Lecture 8
DIRECT SHEAR

Plan

1. About direct shear.
2. Calculation of bolted joint.
3. Solved problems.

8.1. About direct shear.

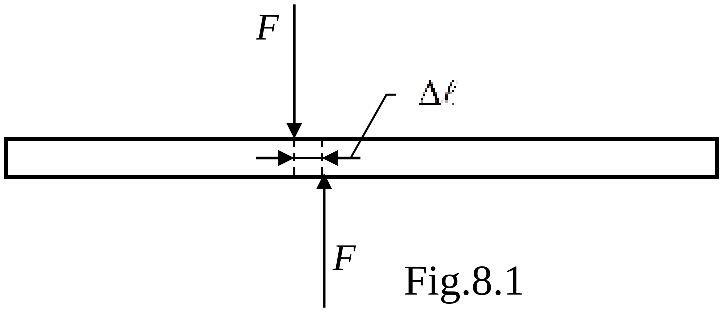


Fig.8.1

If a plane is passed through a body, a force acting along this plane is called a ***shear force*** or ***shearing force***. It will be denoted by Q.

The shear force, divided by the area over which acts, is called the ***shear stress*** or ***shearing stress***. It is denoted by τ. Thus:

$$\tau = \frac{Q}{A}. \quad (8.1)$$

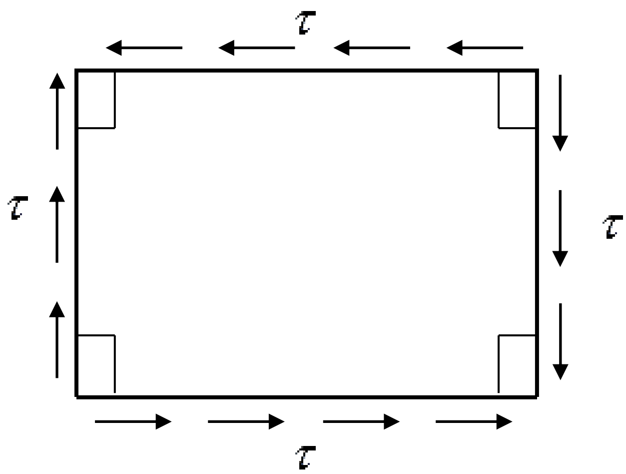
Let us consider a bar cut by a plane a - a perpendicular to its axis, as shown in Fig. 8.1. A normal stress σ is perpendicular to this plane. This is the type of stress considered in lecture 2.

A shear stress is one acting along the plane, as shown by the stress τ. Hence the distinction between normal stresses and shear stresses is one of direction.

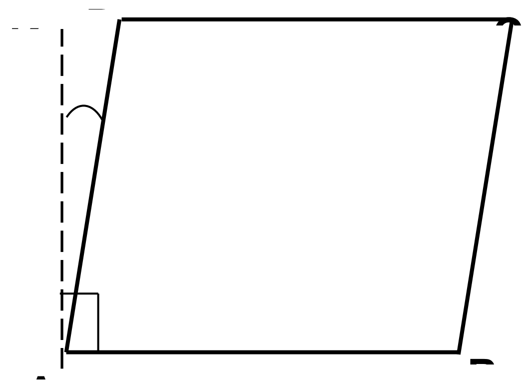
It is necessary to make some assumption regarding the manner or distribution of shear stresses, and for lack of any more precise knowledge it will be taken to be uniform in some problems discussed in this lecture. Thus, the expression (8.1) indicates an average shear stress over the area.

Let us consider the deformation of a plane rectangular element cut from a solid where the forces acting on the element are known to be shearing stresses τ in the directions shown in Fig. 8.2, a.

The races of the element parallel to the plane of the paper are assumed to be load free. Since there are no normal stresses acting on the element, the lengths of the sides or the originally rectangular element will not change when the shearing stresses assume the value τ. However, there will be a distortion of the originally right angles of the element, and after this distortion due to the shearing stresses the element assumes the configuration shown by the dashed lines in Fig. 8.2, b.



a



b

Fig. 8.2

The change of angle at the corner of an originally rectangular element is defined as the shear strain.

It must be expressed in radian measure and is usually denoted by γ.

The ratio of the shear stress τ to the shear strain γ is called the ***modulus of elasticity in shear*** and is usually denoted by G. Thus

$$\tau = G\gamma. \tag{8.2}$$

G is also known as the modulus of rigidity.

