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FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

MEPS102:Strength of Material

Lecture 4

Topic: Shear Stress & Shear Strain

Instructor:

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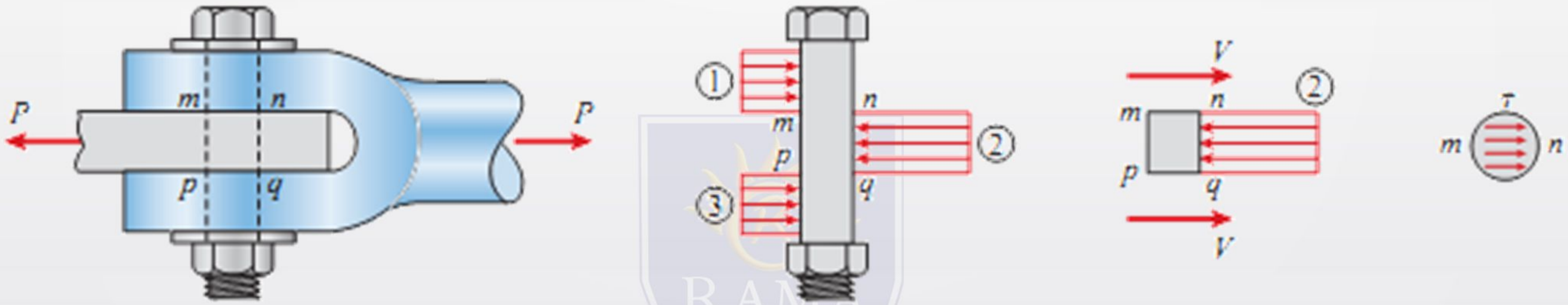
Shear Stress

- ✓ A shear stress, acts tangential to the surface of the material



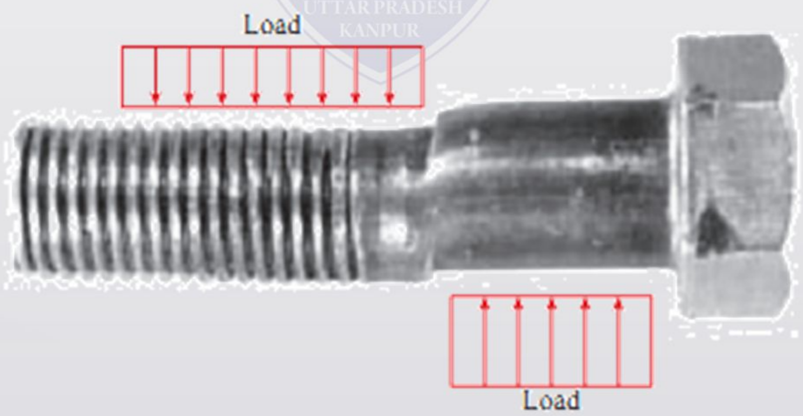
- ✓ The free-body diagram shows that there is a tendency to shear the bolt along cross sections mn and pq.
- ✓ From a free-body diagram of the portion mnpq of the bolt , we see that shear forces V act over the cut surfaces of the bolt.
- ✓ There are two planes of shear (mn and pq), and so the bolt is said to be in double shear.

Shear Stress

- ✓ The average shear stress on the cross section of a bolt is obtained by dividing the total shear force V by the area A of the cross section on which it acts

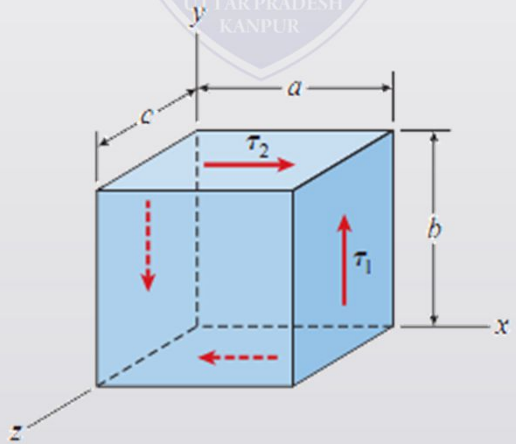
$$\tau_{avg} = \frac{V}{A}$$

- ✓ The loading arrangements shown in previous slide are examples of **direct shear** (or simple shear) in which the shear stresses are created by the direct action of the forces in trying to cut through the material. Direct shear arises in the design of bolts, pins, rivets, keys, welds, and glued joints
- ✓ The deformation of a bolt loaded almost to fracture in single shear



