Lecture 15, Oct 18, 2021

Design Process for Trusses

1. Determine loading
2. Determine joint forces
3. Solve for forces in the truss (method of joints or method of sections)
4. Select the **size** and **safety** of the members

Design of Tension Members

- Structures are designed according to the yield instead of the ultimate strength, since the savings are not worth the risks and large deformations are undesirable
- An appropriate FoS for yield is 2.0, with most steel having a $\sigma_y = 350\text{MPa}$
- Second moments of area don't need to be considered for tension members since they cannot buckle

Design of Compression Members

- To prevent crushing/squashing, the same FoS and design process for tension members can be used
- To prevent buckling, a higher FoS of 3.0 is used because bucking is more dangerous
  - Buckling occurs more suddenly and is more unstable so the consequences are greater
  - Post-bucking strength can be 0, unlike post-yielding strength which is greater than the yield strength
  - If a member must carry a compressive force F, then $P_e = \dfrac{\pi^2 EI}{L^2} \implies I = \dfrac{P_e L^2}{\pi^2 E} \implies I \geq 3.0\dfrac{FL^2}{\pi^2 E}$
- Unlike the yield stress, the Euler buckling stress $\sigma_e = \dfrac{P_e}{A} = \dfrac{\pi^2 EI}{AL^2}$ does depend on the length of the member and is not a material property
  - If we set the *radius of gyration* $r = \sqrt{\dfrac{I}{A}}$, then $\sigma_e = \dfrac{\pi^2 EI}{AL^2} = \dfrac{\pi^2 E}{L^2}\dfrac{I}{A} = \dfrac{\pi^2 E}{L^2}r^2 = \dfrac{\pi^2 E}{\left(\frac{L}{r}\right)^2}$
  - $\dfrac{L}{r}$ is the *slenderness ratio*, a dimensionless quantity that describes how easy the member buckles; members with larger values tend to buckle instead of squash
    - Larger values means that σ_e is smaller, so the stress required to cause buckling is smaller so buckling is more likely
  - The radius of gyration is not a physical quantity and does not actually correspond to a circle
    - Since I is a property that affects the flexural stiffness of a member and A affects the axial stiffness, the radius of gyration is a ratio of a member's flexural stiffness to its axial stiffness
    - If a member is more easily bent than stretched/compressed (low flexural stiffness, high axial stiffness), then r will be small, which means the slenderness ratio is large and the member is more likely to buckle
    - If we had 2 point areas, both $\dfrac{A}{2}$, with a distance between $2r$ between them, and this had the same moment of inertia as the member, the r is the radius of gyration
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- For low slenderness ratios σ_e is very high so the member fails at its yield strength; for large slenderness ratios σ_e decreases rapidly so the member fails at a fraction of its yield strength
- The red curve is the failure stress of the member, also known as the *failure envelope*
- The blue curve instead considers the minimum of the allowable yield stress and buckling stress and is the one we should design for
- Under the blue curve is safe, between blue and red is unsafe but won't fail, and outside red will fail

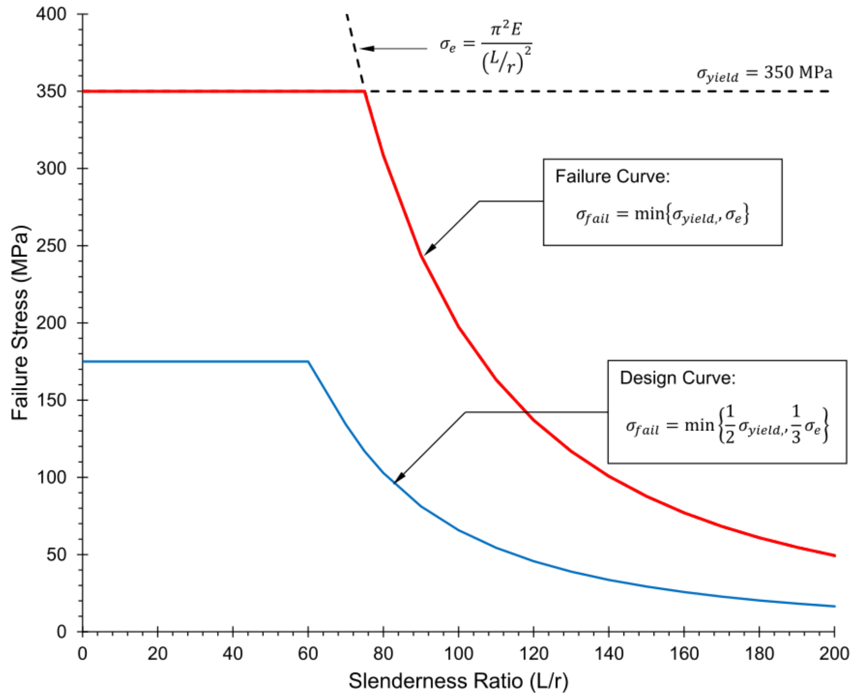

Figure 1: Plot of failure stress against slenderness ratio

- Modern design codes also limit the slenderness ratio (often to 200) to discourage the use of very slender members that are vulnerable to unexpected load changes; $\frac{L}{r} \leq 200 \implies r \geq \frac{L}{200}$

Hollow Structural Sections (HSS)

- HSS are hollow steel tubes formed by rolling sheets of steel and come in square, rectangular, or circular cross sections; they are light, strong and stiff and often used for truss design
- HSS are strong, stiff, and light
- Height, width and thickness are the key geometric properties for HSS

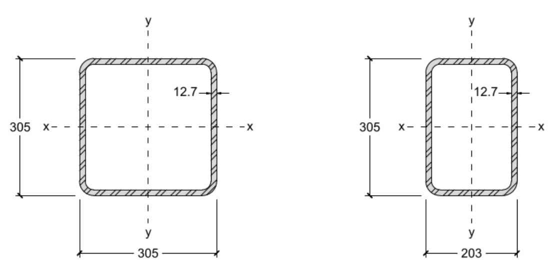

Fig. 15.2 – HSS 305x305x13 (left) and HSS 305x203x13 (right). All dimensions in mm.

Figure 2: HSS

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- The *designation* of an HSS (the nominal dimensions) is different than the size (the actual dimensions);

in reality HSS 305x203x13 will have a wall thickness of 12.7mm, not 13mm, because imperial vs metric units

- Typically one HSS size is chosen for the entire top chord or bottom chord of a bridge; the web members (which are smaller than the chords so they can connect together) can be individually sized to their loads