The units of G are the same as those of the shear stress. e.g., N/m^2 or Pa since the shear strain is dimensionless. The experimental determination of G and the region of linear action of τ and γ will be discussed in further. Stress-strain diagrams for various materials may be drawn for shearing loads. just as they were drawn for normal loads in lecture 2. They have the same general appearance as those sketched in lecture 2 but the numerical values associated with the plots are of course different.

In electron beam welding (EBW), coalescence of metals is achieved by having a focused beam of high-velocity electrons striking the surfaces to be joined. This beam of electrons carries a very high energy density that is capable of producing deep, narrow welds. Such welds can be produced much more quickly and with less distortion of the parent metals than with either gas or are welding. Negative aspects of EBW are surfaces to be joined must be very accurately aligned. and in certain situations EBW must be done in a partial vacuum. Also, safety precautions must be taken to protect personnel from the electron beam.

In laser beam welding (LBW). joining of metals is carried out by having an optical energy source focused over a very small spot, such as the diameter of a circle ranging from 100 to 1000 mm (0,004 to 0,040 in). The term "laser" is an acronym for light applification by timulated mission of radiation. Energy densities of the order of 10 watts/cm^2 ($6 \cdot 10^6$ watts/in^2) make the laser beam suitable for welding of metals. Laser beams can produce welds of high quality, but precautions must be taken to guard the operators of the laser, particularly with regard to damage to the human eye.

Let us consider some examples of solved problem of this theory.

On beginning

8.2. Calculation of bolted joint.

Consider the bolted joint shown in Fig. 8.8. The force F is 30 kN and the diameter of the bolt is 10 mm.

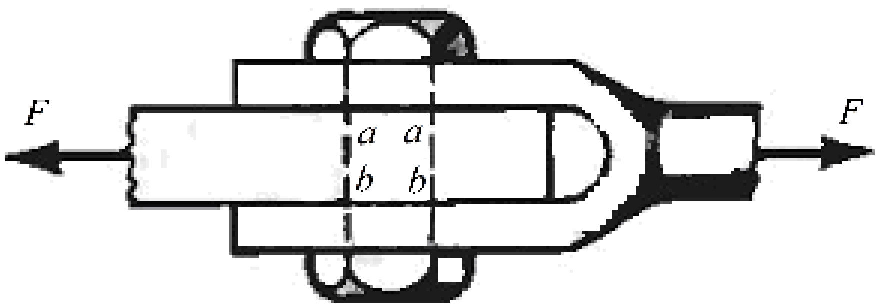


Fig. 3.3

Determine the average value of the shearing stress existing across either of the planes a - a or b - b.

Lacking any more precise information we can only assume that force F is equally divided between the sections a - a and b - b. Consequently a force of $\frac{1}{2} 30 \cdot 10^3 = 15 \cdot 10^3$ N acts across cither of these planes over a cross - sectional area

$$A = \frac{1}{4} \pi \cdot 10^2 = 78,6 \text{ mm}^2.$$

Thus the average shearing stress across either plane is:

$$\tau = \frac{1}{2}\frac{F}{A} = \frac{15 \cdot 10^3}{78{,}6 \cdot 10^{-6}} = 192 \text{ MPa.}$$

On beginning

8.3. Solved problems.

Let us consider some typical examples of calculation on this type of deformation for rivets and fillet weld.

Example 8.1.

A single rivet is used to join two plates as shown in Fig.8.8. If the diameter of the rivet is 20 mm and the load F is 30 kN.

What is the average shearing stress developed in the rivet?

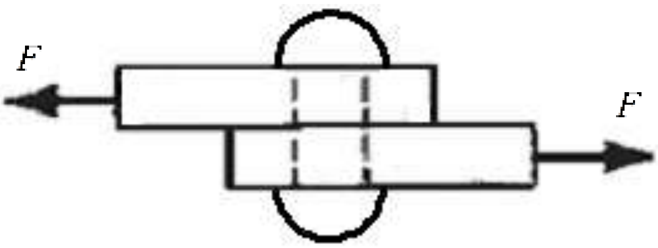


Fig 3.4

Here the average shear stress in the rivet is $\frac{F}{A}$ where A is the cross - sectional area of the rivet. However, rivet holes are usually 1,5 mm larger in diameter than the rivet and it is customary to assume that the rivet fills the hole completely. Hence the shearing stress is given by:

$$\tau = \frac{30000}{(3{,}14/4)(0{,}0215)^2} = 8{,}26 \cdot 10^7 \text{ N/m}^2,$$

or

$$\tau = 82{,}6 \text{ MPa.}$$

Example 8.2.

