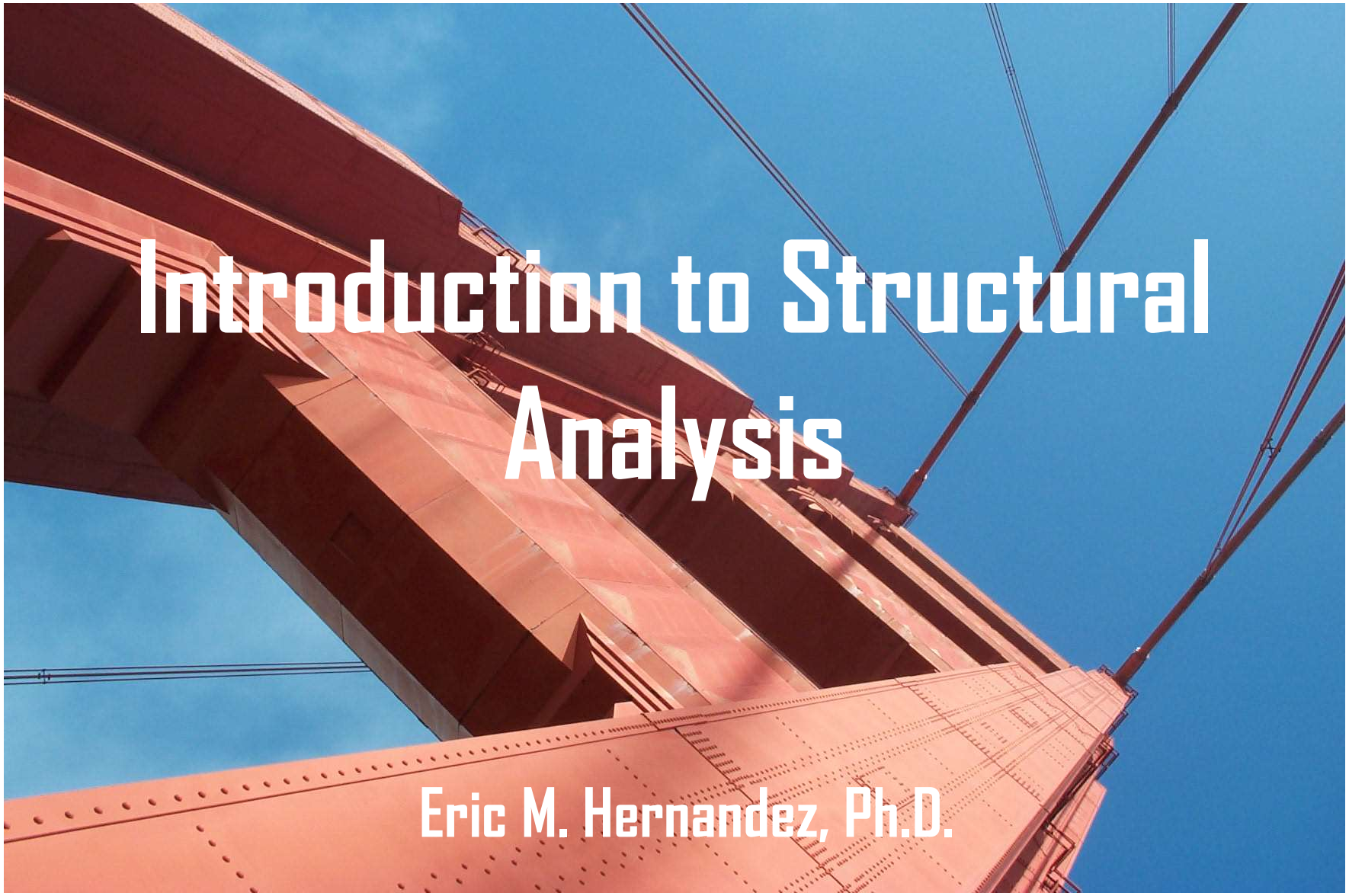
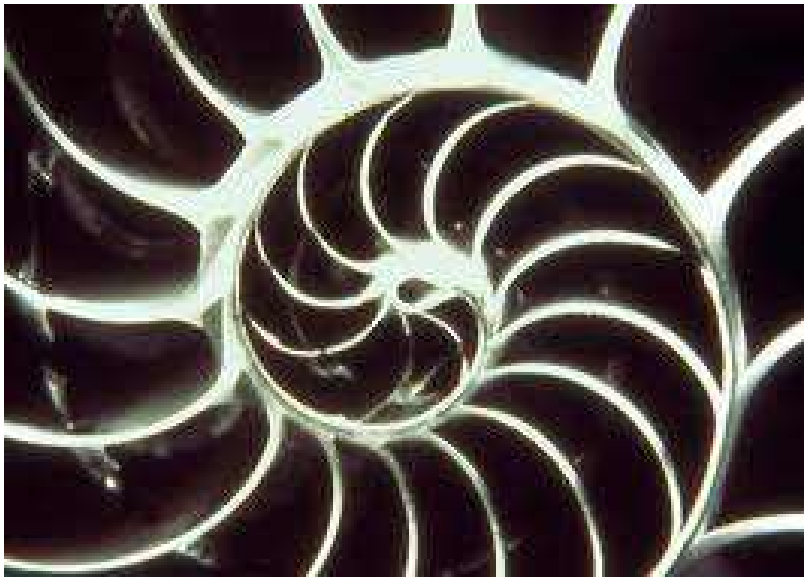
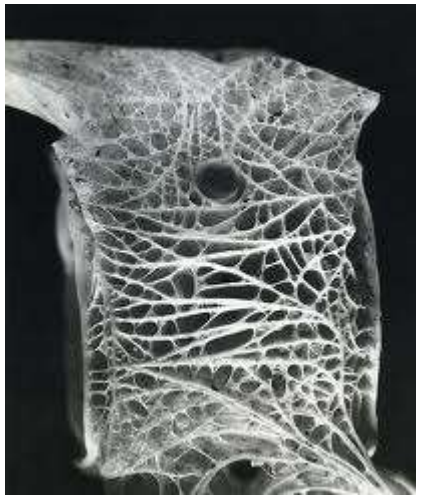

