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Failures of Civil Infrastructure

Tzu-Yang Yu

Assistant Professor, Ph.D.

Structural Engineering Research Group (SERG)
Department of Civil and Environmental Engineering
University of Massachusetts Lowell (UML)
Lowell, Massachusetts

SERG

Outline

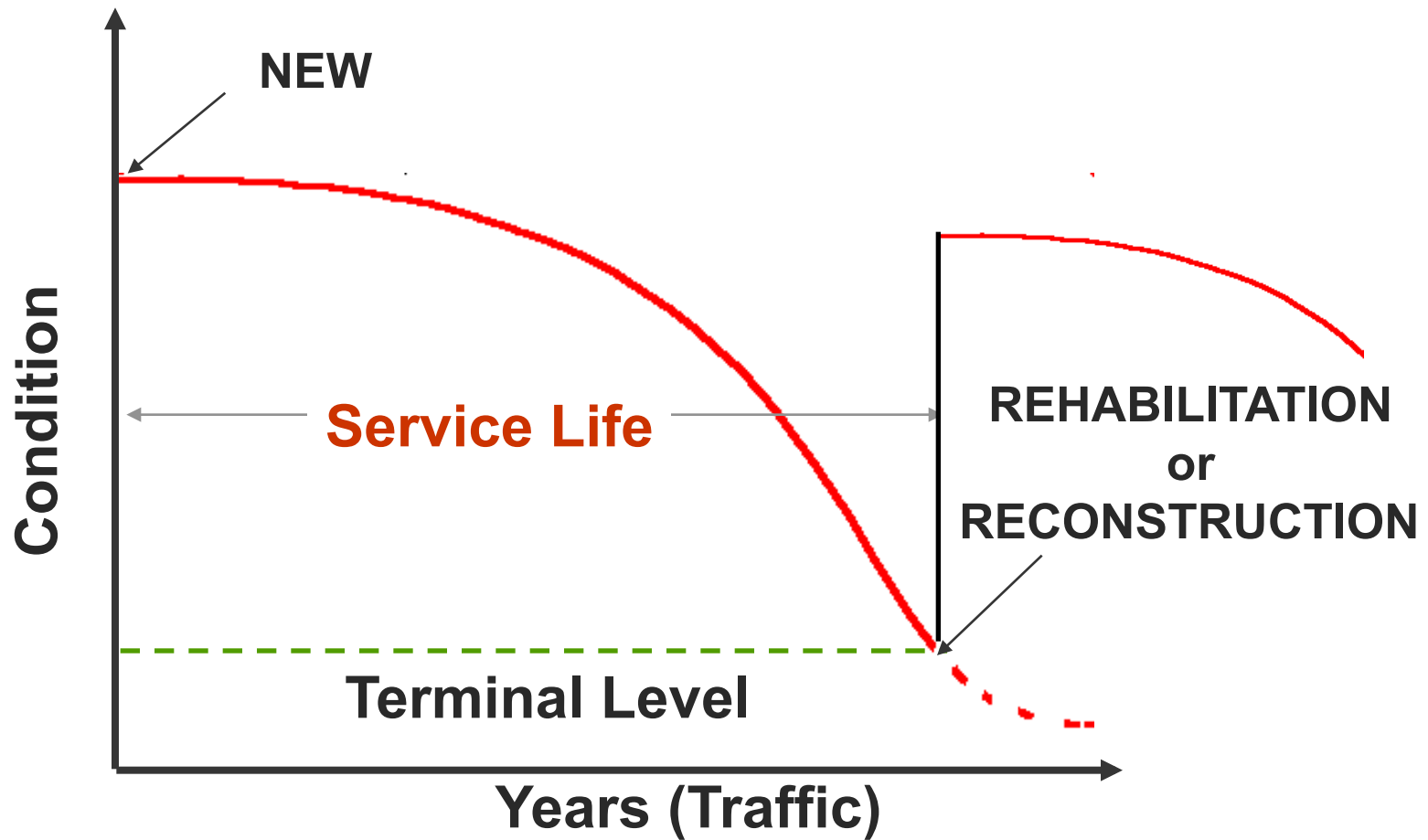
- Introduction
- Types of Civil Infrastructure
 - Buildings
 - Bridges
 - Dams
 - Nuclear Power Plants
- Causes of Engineering Failures
- Summary

Introduction

- U.S. Civil Infrastructure (2006)
 - 6.3 million km of street, roads, and highways,
 - More than 570,000 bridges,
 - 230,000 kilometers of railroads
 - 41,000 kilometers of navigable channels
 - 2.4 million kilometers of oil and gas pipelines
 - 200 large ports
 - More than 20,000 airports
- Estimated Cost: *\$34 trillion dollars*

Introduction

- Infrastructure deterioration cycle



Introduction

- Impact of infrastructure deterioration:
 - Infrastructure in the U.S. is the cornerstone of the economy and directly affects competition in the foreign market.
 - Historically, infrastructure and development are strongly linked.
- Quality of life depends on infrastructure condition.
- Transportation Infrastructure is deteriorating.
- The U.S. Economy depends heavily on transportation infrastructure.
- Job creation

