Lecture 7, Sep 27, 2021

Safety

- Types of forces
  1. Dead loads – Things that can't move – e.g. self-weight, added features (e.g. asphalt on a suspension bridge, chairs in this lecture hall, often called *superimposed* dead loads)
     - Generally well-known during design, low-uncertainty
  2. Live loads – Things that can move – e.g. cars, people, wind
     - Generally more uncertain and unpredictable
     - To design for these, we look for worst cases
- Once we know the types of load, we make a best guess
  - For some things we take the average, e.g. cars

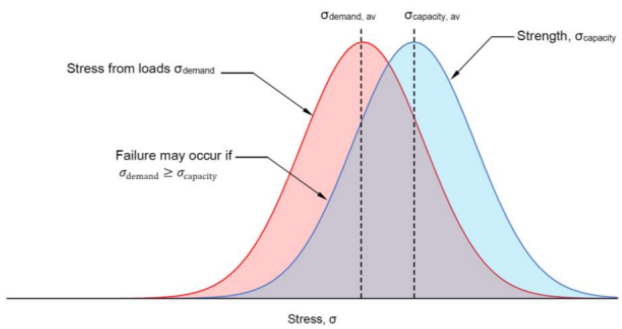

Figure 1: probablity distribution of stress

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- The basic safety equation: $\sigma_{demand} < \sigma_{capacity}$, i.e. your structure should be able to handle more stress than demanded
  - This just tells you whether the structure will fall down, not whether it is safe
  - $\sigma_{capacity}$: Yield or ultimate strength?
    * Generally if we have a yield strength σ_y, we should use that, because the ultimate strength of e.g. steel is hard to measure and uncertain
  - Stress demand and capacity usually follow a normal distribution (bell curve); there might be structural imperfections leading to uncertainties in dead loads, and material imperfections might lead to uncertainties in stress capacity
    * This means that even if the average σ_{demand} is greater than the average $\sigma_{capacity}$, they might still overlap
    * The overlap is where the uncertainties make the stress demand greater than the capacity and so the structure fails
    * We want to minimize this overlap but it is not possible to make this zero (size of overlap is related to *risk* of failure)
- A safe structure has $\sigma_{demand} < \sigma_{capacity}$ and a low risk of it being otherwise
- 2 ways to deal with risk:
  1. Limit states design (very complicated and an entire course on its own)
  2. Allowable stress design (this course), aka working stress design
     - Key concept: Factor of Safety FoS $= \dfrac{\sigma_{capacity}}{\sigma_{demand}}$
       * If this number is less than 1, it will fall down
       * If this number is greater than "some specified number", then it is safe

    - This "some specified number" can be determined using limit states design
    - In the 1800s this would be 3-10 based on consequences for failure and warning (e.g. for ductile metals like steel the FoS can be lower since there is a lot of warning before it fails)
    - In the 1960s FoS of 2 is typical
    - Today, with more control on the materials, the FoS is typically about 1.7
    - e.g. The Brooklyn bridge built in the 1980s has an FoS of 5, the Golden Gate bridge has 2.68, the Akashi Kaikyo bridge has 2.25; numbers go down over time because materials are more well understood and uncertainties decrease

- Allowable stress: $\frac{\sigma_y}{\text{FoS}}$ and this is the amount of stress that the structure is allowed to take
  - In this class the FoS will be given