Introduction to Structural Analysis
Eric M. Hernandez, Ph.D.

What is a structure?

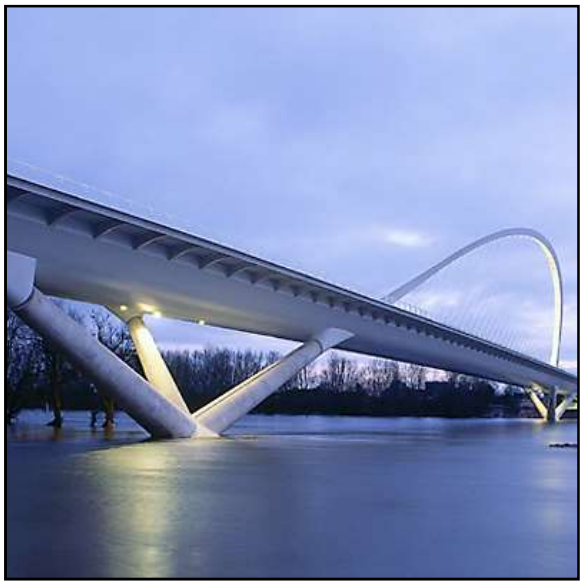
The inherent strength and stiffness possessed by solids which allows stable forms to exist is their *structure*. Some structures arise spontaneously in nature others are engineered by humans.

