!

TECHNOLOGICAL STRUCTURES

Many of Nature's structures have been copied by humans. The hexagonal honeycomb found in nature is an efficient structure for containing and supporting honey. When copied by humans, it provides a rigid structure which can be used to make aircraft skins, lightweight doors and packaging. The strength and flexibility of large trees have been studied and the underlying principles used to design and build modern skyscrapers. Fishing net design has copied spiders' webs. Indoor household plumbing design has copied blood vessels. Hydro electric dam design has copied beaver dams.

Did you know? Toronto's CN Tower sways over 3m at the very top!
Did you know? The Great Wall of China can be seen from the moon and is one of the largest technological structures in the world.

STRUCTURAL FAILURE

A structure must be able to withstand the loads designed to put on it. If it cannot, then it will collapse. This is known as structural failure. Structural failure can have disastrous results, especially if the structure is a building or bridge, when the cost is counted in terms of death and injury. It is the responsibility of the Civil Engineers/ Designers to make sure that structures can withstand the loads or forces applied to them. A famous example of structural failure is the Tacoma Narrows bridge in the USA, which collapsed when exposed to winds of only 42 m.p.h.. You may have seen the damage on the Bill Nye structures video.

Did you know? The Leaning Tower of Pisa in Italy, leans because of soft, marshy ground underneath.

MASS, WEIGHT AND LOAD

Mass, weight and load are important terms but they can be confusing. To help you remember here's a trick! Think about holding a handful of identical marbles.

The mass is the amount of matter in an object and would be represented by the number of marbles in your hand. That number won't change if you took the marbles to the top of Mount Everest or even to the moon on the Space Shuttle with Canada's newest astronaut Steve MacLean.

The weight is the force of the earth's gravity acting upon the object – in this case the marbles. It is how heavy the marbles feel on earth. Weight depends on the magnitude of the gravitational pull. The weight decreases farther away from the earth you go. What would happen if you took the marbles to the moon? Well, the moon has less gravity, so the marbles would weigh less, but the mass would not change.

The load would be the external force you feel acting upon your hand as you hold the marbles. Load can be measured as the weight.

FORCES

Can you imagine what would happen if the tower you were designing and constructing collapsed under the weight of one brick! When you place a brick on your tower the weight of the brick is pressing down on the tower - this downward pressure is called a force. In order for the tower to be able to support the weight and not collapse, there must be another force inside the tower. This force will enable the tower to withstand the weight and will prevent it from collapsing. Your design and subsequent construction of the tower will determine its strength.

The effect of a force on a structure depends on the direction of the force, the magnitude of the force, and the location where the force acts on a structure.

When you place the brick on the tower, the force you put on the tower is called an external force. The forces inside the tower which prevent it from collapsing are called internal forces. The internal forces act against the external forces. If the external force is greater than the internal force, then the tower will collapse. You are sitting on a stool in the D&T centre, right! Well the reason you are not ending up on the floor is that the internal force inside the stool, that has been designed and fabricated to hold people, is supporting you - you the external force acting upon the stool. The internal force of the stool exceeds your external force put upon the stool.

When the tower is still, which means not moving, then the force is still also. This still force is called a static force. Your tower without any bricks on it is undergoing a static force. The internal forces in the tower will also be static then. The weight of the tower itself is one kind of static force; the static loads are caused by gravity and increase slowly, if at all. At the moment you actually place the brick on the tower, the force becomes moving. Moving forces are called dynamic forces. Dynamic forces grow quickly; and can include winds and earthquakes. Dynamic forces are much greater (more powerful) than static forces. The dynamic force of the wind collapsed the Tacoma Narrows Bridge. Please note however that a parked car on a bridge is a dynamic load on that bridge since the car has the potential of moving and exerts a force on a static structure.

Did you remember? On Jan 5th, 1998, an ice storm hit eastern Ontario and for several days heavy rain fell and then froze, creating thick layers of ice on roads, buildings, trees and hydro towers. The weight of this ice – over 10 cm thick in places – was too much for many structures to bear. Tree branches snapped, damaging cars and building and blocking roadways. Tension and compression forces caused by the weight of the ice crumpled hydro towers, cutting off electricity to many areas. The ice storm lasted about a week but the damage took months to clear up

When a force is applied, motion or change occurs. The forces that affect civil engineering structures can be classified as: compression, tension, complementary, torsion, or shear.

TENSION

If we take a material and try to pull it apart from either end, we are putting it into tension. A tow rope for a water skier has to resist the forces of tension. Tension is a pulling force. The coping saw blade is held in tension.

COMPRESSION

Compression is a force that tends to press a material - a squashing force. Compression increases as height increases, so the parts at the base of the structure have to be made stronger than those near the top. That's the reason tree trunks are thicker at the bottom that at the top. The chuck of the drill holds the bit in compression.

COMPLEMENTARY FORCES

When you plan a fair test of a structure's performance, you consider only one factor, or force, acting on the structure at a time. This lets you see the effect of that force. However, in real life, a structure must resist combinations of forces. In fact, some kinds of internal forces occur together. These are called complementary forces. Tension and compression act together when the load is applied to your tower.

