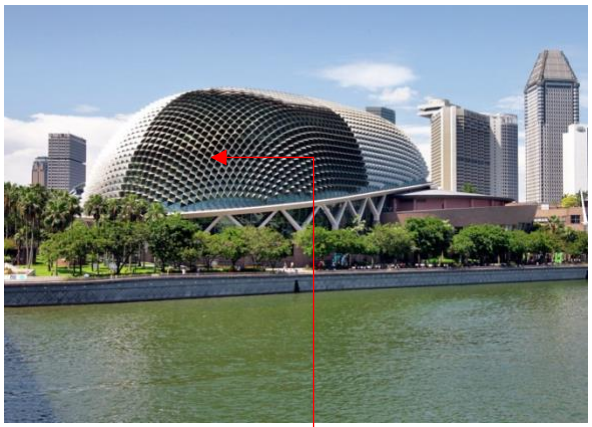
Structures 1.1 / [Types and functions]

- A structure is something that will support an object or a load. It must be strong enough to support its own weight and any additional compounded weight. All structures are to;
  - resist forces, not collapse during usage, and hold parts vis-a-vis appropriate position.

Natural Structures – are structures which are the result of animals or natural forces.	E.g Skeleton	 *Chicken Skeleton*
Manufactured Structures – are structures which are human made.	E.g Bridge	 *Russkiy Bridge, Vladivostok, Primorskiy Krai*

- Additionally, man made structures derive inspiration from nature.



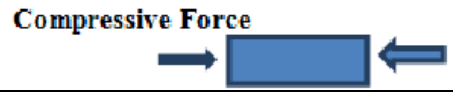
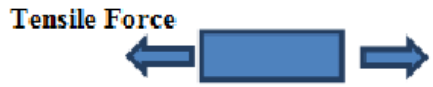
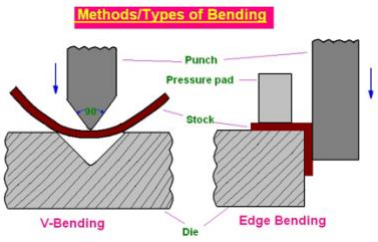
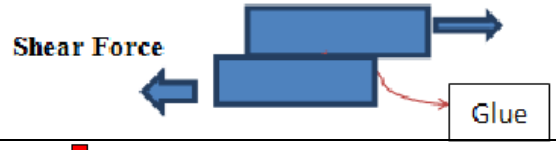
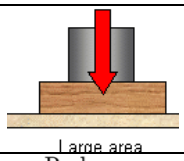
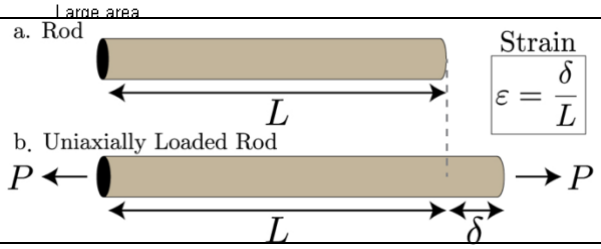
The Esplanade in Singapores' Central District derived inspiration from the Durian fruit, a pungent fruit predominantly associated with the Southeast-Asian region. This is one example of nature-derived inspiration incorporated into the built environment.

Structures 1.2 / [Loads, Forces, Equilibrium, and Failure]

1) Types of Loads

Static Load	Stationary load
Dynamic Load	Dynamic load (moving)
Dead Load	Component

2) Types of Forces

Compression		A force that tries to squash an object
Tension		A force that tries to pull something apart
Bending		A structure subjected to bending is being simultaneously squashed and stretched. - Beam is a member supported at both ends - Cantilever is supported at one end only
Torsion		A turning or twisting force caused by torque
Shear		A shear force is created when two opposite forces try to cut or rip something in two
Stress		Measure of force acting on a unit area of material
Strain		Measure of the amount of extension per unit area of material

3) Equilibrium

The state of equilibrium is achieved when all forces acting on an object are balanced, giving 0 resultant force.