Natural Structures



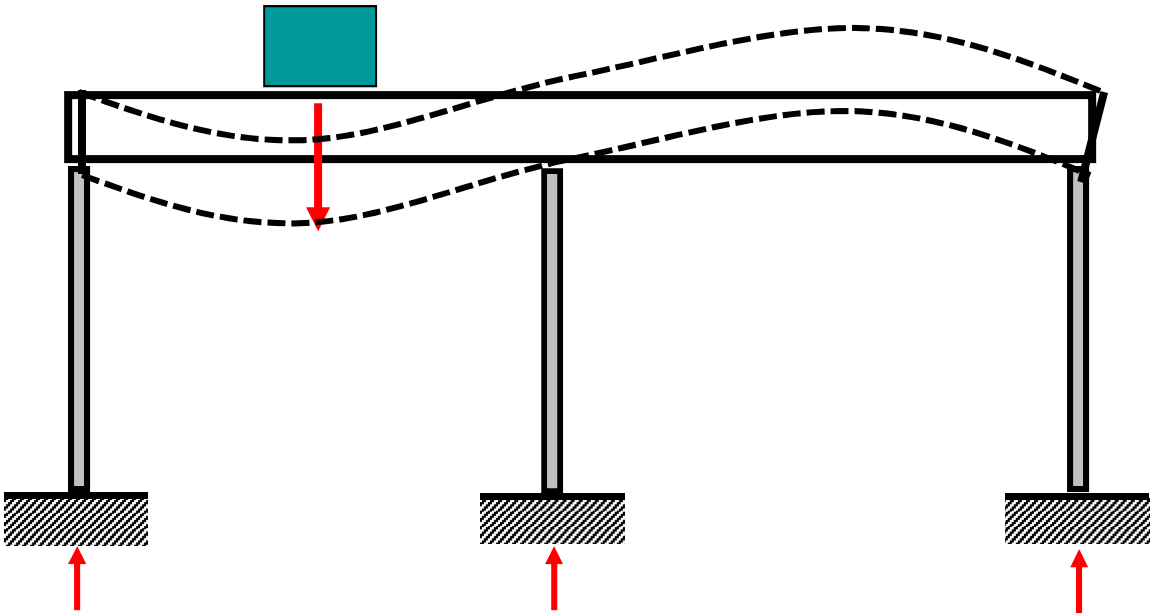


Engineered Structures

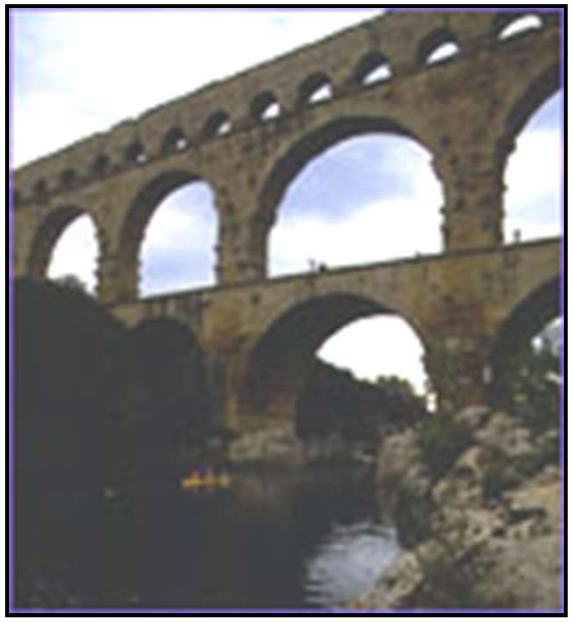


Structural Analysis

Encompasses a collection of mathematical and graphical procedures consistent with *classical mechanics* which seek to investigate how actions (loads) propagate within a structure and what are its kinematic effects.



Why structural analysis…?
these guys didn't know much about it
and they did very impressive work…



