ENCE 353: An Overview of Structural Analysis and Design: Part 2

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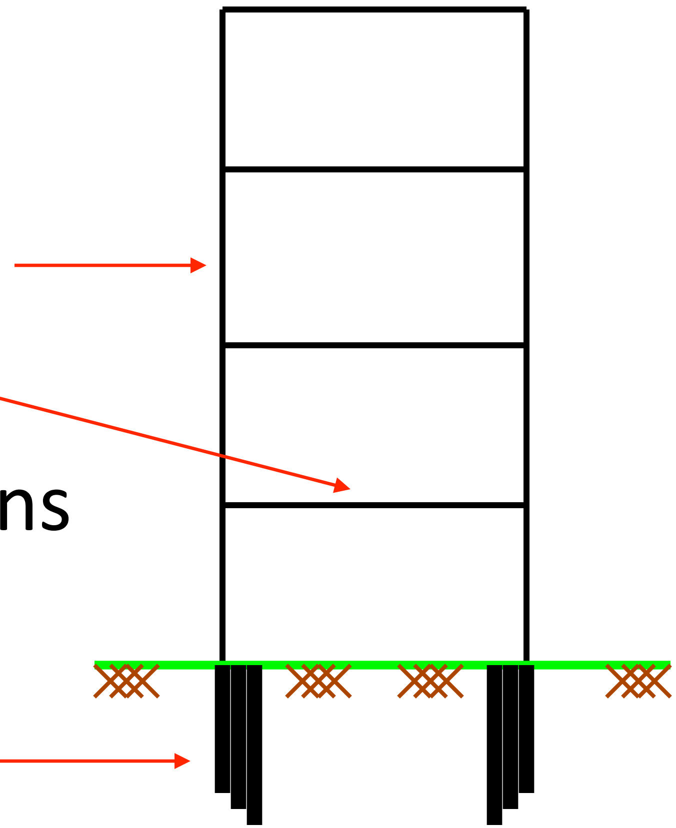
Fall Semester 2020

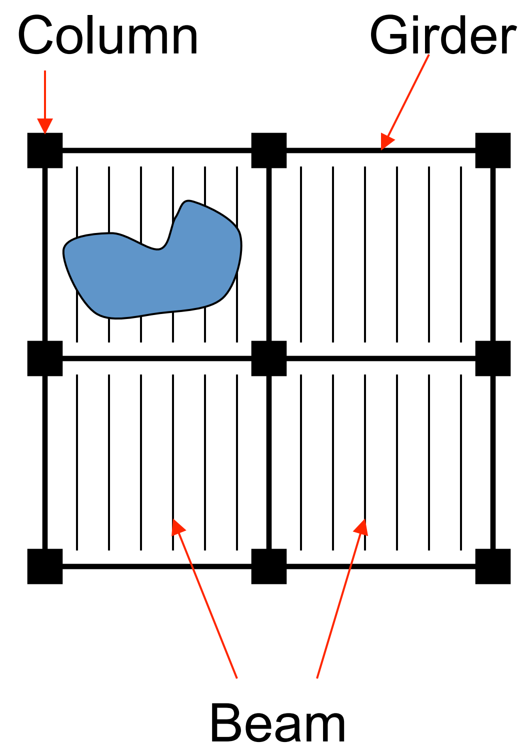
Outline

- Objectives of Structural Engineering
- A little history
- Structural Engineering Process
- Types of loads
- Types of structures
- Civil Engineering Materials
- Load paths in structures
- How can structures fail?
- Summary

Structural Components

- Beams
- Girders
- Columns
- Floors
- Foundations





Load Path

- Floor

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- Beams

  ↓

- Girders

  ↓

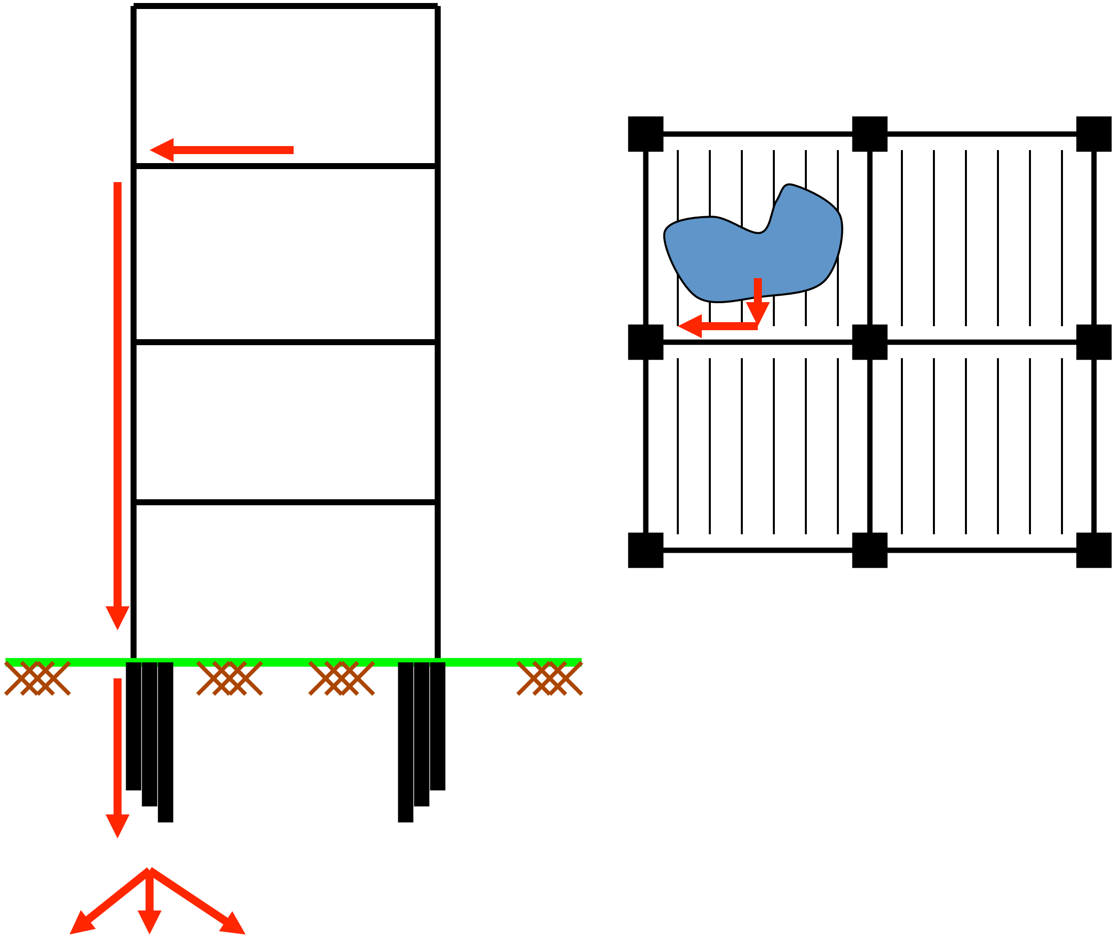
- Columns

  ↓

- Foundation

  ↓

- Soil/Bedrock



Overview of Structural Behavior

Depends on:

- Material properties (e.g., steel, concrete).
- Structural stiffness (e.g. axial stiffness, bending stiffness)
- Structural strength (e.g., ultimate member strength).

