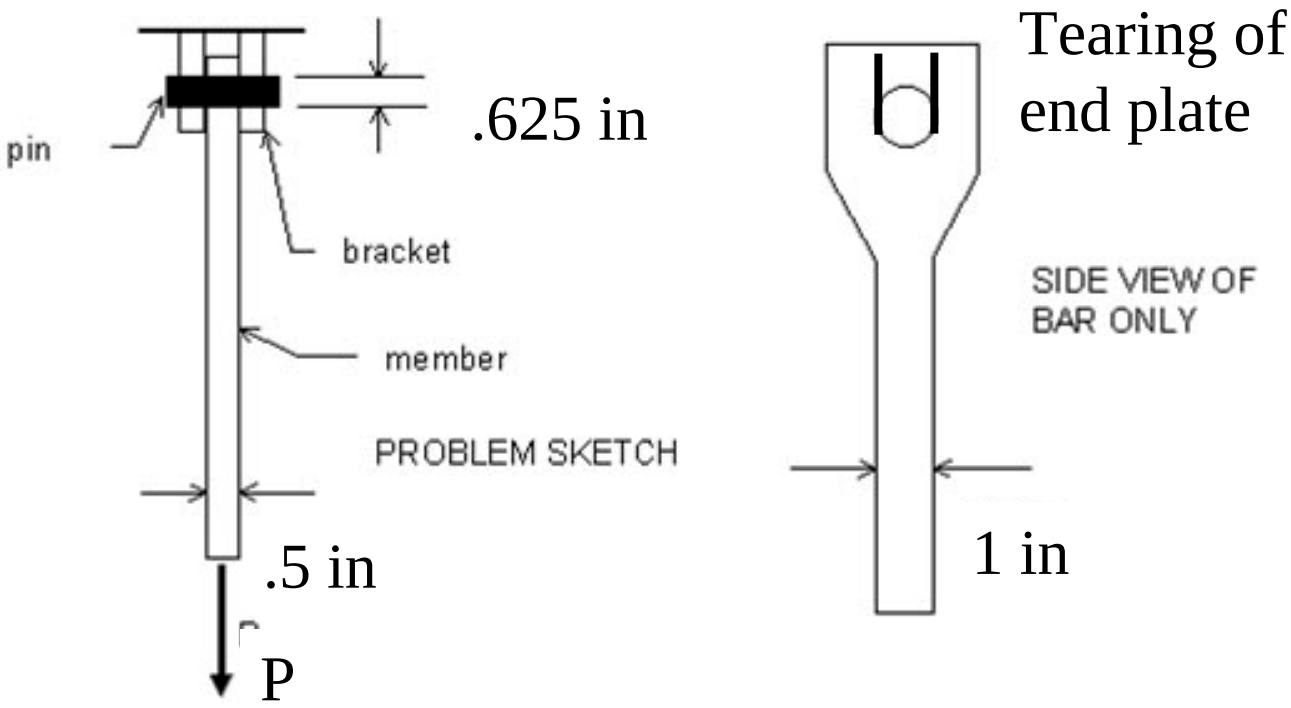
Structural Failure

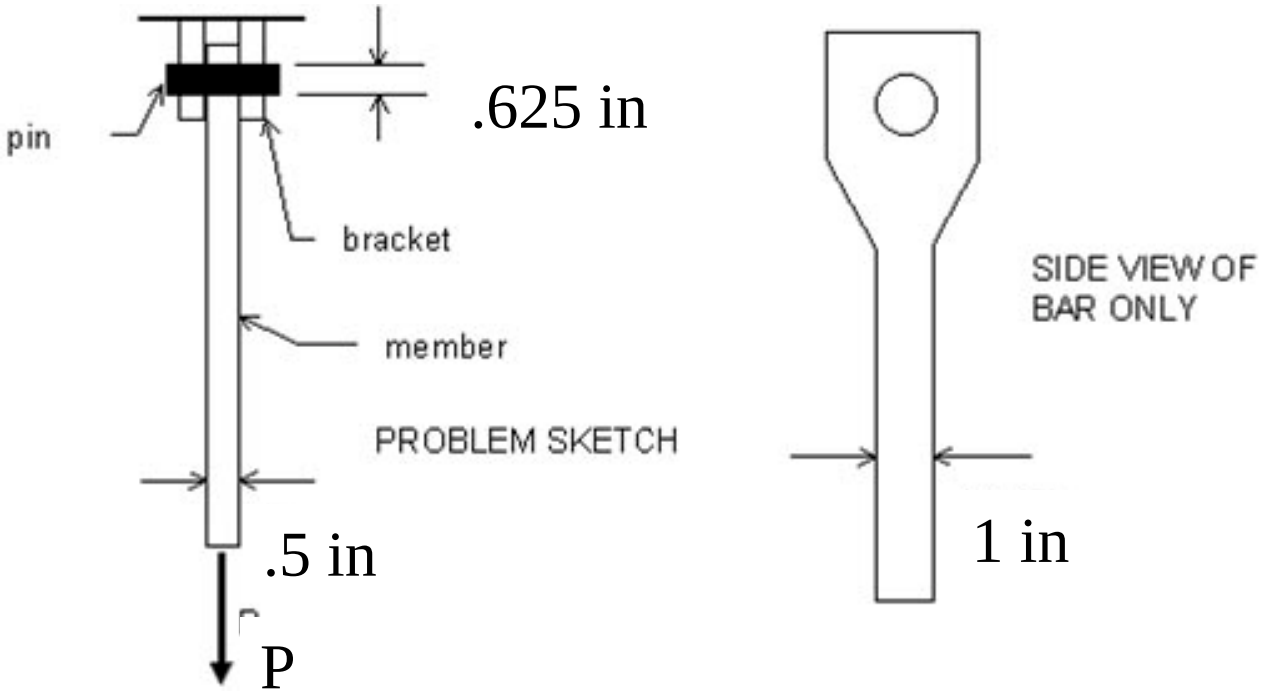
- Be clear in the function of the connection
  - What loads does it have to resist?
- How could it fail?
- Will it be easy to maintain in the future?