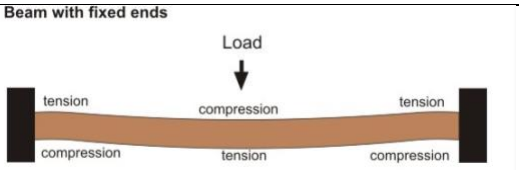
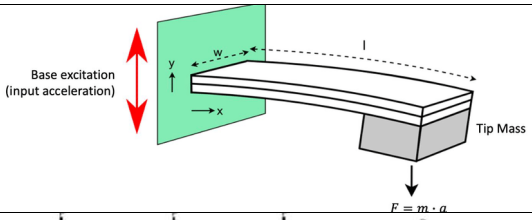
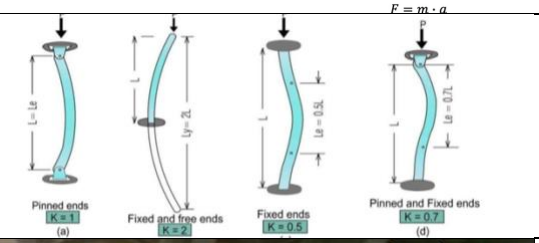
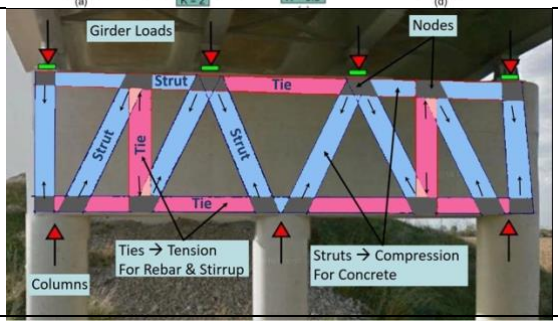
4) Factors Causing Structural Failure

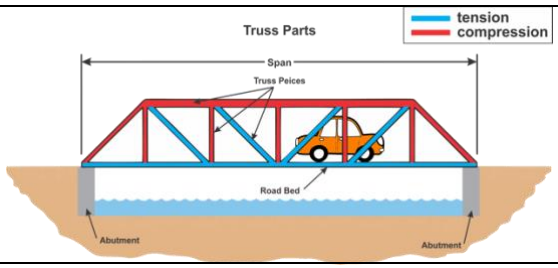
Poor selection and application of materials	E.g wood used in outdoor construction. When wood comes into moisture w/o sufficient weather-proofing, it detoriates and degrades, causing structural failure as material cannot support stress applied.	
A lack of understanding of the forces involved in a design	E.g the Hotel New World collapse in S'pore was caused by only considering the live weight (weight of occupants) while neglecting the dead weight (weight of structure). This resulted in foundation being insufficient to tolerate stress applied.	
Failure of a joint	E.g failure of column-beam joints	
Fatigue resulting from changes in the properties of a material over a period of time.	E.g the rusting of metal can reduce the ability to withstand stress applied. - In Genoa, rusting and corrosion of rebar in concrete caused bridge structural failure.	
Excessive loads	Stress on structure exceeds the carrying capacity of structure, resulting in structural failure as it is unable to tolerate it. - In Ghana, building collapse due to excessive load of occupants	

Incomplete knowledge of the conditions a structure is likely to face.	- Tacoma Bridge collapse was caused by insufficient material ability to withstand wind torsion	

Structures 1.3 / [Structural Elements and Properties]

- Structural elements

Beams		- Experiences bending
Cantilevers		- Experiences bending
Columns		- Experiences compressive force
Strut and Tie		- Struts experience compressional force - Ties experience tensional force

Truss		- a framework, typically consisting of rafters, posts, and struts, supporting a roof, bridge, or other structure.

- Properties of Structures

Strength	- The ability of objects and buildings to withstand forces
Hardness	- The ability of a substance (as a mineral) to scratch another substance or be itself scratched.
Toughness	- The quality known as toughness describes the way a material reacts under sudden impacts. It is defined as the work required to deform one cubic inch of material until it fractures.
Elasticity	- ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed.

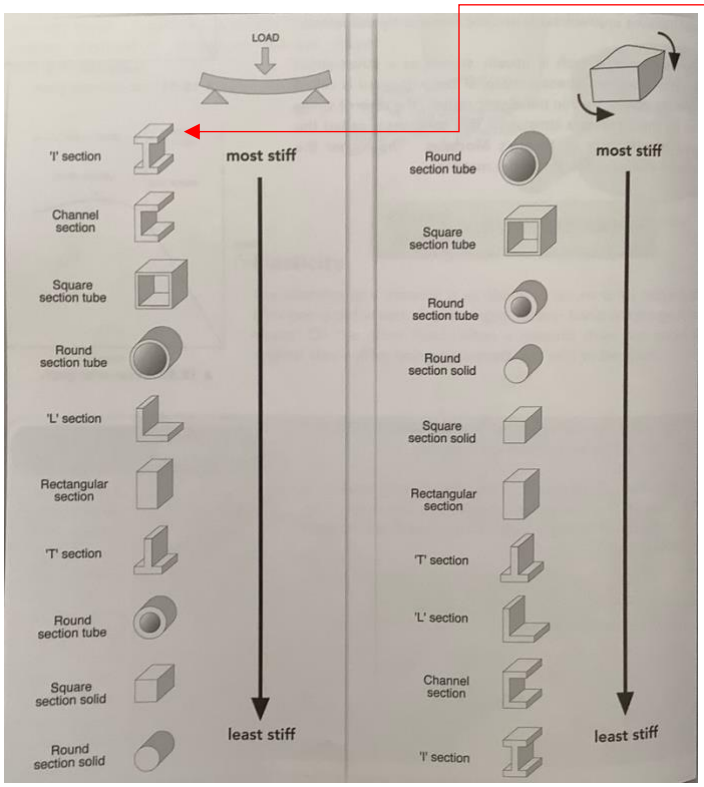
Structures 1.4 / [Structural Cross-sections & Reinforcement]

- Structures have 3 variants.