Design challenges (many tradeoffs to consider):

- If the structural stiffness is too low, then the displacements will be too large,
- In dynamics applications a high structural stiffness may attract high inertia forces.
- If the structural strength is too low, then the structural system may fail prematurely.

Engineering Properties of Materials

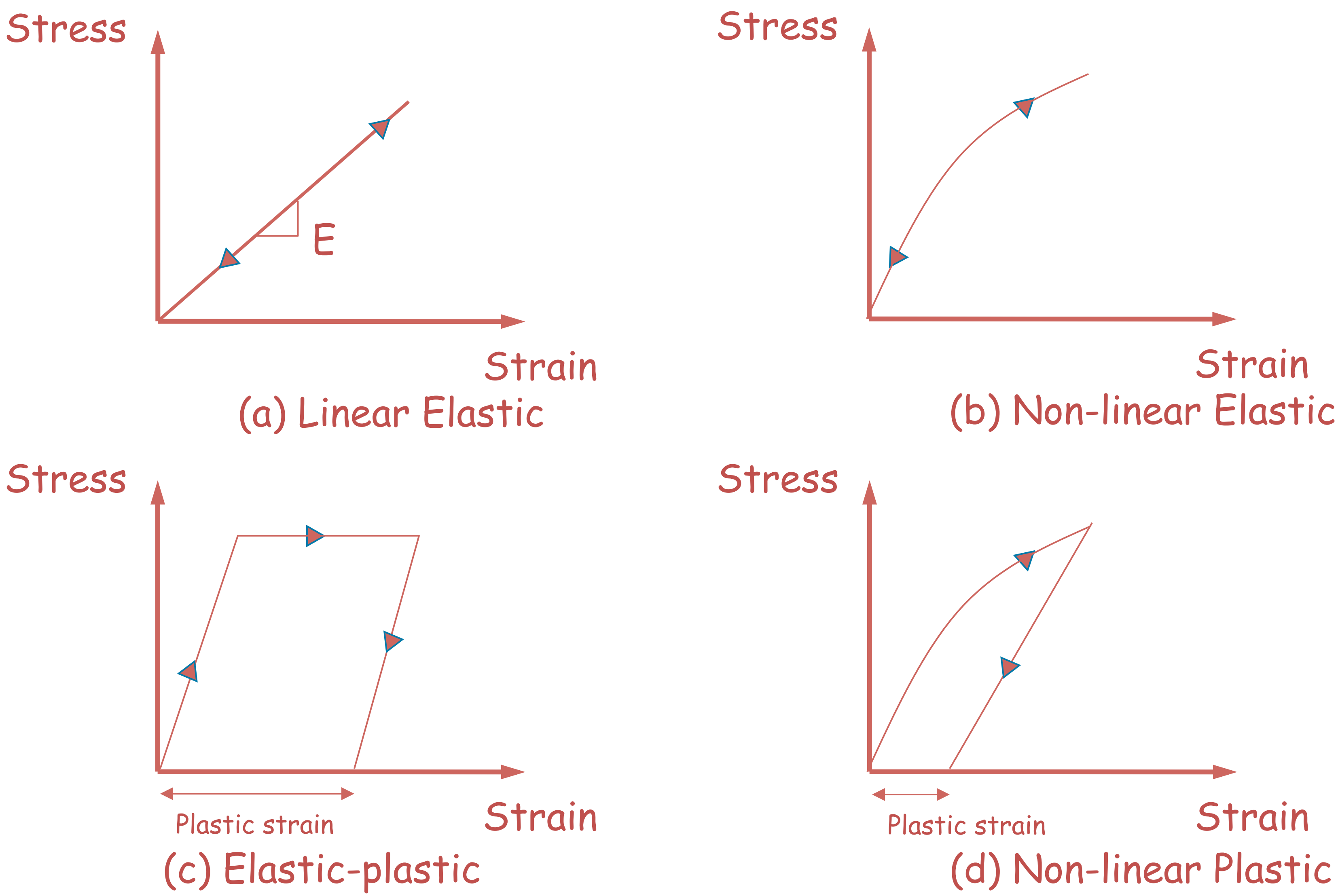
- Steel
  - Maximum stress: 40,000 – 120,000 lb/in^2
  - Maximum strain: 0.2 – 0.4
  - Modulus of elasticity: 29,000,000 lb/in^2

- Concrete
  - Maximum stress: 4,000 – 12,000 lb/in^2
  - Maximum strain: 0.004
  - Modulus of elasticity: 3,600,000 – 6,200,000 lb/in^2

- Wood

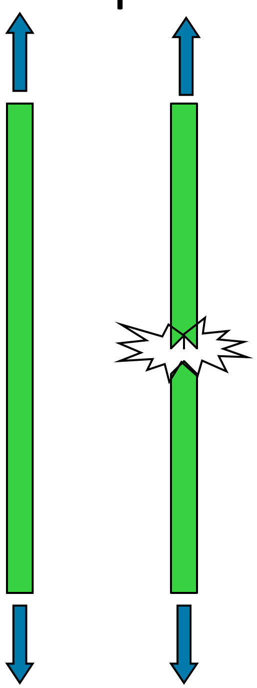
  Values depend on wood grade. Below are some samples
  - Tension stress: 1300 lb/in^2
  - Compression stress: 1500 lb/in^2
  - Modulus of elasticity: 1,600,000 lb/in^2

