

BRIDGE FAILURES

Presented by:

Nabil Al-Bayati, MAsC., P.Eng

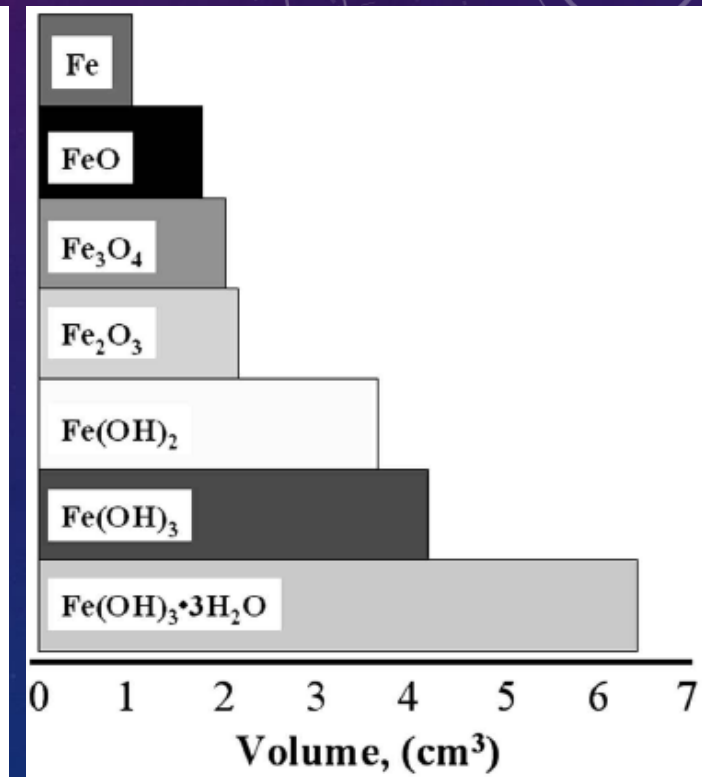
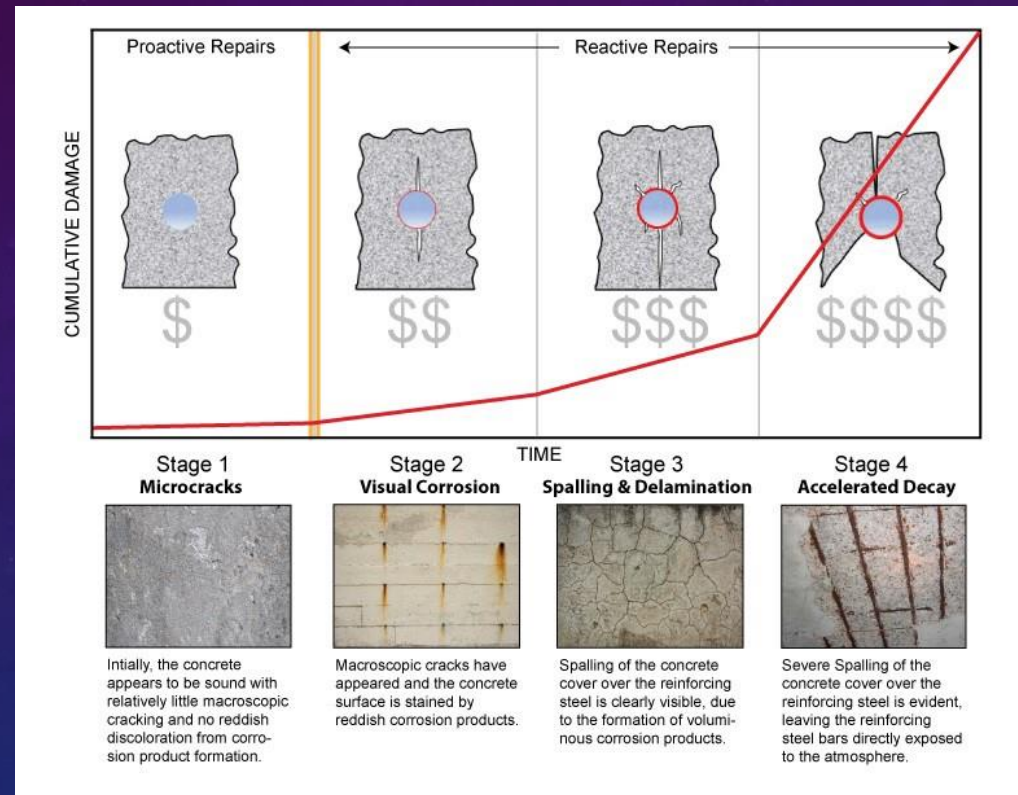
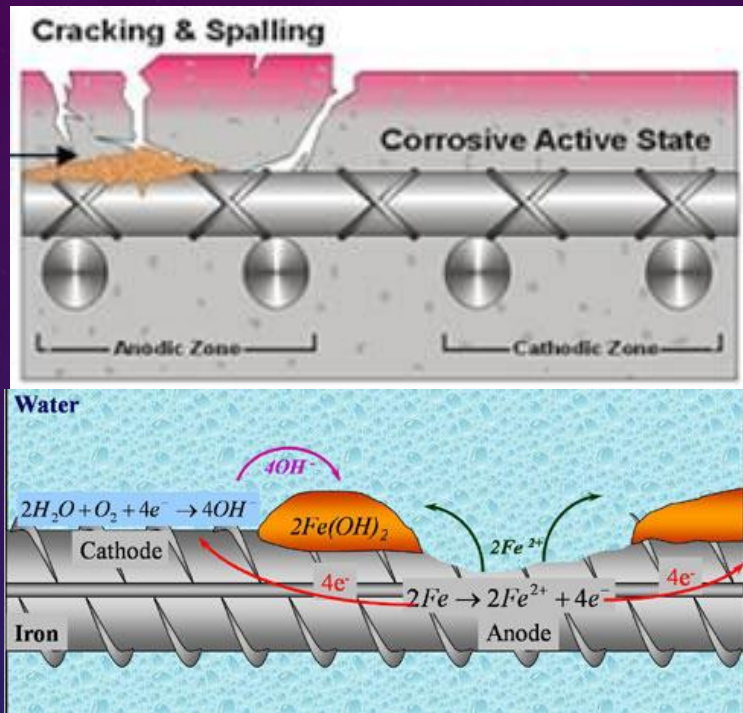
Structural and Bridge Engineer

PRESENTATION OUTLINE

- 1) Corrosion of rebars and structural steel
- 2) Earthquakes
- 3) Tornados
- 4) River flooding
- 5) Barge collision (or any other heavy body) accidents
- 6) Design issues
- 7) Military aggression