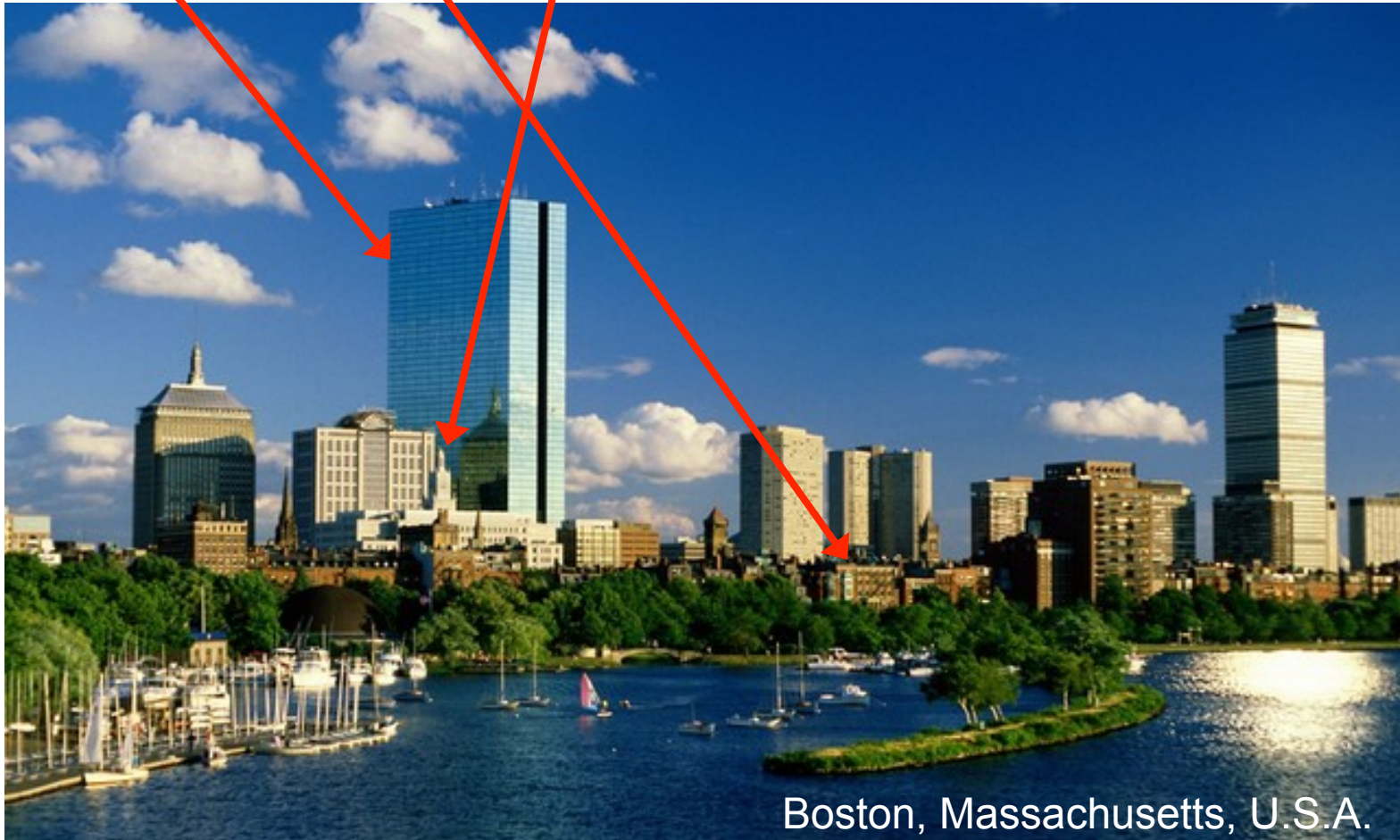
Introduction

- Example of Infrastructure Crisis: Highway System (2006)
 - 3.9 million miles, 575,600 bridges and 2.2 trillion vehicle-miles
 - Expenditures 17% of the GNP and 620,000 jobs
 - Supports domestic traveling, work trips, goods moving
 - 30% of the bridges are deficient
 - 25% of the highways need better care

Q: How should we maintain these structures to keep them in good shape on a regular basis?

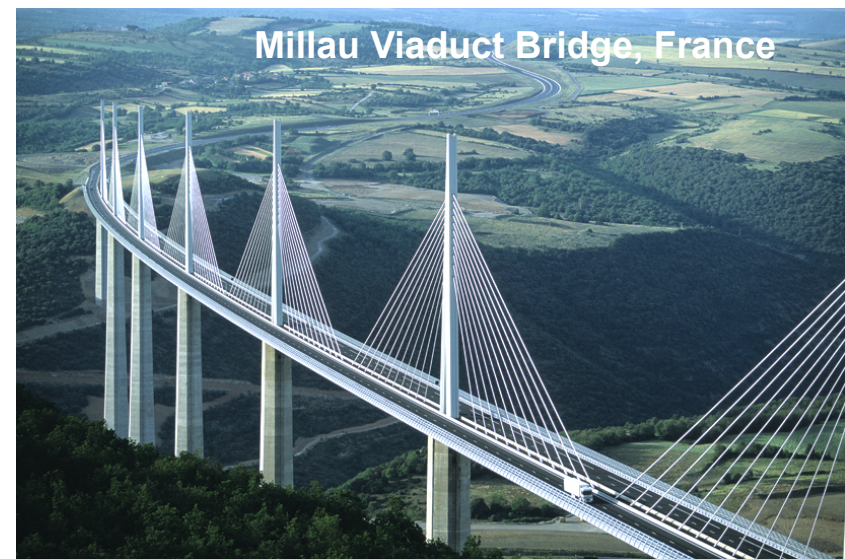
Types of Civil Infrastructure

- Buildings
 - Commercial, residential, facility, etc.