Equality of Shear Stresses on Perpendicular Planes

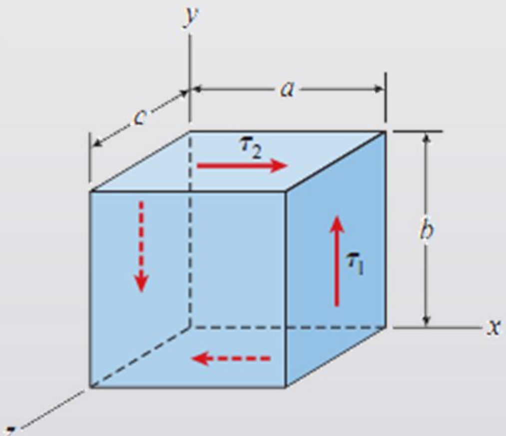
- ✓ Assume that a shear stress $\boldsymbol{\tau_1}$ is distributed uniformly over the right-hand face, which has area $\boldsymbol{bc}$.
- ✓ For equilibrium in the y direction, the total shear force $\boldsymbol{\tau_1 bc}$ acting on the right-hand face must be balanced by an equal but oppositely directed shear force on the left-hand face.
- ✓ Areas of these two faces are equal, it follows that the shear stresses on the two faces must be equal.

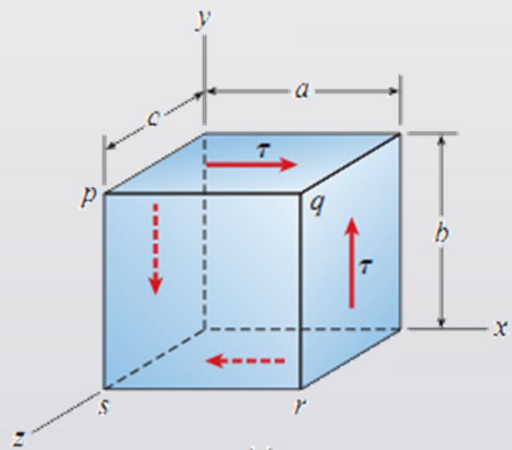


Equality of Shear Stresses on Perpendicular Planes

- ✓ The forces $\tau_1 bc$ acting on the left- and right-hand side faces a couple having a moment about the z axis of magnitude $\tau_1 abc$, acting counter-clockwise.
- ✓ Equilibrium of the element requires that this moment be balanced by an equal and opposite moment resulting from shear stresses acting on the top and bottom faces of the element.
- ✓ Let the stresses on the top and bottom faces as τ_2 , then a clockwise couple of moment $\tau_2 abc$.
- ✓ From moment equilibrium of the element about the z axis, we see that $\tau_1 abc$ equals $\tau_2 abc$,

$$\tau_1 = \tau_2$$





General Observations regarding Shear Stresses

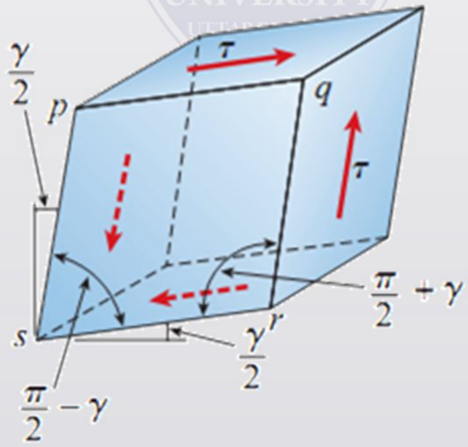
1. Shear stresses on opposite (and parallel) faces of an element are equal in magnitude and opposite in direction.
2. Shear stresses on adjacent (and perpendicular) faces of an element are equal in magnitude and have directions such that both stresses point toward, or both point away from, the line of intersection of the faces