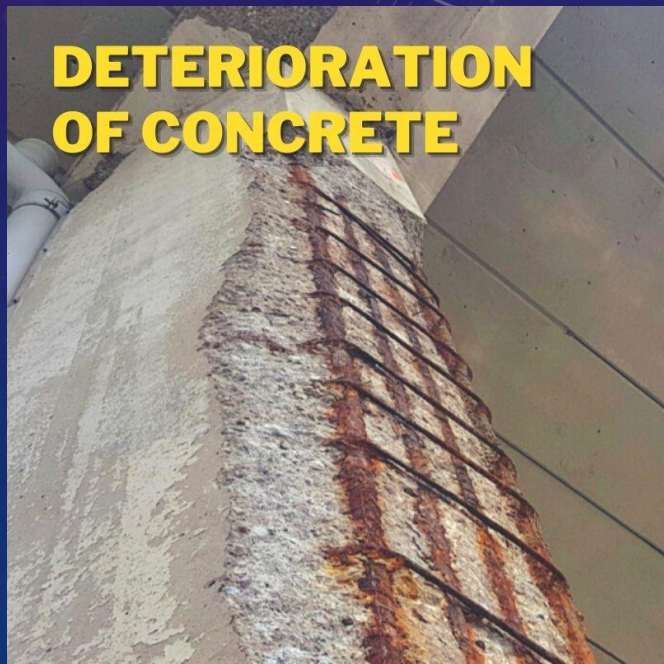
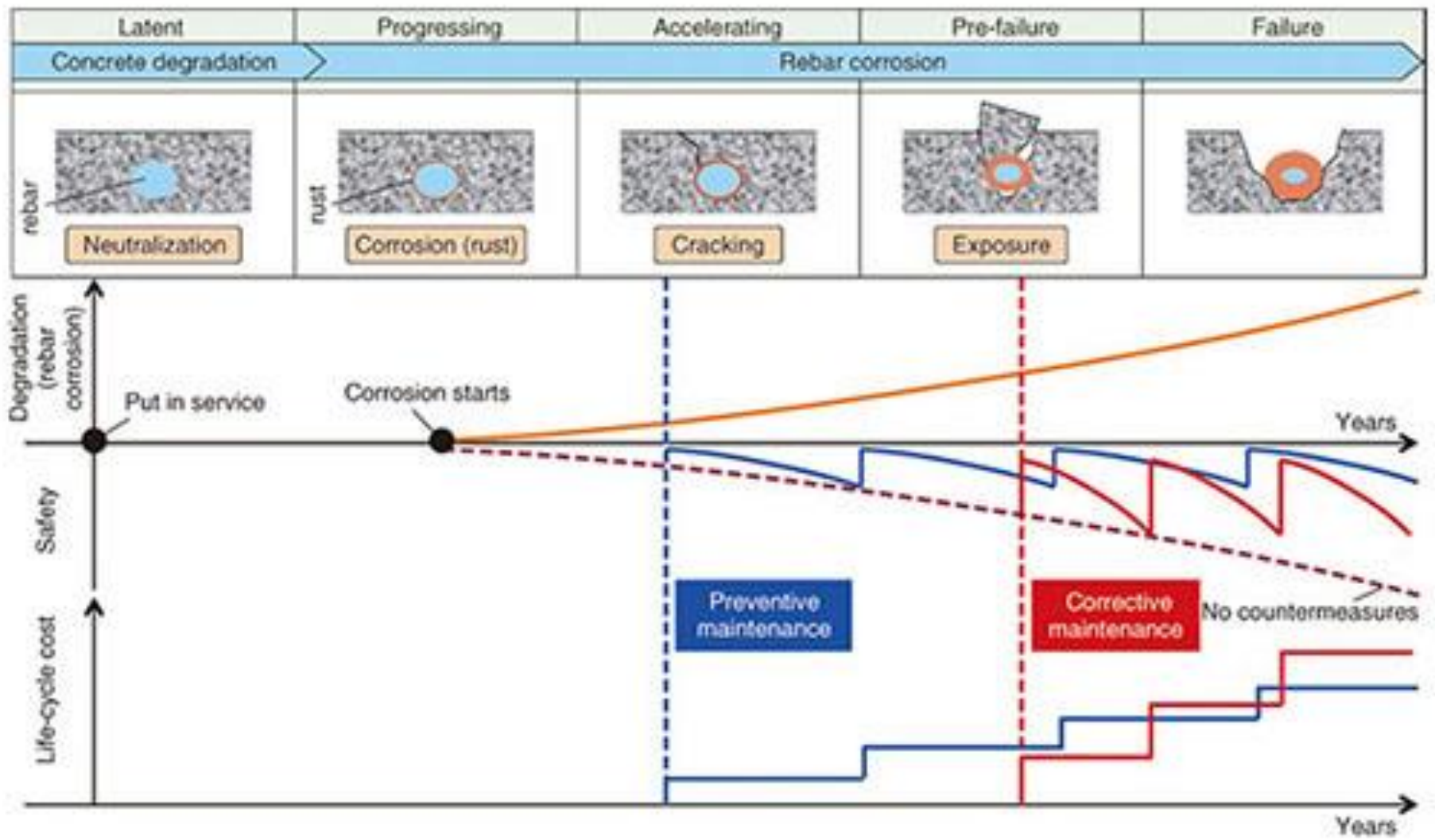
Definition - What does *Corrosion* mean?

- Corrosion is the deterioration and loss of a material and its critical properties due to chemical, electrochemical and other reactions of the exposed material surface with the surrounding environment.



The relative volumes of iron and its reaction product (ACI 222R-01)





DETERIORATION OF CONCRETE

The Canadian Cases:

Highway Bridge collapse at LAVAL,
Quebec, Oct.1,2006

1. The collapsed span is a highway overpass, with three lanes of 65 ft span, built on 1970.
2. The inquiries concluded construction company did not properly secure the concrete beams
3. It was the second serious overpass collapse in Laval in the last six years
4. Transport Quebec spokes woman Josee Seguin said the department heard about an hour before the accident that some pieces of concrete were falling off the overpass
5. Most of the experts refer to the huge amount of CORROSION and low resources for maintenance as a direct reason for these bridge failures.



A section of highway overpass collapsed in Laval, Quebec, outside Montreal, Saturday, September 30, 2006. Five people were killed and six people were injured. (AP Photo)



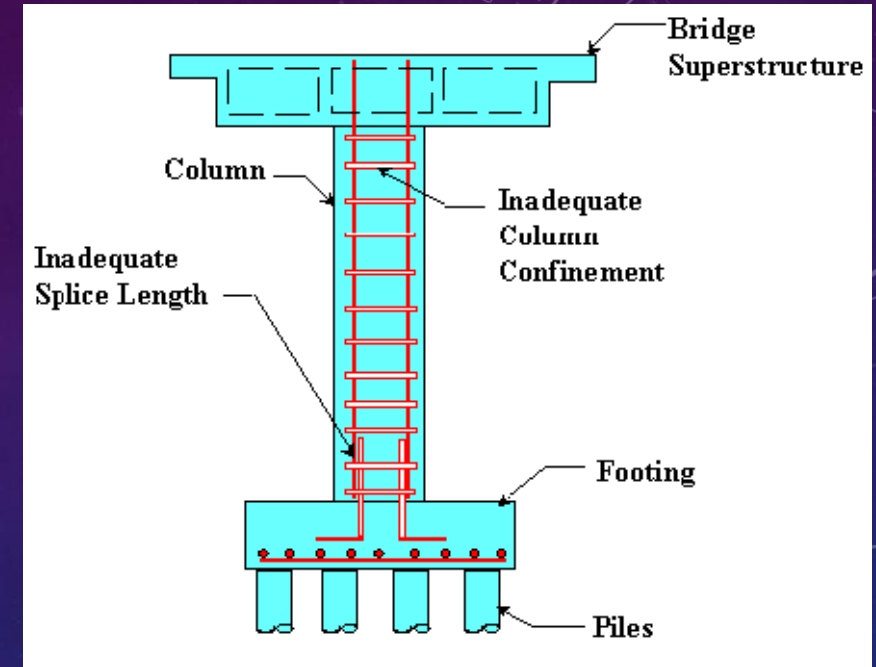
Rescue workers survey the site of an overpass that collapsed onto Highway 19 in Laval, Canada, Saturday, Sept. 30, 2006. (AP Photo/CP, Ryan Remiorz)

Bridges that failed due to Nature Disasters:

Bridge failures due to Earthquakes

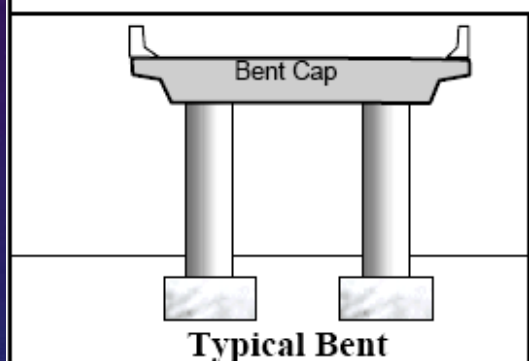
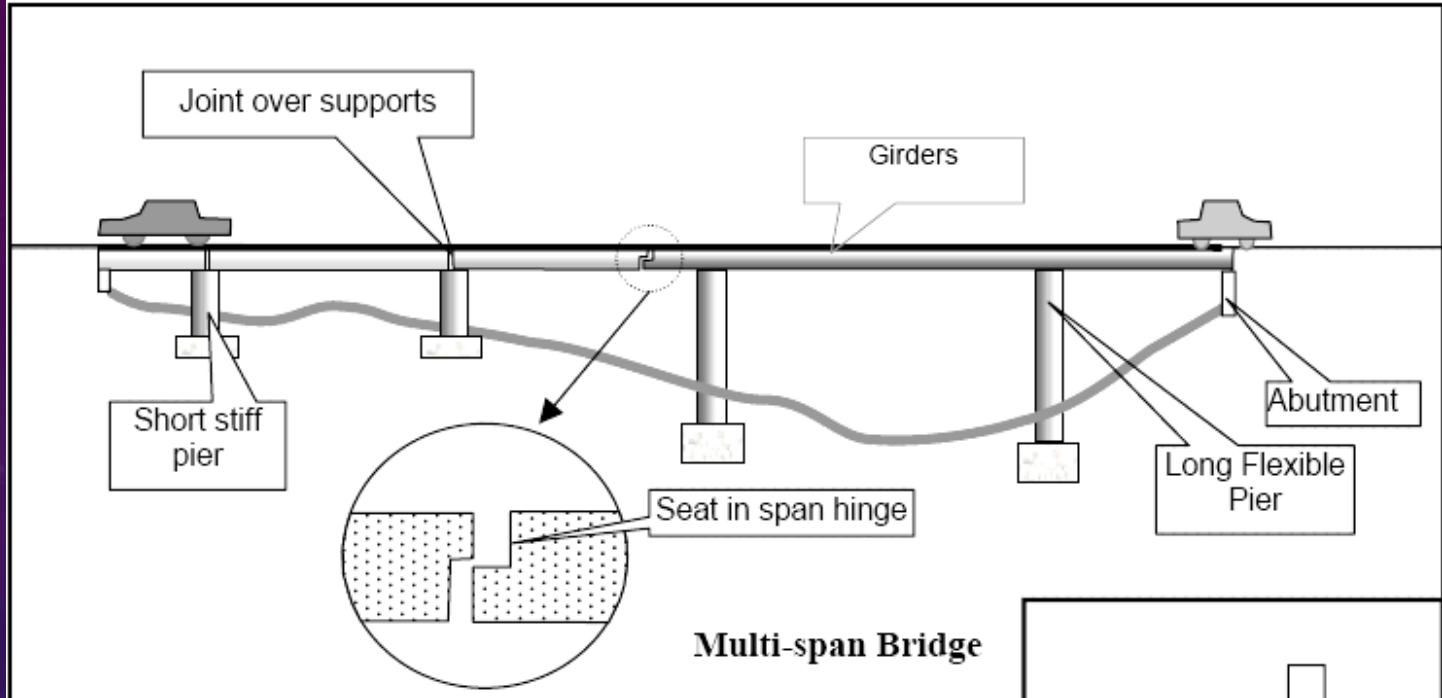
The principal areas of substructure deficiency of older bridges when compared to current design criteria are as follows:

1. Inadequate confinement reinforcement for main longitudinal reinforcing steel in concrete columns.
2. Inadequate splice length of main longitudinal column reinforcing to footing dowels.
3. Inadequate development length of footing dowels (footing embedment).
4. Absence of reinforcement in the tops of footings.
5. Inadequate footing support capacity.



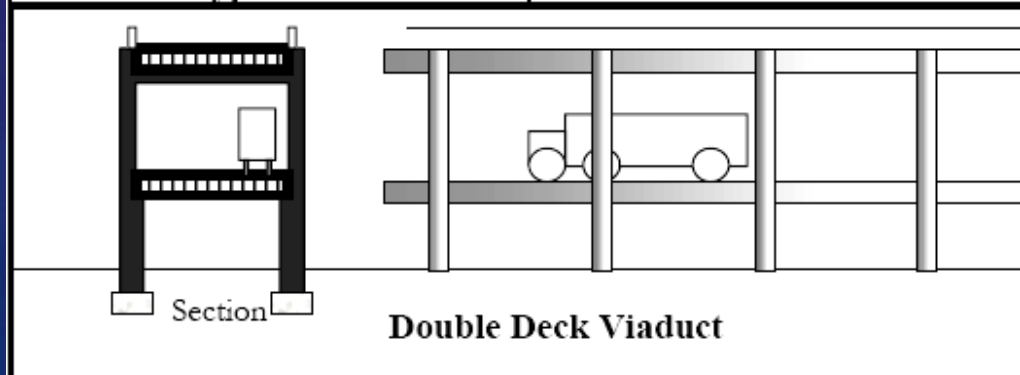
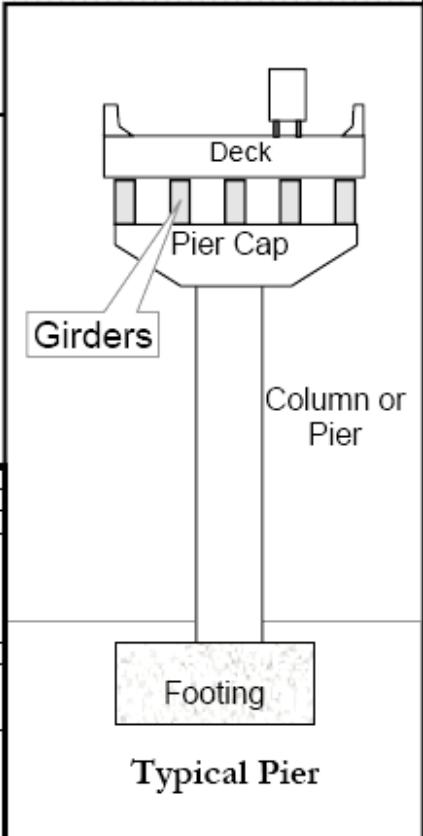
TYPICAL COLUMN DEFICIENCIES

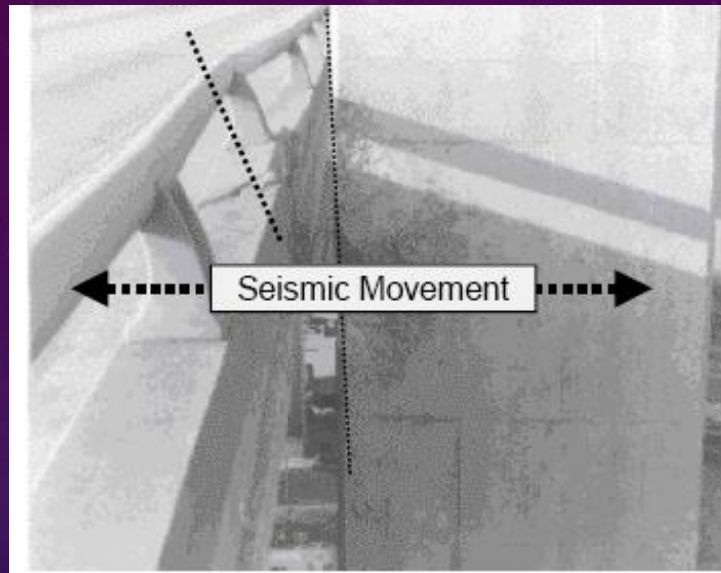




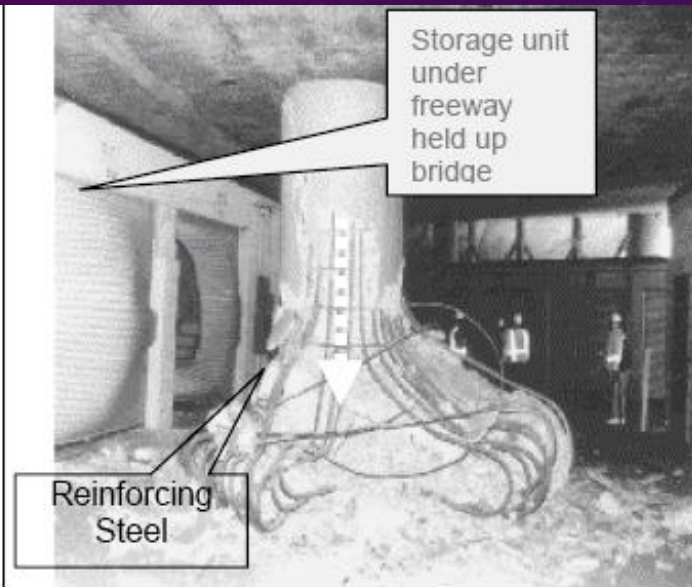
BRIDGE BASICS

The information on this page represents the basic components of bridges.
No Scale

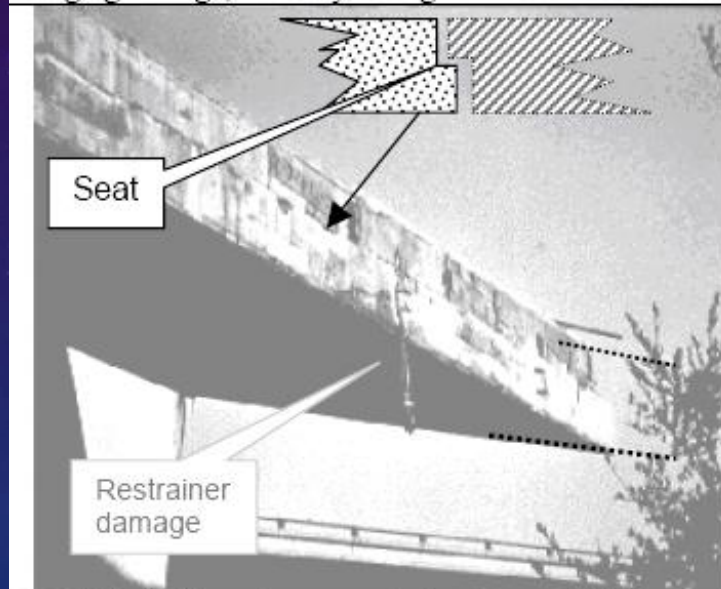




1989 Loma Prieta – Interstate 280 San Francisco , banging damage, roadway hitting column



1994 Northridge - Interstate 10 Los Angeles, La Cienega U.C. Concrete column damage



1994 Northridge – Interstate 5, San Fernando Valley, Galvin Canyon crossing. Adjacent span collapse due to unseating .



1994 Northridge – Interstate 10, La Cienega Bl. Column failure, bridge collapse

**Collapse of Spans
on Bridge Due to
1976 Earthquake
in Guatemala**



Collapses due to river floods:

