

## **I. Definition of force and stress**

### **1. Force:**

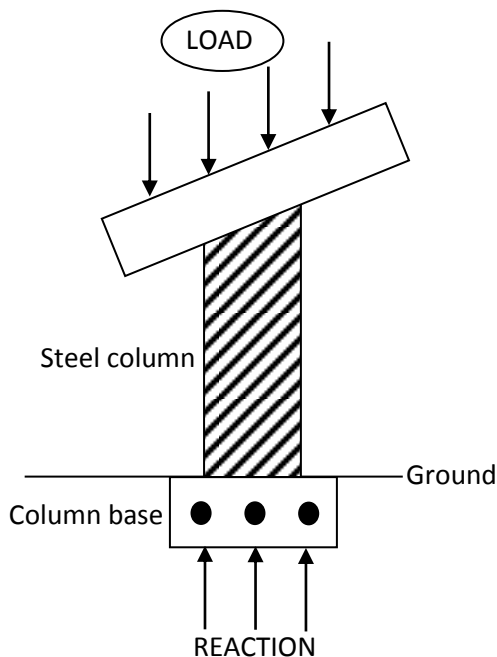
Force may be defined as that which exerts:

- pressure,
- tension, or
- motion.

Force has both magnitude and direction making it a vector quantity.

We are concerned here with forces at rest or equilibrium. If a force is at rest, it must be held so by some other force or forces.

*Example:*



As shown in this figure, a steel column in a building structure supports a given load, which due to gravity is downward.

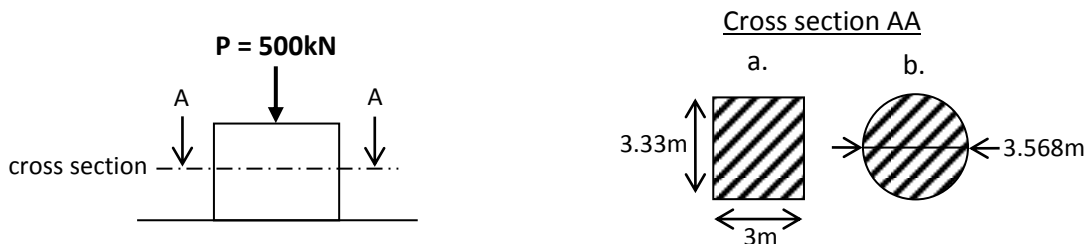
The column transfers the load to the base.

The resultant upward pressure on the base equals the load in magnitude and is called **reaction**.

The 2 forces (load & reaction) are opposite in direction, have the same line of action, and are equal in magnitude. The system is in equilibrium, that is, there is no motion.

### **2. Stress:**

Assume that a short column has a load of 500kN ( $= 5 \times 10^5 \text{ N} = 500,000 \text{ N}$ ) applied to its end as shown as follows:



Calculation of the area of the cross section:

a.  $\text{Area} = 3 \times 3.33 = 10 \text{ m}^2$

Or, if it was a circular cross-section:

b.  $\text{Area} = \pi \times r^2$   
 $= \pi \times 1.784^2$   
 $= 10 \text{ m}^2$

In the example, the load P is evenly distributed over the cross-sectional area A.

We can say that 500 kN is distributed over  $10 \text{ m}^2$  or  $\frac{500,000}{10} = 50,000 \text{ N}$  acting on each square m. In this instance the unit stress in the column is:

$$50 \times 10^3 \text{ N/m}^2 = 50 \times 10^3 \text{ Pascal (symbol Pa)}$$

**Notes:**

- The unit of stress is the same as that of pressure, which is also a measure of force per unit area.
- Engineering quantities are usually measured:
  - in megapascals (MPa), where:  $1 \text{ MPa} = 1 \times 10^6 \text{ Pa}$
  - or gigapascals (GPa), where:  $1 \text{ GPa} = 1 \times 10^9 \text{ Pa}$
- In imperial units, stress is expressed in pounds-force per square inch (psi) or kilopounds-force per square inch (ksi).
- A stress in a body is an internal resistance to an external force, or the intensity of the force distributed over a given cross-section.

## II. **Types of stresses**

The 3 primary stresses are:

- tension
  - compression
  - shear
- } which are classified as **direct** stresses

Unless noted otherwise, we will assume that forces are axial and that the stresses are uniformly distributed over the cross-sectional area of the body under stress.

We normally call:

- the load or external force  $P$
- the area or cross section  $A$
- the stress  $\sigma$  (sigma)

As discussed previously, the load divided by the section area will give the **direct stress  $\sigma$** . This is stated as a fundamental principle:

$$\text{direct stress } \sigma = \frac{P}{A}$$

$N/m^2 \equiv Pa$        $N$        $m^2$

### 1. Tension:

When a force acts on a body in such a manner that the body tends to lengthen or pull apart, the force is called **tensile**. The stresses in the bar due to the tensile force  $P$  are called **tensile stresses**.