Example problem



- **Other modes of failure?**

Example problem



- **Conclusion: Even the simplest connections can fail in many ways**

Four-Legged Stool Example

Now imagine the load is increased to cause failure

When load is 270 lbs, the two legs will begin to fail

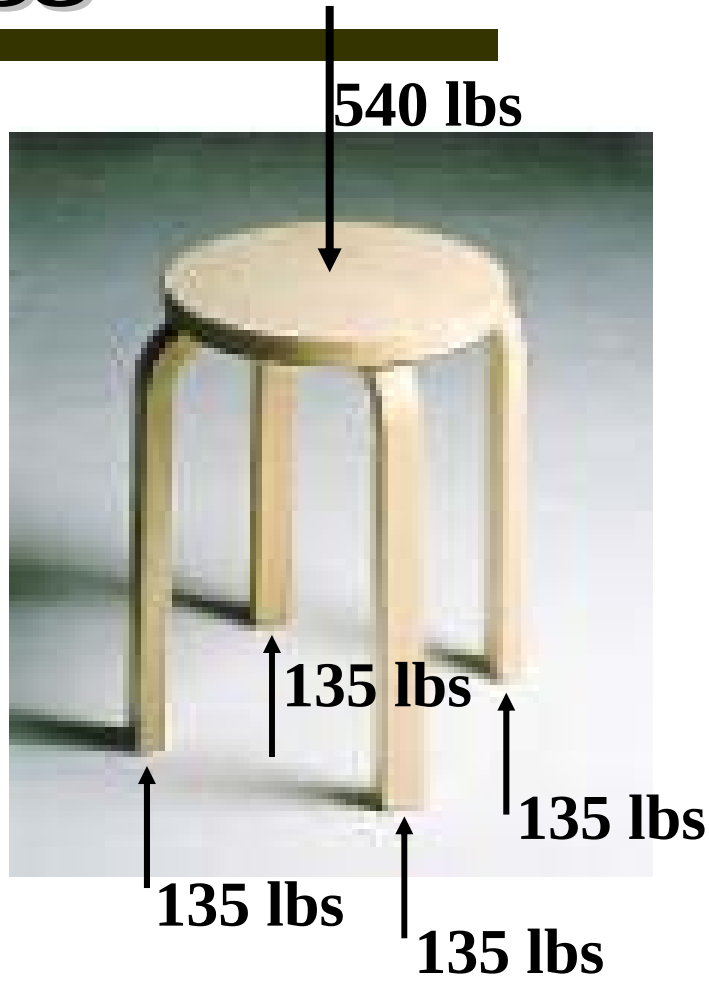
As they "squash," the other two legs will start to carry load also

Collapse of a 4-Legged Stool

At final collapse state, all four legs carry 135 pounds and the stool carries 540 pounds.

