
**CIVE.5120 Structural Stability (3-0-3)**
**01/17/17**


# Structural Stability
# – Introduction –

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# Outline

- Concept of structural failures
- Structural failures due to instability
- Types of instability
- Approaches in structural stability
- Classical beam-column problem
- Examples
- Design philosophies

# Concept

- Material failures:
  - Brittle failure
  - Ductile failure
  - Fatigue failure

- Structural failures:
  - Local material failure (e.g., cracking, yielding, imperfection)
  - Global material failure (e.g., aging)
  - Local system failure (e.g., buckling, manufacturing errors)
  - Global system failure (e.g., buckling, excessive loading)

# Structural Failures

- Global buckling of a wind turbine tower

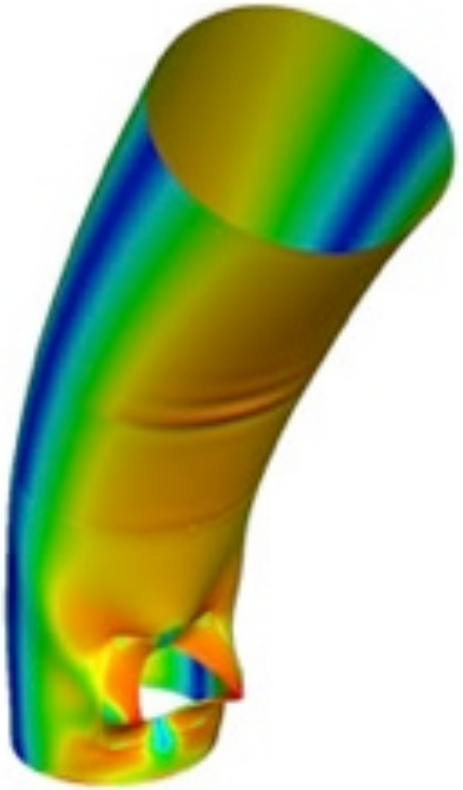
(Note: Temperature = **-54°F**)

Wyoming (02/01/11)

# Structural Failures

- Global buckling of a wind turbine tower

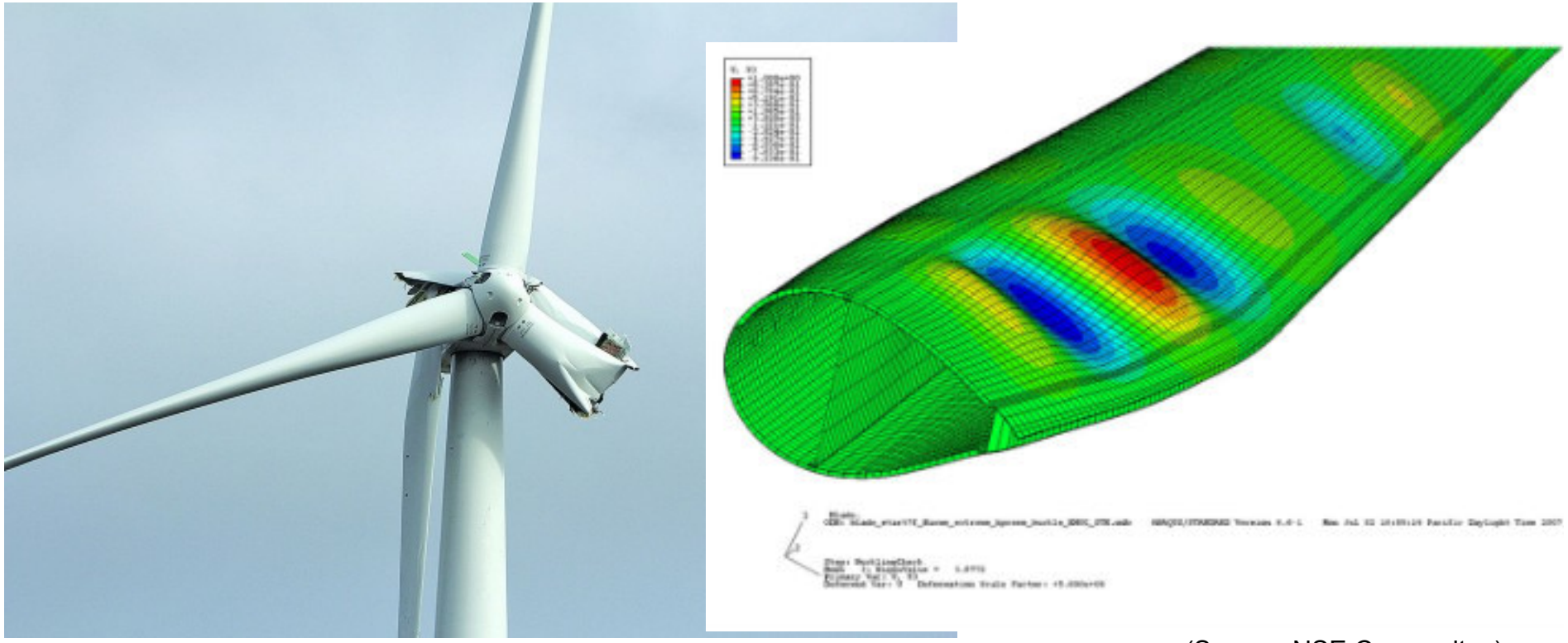
(Source: Unknown)