Types of Stress-Strain Behavior

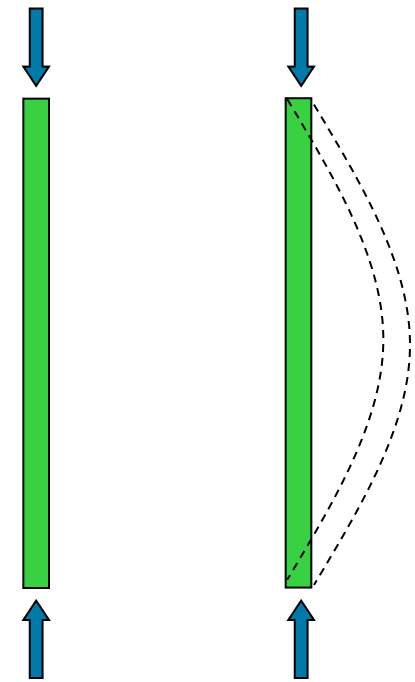


Engineering Properties of Structural Elements

- Strength
  - Ability to withstand a given stress without failure
    - Depends on type of material and type of force (tension or compression)

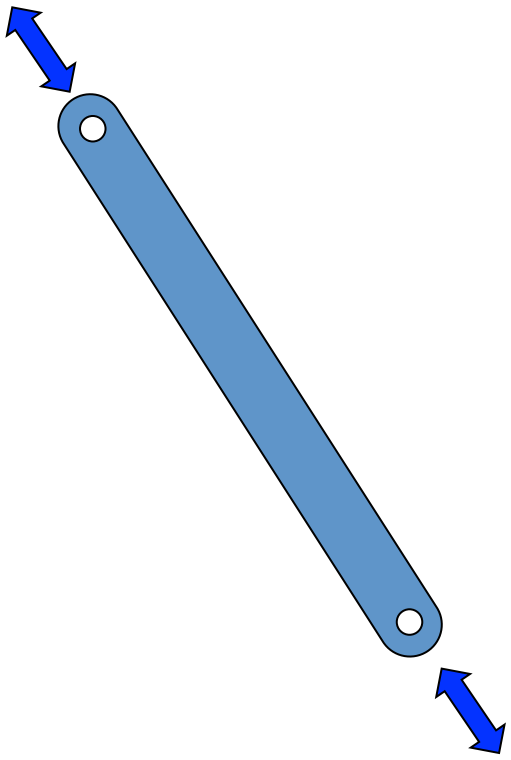


Tensile Failure

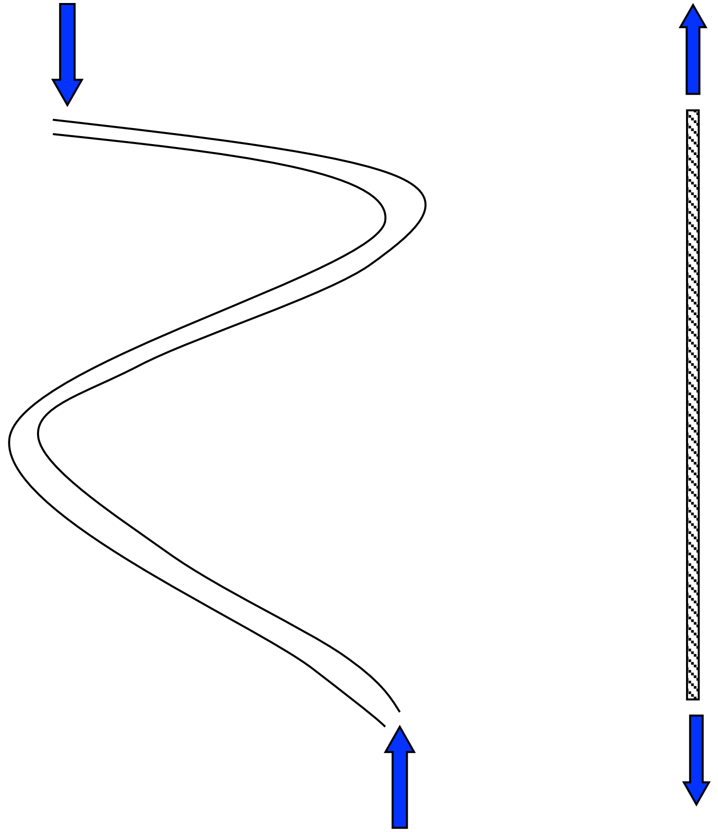


Compressive Failure

Types of Structural Elements – Bars and Cables

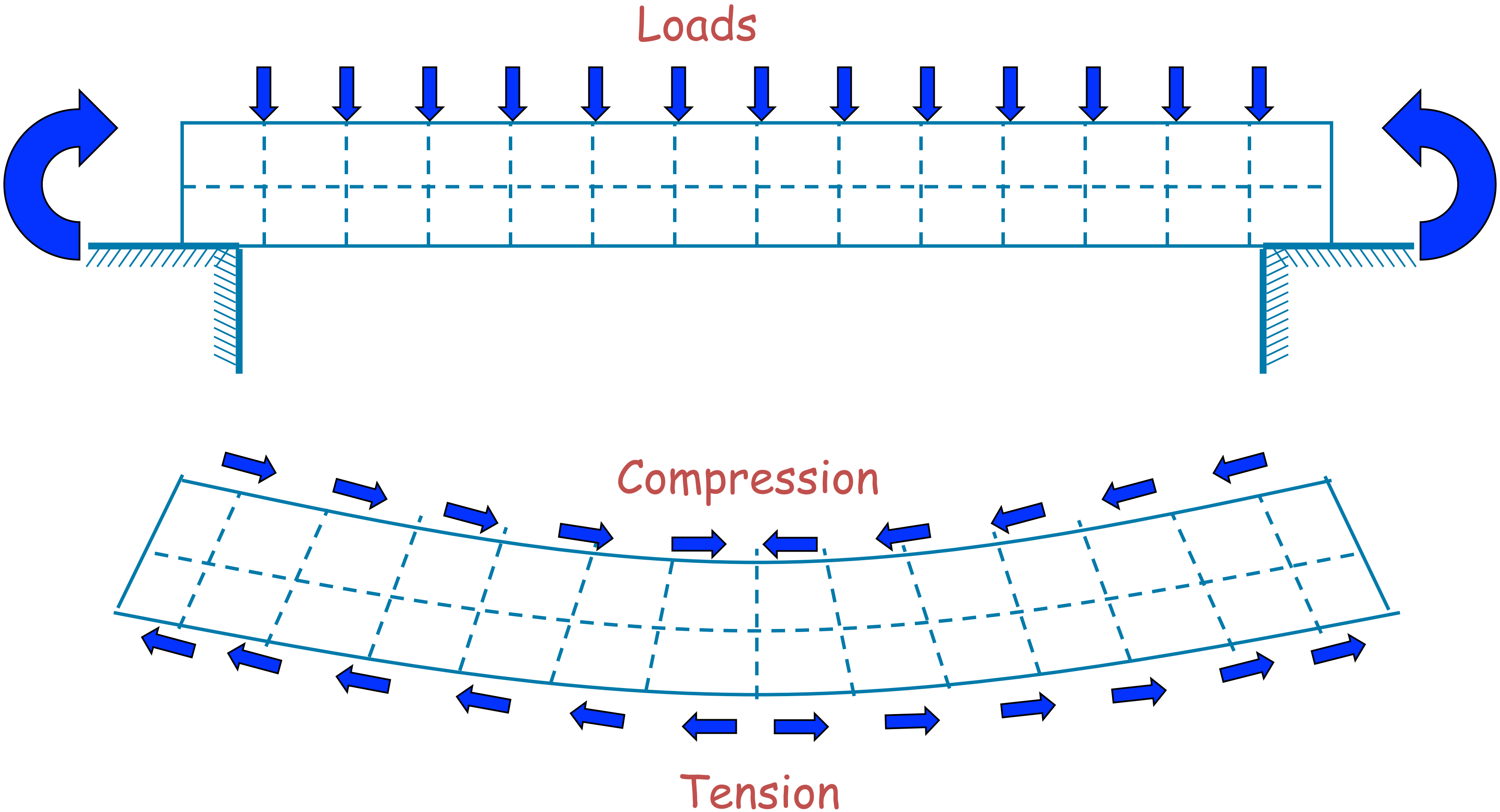


Bars can carry either tension or compression

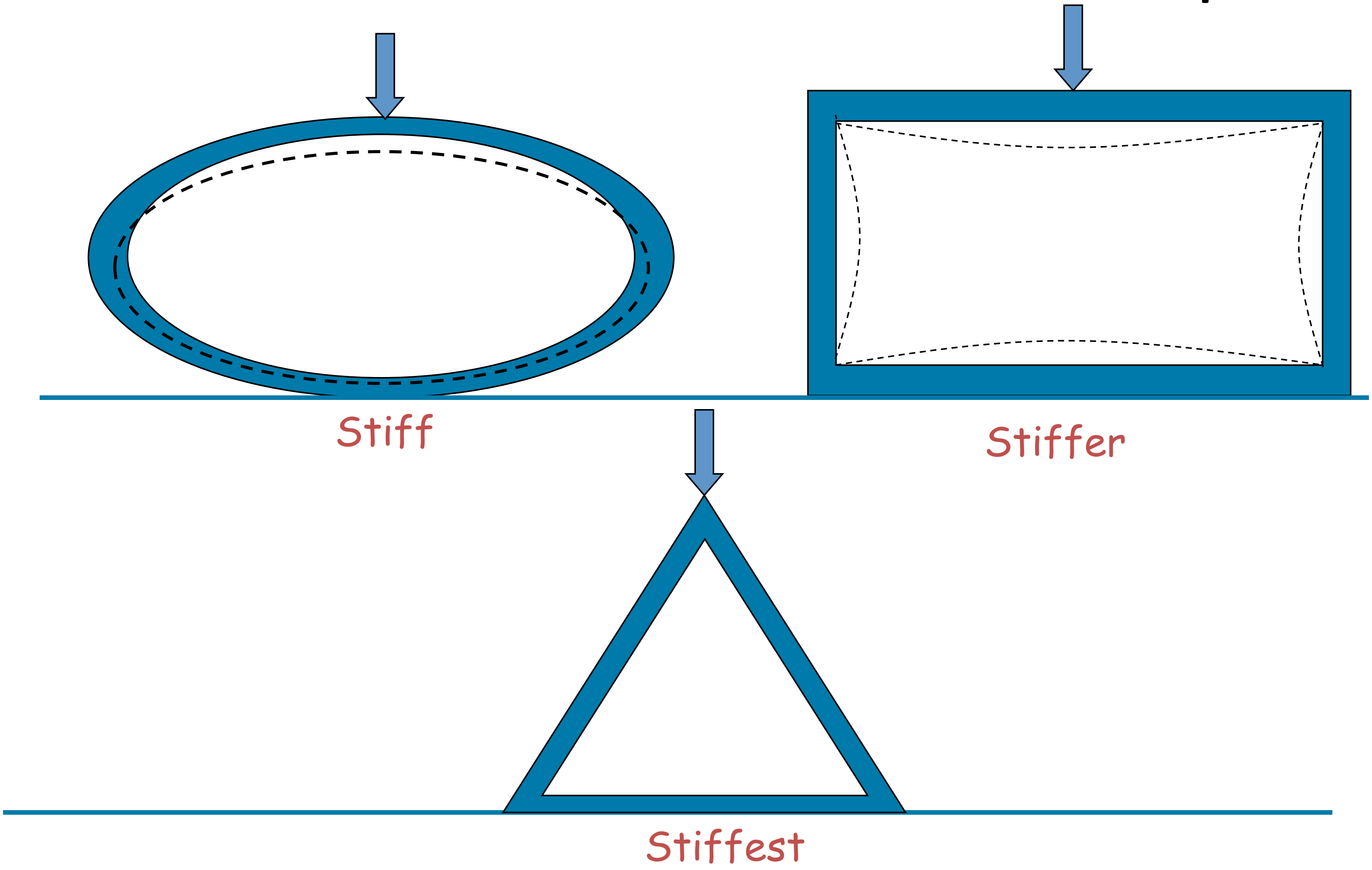


Cables can only carry tension

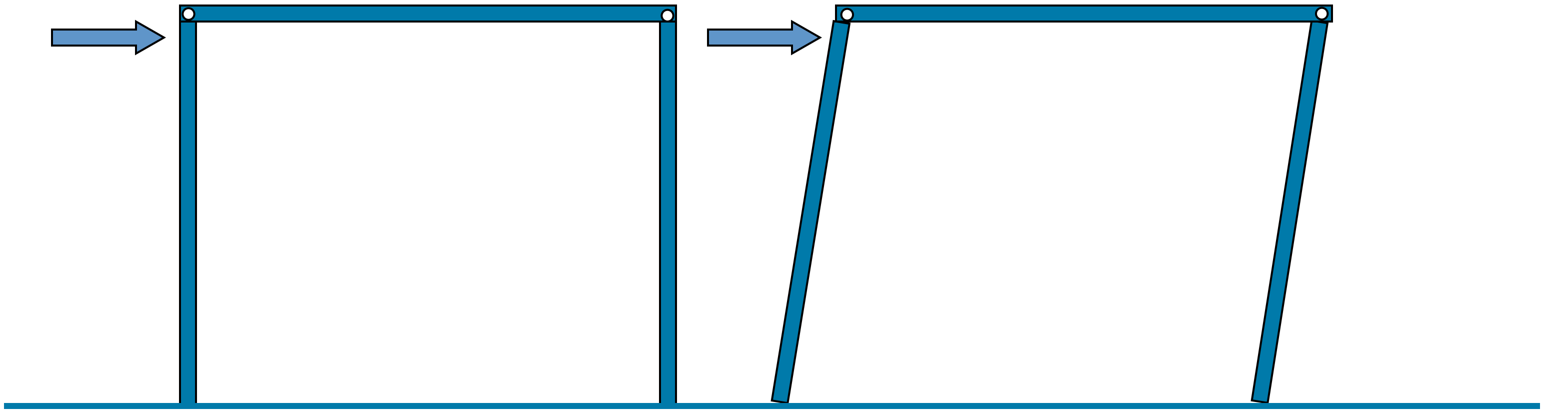
Types of Structural Elements – Beams