Alcantara Aqueduct Bridge

Roman Colosseum

Giza Pyramids

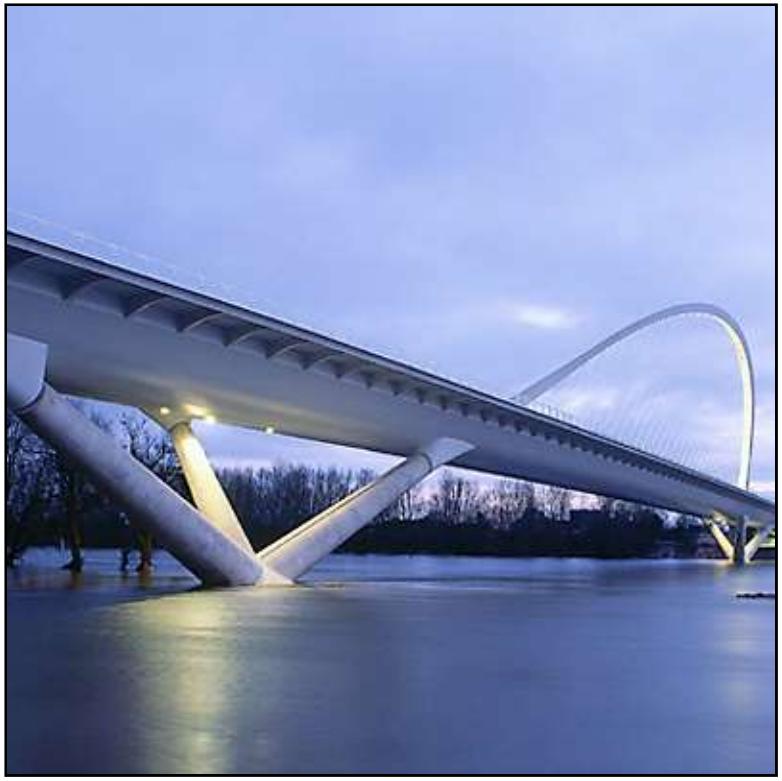
Optimization ($)

Ancient Bridge

Modern Bridge

An engineer does with one dollar what any fool can do with two…

Elegance + Safety



Using Structural analysis we can now predict the behavior of complex structural systems

Structural Analysis

All procedures in structural analysis have to satisfy the following three criteria :

- **Equilibrium**
- **Compatibility**
- **Constitutive Laws**

Equilibrium

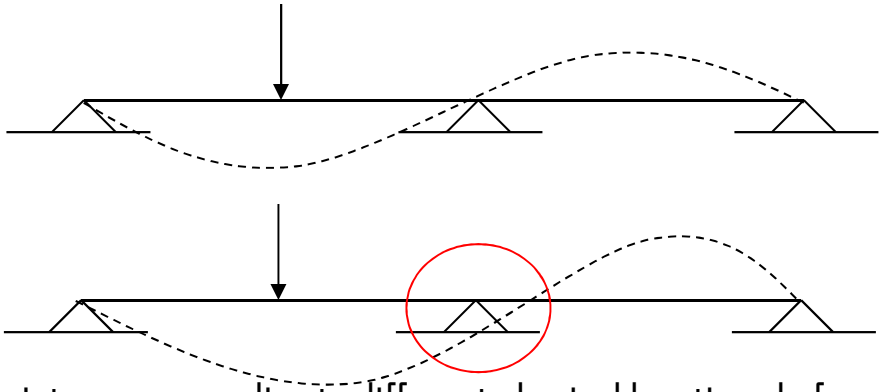
$$\sum F = 0 \quad \begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \\ \sum F_z = 0 \end{cases}$$

$$\sum M = 0 \quad \begin{cases} \sum M_x = 0 \\ \sum M_y = 0 \\ \sum M_z = 0 \end{cases}$$

Compatibility

After the actions are applied, the structure has to deform in a way which is consistent with the external constraints and the internal distribution of mass. For example:

- The deflected shape needs to be in contact with the supports

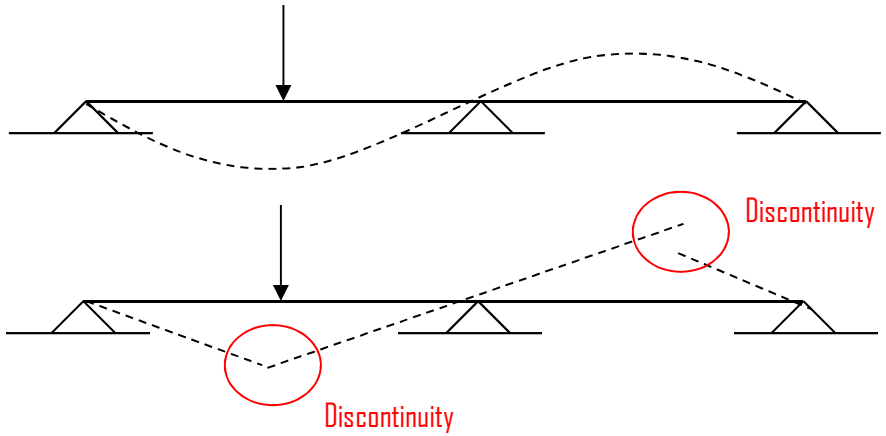


Incompatible deflected shape !

- Two points corresponding to different physical locations before deformation can not be in the same location after the deformation

Compatibility

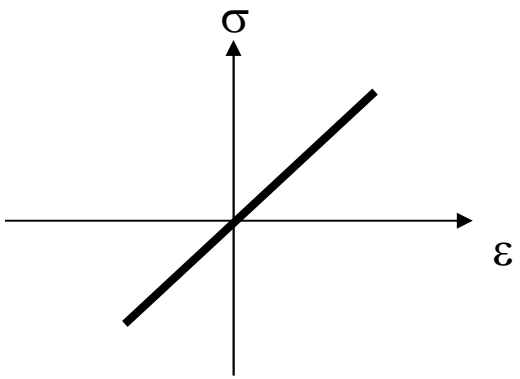
- The deflected shape needs to be a continuous and differentiable function



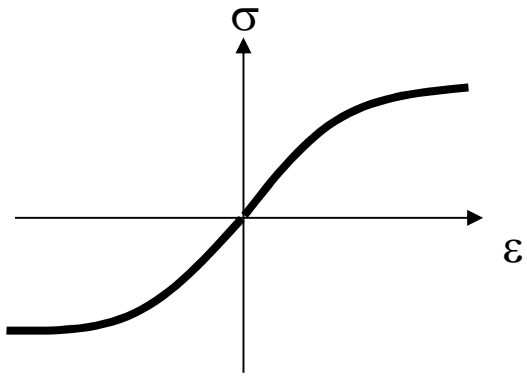
Incompatible deflected shape !

Constitutive Laws

Refers to the relationship between local stress and strain in a material. These relationship the global Force-Displacement relationship in the structure. Procedures in structural analysis need to be consistent with the true constitutive laws of the material from which the structure is built.



LINEAR



NON - LINEAR

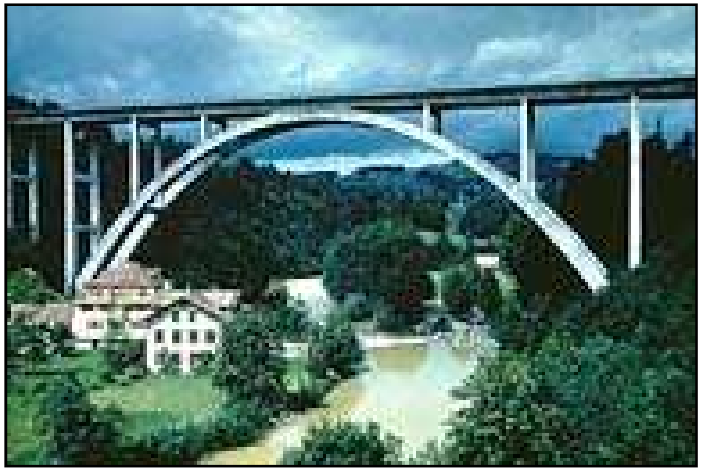
This course will be limited to linear materials

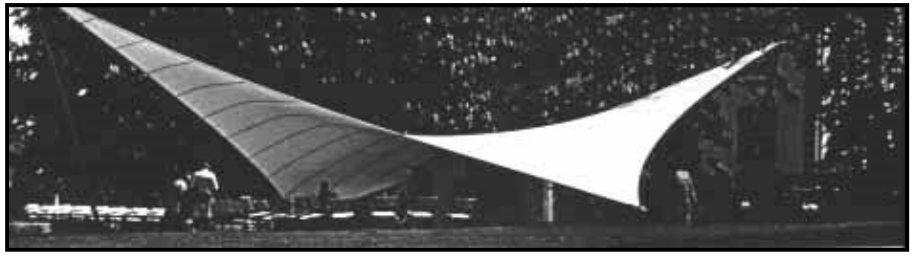
Structural Types

Structures can be classified into four large groups according to the way that they propagate the loads.

