AE333

Mechanics of Materials

Lecture 3 - Average Stress

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schedule

- 27 Jan - Average stress, Intro HW Due
- 29 Jan - Assessment Test
- 31 Jan - Allowable stress, Strain
- 3 Feb - Strain, Mechanical Properties

office hours

- Office hours will be TBD
- Send me an e-mail if you have a question and can't make it then
- My office is in WH 200D (inside the main AE offices in Wallace Hall)

outline

- assessment test
- stress review
- average normal stress
- average shear stress

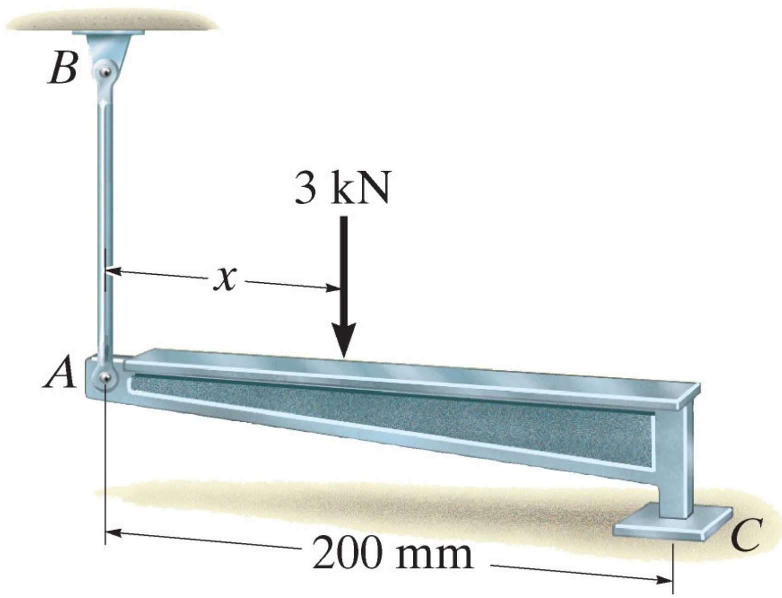
assessment test

assessment test

- 5 (multi-part) problems
- Integration of basic functions (polynomials, not trig)
- Moment with respect to an axis
- Vector addition, particle equilibrium
- Distributed loads
- Moments of inertia

review

example 1.8



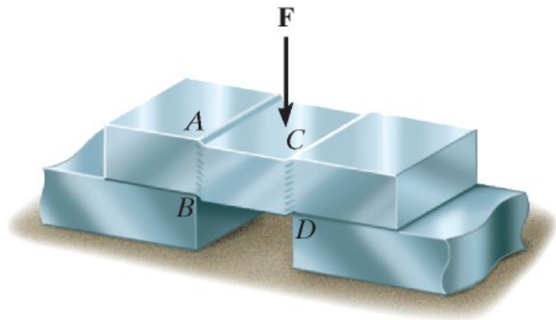
Determine the position, x, of the load so that the average compressive stress at C is equal to the average tensile stress in the rod AB. The rod has an area of 400 mm^2 and the contact at C has an area of 650 mm^2.

average shear stress

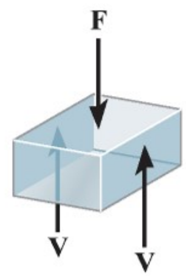
shear stress

- If we consider a section from a bridge-like structure we can demonstrate one way shear stress can be formed in a material
- As a reminder, shear stress is formed by forces acting in the plane of a section cut

shear stress



(a)



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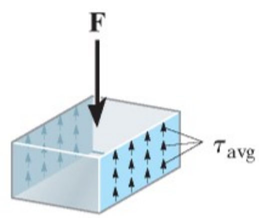
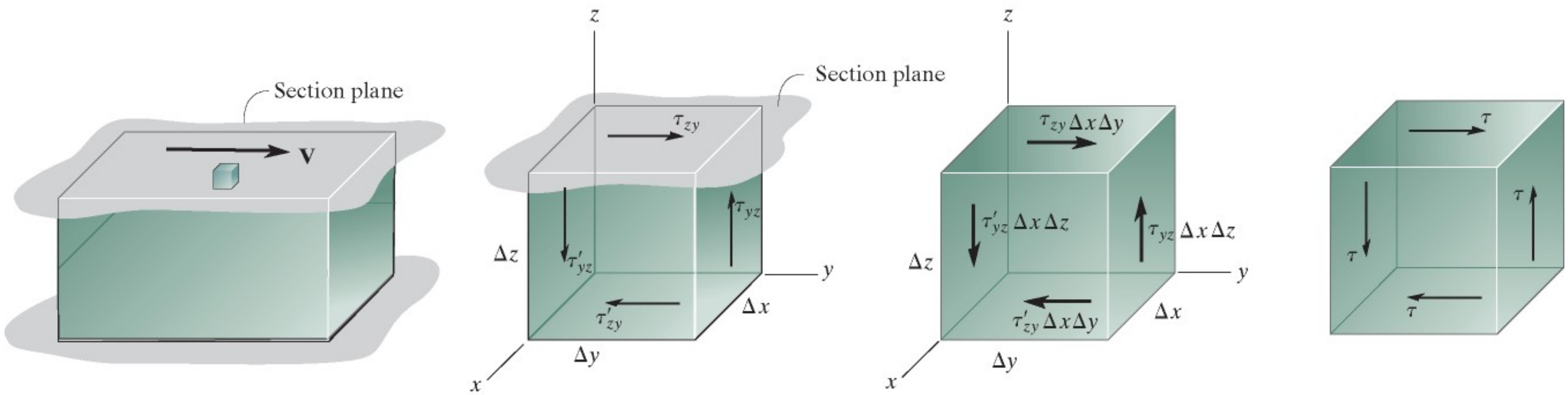