TORSION

When you twist the top of a bottle or jar to undo it, you are using a torsion force. Torsion is a turning or twisting force. When you use a wrench to tighten or undo a bolt, you are using torsion. The turning effect produced by the wrench is called torque. Wind for example, can exert torque on bridges, especially on suspension bridges.

SHEAR

Shear tends to make portions of an object move in parallel, but opposite directions. When two pieces are joined and are under tension, shear forces tend to break the fastener that holds them together. One piece pulls in one direction; the other piece pulls in the opposite direction. Bolts, rivets and welds on bridges/towers are subject to shear forces. When you use a pair of scissors to cut a piece of paper you are using a shear force.

STABILISING STRUCTURES

Structures must be stabilized to prevent them from collapsing when loads are put on them. Think of how you can prevent your tower from collapsing under the weight of 60 lbs., or 6 bricks. We know that a structure collapses when the external forces are greater than the internal forces. Therefore, you must ensure the internal forces are greater that the external forces under all “normal” conditions. But how can you do this?

Triangles are very useful when building structures; they can help make a very strong and rigid tower. Racking is a kind of stress which distorts a square or rectangle, causing it to become a parallelogram.

Look at the simple structure shown on the board. If a load is put on it from one side, such as a strong wind, the structure will turn from the corners and lean over. It needs to be stabilized. To strengthen a square or rectangle, a diagonal brace converts the rectangle into two triangles, making the figure much stronger. The brace serves to keep the length of the diagonal constant. This action minimizes the racking effect. When designing towers/bridges, Civil Engineers often convert figures into triangles, since triangles are the strongest possible figure. This way of making structures more stable is called triangulation.

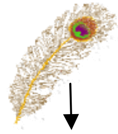
One way of making this structure more rigid would be to put in one more brace (member) going from the upper corner to opposite lower corner. Four triangles would have then been made in the structure. We have now produced a very strong and stable structure, but we may have overdone it. Do you really need to put in two extra members? The answer is no. Two triangles within the structure would be enough to stabilize it. The second extra member (making four triangles) is not needed and is called a redundant member. When designing structures, it is easy to use more materials/members than are really needed. But you must remember that they will only add more weight to the finished structure and make it more expensive. Also if your materials are limited, using redundant members may not be a good idea. Remember you are designing and constructing your tower for efficiency, which means making the lightest tower possible that can support the greatest number of bricks. Remember a pizza lunch is up for grabs here!!!!! Copy down the three rectangles from the blackboard, along with the added braces / supports. Clearly identify the redundant member with an arrow. Note why redundant members should not occur on your tower, - i.e. added weight, waste of material ect. and be prepared to answer such a question on a test. OK.

NOTES

Grade 7 - Unit 4 – **Structures and Forces** Concepts

Solid (Mass)

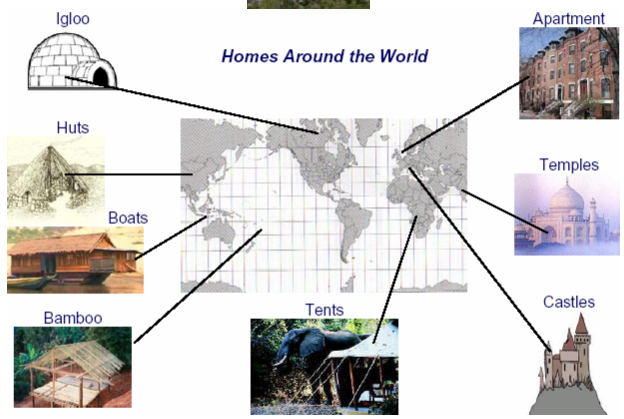
Frame



Shell

Combination

Function
Containing
Transporting
Sheltering
Supporting
Lifting
Fastening
Separating
Communicating
Breaking
Holding



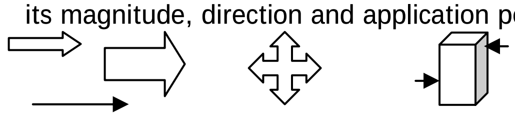
Design
Natural

Manufactured

External Force
↕
Internal Force

Force is a push or pull causing an object to change shape, or movement.

Force affects a structure depending on –
its magnitude, direction and application point



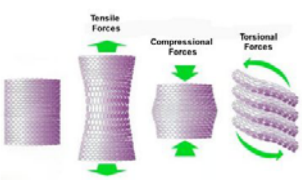
Static Load
↕
Dynamic Load

Compression

Tension

Shear

Torsion



Supporting the Load
Centre of Gravity
Symmetry
Structural Stability
(firm foundation, strength & stiffness of materials)

Structural Failure
buckling shearing separating deforming
Metal Fatigue

Bridge Types
Beam
(simple, i-beam, girder)
Truss
(interlocking triangles)
Suspension
Arch
(keystone spreads load)
Cantilever

Material Properties

Corrugation
Lamination
Composite
Woven and Knit
Different Arrangements
Better Fasteners
New Materials

Human

Joints (FIXED or MOVABLE)
Friction
Interlocking
Mass
Ties
Bonding (Adhesive, Melted)

Plants

Natural Forces
Climate (Weather) – Terrain – Earthquakes

Evaluating Structural Design
Costs
Benefits
Reliability
Effectiveness & Efficiency
Margin of Safety
Environmental Impact