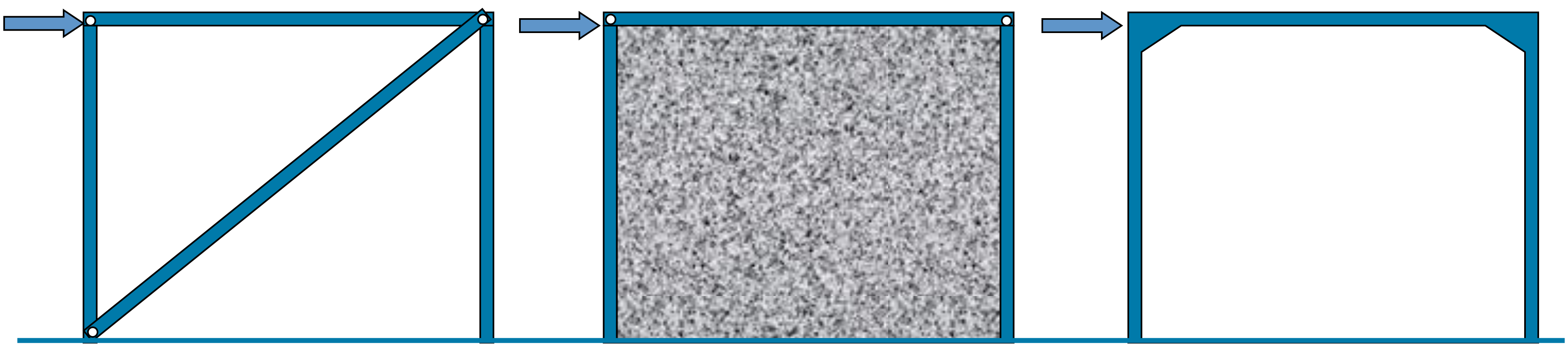
Stiffness of Different Structural Shapes



Providing Stability for Lateral Loads



Racking Failure of Pinned Frame



Braced Frame   Infilled Frame   Rigid Joints

Failure Mechanisms

Structural failure refers to loss in the load-carrying capacity of a component or member within a structure.

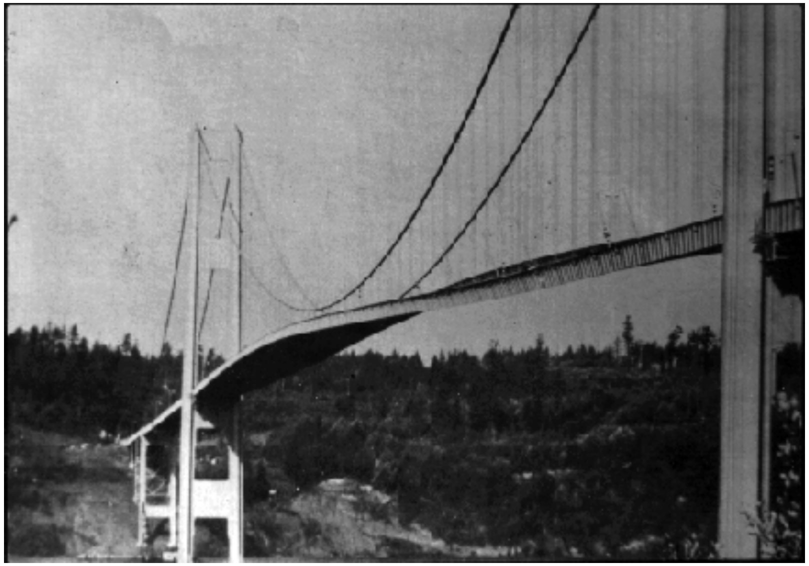
Failure is initiated when the material is stressed to the strength limit, thus causing fracture or excessive deformations.

Ultimate failure is usually associated with extreme events.

The structural engineer needs to prevent loss of life by prohibiting total collapse of the structural system.

Failure due to Dynamic Instability

Failure to understand aeroelastic flutter can be catastrophic.



The Tacoma Narrows bridge opened in July 1940 and collapsed a few months later (November 1940) in a 40 mph wind.

Failure completely changed the way in which suspension bridges are analyzed and designed.

America’s Infrastructure Crisis

Two key problems:

- Much of America's infrastructure was built post World War II -- it's now 50-60 years old, and being attacked by decay and neglect.

- The US population is growing! This puts additional demands on infrastructure.

Quote from W.P. Henry, former president of ASCE:

Our infrastructure is in crisis mode ...