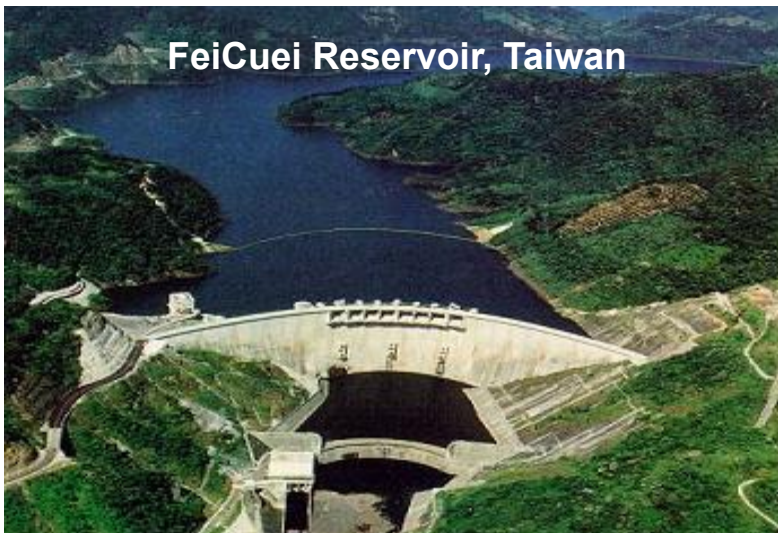
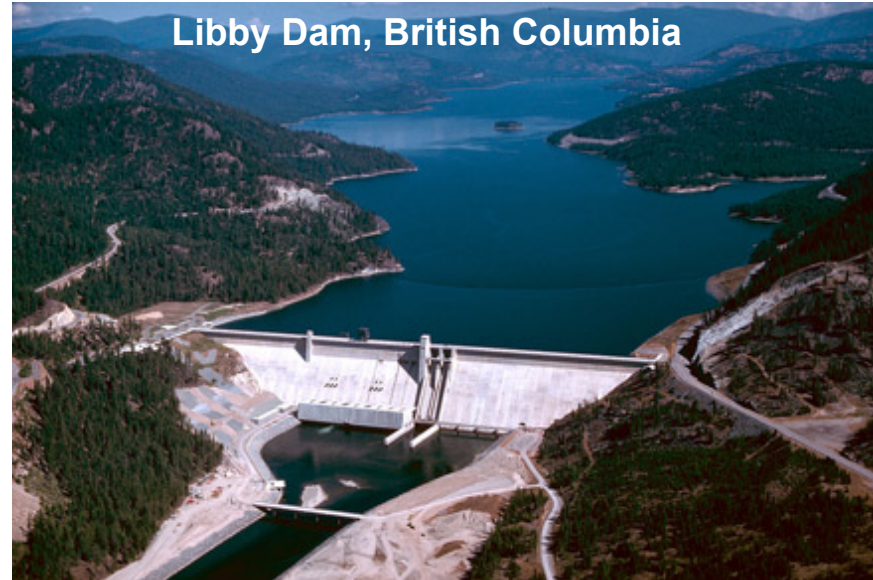
Types of Civil Infrastructure

- Bridges



Types of Civil Infrastructure

- Dams



Types of Civil Infrastructure

- Nuclear Power Plant (NPS)