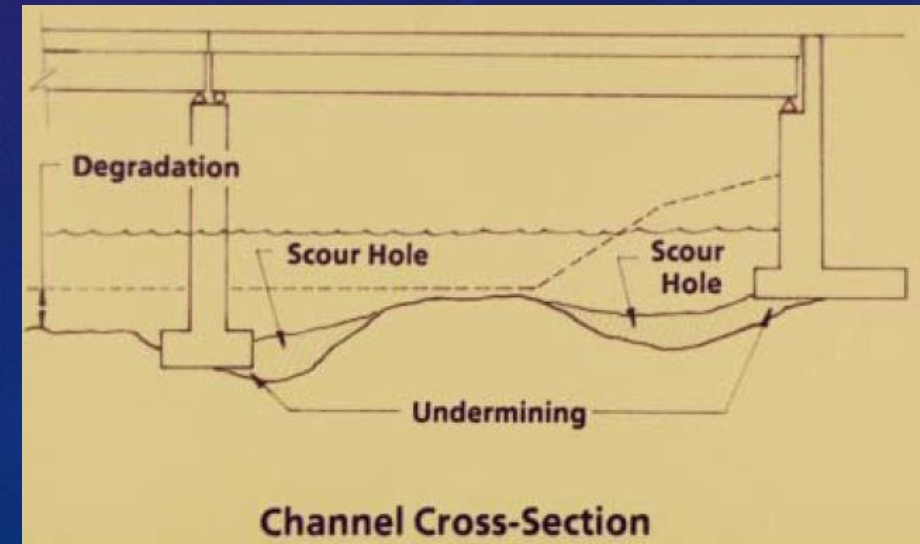
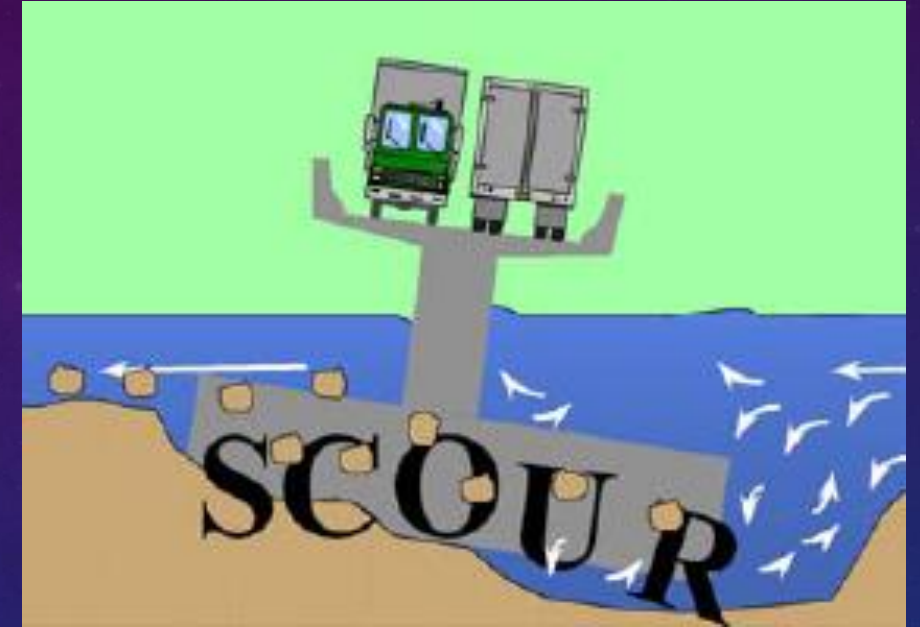
Bridges across Tachia River (Taiwan) and to the South along Highway 3





Most of the flood collapses are because of :

1. Scour underneath and around the piers and columns.
2. The direct impact of flooded water on the Piers, Supporting seats, pads and Superstructure.

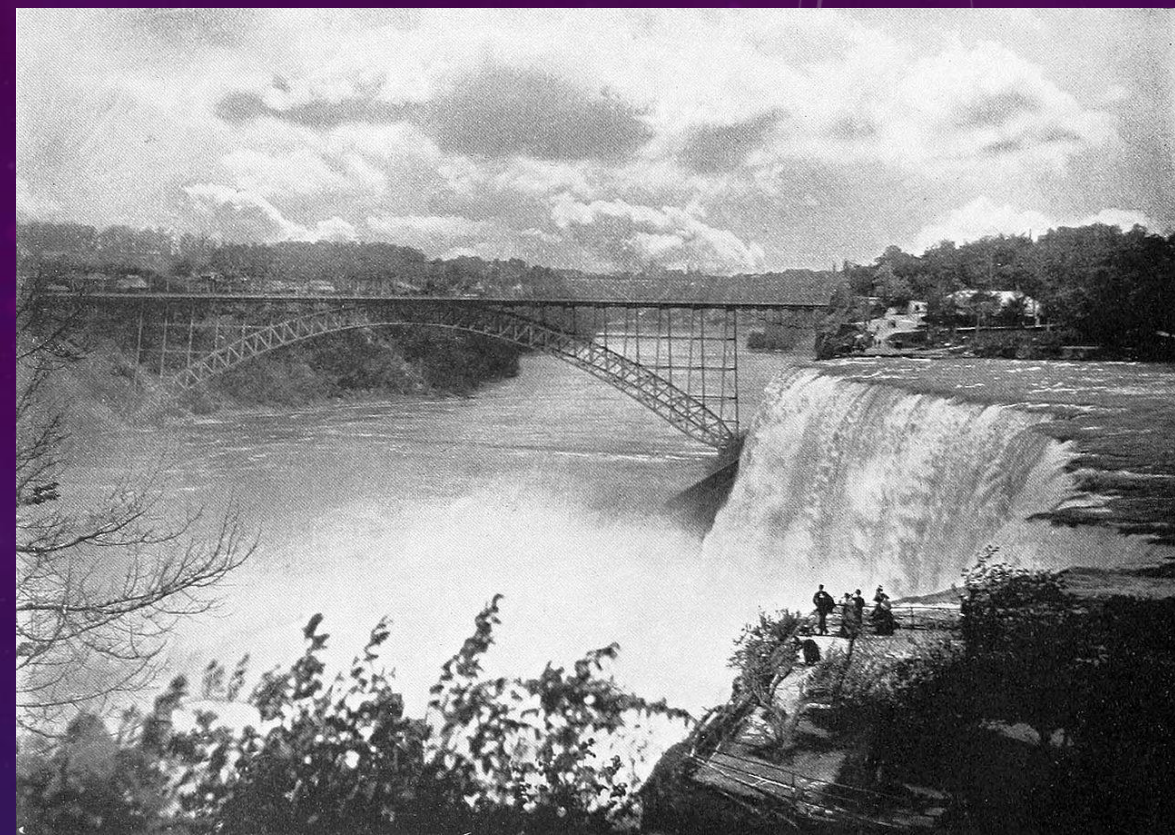




Tadcaster Bridge 2018, North Yorkshire, England, U.K, 300 year old Stone Bridge Grade II Listed on July 12, 1985



Partially collapsed Tadcaster Bridge (30th December 2015)
The bridge on the day after the collapse. This collapse also caused a substantial gas leak



Honeymoon Bridge (Upper Steel Arch Bridge) located in Niagara Falls, Built in 1897–98, and collapsed on January 27, 1938