This occurs only if the structure is ductile (ie, if the legs can "squash")

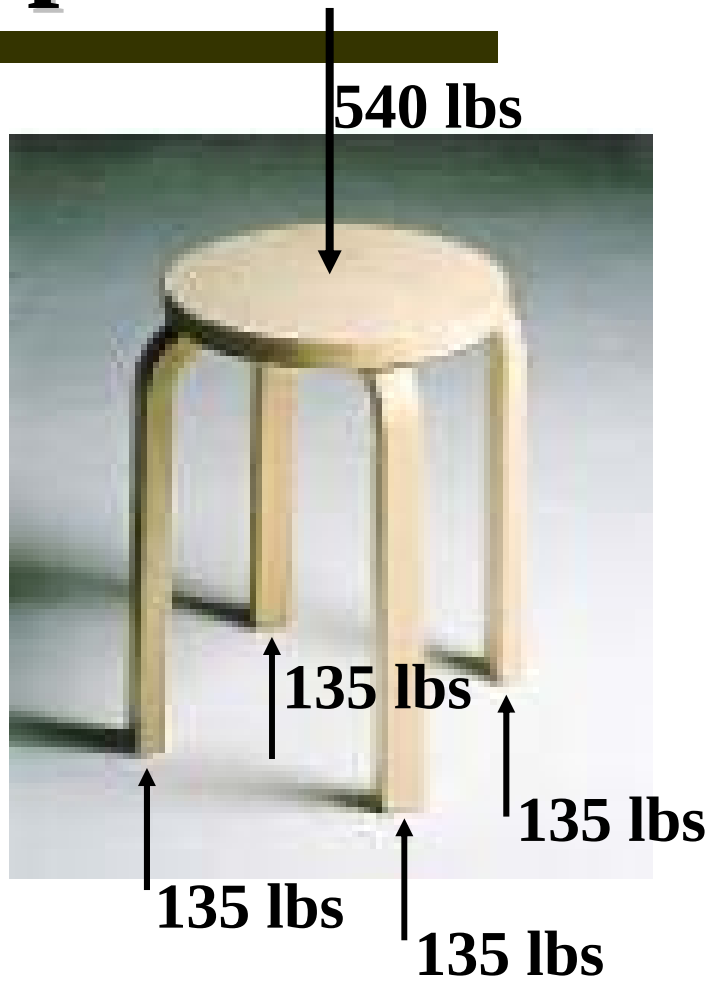
Is NOT valid if buckling occurs, because one leg will fail suddenly



Ductile Collapse

So small imperfections do not matter, as long as the structural elements are ductile

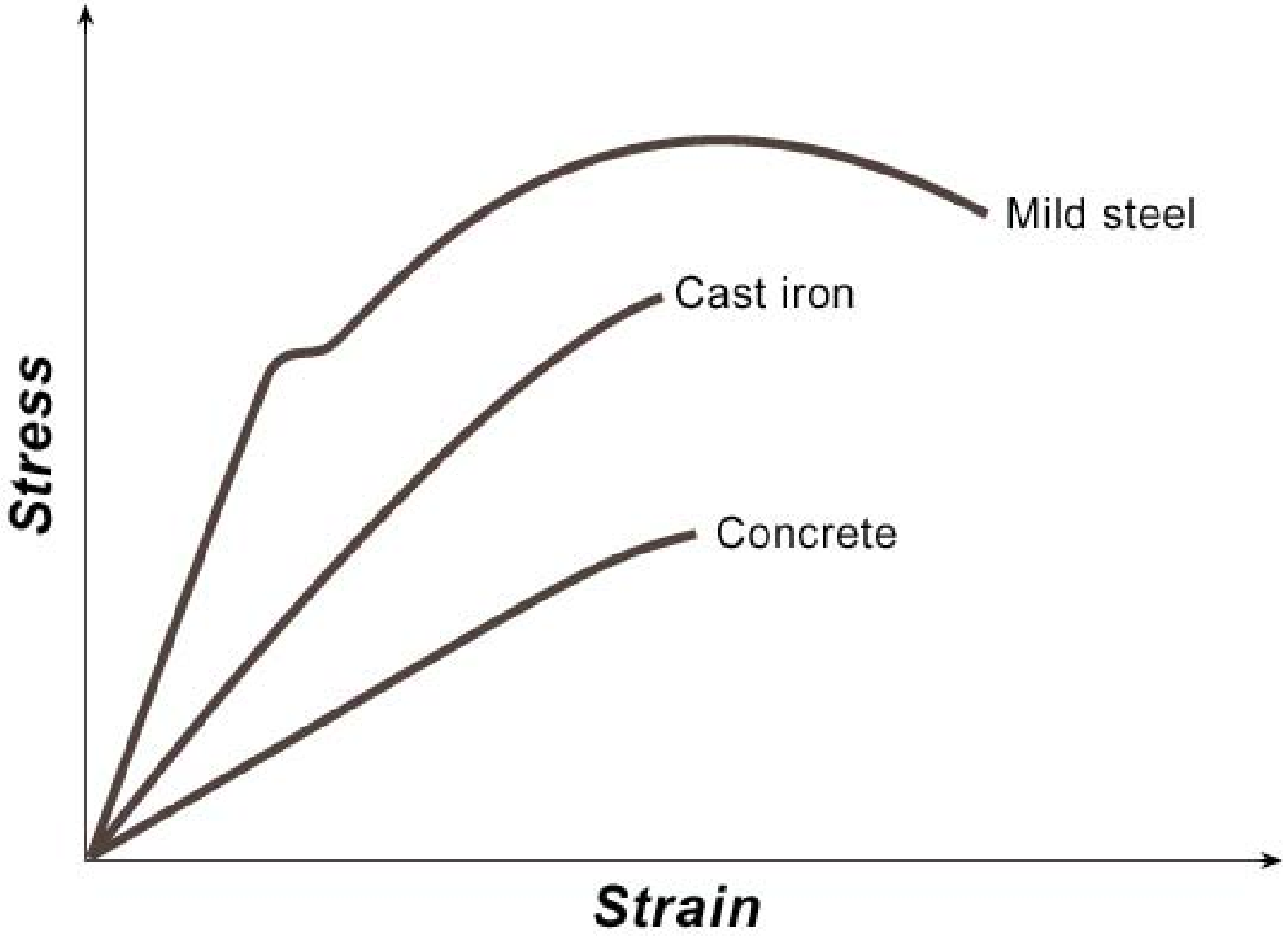
The forces in a hyperstatic structure cannot be known exactly, but this is not important as long as we can predict a ductile collapse state