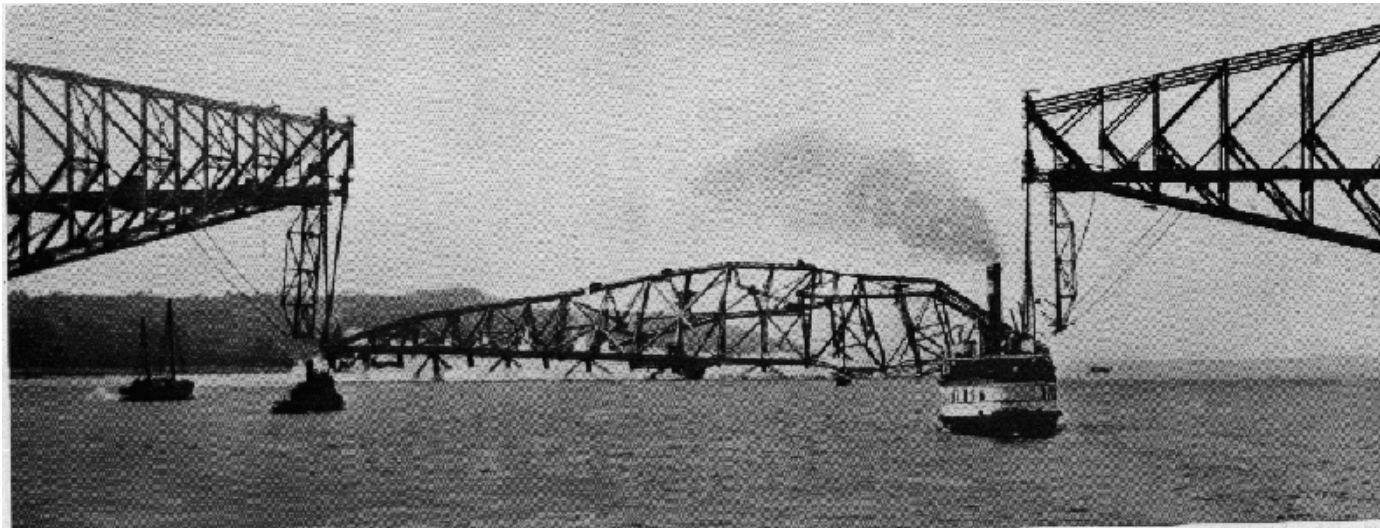
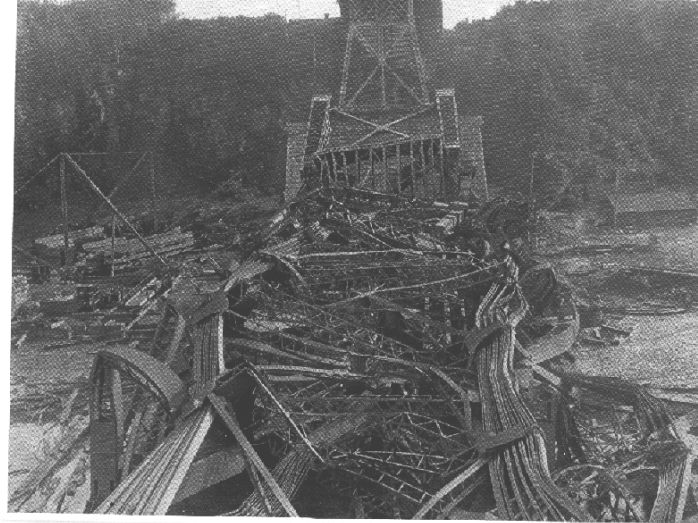


Causes of Eng Failures

- Design
- Construction
- Deterioration/aging
- Mechanical instability
- Excessive loading
- Fire
- Extreme natural hazards
 - Earthquakes
 - Hurricanes/typhoons/tornados
 - Flooding
 - Landslides
 - Volcano eruption
- Terrorism

Causes of Eng Failures

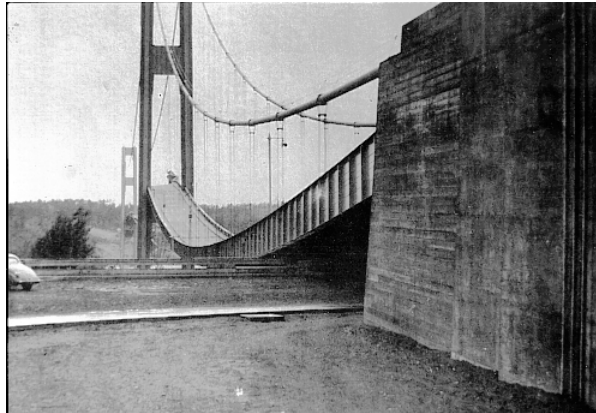
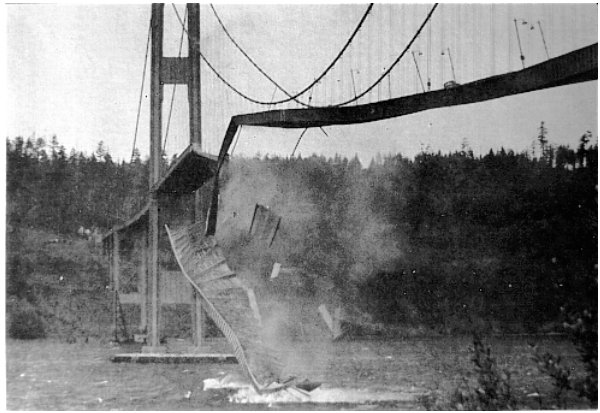
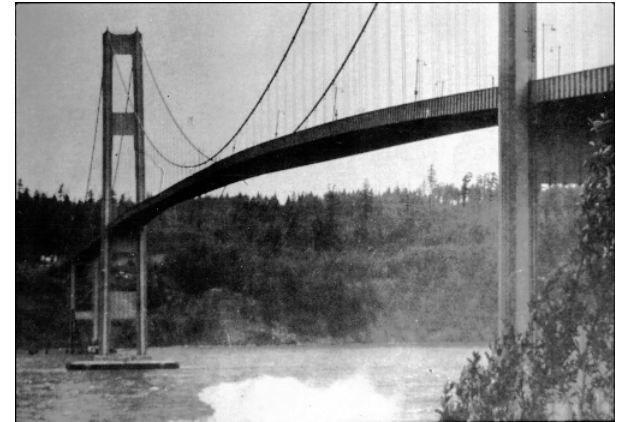
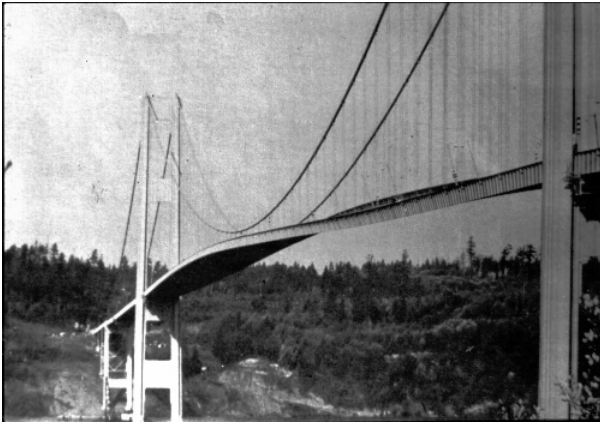
- Design error – Quebec Bridge, Canada (1907)



→ Collapsed during construction: design error, bridge unable to support own weight.