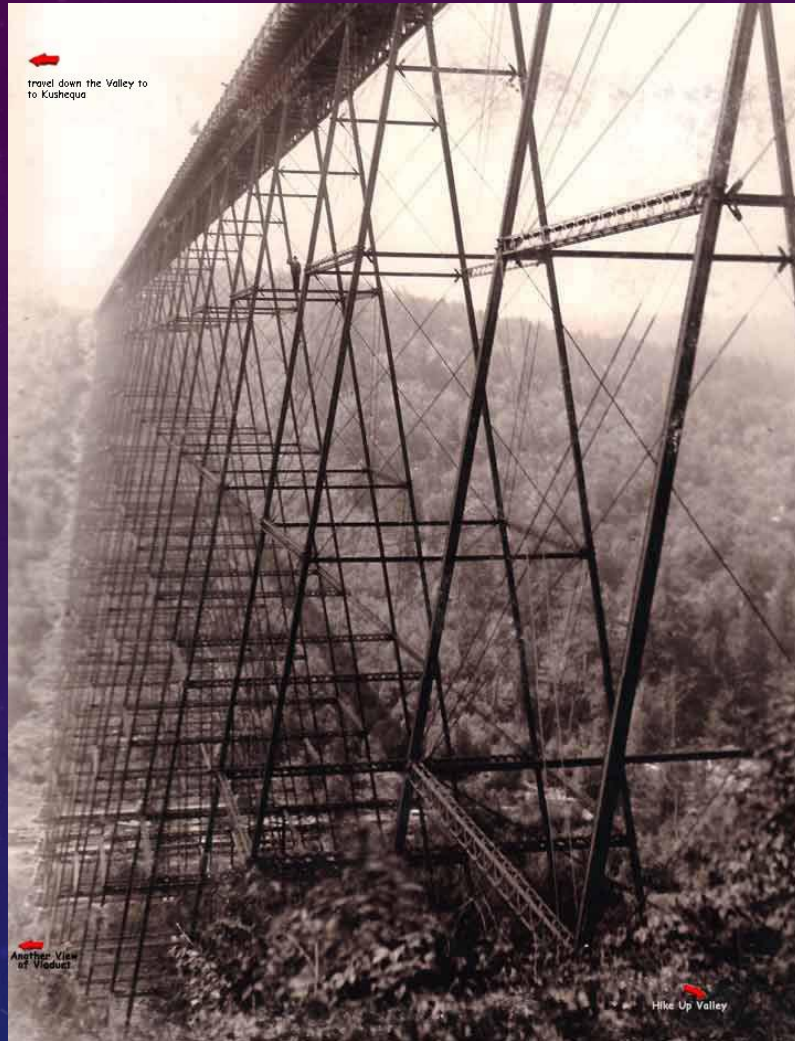


A sudden wind storm on Lake Erie sent a massive amount of ice over the falls, resulting in nearly 100 ft (30 m) of ice pushing against the bridge.



Failures due to Tornados and Hurricanes

2003: Kinzua Bridge Collapse



1883 Kinzua Bridge



1900's Kinzua Reconstruction

Kinzua Viaduct Fall of 2001



2003: Kinzua Bridge Collapse

Tornado blew Kinzua Viaduct down



© 2003 Francie Long Bradford Era via Associated Press

Bridges that collapsed after collision accidents



The Almö Bridge in 1962, Stenungsund, Sweden, 18 January 1980, Steel arch bridge



The collapsed bridge and MS Star Clipper Ship collision during bad visibility (mist)

Some Design Problems

1. Lack of Expansion or contraction support area:



Partial Failure Pier 11, East Fascia



Failed Condition at East Fascia

2. Lack of design information and material specifications:



Broughton Suspension Bridge built in 1826, located in Manchester, England. On 12 April 1831, the bridge collapsed, reportedly due to mechanical resonance induced by troops marching. As a result of the incident, the British Army issued an order that troops should "break step" when crossing a bridge



In 1924 it was replaced by a Pratt truss footbridge, still in use

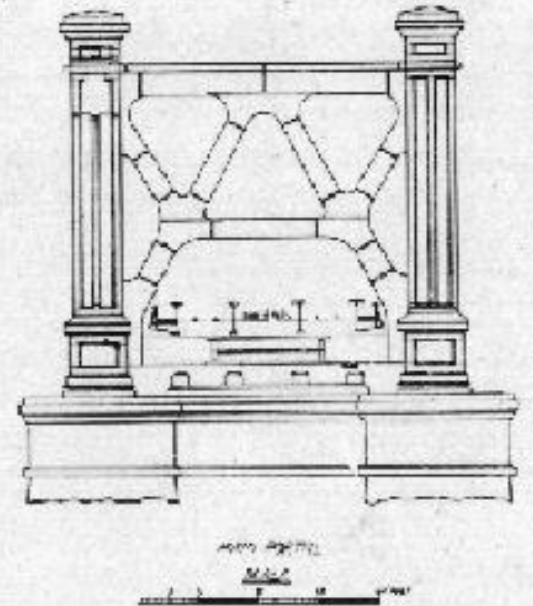
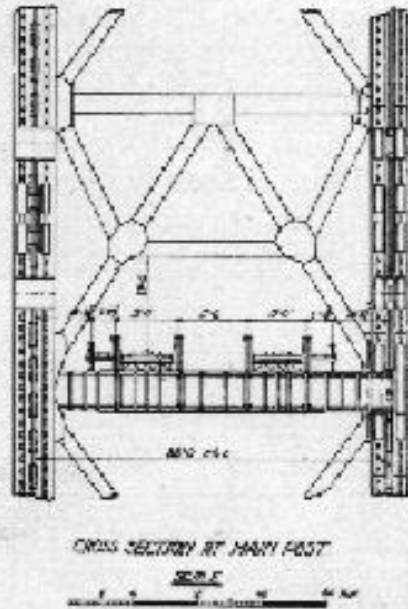
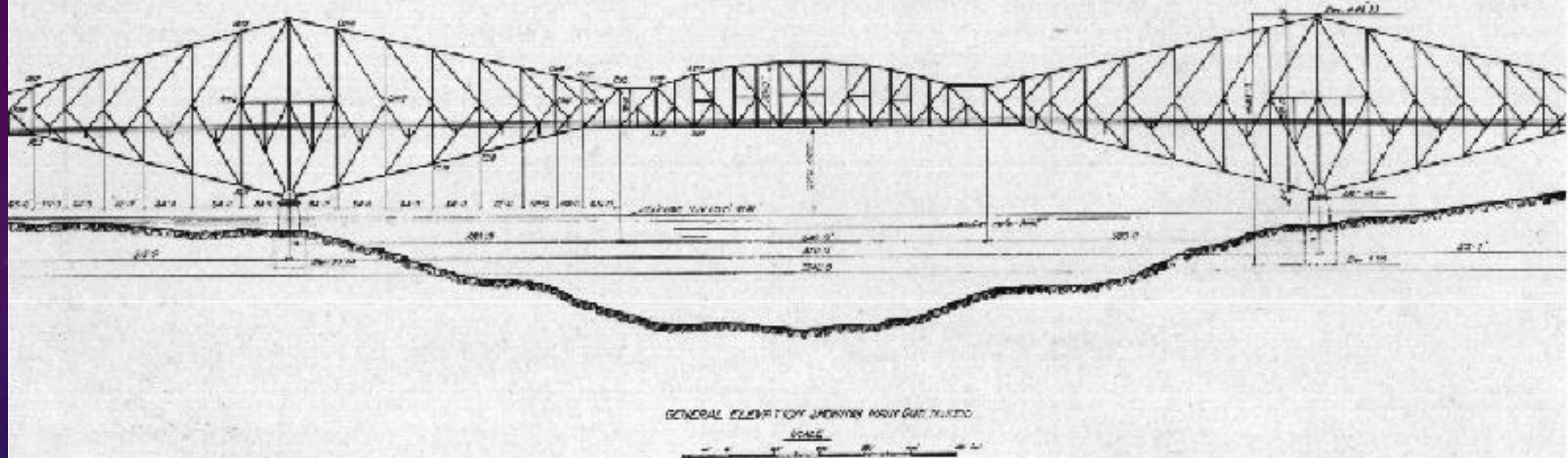
Quebec Bridge /
August 29, 1907

The Original Design:

1. Cantilever
superstructure with
two main supports
placed 1600 feet apart

2. Weighed a total of
62 million pounds

3. The head engineer
of the project
"Theodore Cooper"
said that this would
be the best and
cheapest plan and
proposal



A Change in Plans

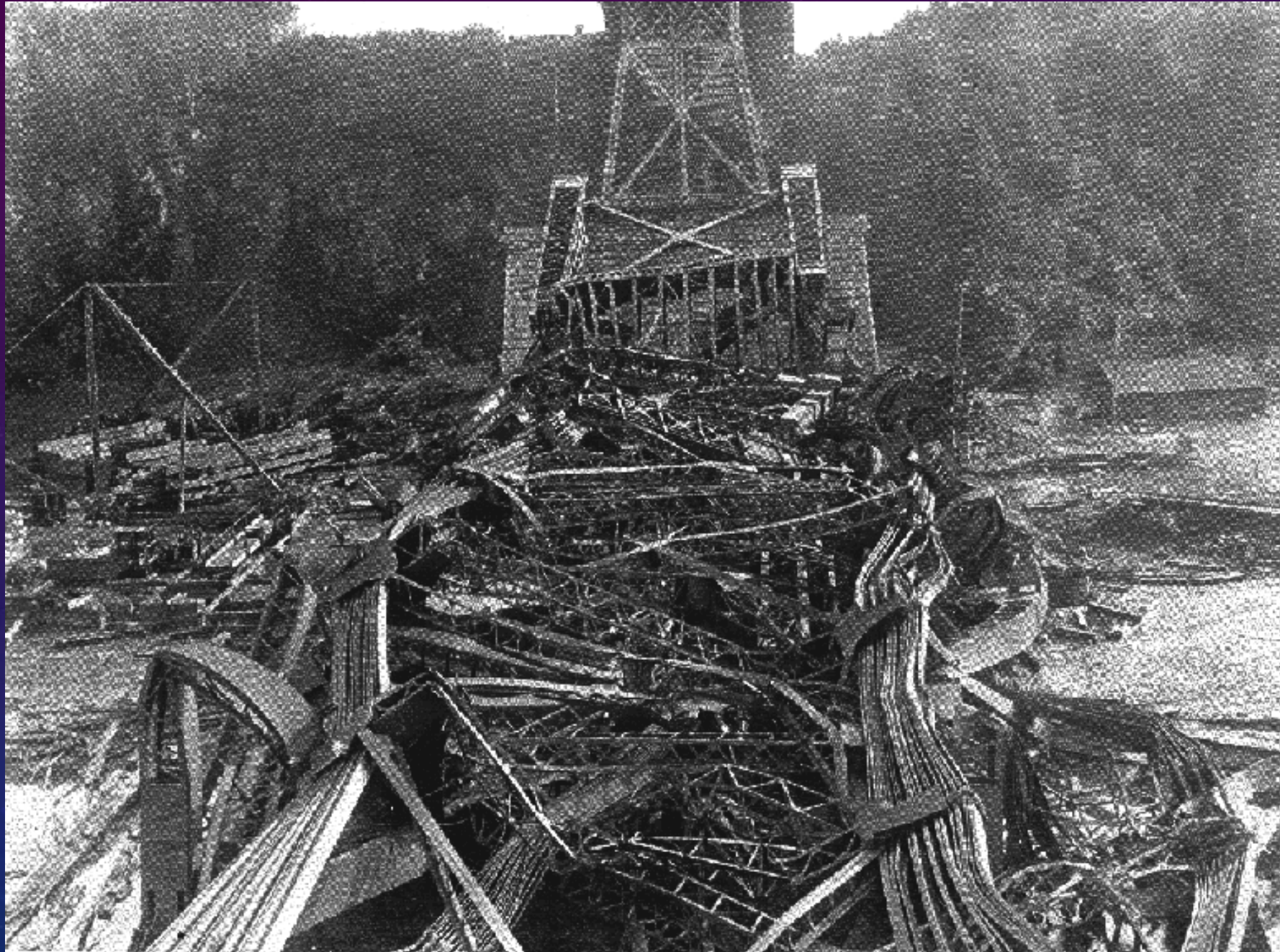
1. Before construction was to begin Cooper lengthened the span from 1600 ft to 1800 ft
2. He also modified specifications that would allow for higher unit stresses
3. There was no preliminary tests or research studies conducted to check these design changes
4. Cooper visited the site only 3 times, this left a lack of authority on the construction site

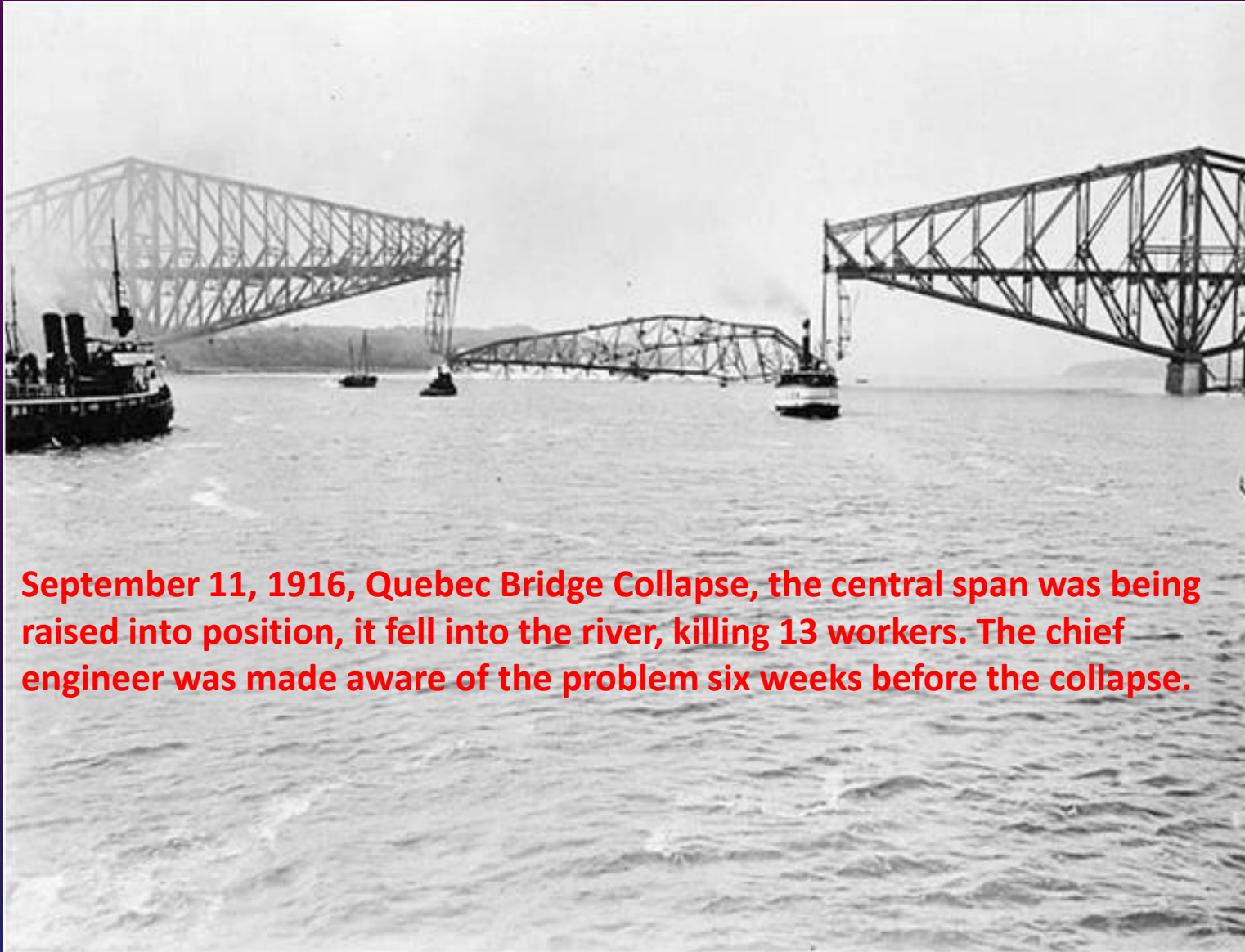
Troubles During Construction

1. The actual weight of steel put into the bridge had far exceeded the original weight
2. Compressive chords 7-L and 8-L of the south cantilever arm were bent
3. On August 27, 1907, it was reported that the deflection in chord 9-L had increased from three-quarters of an inch out of line to two and one-quarter inches in just a weeks time
4. Yet construction continued!!
5. For the Inaccurate theoretical estimates of the bridge's weight and the Unchecked changes
At August 29, 1907 the

bridge → Collapsed

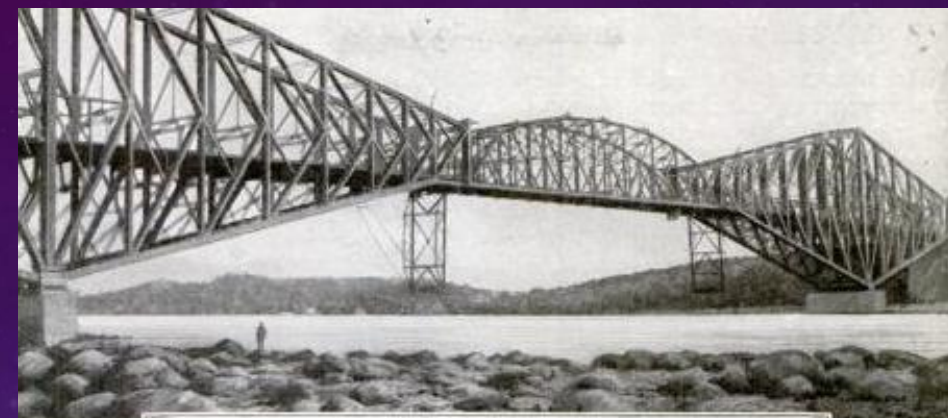
The Collapse at August 29, 1907





September 11, 1916, Quebec Bridge Collapse, the central span was being raised into position, it fell into the river, killing 13 workers. The chief engineer was made aware of the problem six weeks before the collapse.

