4.1. Introduction

Let us consider a thin material block (Fig. 4.1) glued to a table; suppose that a thin plate is now glued to the upper surface of the block. If a horizontal force F is applied to the plate, it will tend to slide along the surface of the block, and the block itself will tend to slide along the table.

If the glued surfaces remain intact, the table resists the sliding of the block, and the block resists the sliding of the plate on its surface. If we imagine that the block is divided by any horizontal imaginary plane, such as the plane ab, the part of the block above this plane will tend to slide over the part below it.

Each of the two portions of the divided system will therefore tend to slide relative to the other along the plane ab. Each part will thus be subjected to a shearing action; the stresses resulting from these actions are called shear stresses.

Shear stresses act tangentially to the surface.

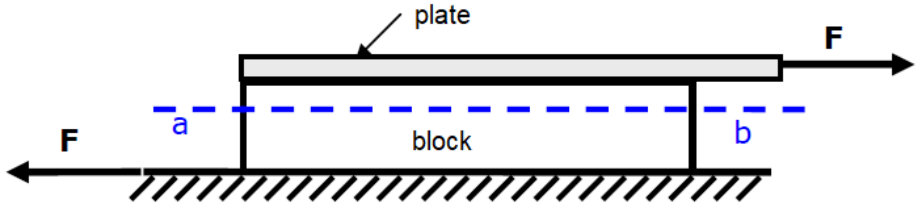


Fig 4.1. Shear stresses caused by shear forces

4.2. Definition

Shearing occurs when a part is subjected to two equal forces acting along the same line but in opposite directions, tending to make two portions of the part slide over one another. Example: the action of a pair of scissors on a sheet of paper, or the action of a punch on a metal plate.

4.3. Shear Stress

Consider a metal sheet with cross-sectional area **S**, fixed at one end to a rigid support (Fig. 4.2). Along this support, a shear blade is applied vertically with a force T, called the shear force.

According to the principle of action and reaction, the support exerts a reaction force equal and opposite to T. The sheet is therefore subjected to shear. If the shear blade is sharp enough, it causes the adjacent sections of the sheet to slide over one another at the point of fixation.

Assuming that all the fibers of the sheet are subjected to the same shear stress τ, its value is given by:

$$\tau = \frac{T}{S} \qquad 4.1$$

- τ is called the shear stress: it is the intensity of the shear force per unit area. It is measured in (N/m²), or (Pa).

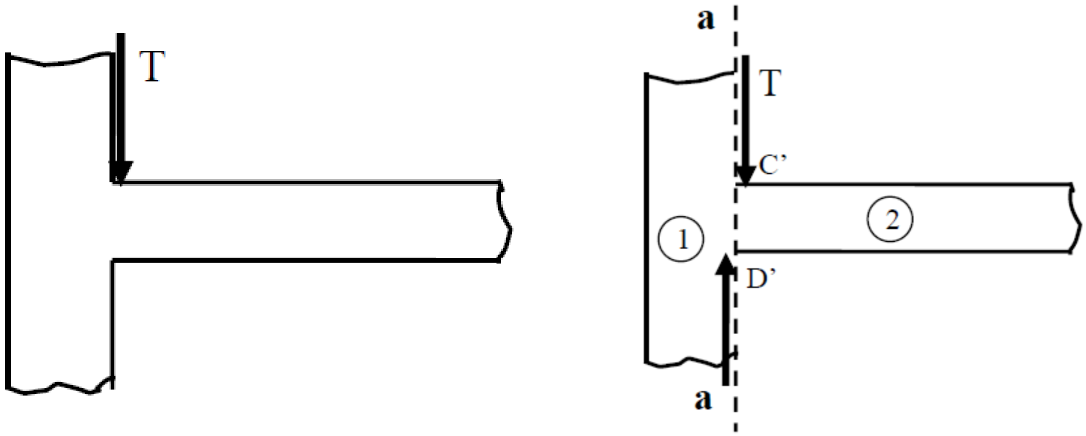
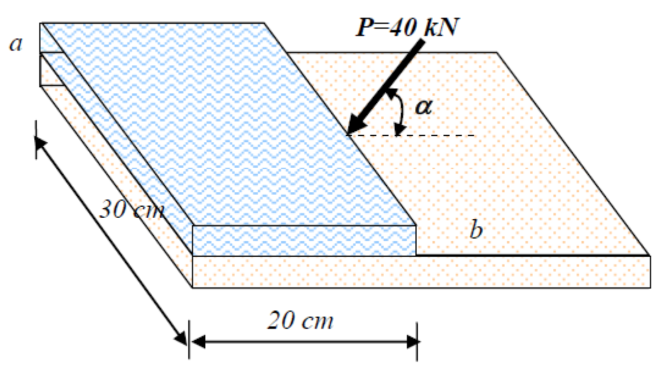


Fig 4.2. System subjected to a shear force

- **Example 4.1**

  Calculate the average stress on the plane ab in the figure below.



- **Solution 4.1**

The average shear stress on plane ab is:

$$\tau = \frac{T}{S} = \frac{p\cos\alpha}{S}$$

Therefore, for α = 45°, for example, we have:

$$\tau = \frac{40\sqrt{2}}{2(20x30)} = 0.047\ KN/cm^2$$

4.4. Hooke's Law

For many materials, the shear deformation is linearly proportional to the shear stress within certain limits. This linear relationship is similar to the case of direct tension and compression.
Within the limits of proportionality, we have:

$$\tau = G.\gamma \qquad 4.2$$

Where:

- τ is shear stress
- G is shear modulus of the material

It is noted that G is related to E by the formula

$$G = \frac{E}{2(1+\nu)} \qquad 4.3$$

ν is Poisson's ratio.

4.5. Condition for Shear Strength

In certain cases, it is important that a part subjected to shear can safely resist this type of loading.
For a part under shear to remain safe, the shear stress must not exceed a critical value $[\tau]$ called the allowable (or permissible) shear stress:

$$\tau \leq [\tau] \qquad 4.4$$

$[\tau]$ is a material property; it does not depend on the dimensions of the part subjected to shear. It generally represents (possibly with a safety factor applied) the transverse elastic limit of the material that is, the stress beyond which the part does not return to its original shape after the removal of the applied shear force.

$$[\tau] = \frac{\tau_e}{n} \qquad 4.5$$

τ_e The elastic limit in shear, and n is the safety factor.

- **Elastic Limit**

For steels, the elastic limit in shear (τ_e) is equal to half of the elastic limit in tension or compression (σ_e). That is:

$$\sigma_e = \sigma_{et} = \sigma_{ec} = 2\tau_e \qquad 4.6$$

- **Example 4.2**

The shear stress in a metallic body is equal to 1050 kg/cm². If the shear modulus is 8400 kN/cm², determine the shear deformation.

- **Solution 4.2**

From equation (4.2), we have:

$$\gamma = \frac{\tau}{G}$$

$$\gamma = \frac{1050}{840000} = \ 0.00125rad = 0.225°$$