- **Active Form :** structures that derive their strength mainly from their shape or geometry. Arches, prestressed membranes, cable structures and suspension strucures belong to this group.

Active Form Structures





Structural Types

Structures can be classified into four large groups according to the way that they propagate the loads.

- **Active Form :** structures that derive their strength mainly from their shape or geometry. Arches, prestressed membranes, cable structures and suspension strucures belong to this group.
- **Active Vector :** structures that derive their strength from vectorial decomposition of the external loads. Trusses constitute the vast majority of these structures.

Active Vector Structures

Connection detail

Structural Types

Structures can be classified into four large groups according to the way that they propagate the loads.

- **Active Form :** structures that derive their strength mainly from their shape or geometry. Arches, prestressed membranes, cable structures and suspension strucures belong to this group.
- **Active Vector :** structures that derive their strength from vectorial decomposition of the external loads. Trusses constitute the vast majority of these structures.
- **Active Section :** structures that derive their strength thru bending mechanism, that is, tension and compression of the cross section. Beams and framed structures constitute an example of this type of structure.

Active Section Structures

← Stone henge

Structural Types

Structures can be classified into four large groups according to the way that they propagate the loads.

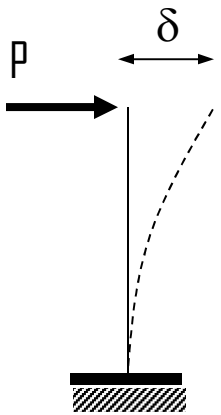
- **Active Form :** structures that derive their strength mainly from their shape or geometry. Arches, prestressed membranes, cable structures and suspension strucures belong to this group.
- **Active Vector :** structures that derive their strength from vectorial decomposition of the external loads. Trusses constitute the vast majority of these structures.
- **Active Section :** structures that derive their strength thru bending mechanism, that is, tension and compression of the cross section. Beams and framed structures constitute an example of this type of structure.
- **Active Surface :** superficial structures which develop their strength from a combination of adequate geometry and flexural mechanism. Hyperbolic paraboloids, shells, domes are examples of this type of structures.

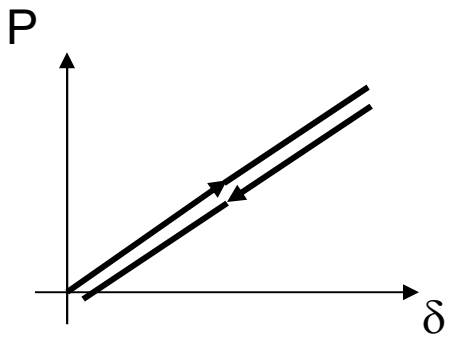
Active Surface Structures

Behavior of the Structure under Loading

Structures can be classified into :

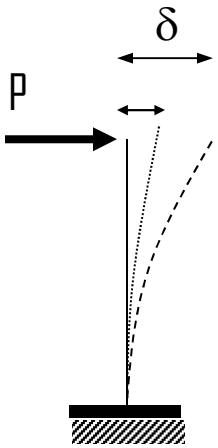
- **Elastic**

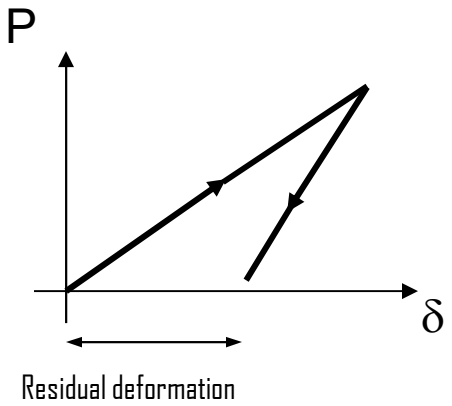




The structure returns to its original undeformed shape after the loads are removed

- **Inelastic**





The structure DOES NOT return to its original undeformed shape after the loads are removed

Behavior of the Structure under Loading

Structures can also be classified into:

- **Linear :** If the constitutive relation of the material is linear and the deformations are small.