Frame structures	- Made from many small parts (members) joined together to support (bridges, scaffolding) and protect various parts.	
Shell structures	- Composed of a singular outer shell to provide strength. Mostly made with thin sheet material (for lightness) and having ridges molded into them.	

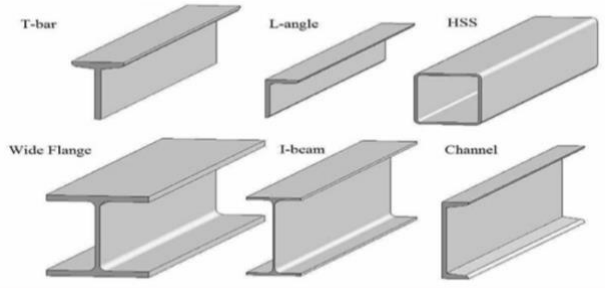
Mass structures	- It is held in place by its own weight. Hence, loosing small parts has negligible deleterious impact on structural integrity.	

Structures 1.5 / [Reinforcment via stiffness of cross-section]

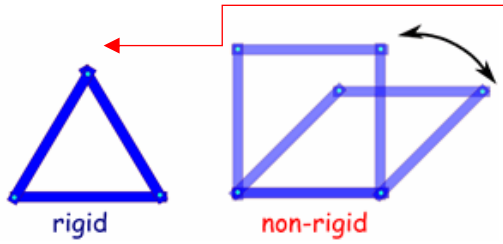


In I-shaped sections, majority of the material is located at the edges where stresses are compounded, resulting in primary application in buildings and bridges.

- They are usually known as RSJ (Rolled-steel joists).
- The I-shape is also applicable in manufacturing vehicles, furniture and cutlery.

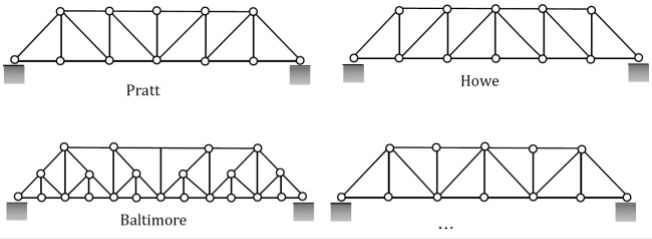


Structures 1.6 / [Rigidity]



*The **triangle** is one of the strongest shapes in structural design as it will not distort easily.*

- ***Triangular parts are incorporated** into frameworks such as the truss to provide strength and rigidity.*



- Triangulated frameworks consists of frameworks comprising of triangulated parts. This includes a geodesic dome, which forms a rigid spherical structure used in building design.

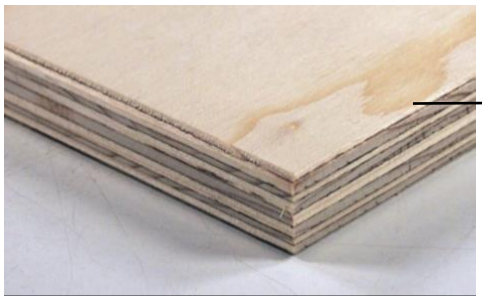
Stiffened Folds;

- Sheet material can be stiffened via folding. For example, metal sheeting can be reinforced via folding the edges.

Folded metal edges in sheet-metal table provides rigidity and strength.

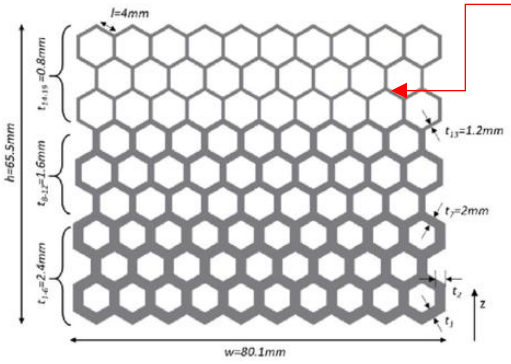
Lamination;

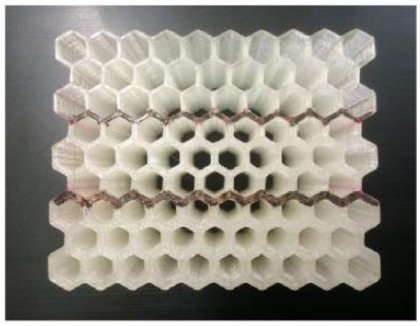
- The strength of thin sheet materials are generally lacking. This can be circumvented via laminating several sheets together.