(c)

shear stress equilibrium

- If we consider equilibrium of an element subjected to shear on one face, we will find that there must be shear forces on other faces to remain in equilibrium
- In the following example, we will consider the sum of forces in the y-direction and the sum of moments about the x-axis
- We can convert between stresses and forces by recalling that $\sigma = F/A$, or $F = \sigma A$

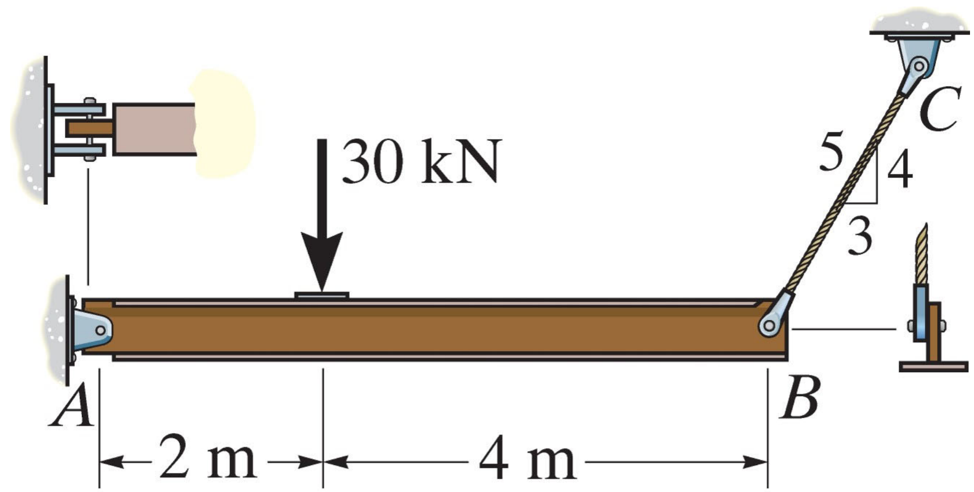
shear stress equilibrium



Free-body diagram

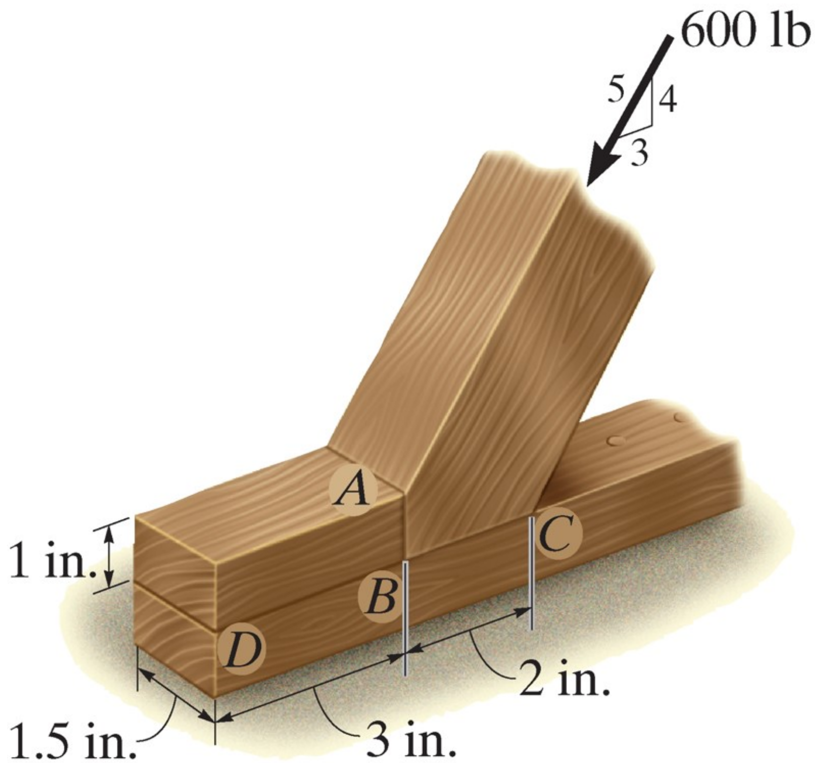
Pure shear

example 1-9



Determine the average shear stress in the 20-mm diameter pin at A and the 30-mm diameter pin at B.