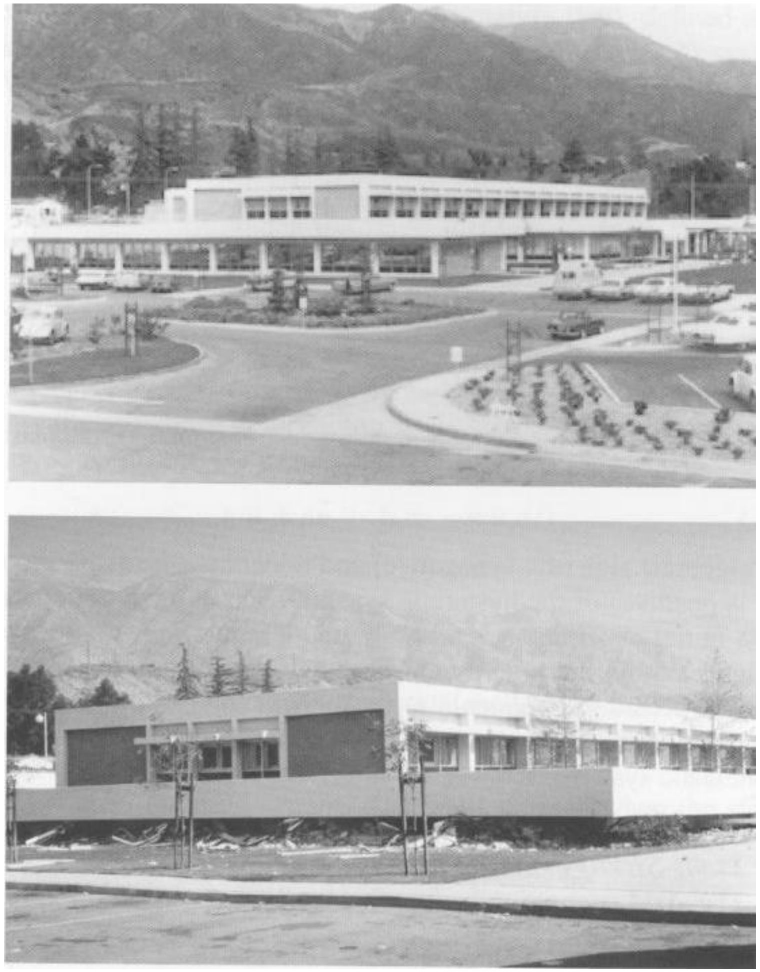
- ... how many more people must die needlessly because we do not take proper care of our infrastructure?

Poster Child: Collapse of the Minneapolis bridge over 135W.

The 40-year old steel deck truss crossing had been considered structurally deficient since 1990, but engineers with the Minnesota Department of Transportation had not believed the bridge to be in danger of imminent collapse.

Thirteen commuters were killed and more than 100 were injured on August 1, 2007.

Failure due to lack of Ductility in Concrete Columns



Olive View Hospital
M 6.7 1971 San Fernando Earthquake

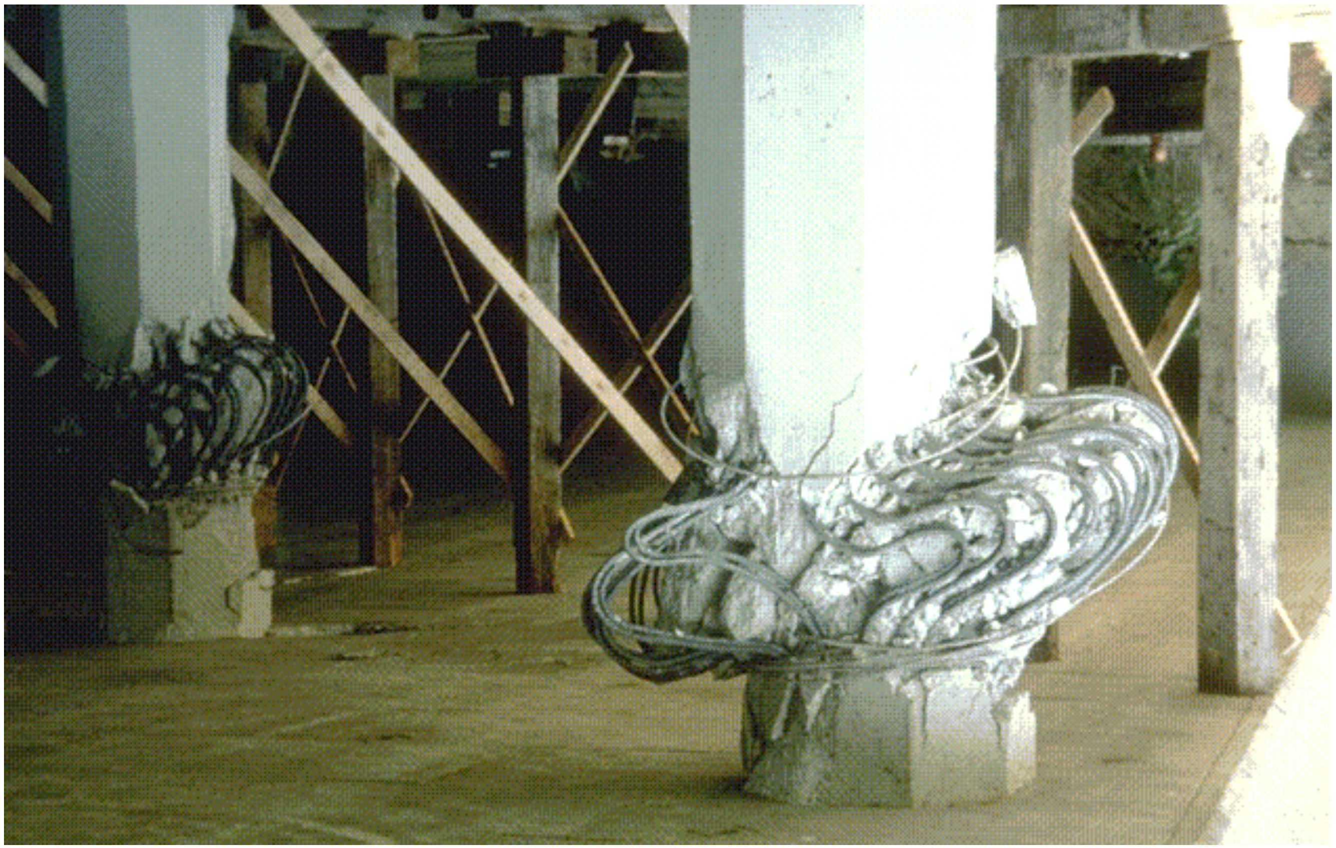
Frame buildings can have also be built with concrete columns and beams (as opposed to steel)

1971 San Fernando earthquake showed that many concrete frames were brittle

Potential for collapse at drifts of about 0.01 (lower than for steel buildings)

There are thousands of these buildings in California and occupants have not been notified