A thin sheet of wood breaks along its grain easily. When multiple sheets are laminated together with their grains at 90° to each other, the materials' strength and rigidity is improved.

Honeycomb Structure.

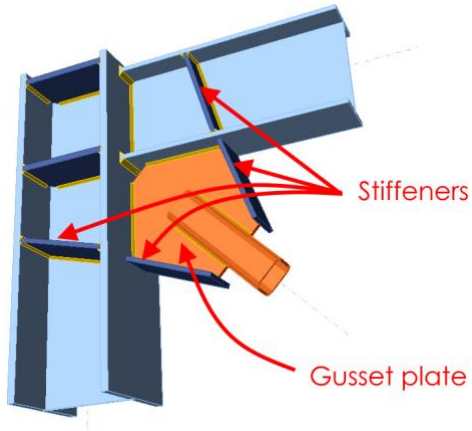


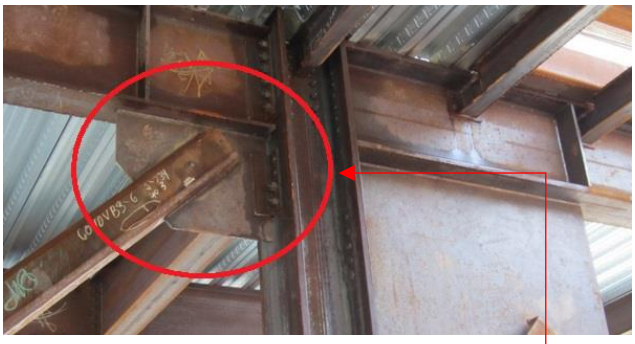


The honeycomb structure is light but strong when under compression, which is suitable in applications such as cavities inside doors and walls. The honeycomb keeps the sides of the door apart, keeping the door weight light

Gusset Plates

- Gusset Plates are used to increase the area of a joint, adding strength by helping to more effectively distribute stress evenly.

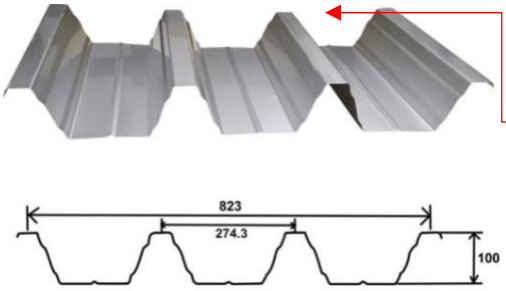




Gusset plates are primarily used to connect **beams and girders to columns.** A gusset plate can be fastened to a permanent member either by bolts, rivets or welding or a combination of the three. They are used in bridges and buildings, as well as other structures.

Ribs

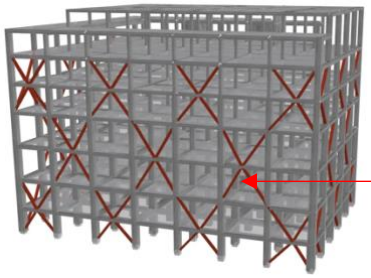
- Ribs are used to add strength to the walls of structures via preventing caving-in of walls. Ribs are used in large structures such as aircraft-wings and small structures such as cardboard-boxes. They are also useful in manufacturing light and strong packaging (i.e. cardboard boxes).



Ribs are primarily used in adding structural strength such as in **metal roofing** (*corrugated iron),* **internal wall structures,** or **adding strength to roofs.** They are also commonplace in light packaging such as **corrugated cardboard** and **corrugated plastic sheeting.**

Braces

- Braces add strength to joints.



Braces are commonly applied in uses such as supporting **shelf brackets** , **wall brackets** , **cantilever beams,** as well as providing *additional* **support in buildings**. They are also used in supporting other structures, such as street lamps.

Structures 1.6 / [Calculation of Moments]

- When a tower lifts its load, the load may cause the jib of the crane to topple due to the turning effect
- This turning effect of force is called the **Moment.** It is the product of load [measured in Newtons, (N)] and its perpendicular distance from the fulcrum/pivot [measured in Metres, (M)]
- $Moment = \ Force\ (N)$ x $Perpendicular\ distance\ from\ fulcrum$