(Source: Dassault Systems)

# Structural Failures

- Global buckling of a wind turbine blade



Sigel, Michigan (02/24/16)

(Source: NSE Composites)

# Structural Failures

- Torsional buckling of an I-beam member

- Local buckling of the compression flange

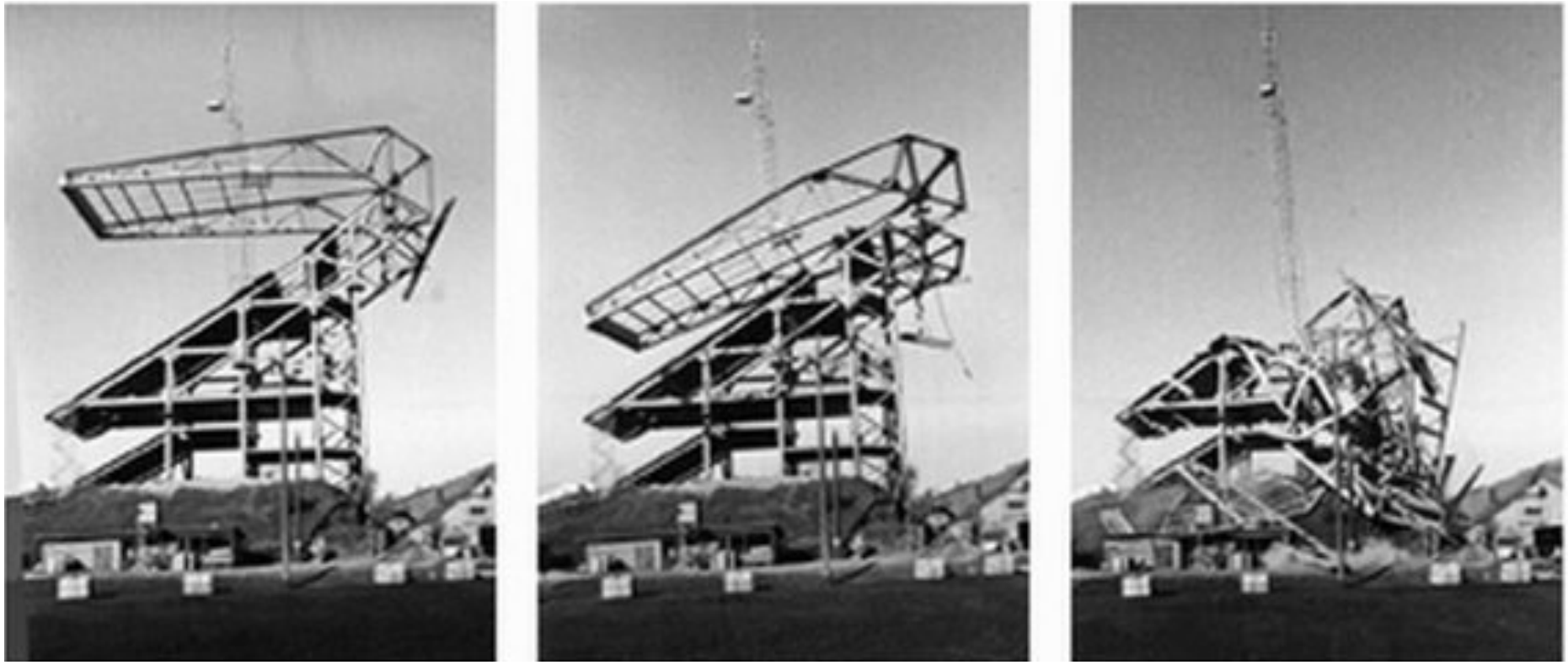
# Structural Failures

- Global buckling of a truss system

Hartford
Civic Center
Stadium, CN
(01/18/78)