One common type of weld for joining two plates is the fillet weld. This weld undergoes shear as well as tension or compression and frequently bending in addition. For the two plates shown in Fig. 8.5, determine the allowable tensile force F that may be applied using an allowable working stress of 113001b/in^2 for shear loading as indicated by the Code for Fusion Welding of the American Welding Society.

Let us consider only shearing stresses in the weld. The load is applied midway between the two welds.

The minimum dimension of the weld cross section is termed the throat, which in this case is $\frac{1}{2}\sin 45^0 = 0{,}353$ in. The effective weld area that resists shearing is given by the length of the weld times the throat dimension, or weld area is equal:

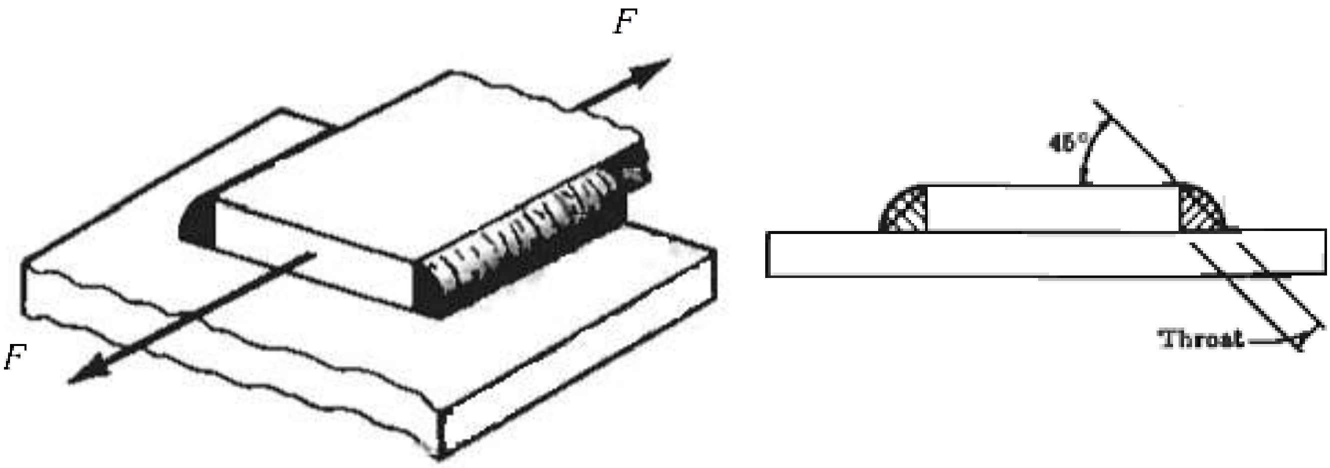


Fig. 8.5

$$7 \cdot 0{,}353 = 2{,}47 \text{ in}^2$$

for each of the two welds. Thus the allowable tensile load F is given by the product of the working stress in shear times the area resisting shear, or:

$$F = 11{,}3 \cdot 2 \cdot 2{,}47 = 56 \text{ lb.}$$

Example 8.3.

A building that is 60 m tall has essentially the rectangular configuration shown in Fig. 8.6. Horizontal wind loads will act on the building exerting pressures on the vertical face that may be approximated as uniform within each of the three "layers" as shown. From empirical expressions for wind pressures at the midpoint of each of the three layers, we have a pressure of 781 N/m^2 on the lower layer, 1264 N/m^2 on the middle layer, and 1530 N/m^2 on the top layer.

Determine the resisting shear that the foundation must develop to withstand this wind load.