example 1-11



Determine the average compressive stress along the smooth contact of AB and BC and the average shear stress along the horizontal plane DB.

allowable stress design

allowable stress

- Most of the time, we design structures so the stress is less than some limit
- By setting a conservative allowable stress, we account for some manufacturing tolerances, unintended loads, and variability in mechanical properties

factor of safety

- The factor of safety is the failure load divided by the allowable load

$$FS = \frac{F_{fail}}{F_{allow}}$$

- Since load and stress are linearly proportional, we could also define the factor of safety in terms of stress and it would be identical

factor of safety

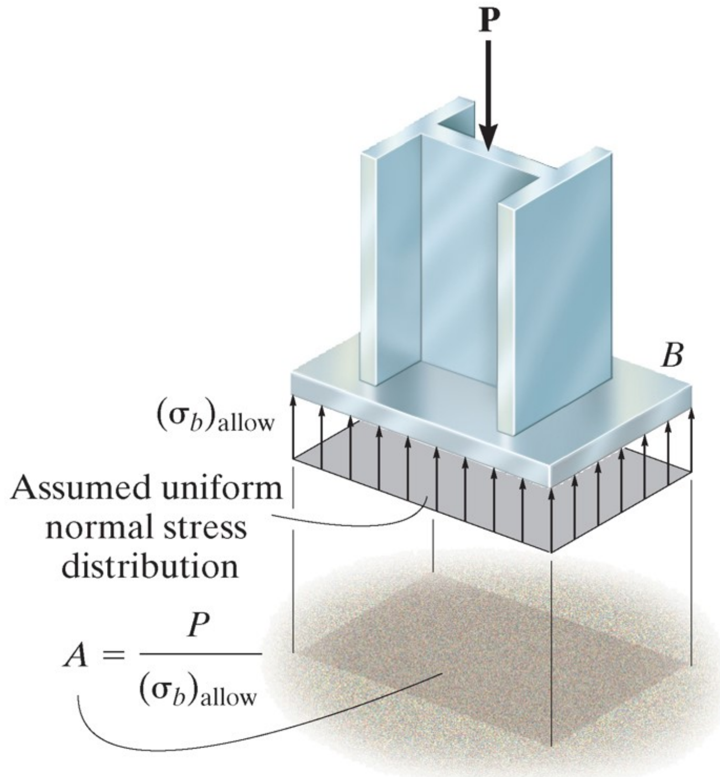
- Typical values for the factor of safety will vary based on application
- Aircraft and space vehicles might have a factor close to 1 to minimize weight
- Nuclear power plants might have a factor close to 3 since weight is not as important and failure would be catastrophic

simple connections

- We can rearrange the equations $\sigma = N/A$ and $\tau = V/A$ to size components based on some allowable stress

$$A = \frac{N}{\sigma_{allow}}$$
$$A = \frac{V}{\tau_{allow}}$$

bearing stress

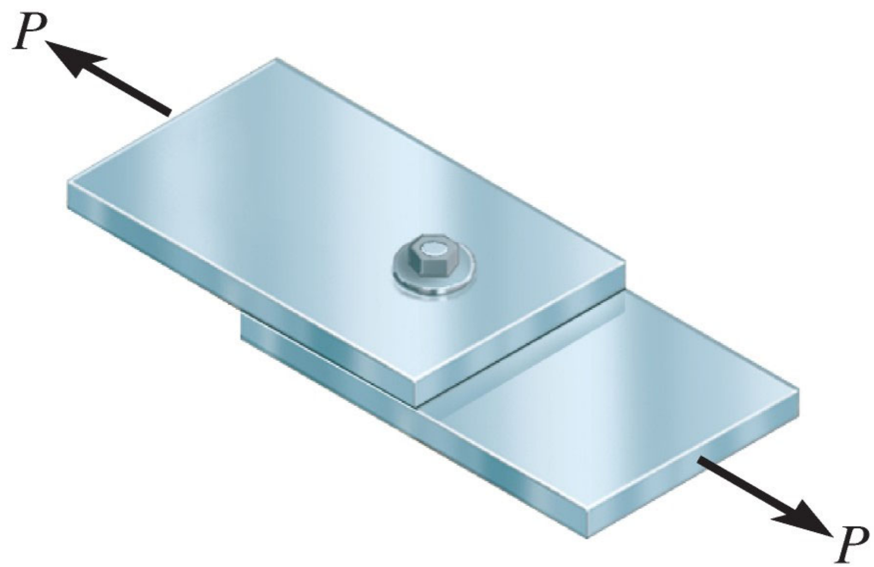


The area of the column base plate B is determined from the allowable bearing stress for the concrete.