Causes of Eng Failures

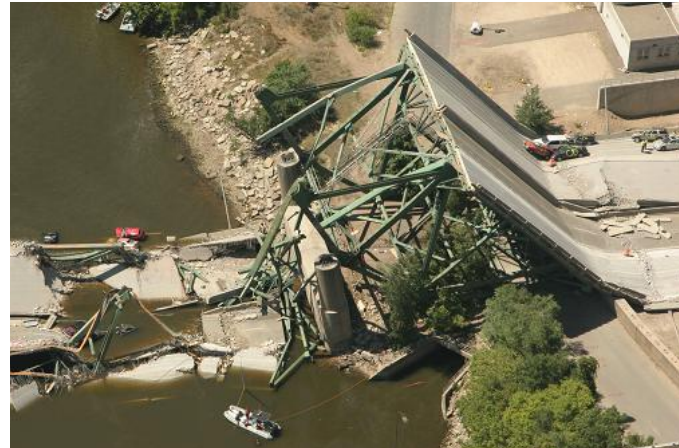
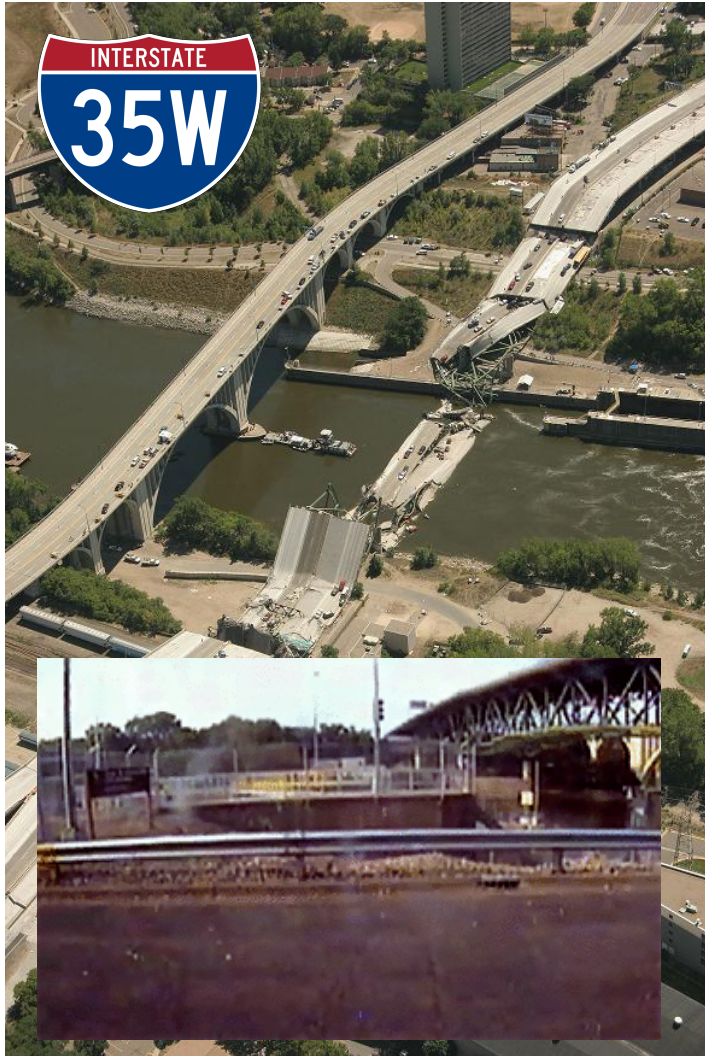
- Design error – Tacoma Bridge, Washington, USA (1940)



→ *Aerodynamic coupling effects were not considered in the design of the bridge.*