These observations were obtained for an element subjected only to shear stresses (no normal stresses), This state of stress is called **pure shear**

For most purposes, the preceding conclusions remain valid even when normal stresses act on the faces of the element. The reason is that the normal stresses on opposite faces of a small element usually are equal in magnitude and opposite in direction; hence they do not alter the equilibrium equations used in reaching the preceding conclusions.

Shear Strain

- ✓ Shear stresses acting on an element of material are accompanied by shear strains.
- ✓ The shear stresses produce a change in the shape of the element. The original element, which is a rectangular parallelepiped, is deformed into an oblique parallelepiped, and the front and rear faces become rhomboids
- ✓ Because of this deformation, the angles between the side faces change



Sign Conventions for Shear Stresses and Strains

✓ Sign convention for shear stresses

A shear stress acting on a positive face of an element is positive if it acts in the positive direction of one of the coordinate axes and negative if it acts in the negative direction of an axis. A shear stress acting on a negative face of an element is positive if it acts in the negative direction of an axis and negative if it acts in a positive direction.

✓ Sign convention for shear strains

Shear strain in an element is positive when the angle between two positive faces (or two negative faces) is reduced. The strain is negative when the angle between two positive (or two negative) faces is increased

Hooke's Law in Shear

- ✓ The properties of a material in shear can be determined experimentally from direct-shear tests or from torsion tests.
- ✓ From shear stress-strain diagrams, we can obtain material properties such as the proportional limit, modulus of elasticity, yield stress, and ultimate stress. These properties in shear are usually about half as large as those in tension. For instance, the yield stress for structural steel in shear is 0.5 to 0.6 times the yield stress in tension.
- ✓ The initial part of the shear stress-strain diagram is a straight line through the origin, just as it is in tension. For this linearly elastic region, the shear stress and shear strain are proportional, and therefore we have the following equation for Hooke's law in shear

$$\tau = G\gamma$$

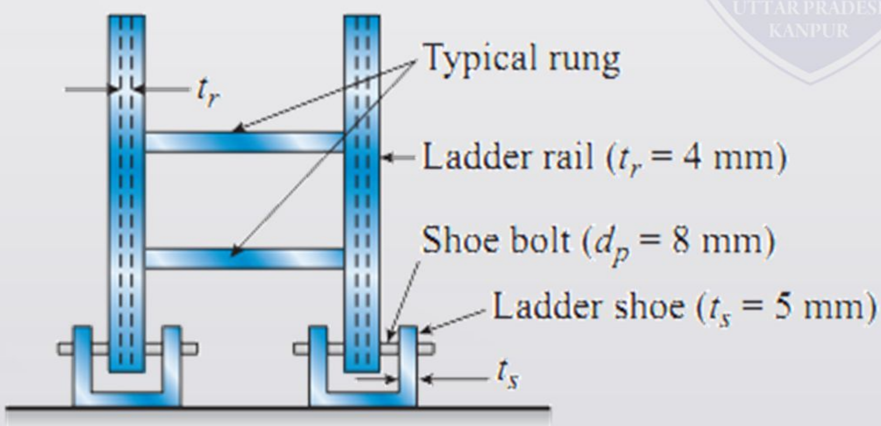
Review Questions

Q1 The inclined ladder AB supports a house painter (82 kg) at C and the self weight (q = 36 N/m) of the ladder itself. Each ladder rail (t_r = 4 mm) is supported by a shoe (t_s = 5 mm) which is attached to the ladder rail by a bolt of diameter d_p = 8 mm.