# Structural Failures

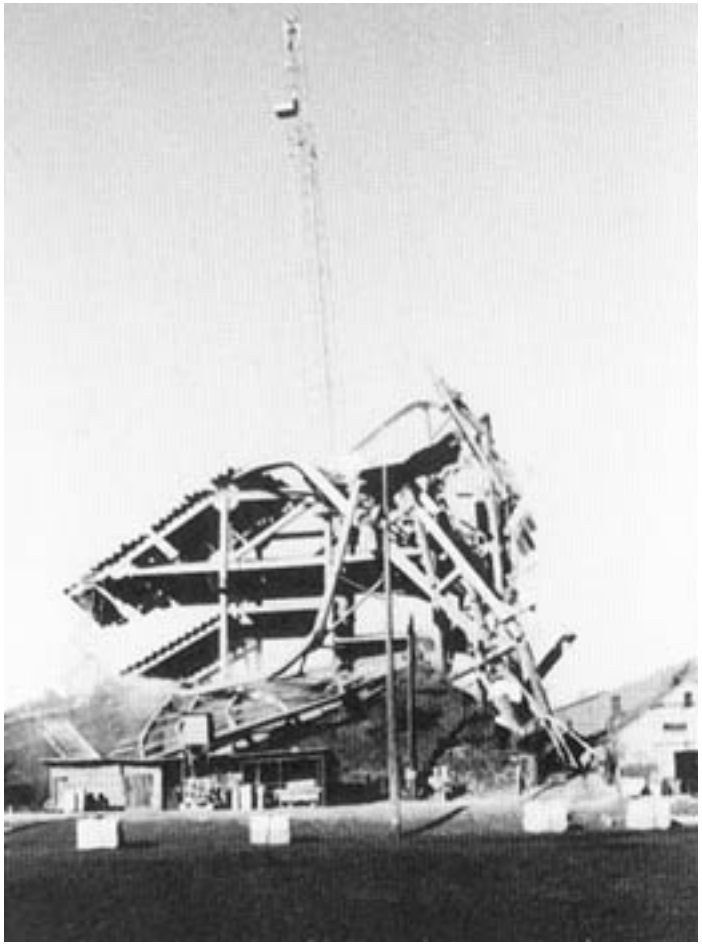
- Global buckling of a truss system



University of Washington, Husky Stadium, Seattle, WA (02/25/87)
(Source: John Stamets)

# Structural Failures

- Global buckling of a truss system



University of Washington, Husky Stadium, Seattle, WA (02/25/87)
(Source: John Stamets)

# Structural Failures

- Global buckling of a truss system

Malaysia (2009)

# Structural Failures

- Global buckling of a truss system

Malaysia
(2009)

# Structural Failures

- Combined buckling of rails

Washington, D.C. (06/23/09)

South Korea

# Structural Failures

- Combined buckling of rails

(Source: Iowa DOT,  Oct. 2013)