Causes of Eng Failures

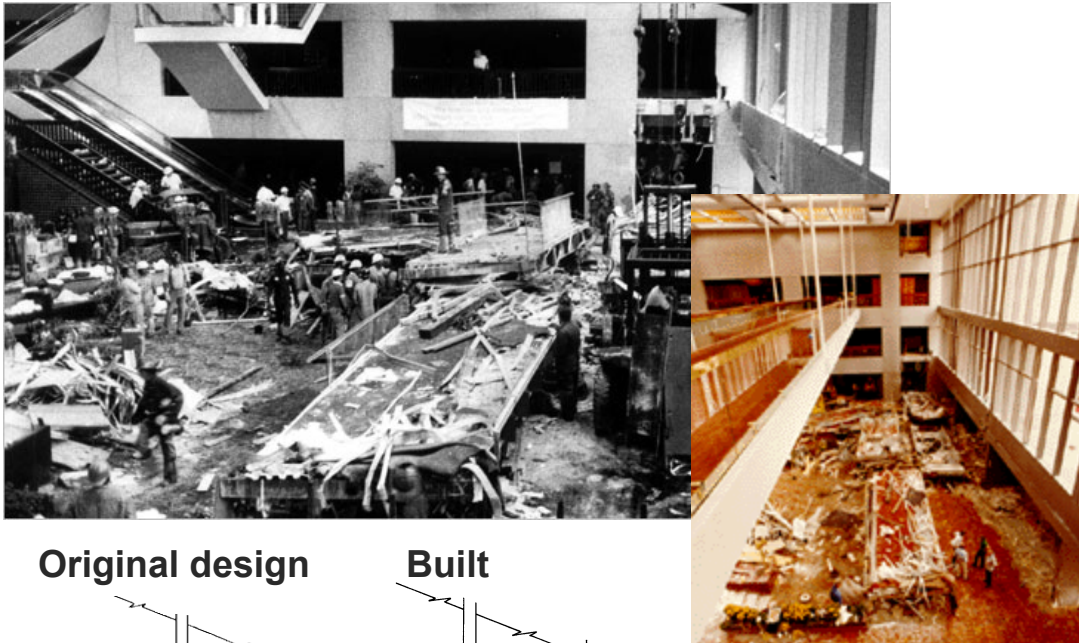
- Design error – I-35W Highway Bridge Collapse, MN, USA (2007)



→ The NTSB cited a design flaw as the likely cause of the collapse, and asserted that additional weight on the bridge at the time of the collapse contributed to the catastrophic failure

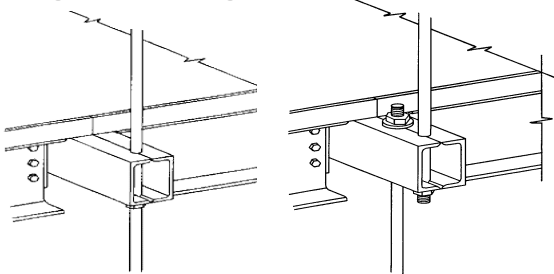
Causes of Eng Failures

- Construction – Hyatt-Regency Walk Collapse, IL, USA (1981)

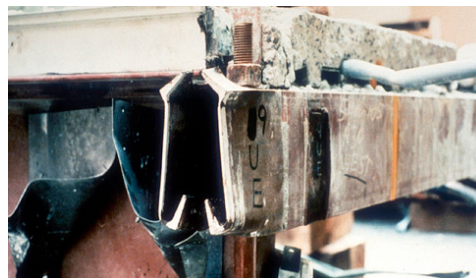


Original design

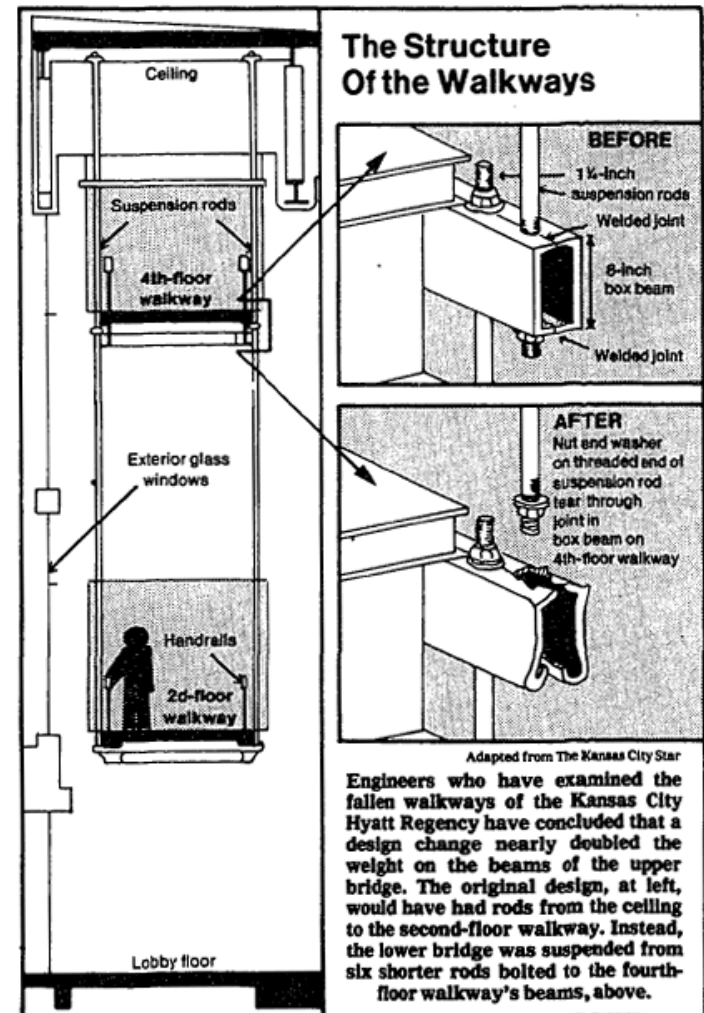
Built



→ Contractor changed the original connection design.