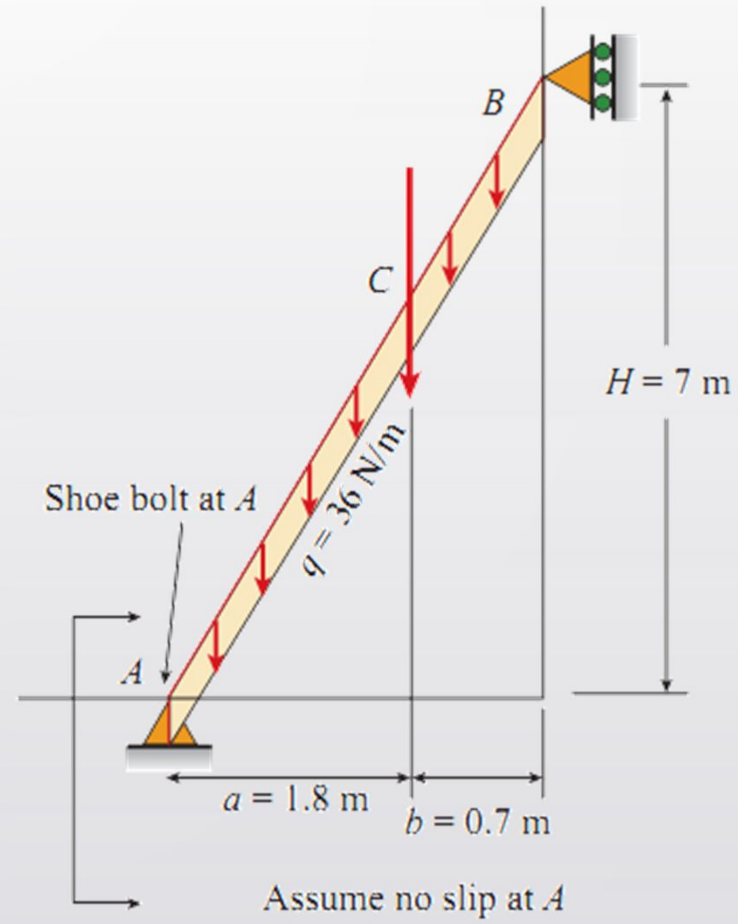
(a) Find support reactions at A and B.

(b) Find the resultant force in the shoe bolt at A.