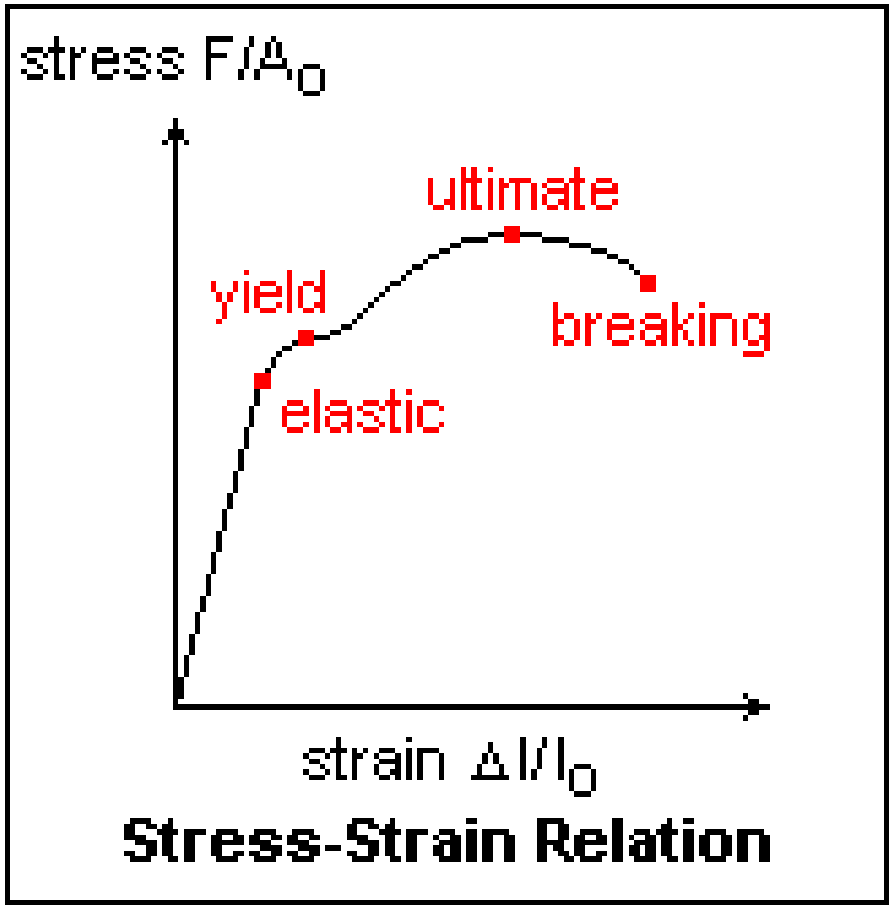
Why is steel a good structural material?

- High strength
- Ductile material

Ductility of Steel



Yield Stress of Steel



Failure of Independent Elements

- **Tension element: breaking stress exceeded**
- **Compression element:**
  - **Crushing stress exceeded**
  - **Buckling occurs**
- **Truss:**
  - **Statically determinate: one element fails**
  - **Indeterminate to *n* degrees: *n* elements fail**
- **Beam:**
  - **Either flange fails in compression or tension will form a hinge (Indeterminate to *n* degree: *n* hinges form)**
  - **Shear failure**

Parallel Axis Theorem

- **To calculate the moment of inertia, I, of a built-up section with respect to an axis other than its centroid:**