114 people died



Causes of Eng Failures

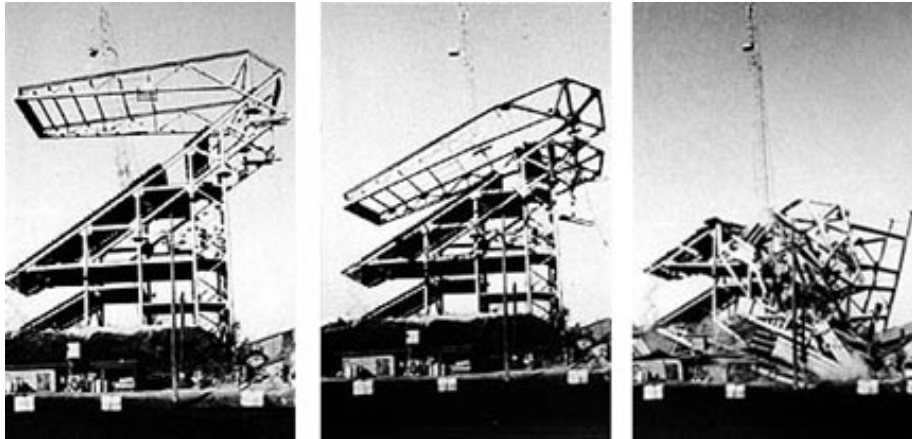
- Construction – AT Tropicana Parking Garage Collapse, NJ, USA (2003)



→ The building was built without the necessary steel required to connect the floors to the walls.

Causes of Eng Failures

- Construction



→ *Construction failures can happen if attention is not paid to detail.*

UW Husky Stadium collapse, Seattle, WA

Causes of Eng Failures

- Deterioration/aging



Reinforced concrete bridge piers, Chicago, IL



Causes of Eng Failures

- Deterioration/aging



1976 Trenton dam failure, New Jersey, USA

Causes of Eng Failures

- Mechanical instability (buckling)



Causes of Eng Failures

- Excessive loading



Pedestrian bridge failed due to overloading by a tank



The Silver Bridge connecting Point Pleasant, West Virginia, over the Ohio River, U.S.A.



On December 15, 1967, the Silver Bridge collapsed while it was full of rush-hour traffic, resulting in the deaths of 46 people.

Causes of Eng Failures

- Fire



One Meridian Plaza, Philadelphia, PA

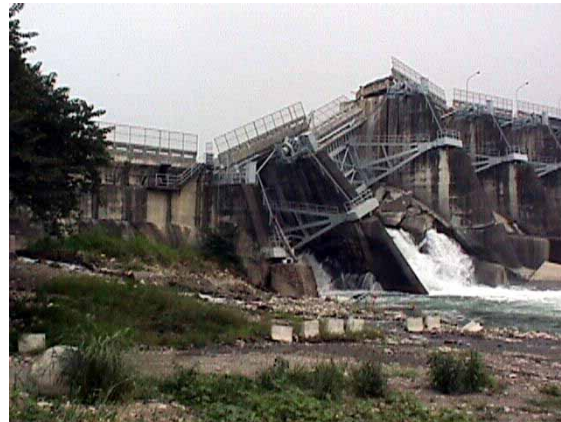


Chinese TV Tower, Beijing, China



Causes of Eng Failures

- Extreme natural hazards – Earthquakes



1999 Chichi Earthquake, Taiwan

Causes of Eng Failures

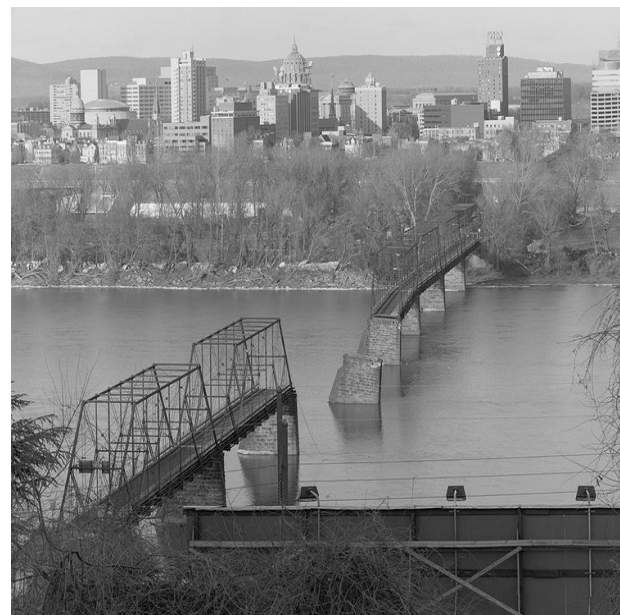
- Extreme natural hazards – Hurricanes/typhoons/tornados