(c) Find maximum average shear (τ) stresses in the shoe bolt at A



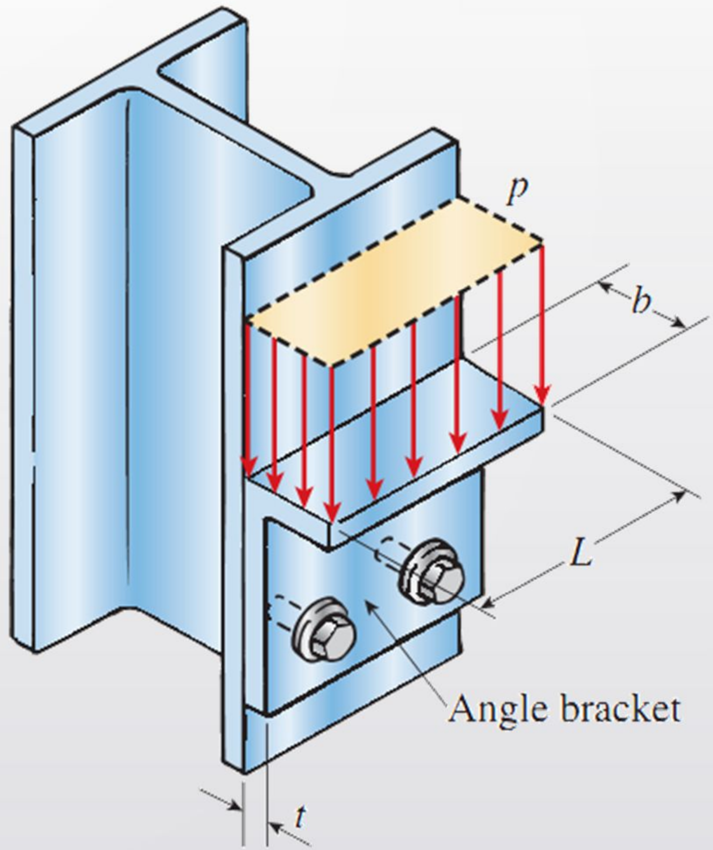
Section at base



Review Questions

1.7-1 An angle bracket having thickness $t = 19$ mm is attached to the flange of a column by two 16 mm diameter bolts (see figure). A uniformly distributed load from a floor joist acts on the top face of the bracket with a pressure $p = 1.9$ MPa. The top face of the bracket has length $L = 200$ mm and width $b = 75$ mm.

Determine the average bearing pressure σ_b between the angle bracket and the bolts and the average shear stress τ_{aver} in the bolts. (Disregard friction between the bracket and the column.)



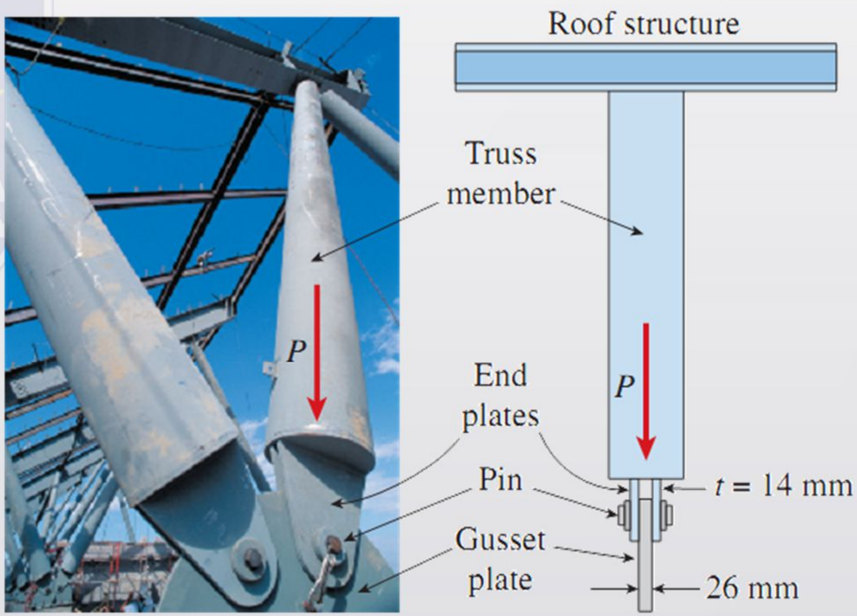
Review Questions

1.7-2 Truss members supporting a roof are connected to a 26-mm-thick gusset plate by a 22-mm diameter pin as shown in the figure and photo. The two end plates on the truss members are each 14 mm thick.

(a) If the load $P = 80$ kN, what is the largest bearing stress acting on the pin?

(b) If the ultimate shear stress for the pin is 190 MPa, what force P_{ult} is required to cause the pin to fail in shear?

(Disregard friction between the plates.)