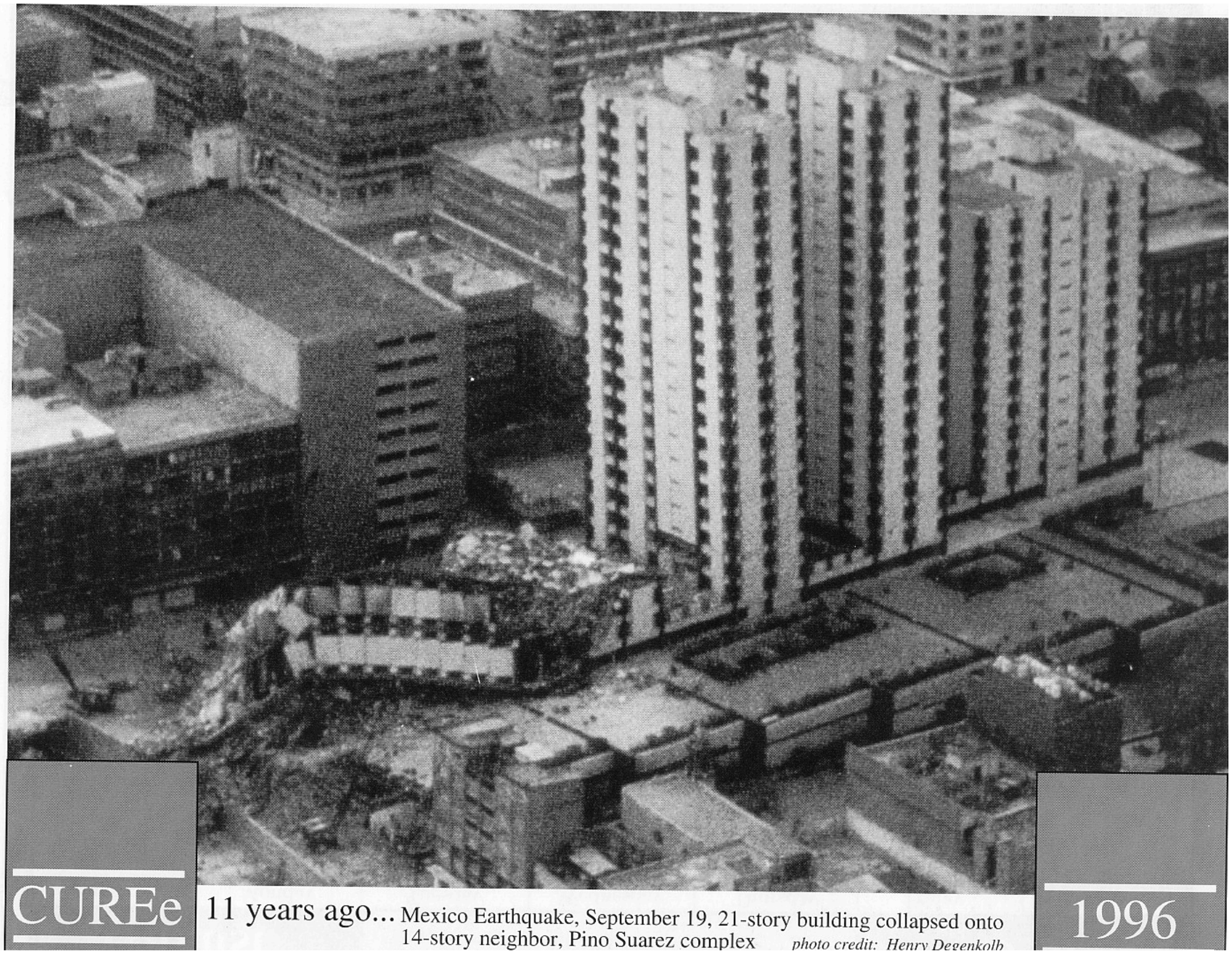
Northridge 118 FWY

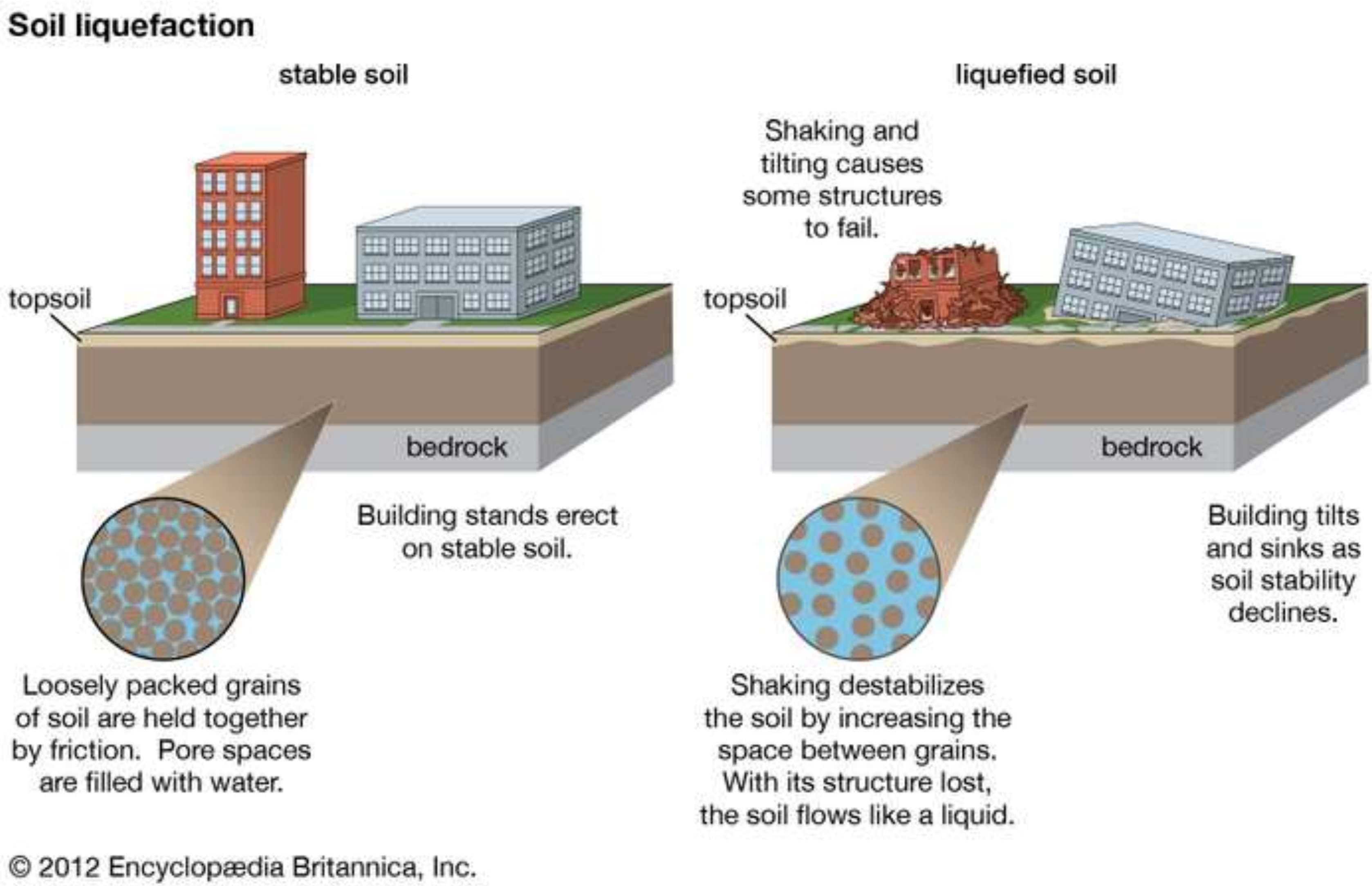


Example of failure of a brittle concrete column (pre-1975 code)

Example of "ductile" behavior of concrete columns. Although the parking structure performed poorly, the exterior columns did not fail.

Mexico City Earthquake, 1996





YouTube Search: liquefaction

San Francisco Earthquake, 1906

Failure due to liquefaction in Japan

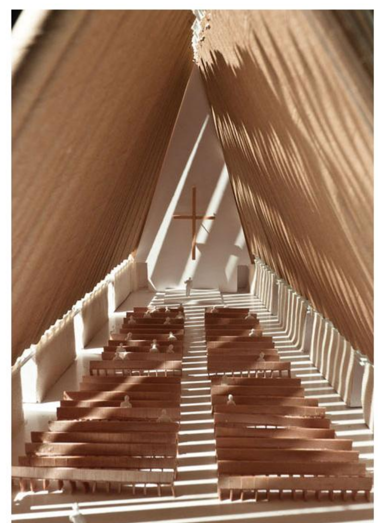
Sometimes you are simply in the wrong place at the wrong time ...

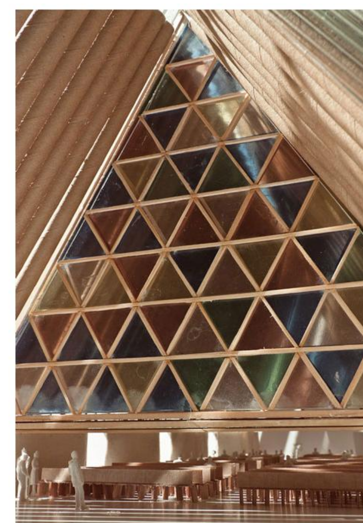
Christchurch, New Zealand, 2011.

Richter Magnitude = 6.3

Failure of the Christchurch Cathedral…

Sometimes extreme events spur real innovation!