**1999 Moore tornado, Okalahoma, USA
(318 mph, the largest tornado on Earth)**

Causes of Eng Failures

- Extreme natural hazards – Flooding



**1996 Walnut St.
Bridge, Harrisburg,
PA, USA**

Causes of Eng Failures

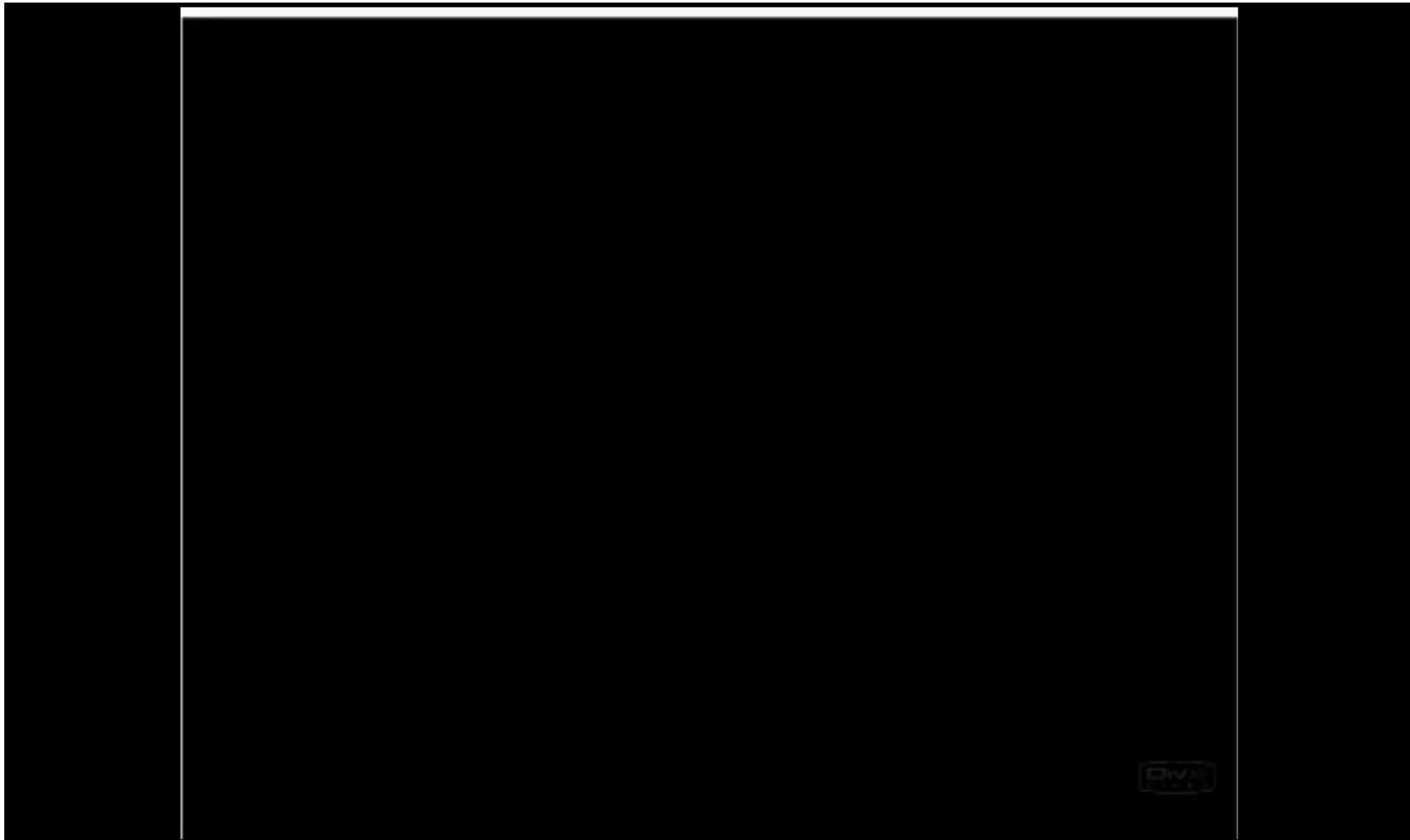
- Extreme natural hazards – Landslides



2010 Chi-du landslide, Taiwan

Causes of Eng Failures

- Extreme natural hazards – Landslides



Causes of Eng Failures

- Extreme natural hazards – Volcano eruption



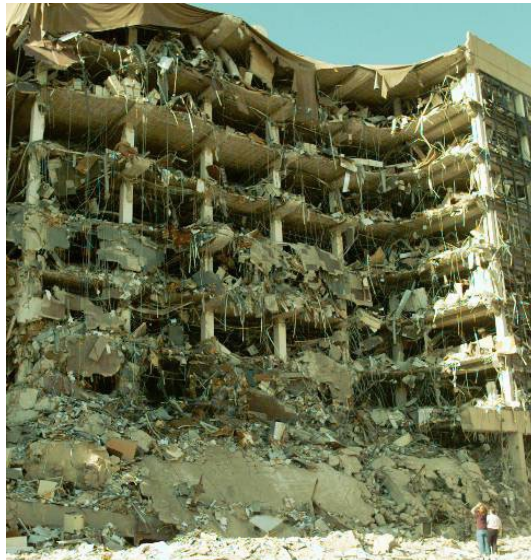
**2008 Chaiten
volcano eruption,
Chile**

Causes of Eng Failures

- Terrorism



1995 Oklahoma City bombing, USA



2001 World Trade Center Towers, New York City, USA



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→ There are many types of engineering failures; how can nondestructive testing (NDT) techniques help?

Summary

- Civil infrastructure fails due to
 - Physical aging
 - Service loading
 - Extreme loading (man-made and natural)
- Local failure of structural components could lead to global failure.
- In most cases, failure causes are combined to trigger progressive and ultimate failure.
- Conventionally, civil engineers are trained to design and construct civil infrastructure. → Emphasis on maintenance (inspection, rehabilitation) and retirement (demolition) is getting important.
- *We need to understand how failures occur in order to prevent them from happening.*

Questions?