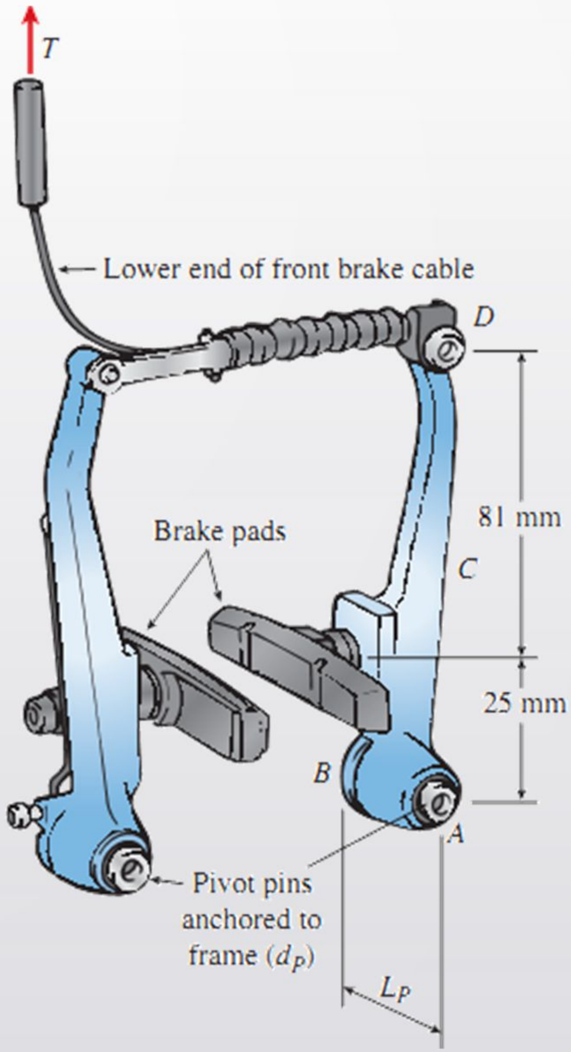
Truss members supporting a roof
(Vince Streano/Getty Images)

Review Questions

1.7-5 The force in the brake cable of the V-brake system shown in the figure is $T = 200$ N. The pivot pin at A has diameter $d_p = 6$ mm and length $L_p = 16$ mm.

Use dimensions show in the figure. Neglect the weight of the brake system.

(a) Find the average shear stress τ_{aver} in the pivot pin where it is anchored to the bicycle frame at B.

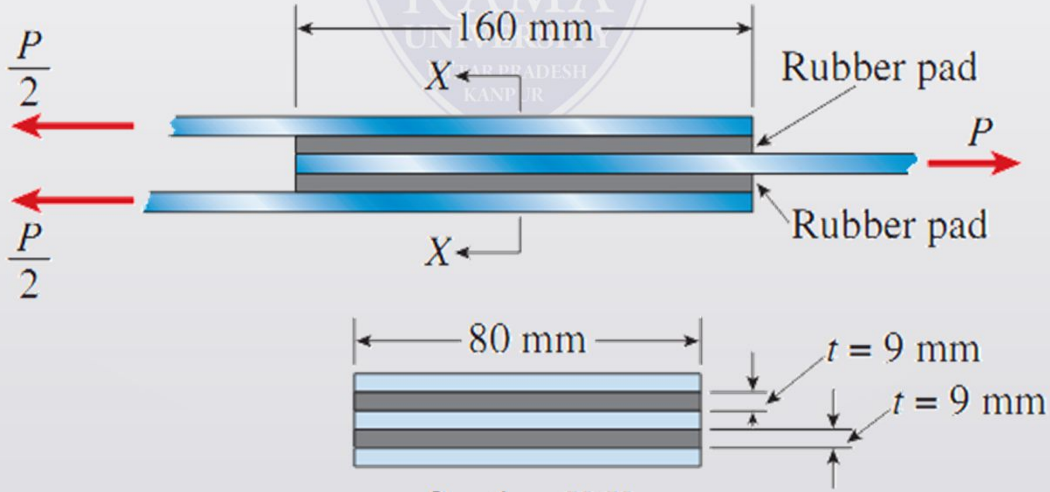


Review Questions

1.7-10 A flexible connection consisting of rubber pads (thickness $t = 9$ mm) bonded to steel plates is shown in the figure. The pads are 160 mm long and 80 mm wide.

(a) Find the average shear strain γ_{aver} in the rubber if the force $P = 16$ kN and the shear modulus for the rubber is $G = 1250$ kPa.

(b) Find the relative horizontal displacement δ between the interior plate and the outer plates.



Section X-X