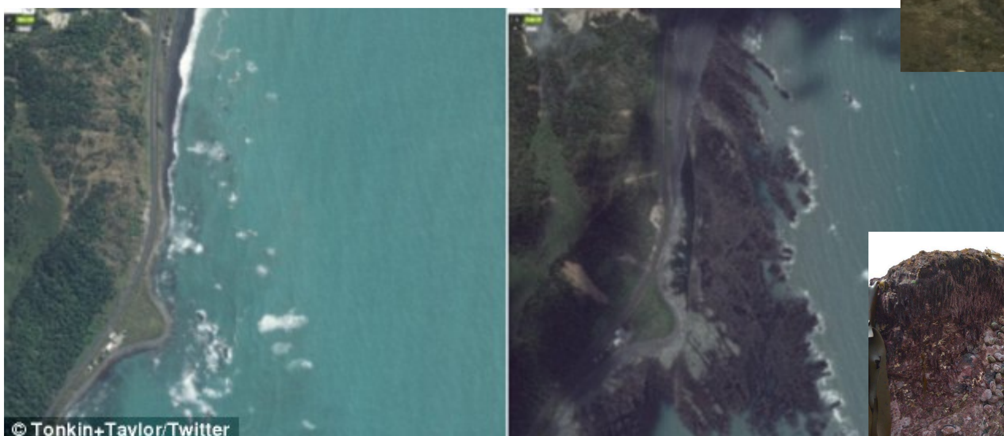




Update for 2016

Richter Magnitude = 7.8 – this is 32 times more energy than the 6.3 magnitude earthquake in 2011.


FROM RIVERS
← NEW "LAKE"
RIVER →
150m high dam from landslide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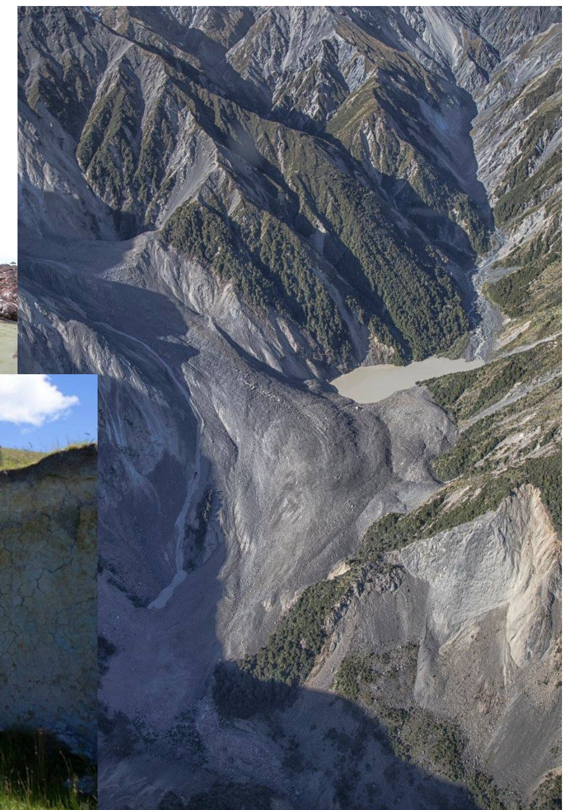

Summary

- Structural Engineering:
  - Identifies loads to be resisted
  - Identifies alternatives for providing load paths (arch, truss, frame, ...)
  - Designs structure to provide safe and economical load paths (material, size, connections)
  - To be economical and safe, we must be able to predict what forces are in structure.

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