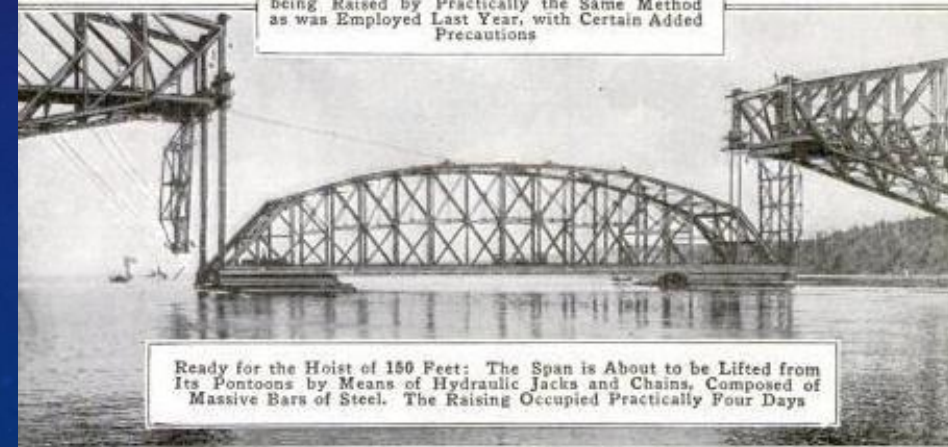
Lifting the center span in place was considered to be a major engineering achievement. Photo caption from Popular Mechanics magazine, December 1917



COPYRIGHT, INTERNATIONAL FILM SERVICE
The 640-Foot Central Span of the Mighty Quebec Bridge in Place: Undismayed by Tragic Failures in 1907 and 1916, the Builders have at Last Achieved One of the Greatest Triumphs in the History of Bridge Building



The Central Span, Weighing Over 5,000 Tons, being Raised by Practically the Same Method as was Employed Last Year, with Certain Added Precautions

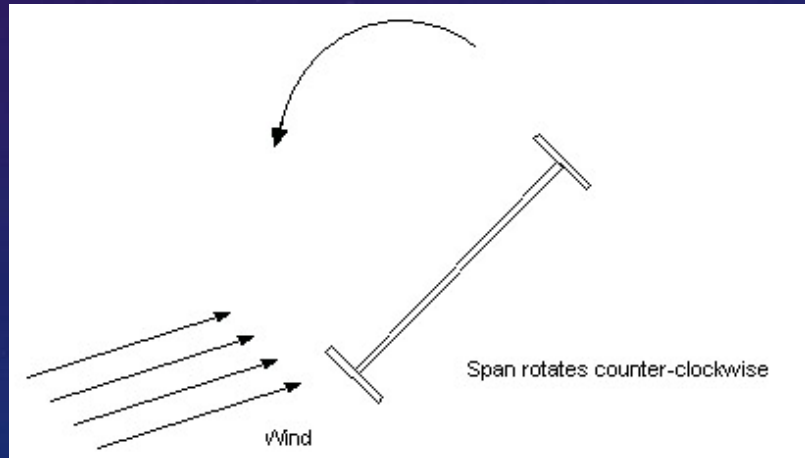
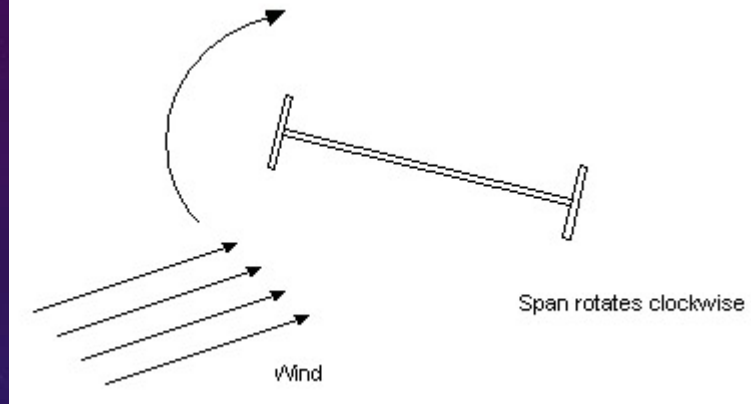
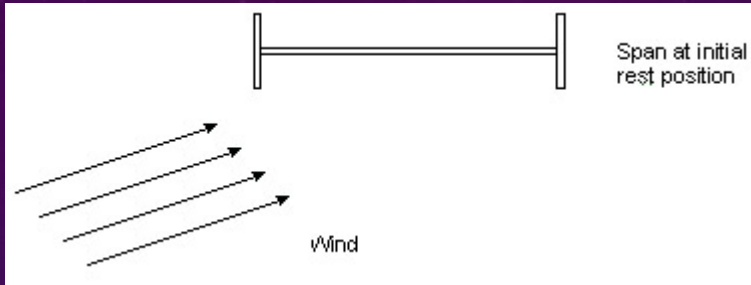


Ready for the Hoist of 150 Feet: The Span is About to be Lifted from its Pontoons by Means of Hydraulic Jacks and Chains, Composed of Massive Bars of Steel. The Raising Occupied Practically Four Days



The most Famous Collapse

Tacoma Narrows Bridge



Aerodynamically poor design resulted in aeroelastic flutter, opened on July 1, 1940 then collapsed on November 7, 1940

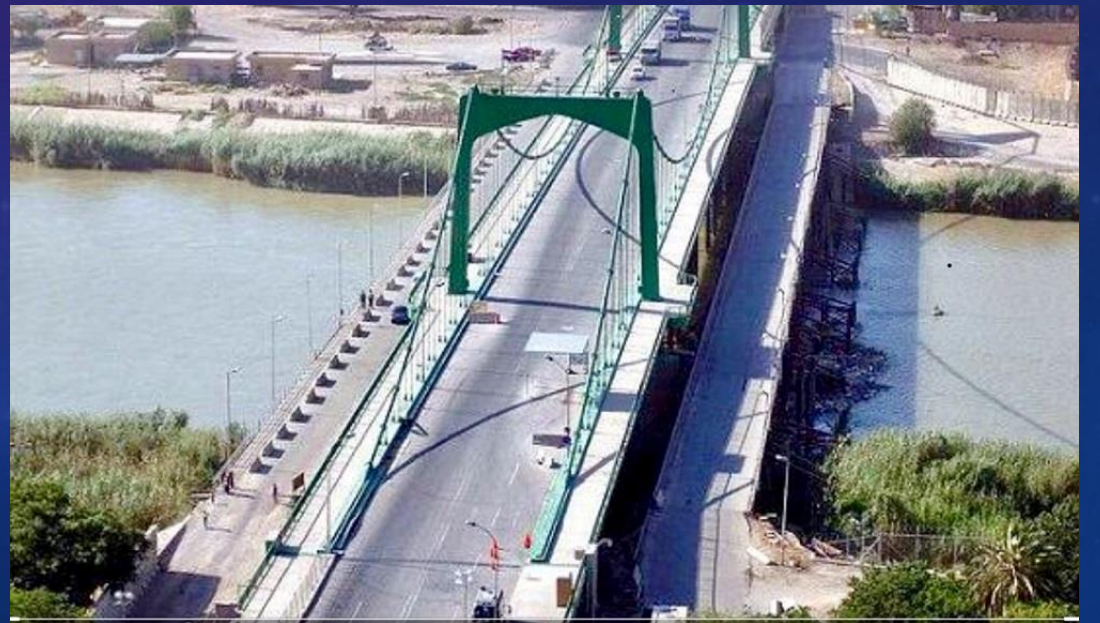
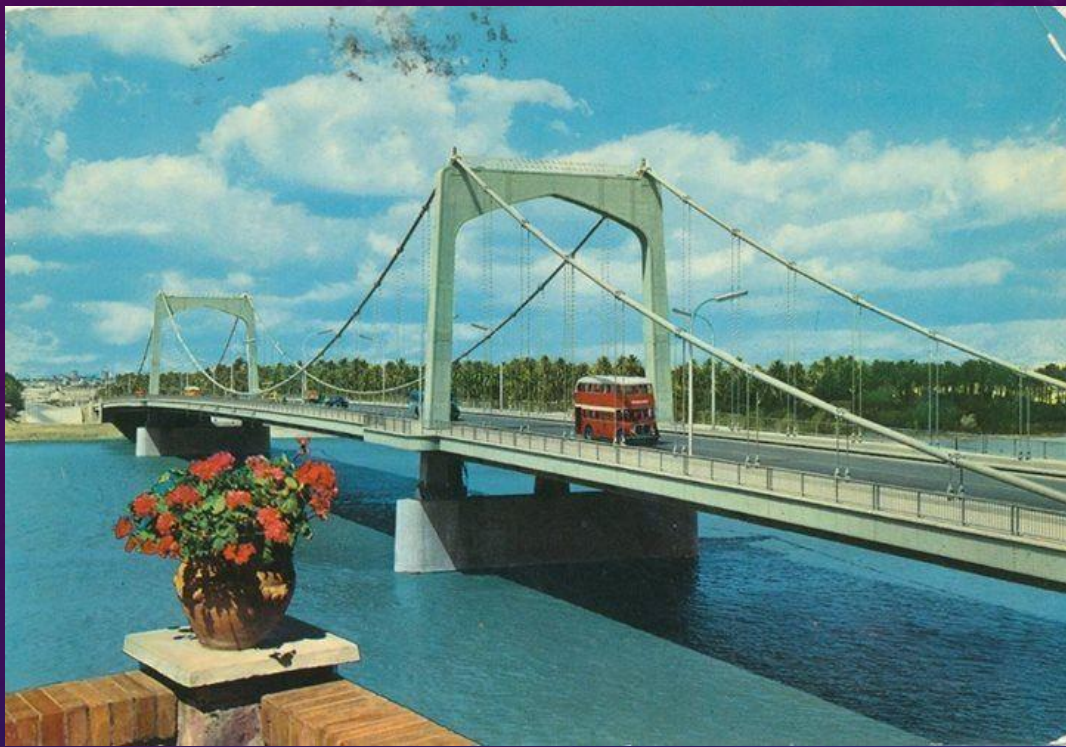
Bridges damaged or collapsed due to military aggression