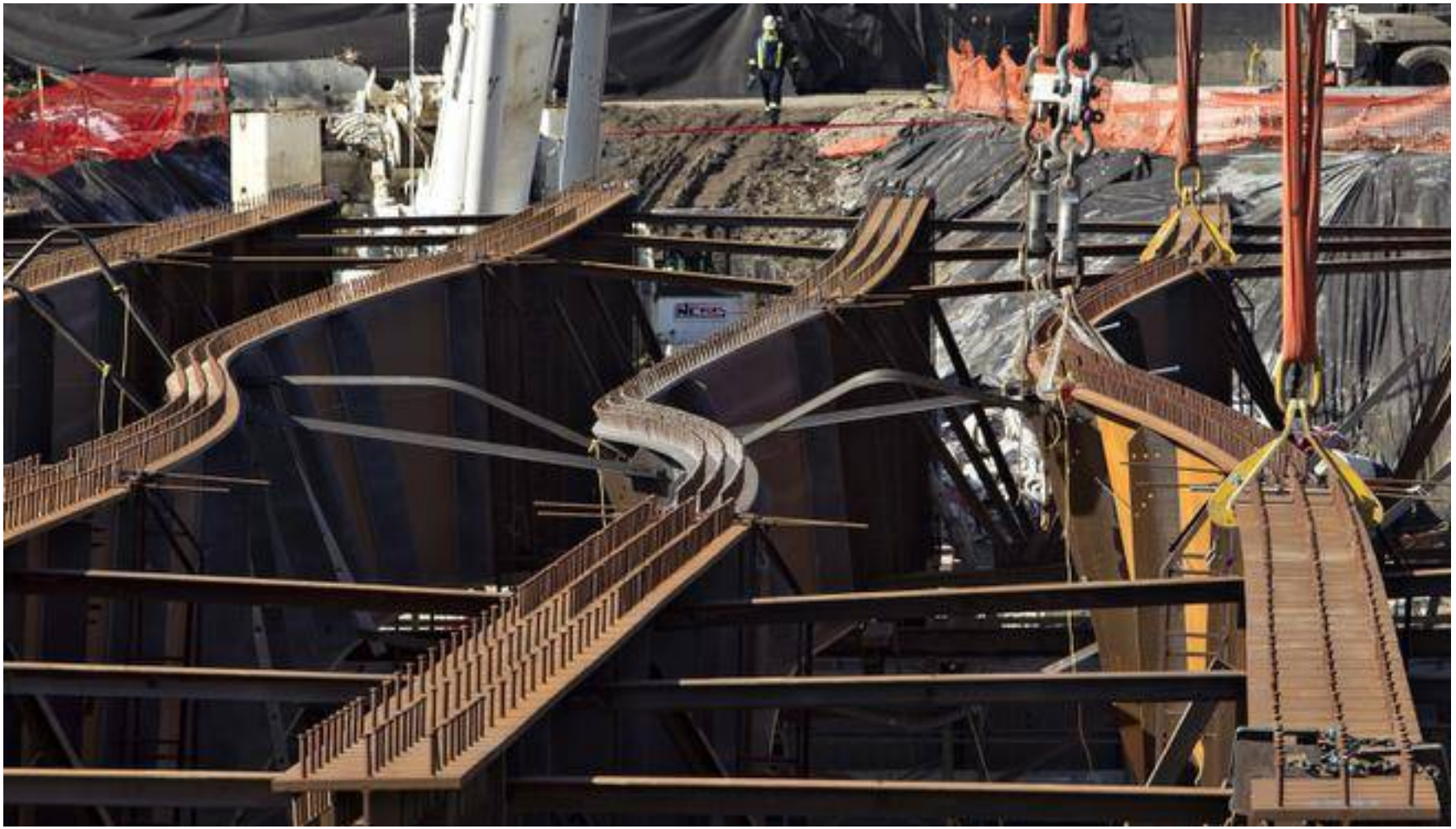
# Structural Failures

- Buckling of bridge girders during construction

Washington (03/18/15)

# Structural Failures

- Buckling of bridge girders during construction



Washington (03/18/15)

# Structural Failures

- Buckling of steel towers

South Australia (10/05/16)

(Source: Unknown)

# Structural Failures

- Buckling of reinforced concrete columns

# Structural Failures

- Buckling of reinforced concrete columns

# Structural Failures

- Failures of reinforced concrete columns in an expressway

1995 Kobe earthquake, Japan

# Types of Instability

- Classical/bifurcation instability (buckling)
  - Symmetric bifurcation
    - Stable and unstable
  - Asymmetric bifurcation
    - Stable and unstable
- Limit-load/snap through instability (buckling)
- Finite-disturbance instability (buckling)

# Types of Instability

- Examples of classical/bifurcation instability
  - Buckling of long straight columns loaded axially
  - Buckling of thin plate loaded by in-plane loads
  - Buckling of rings

# Types of Instability

- Examples of limit-load/snap through instability (buckling)
  - Snapping of a low pinned arch under lateral loads

  - Snapping of clamped shallow spherical caps under uniform lateral pressure

# Types of Instability

- Examples of finite-disturbance instability (buckling)
  - Buckling of thin cylindrical shells under axial compression
  - Buckling of complete, spherical, thin shells under external pressure

# Approaches in Structural Stability

- The Force/Bifurcation Approach
  - Static equilibrium
  - Eigenvalue analysis
- The Energy Approach
  - Principle of virtual work / Hamilton's principle
  - Elastic strain energy, internal work, external work, potential energy
- The Dynamic Approach
- Small deflection analysis vs. large deflection analysis

# Classical Beam-Column Problem

- Timoshenko beam-column with a concentrated lateral load

# Examples

- Spring-bar system subjected to axial loading – **Small** deflection
  - The force approach
  - The energy approach

# Examples

- Spring-bar system subjected to axial loading – **Large** deflection
  - The force approach
  - The energy approach

# Design Philosophies

- Allowable Stress Design (ASD)
- Plastic Design (PD)
- Load and Resistance Factor Design (LRFD)

# Summary

- Structures can fail due to instability/buckling which occurs below the elastic, plastic, or fatigue limit and the fracture strength, in addition to plastic yielding and brittle fracture.

- Structural instability can be local, global, or the combination of both.

- Stability analysis of structural problems means i) finding the minimum buckling load and its mode, ii) determining the post-buckling behavior, and iii) developing strategies for stabilization.

- Three approaches to find the buckling load of a structure; the force/ bifurcation, energy, and dynamic approaches.