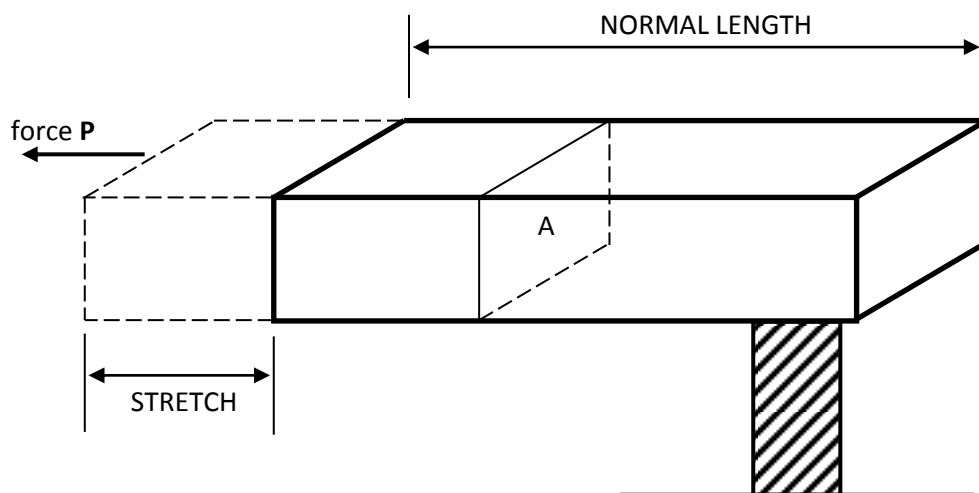


**Fig.** Deformation in a bar under tension

### 2. Compression:

When a force acting on a body has a tendency to shorten it, the force is called **compressive**, and the stresses within the body are **compressive stresses**.

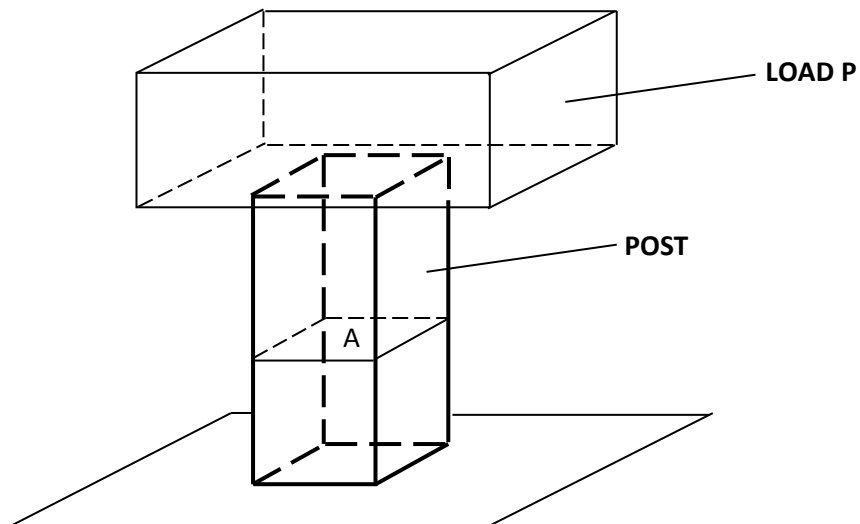


**Fig.** Short timber post under compression due to load P

### 3. Shear stress:

When a force is acting tangent to a body, the force is called **shear**, and the stresses in the body are **shear stresses**.

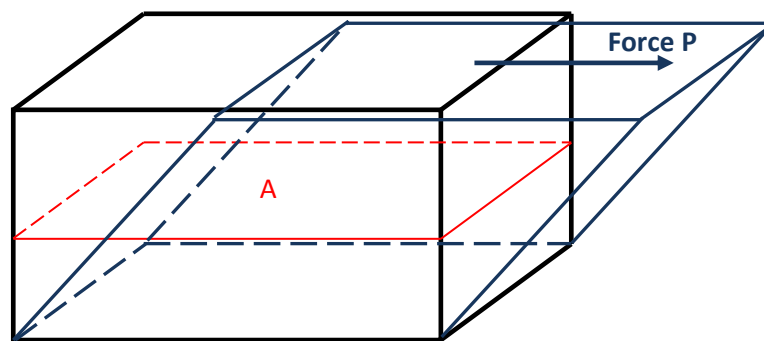


**Fig.** Example of a shear force P applied to the top of the square while the bottom is held in place.

The shear stress is denoted  $\tau$  (Greek letter tau) and is defined as

$$\tau = \frac{P}{A}$$

$N/m^2 \equiv Pa$  (pointing to the left side of the equation)  
 $N$  (pointing to the numerator P)  
 $m^2$  (pointing to the denominator A)

### III. Types of Strains

Strain refers to the elongation per unit length of a body in stressed condition. Note that strain is dimensionless.

#### 1. Direct Strain:



$$\text{Direct Strain } \epsilon = \frac{\text{change in length}}{\text{original length}}$$

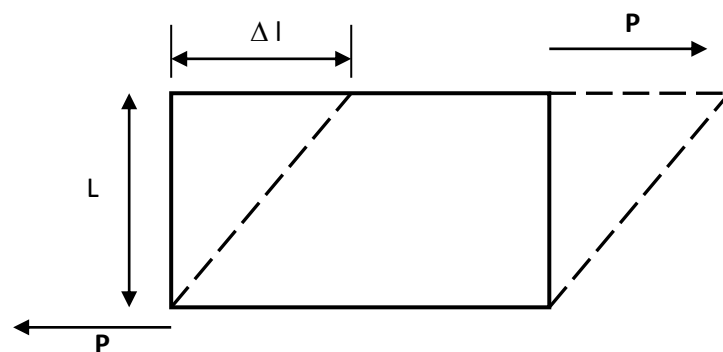
$$\epsilon = \frac{\delta L}{L}$$

unit less

m

m

#### 2. Shear Strain:



If the deformation in the direction of  $P$  is  $\Delta L$  and the distance between the opposite forces is  $L$ , then the shear strain  $\gamma$  is

$$\gamma = \frac{\Delta l}{L}$$

unit less