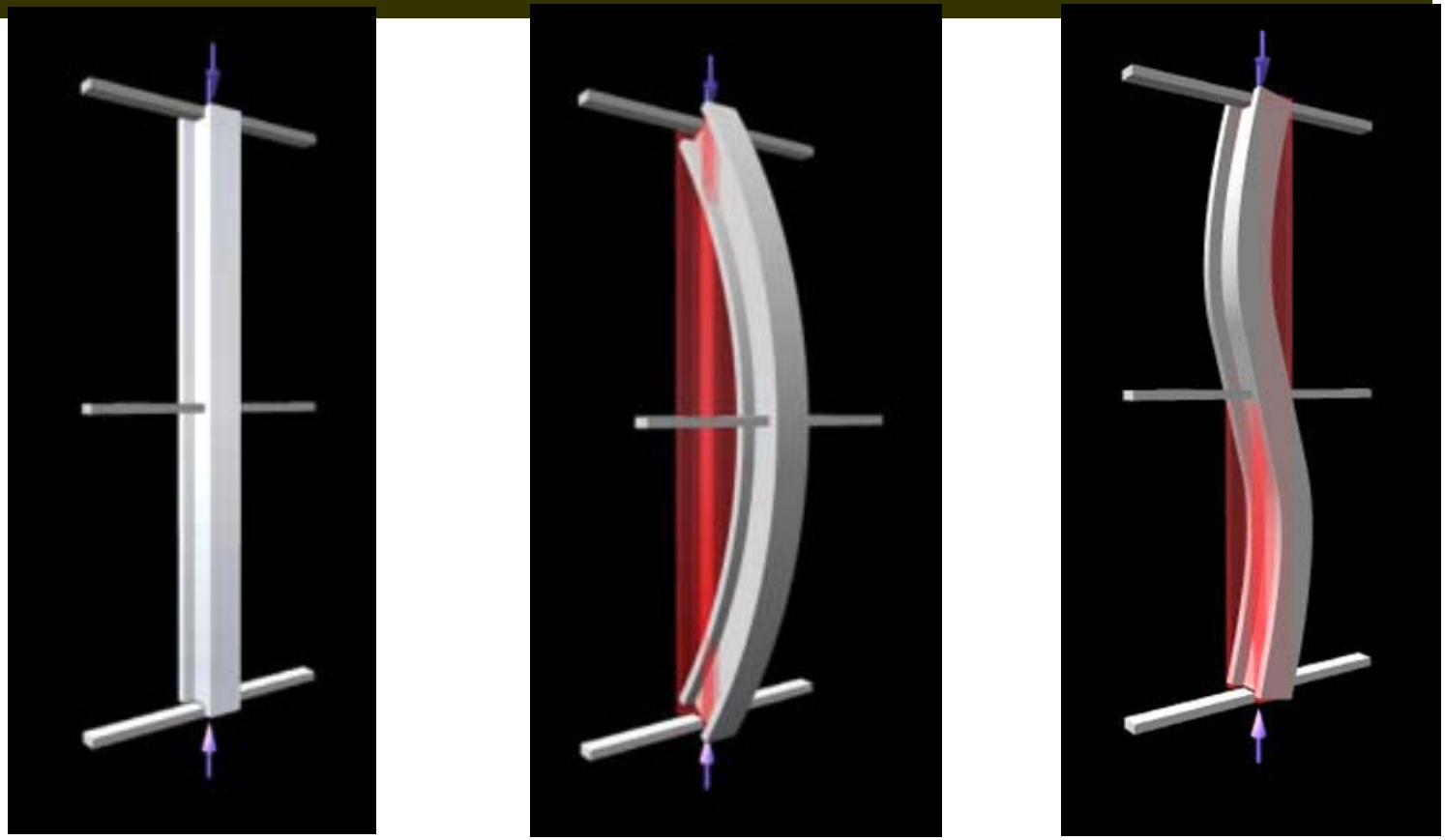
$$I = \Sigma I + \Sigma A d^2$$

Where:

A is the area of the segment

d is the distance from the centroid of the area to the axis being considered

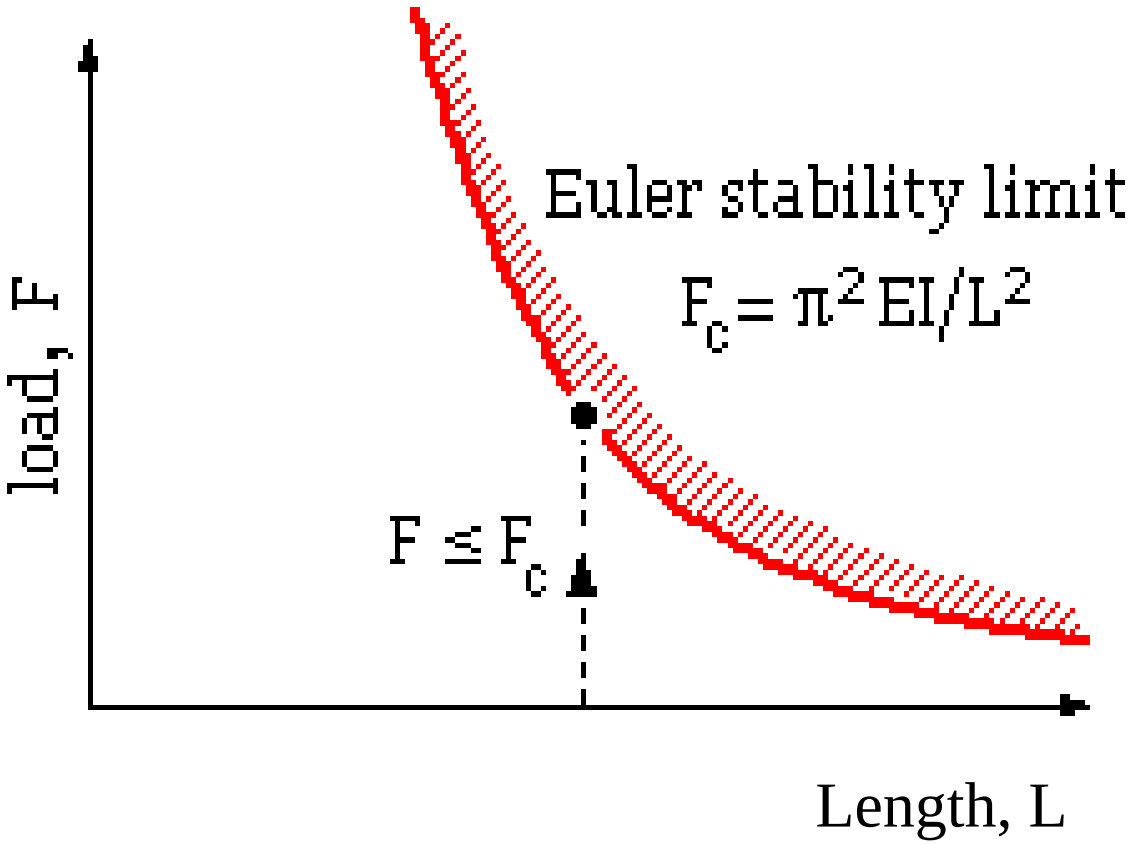
Buckling About a Different Axis



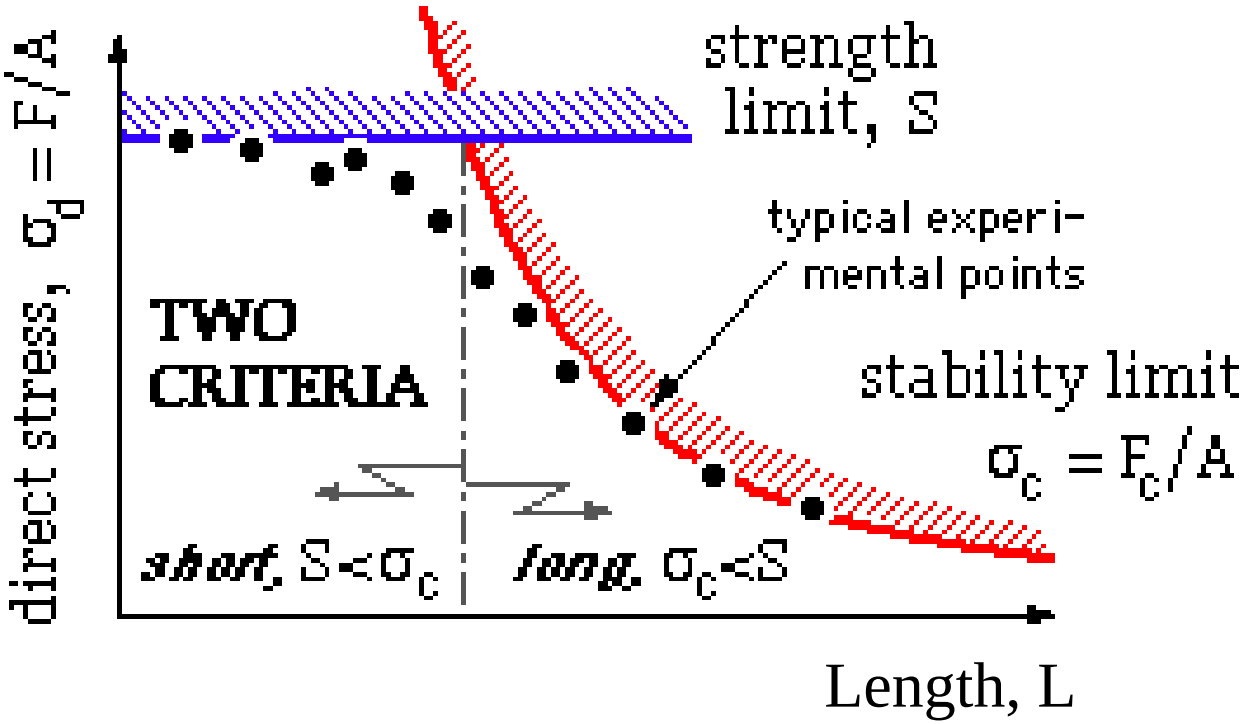
Unbuckled **Strong axis** **Weak axis**