embedded shear stress

The embedded length l of this rod in concrete can be determined using the allowable shear stress of the bonding glue.

lap joint shear



The area of the bolt for this lap joint is determined from the shear stress, which is largest between the plates.

limit state design

limit state design

- Allowable stress design accounts for uncertainty in the applied loading and the material properties in one factor of safety
- Limit state design separates these two into load and resistance factors

load factors

- The load factor combines uncertainty in various types of load
- For example, a building can have loading from a few different sources, such as its own weight, people in the building, and snow on top of the building
- Weight is considered a “dead load” and can usually be determined more precisely than moving things like people

load factors

- In this simple example, we consider a load factor, $\gamma_D = 1.2$ for the dead load, $\gamma_L = 1.6$ and $\gamma_S = 0.5$

$$R = 1.2D + 1.6L + 0.5S$$

- These load factors combine the concept of a safety factor with the probability that loads will occur

resistance factors

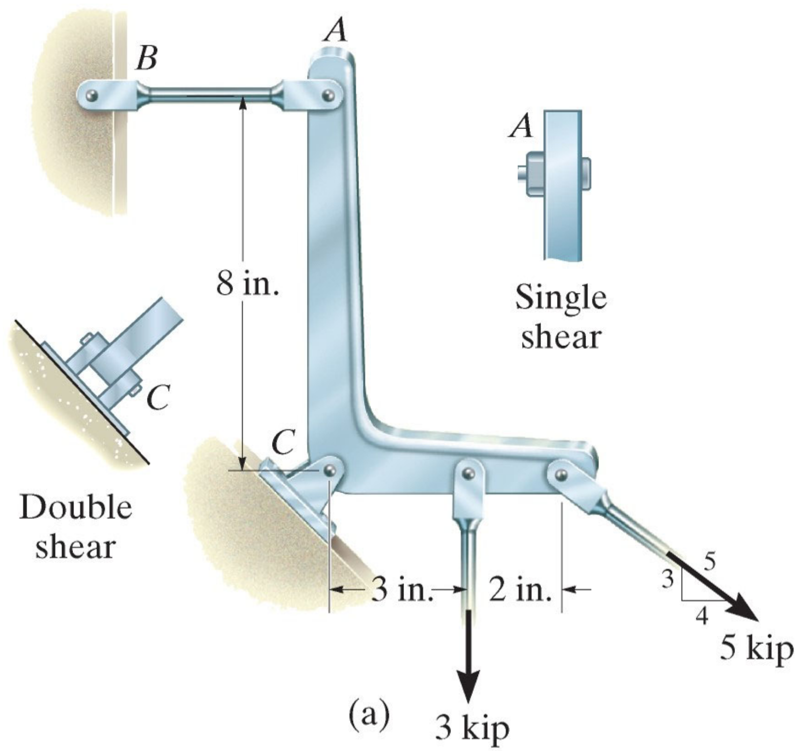
- Resistance factors, ϕ are used to express the probability a material will fail at its limit load
- If we are very confident in the failure stress of a material (i.e. steel has little variability), we might use $\phi = 0.9$
- If we are not as confident, (using a new material, or an organic material like wood with higher variability), we might use $\phi = 0.7$

design criteria

- If we call the nominal load P, then we can combine load and resistance factors using

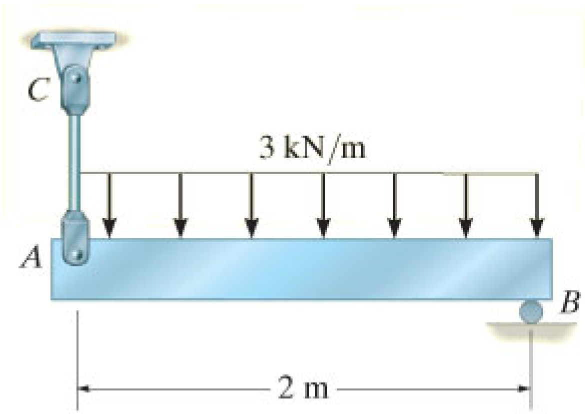
$$\phi P \geq R$$

example 1-12



Determine to the nearest 1/4" the diameters of steel pins at A and C if the factor of safety in shear is 1.5 and the failure shear stress is 12 ksi.

example 1-15



(a)

The 400 kg uniform bar, AB is supported by a steel rod AC and a roller at B. If it supports a live distributed loading, determine the required diameter of the rod. Use $\sigma_{fail} = 345$ MPa with $\phi = 0.9$, $\gamma_D = 1.2$, and $\gamma_L = 1.6$