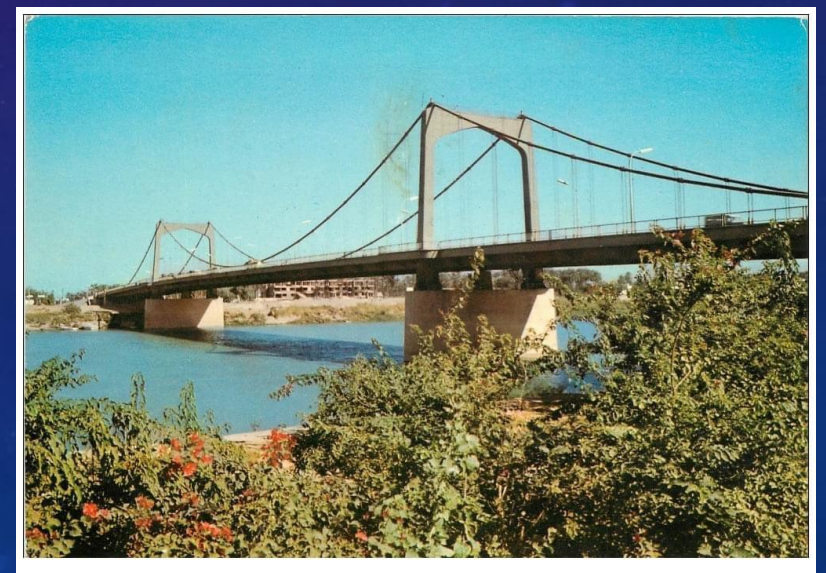
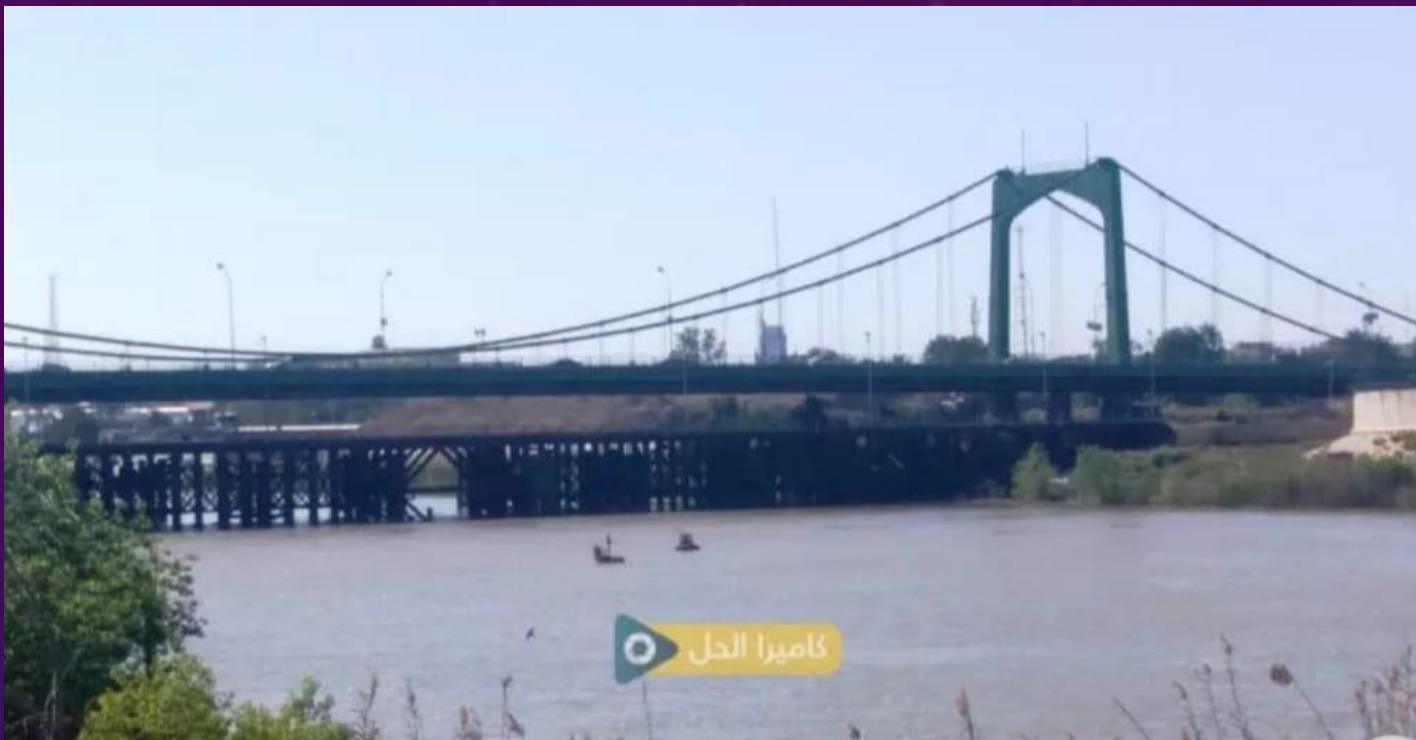


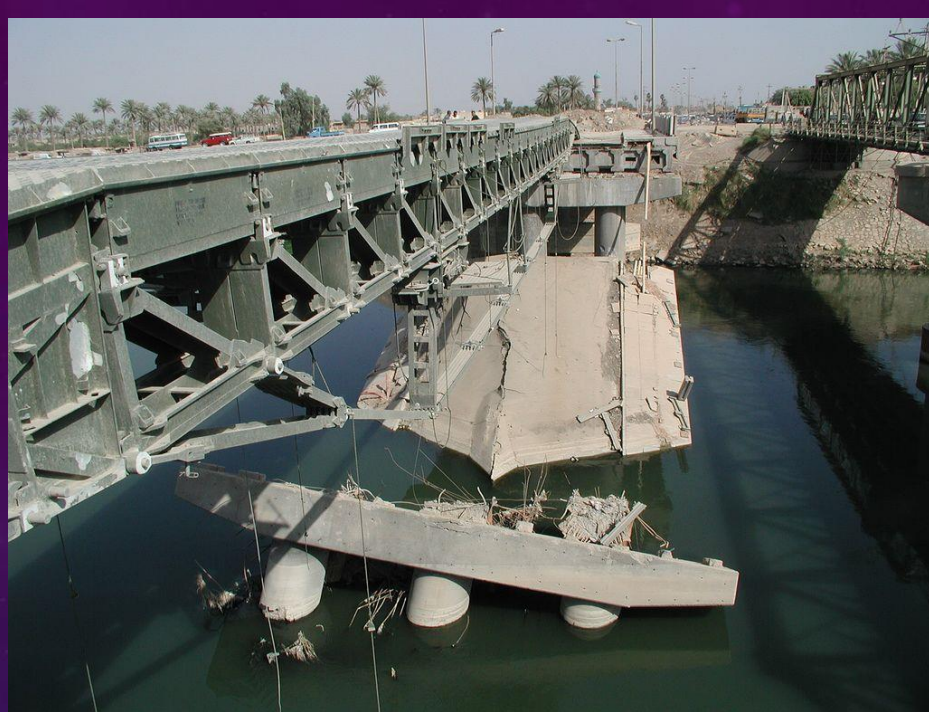
Ludendorff Bridge (Remagen Bridge) side view
Germany



Ludendorff Bridge on March 17, 1945 after the collapse, Collapse due to previous battle damage incurred 7 March 1945









QUESTIONS

The background is a dark blue gradient with a subtle pattern of white stars and technical diagrams. On the right side, there are several circular diagrams resembling gauges or dials. One large gauge has a scale from 0 to 210 in increments of 10, with a white needle pointing towards the 180 mark. Below it is another gauge with a scale from 0 to 100 in increments of 10, with a white needle pointing towards the 60 mark. There are also smaller circular elements and dashed lines scattered across the background.