Must brace columns against weak axis buckling

Buckling Load vs. Length of Column



Failure of Compression Members



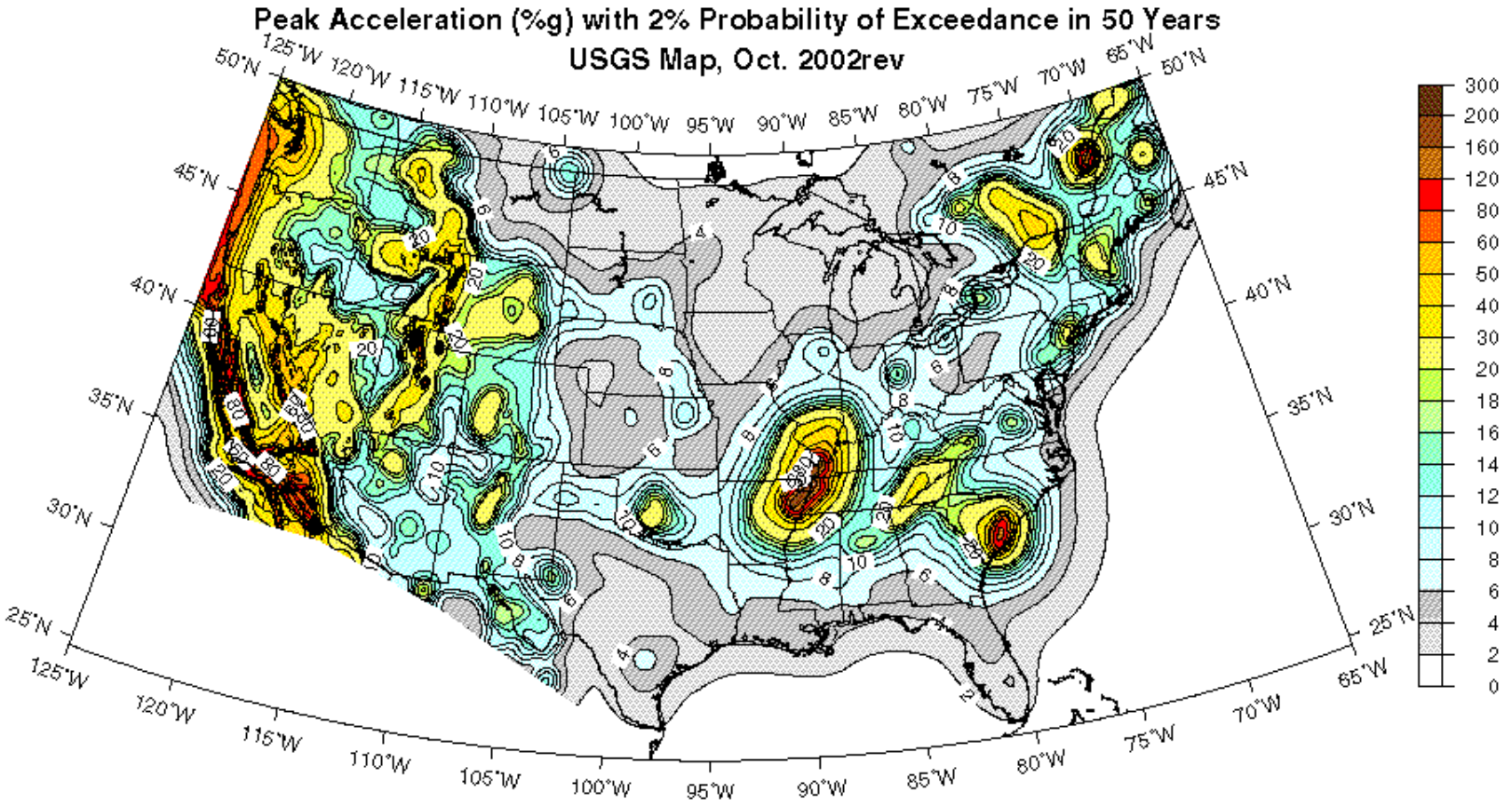
Failure by buckling or crushing
Reality may be in between the two modes