- **Non-linear** : If either the deformations are large or the constitutive relation of the material are nonlinear.

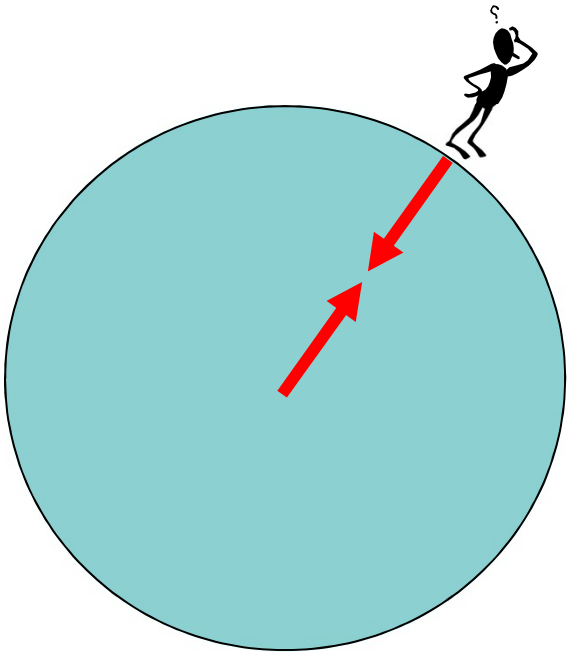
The most general case is that a material is nonlinear, inelastic and the deformations in the structure are large in comparison with it's dimensions.

This course will be limited to the case were material is linear, elastic and deformations are small in comparison with it's dimensions.

Actions on Structures

Gravity

Sir Isaac Newton



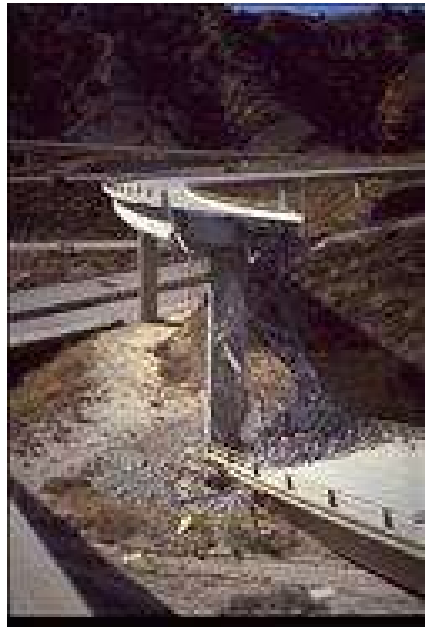
The earth pulls us. But we also pull the earth … with the same force!!!

The effect of gravity on structures can be divided into two:

- **Dead Loads :** Always in the structure. For example the weight of beams, columns, floor slab, partitions, furniture.
- **Live Loads :** Come and go. For example, people in a stadium, cars in bridges. This load usually refers to the effect produced by users of the structure.

Actions on Structures

Earthquakes



Actions on Structures

Wind

Actions on Structures

Water

- Flooding
- Water Waves

Fire

Snow and Ice

Vibrations

- Man induced
- Machine induced
- Nature

Actions on Structures

Blasts and Explosions

Impacts

Temperature Variations

The scope of this course

Arches, Cables, Beams, Frames and Trusses which are :

- Linear
- Elastic
- Small Deformations
- Subjected to static loads

This is certainly a limited range but nevertheless very useful in practice!