The horizontal forces acting on these three layers are found to be:

$$F_1 = 20 \cdot 50 \cdot 781 = 781\ \text{kN};\quad F_2 = 20 \cdot 50 \cdot 1264 = 1264\ \text{kN};$$
$$F_3 = 20 \cdot 50 \cdot 1530 = 1530\ \text{kN}.$$

These forces are taken to act at the midheight of each layer, so the free - body diagram of the building has the appearance of Fig. 8.7, where F_H denotes the horizontal shearing force exerted by the foundation upon the structure. From horizontal equilibrium, we have:

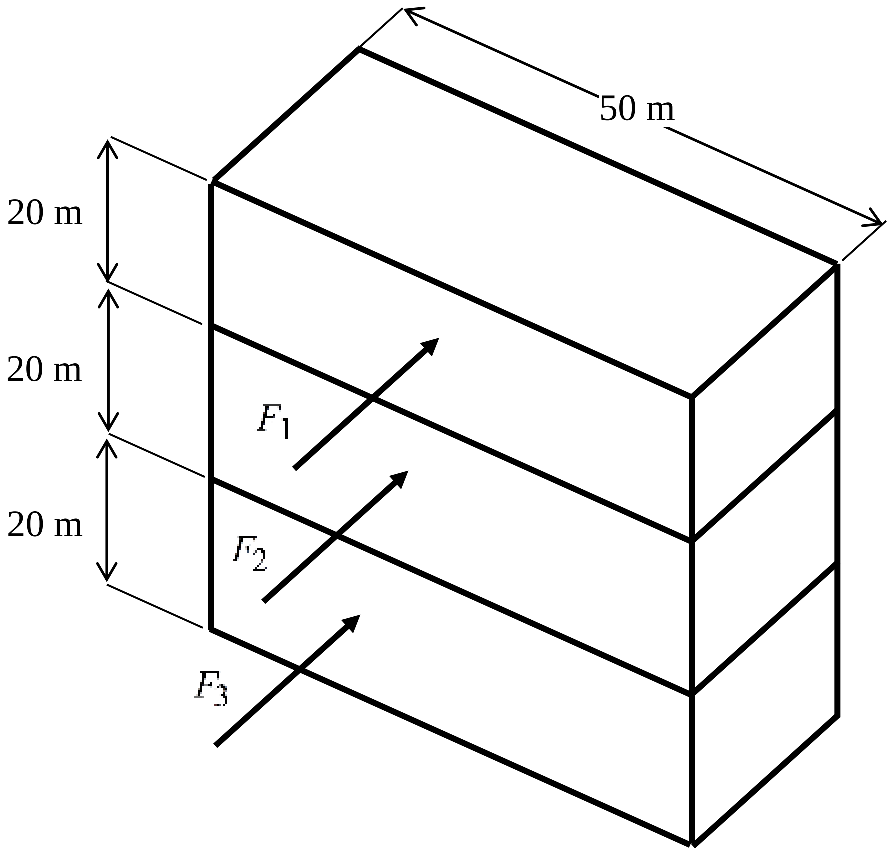


Fig. 3.6

$$\sum F_{x_i} = 1530 + 1264 + 781 - F_H = 0,$$

or

$$F_H = 3575\ \text{kN}.$$

If we assume that this horizontal reaction is uniformly distributed over the base of the structure, the horizontal shearing stress given by Eq. (8.1) is:

$$\tau = \frac{3575}{30 \cdot 50} = 2{,}38\ \text{kN/m}^2.$$

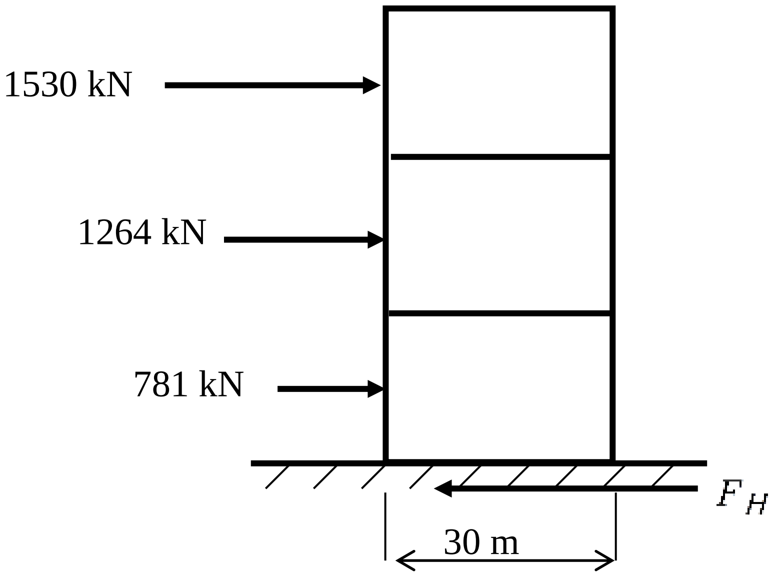


Fig. 8.7

On beginning