Importance of Ductility

- **Large displacements before collapse (as opposed to a *brittle* material, which fails suddenly)**

- **Energy dissipation as the steel yields (important for resisting earthquakes and other overloading)**

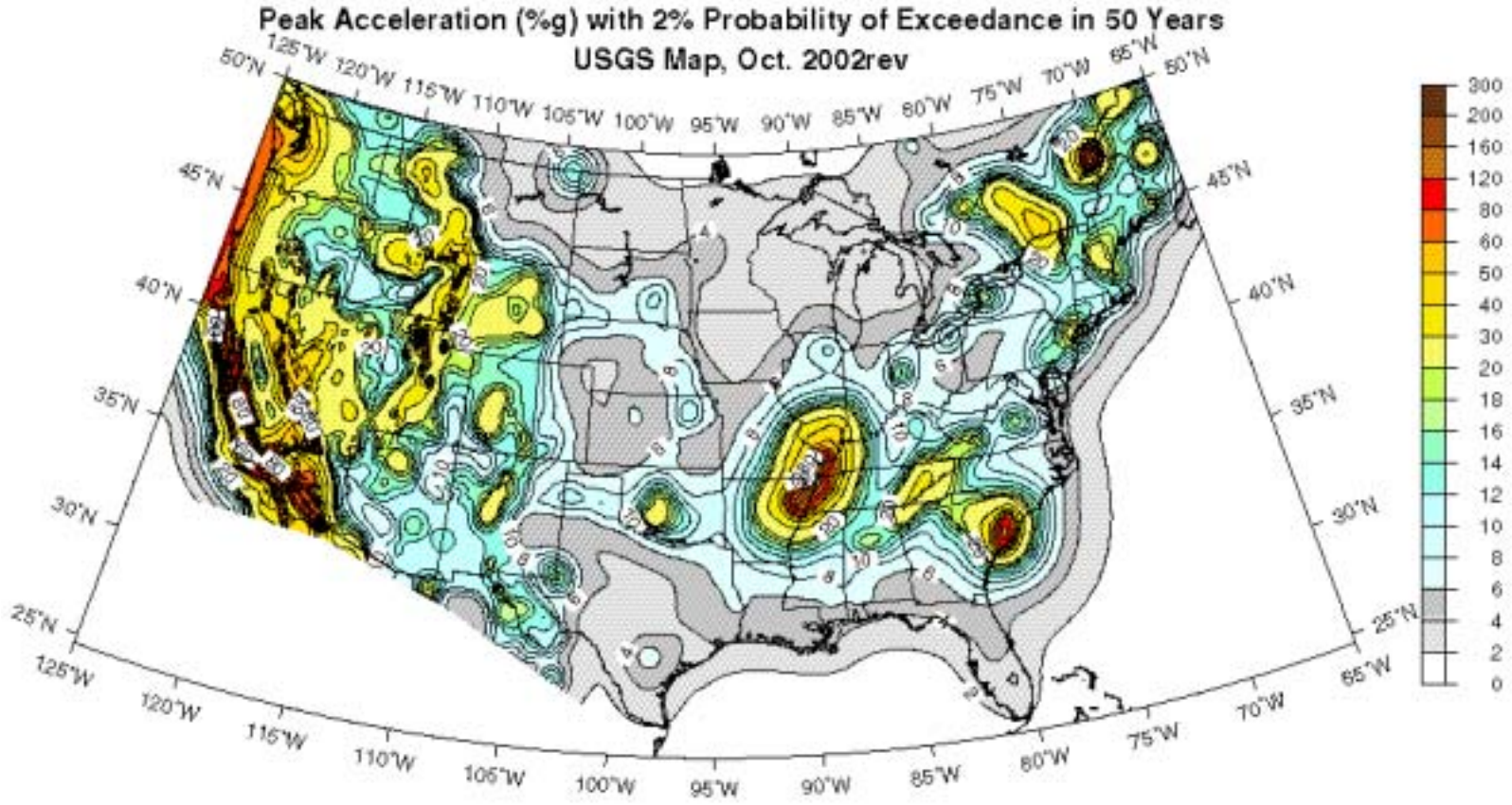
Is there a danger of earthquakes in Boston and other East Coast cities?



US Seismicity

Which state in the mainland US has had the largest earthquake?

US Seismicity



Missouri: 8.2 in New Madrid, MO, 1812

Increased Earthquake Risk

- Growing cities and infrastructure
- Many existing buildings are untested in a major earthquake
- Earthquakes are not dangerous, but our infrastructure is dangerous

Structural Failures

- **How could it fail? What is the weak link in the system?**
- **Buckling is difficult to predict due to sensitivity of the parameters**
- **Some failure modes are *combined* modes, i.e., local crushing can lead to global buckling**