Lessons Learned from Catastrophic* U.S. Bridge Failures (1968 to Present)

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*Involving loss of life and/or having substantial adverse economic impacts
Henry De Soto Bridge Cracks

OTHER TOP STORIES

River Burgues face backup if Memphis bridge remains closed

ECONOMIC IMPACT

Water risk found on route of pipeline

Study cites impact of pipeline

WJET

LAGE
Silver Bridge

- Two lane eye-bar suspension bridge built in 1928
- Spanned about 1500 ft (700 ft main span) across Ohio River between Point Pleasant, West Virginia and Gallipolis, Ohio
- Designed for HS-15 truck loading
- Utilized heat-treated AISI 1060 steel ($f_{ult} = 105$ ksi, $f_y = 75$ ksi)
Silver Bridge Collapse

• Occurred December 15, 1967 under heavy rush hour traffic load (46 fatalities)
• Collapsed due to stress corrosion cracking and subsequent brittle fracture of an eye-bar in one of the non-redundant suspension chains
• Resulted in improvements in U.S. bridge management practice
Silver Bridge Collapse

Improvements in U.S. Bridge Practice following Silver Bridge Collapse

• Mandated regular inspections of all bridges carrying public roads (NBIS -1970)
• Recognition of importance of Fracture Critical Members (FCMs), i.e., tension members whose failure is expected to result in collapse or inability of bridge to perform
• Improved material toughness, detailing, and construction requirements for FCMs in steel bridges (1978 and 1985)
I-40 Hernando deSoto Bridge – Memphis, TN

- Crack Found May 2021
- Closed for 3 Months for Repairs
I-40 Hernando deSoto Fracture

- Immediate criticisms from many sectors of U.S. bridge maintenance and inspection practices
- Calls for more funding even before cause of fracture was determined
Causes of Catastrophic Bridge Failures in the U.S.

1. Mianus River
2. Schoharie Creek
3. Rte 69 - Tennessee River
4. SF/Oakland Bay Bridge to I-580 Connector
5. I-35W - Mississippi River
6. FIU Prosperity Bridge
Mianus River Bridge - Greenwich, CT

June 1983 – 3 fatalities
Main steel girders in collapsed span supported at their ends by pin and hanger detail
Collapse Scenario

- Bridge deck drains covered during repaving project 10 years before collapse
- Water and road salts drain through expansion joints at hanger locations causing hangers to corrode
- Pack rust build-up pushes inside hanger at one girder end off pin
- Increased load in remaining hanger bar leads to its fatigue and brittle fracture
Conclusion:
Mianus River Bridge collapsed due to corrosion of hanger bar caused by poor maintenance
Schoharie Creek Bridge - Albany, NY

April 1987 – 10 fatalities
Bridge Superstructure Supported by Four 2-Column Concrete Piers
Typical pier elevation
Pier 3 foundation post-collapse elevation
Schoharie Creek Bridge

**Conclusion:**
Bridge collapsed when the Pier 3 foundation failed as a result of extensive undermining due to scour.

Fracture in Pier 3 foundation
Route 69 Tennessee River Bridge - Clifton, TN

May 1995 – 1 fatality
Bridge Superstructure

- 1200 ft long, three span, continuous plate girder bridge
- Three 14 ft deep plate girders
- Cross frames bolted to plate girders at 25 ft centers
Extent of girder construction on morning of collapse

Photo from recreational boater’s home video
At time of collapse, contractor had just removed previously installed bent cross frame.
Conclusion:

After a thorough investigation involving recovery and examination of the collapsed girders and cross frames and subsequent as-built structural analysis, it was concluded that the bridge failed due to lateral instability of Girder G1 created by the removal of Cross Frame FG4.
April 2007 –
No fatalities
or injuries
MacArthur Maze

Connector from I-80 west to I-880

Connector from I-580 to bay bridge west

Connector from I-80 west to I-580

Connector from bay bridge east to I-580

Connector from I-80 west to I-580
HOW THE CRASH HAPPENED

On the morning of April 29 at 3:41 a.m. driver James Mosqueda crashed his tanker truck full of gasoline on the southbound connector from I-80 to I-880. The tanker, carrying 8,600 gallons of gasoline, burst into flames causing a fire that reached the I-580 connector above. Bending steel that held up the I-580 connector caused the freeway to collapse.

Mosqueda drives South on I-80 from a refinery in Benicia.
Driving too fast for conditions, he loses control and truck overturns
8600 gallons of fuel in overturned tanker truck ignite and burn
As 8600 gallons of fuel burn, temperatures of steel girders supporting I-580 connector roadway reach 3000 deg. F
Westbound I-80 traffic back-up one day after fire and collapse

- 35,000 cars a day use I-880
- 45,000 cars a day use I-580
Heat from fire caused girders supporting I-580 connector to collapse onto I-880 connector.
Conclusion:
The eastbound connector to I-580 collapsed after a fuel tanker fire below the structure.
I-35W Bridge - Minneapolis, MN

August 2007 –
13 fatalities
145 injured
• Primary structure was a three-span, continuous 1,064 ft long, variable depth, steel deck truss built in 1967

• Truss members were typically riveted, built-up box sections with riveted gusset plate connections at nodes
Gusset Plate Thickness Comparison

Legend:
- 1 3/8” thick gusset plate (100 ksi)
- 1” thick gusset plate (50 ksi)
- 5/8” thick gusset plate (50 ksi)
- ½” thick gusset plate (50 ksi)
Typical ½ inch thick gusset plate recovered after collapse
Conclusion:
An original design error in the U10 gusset plates led to the collapse of the I-35W Mississippi River Bridge after it was loaded to approximately its design load.
Prosperity Pedestrian Bridge – FIU/University City, Florida

March 2018 – 6 fatalities
10 injuries
• Two-span truss; 175 foot main span
• Pylon and stay cables (actually pipes) are architectural features
• Canopy and 32-foot wide deck are post-tensioned
• Most diagonals are post-tensioned
Key members at the north end of the main span, where the collapse initiated
Timeline

- **October 19, 2017**
  - Deck concrete casting

- **February 24, 2018**
  - Shoring removal (cracking observed)

- **March 10, 2018, 12:30 PM**
  - Main span moved into final position

- **March 10, 2018, 3:07 PM**
  - Very significant widening of cracks observed

- **March 15, 2018, 11:49 AM**
  - Re-tensioning of member 11

- **March 15, 2018, 1:45 PM**
  - Main span collapses
Section At East Face of Member 11/12

LEGEND
- OBSERVED CRACK
- ESTIMATED CRACK
- SPALL
- BREAKOUT

NOTE: REINFORCEMENT IN PLAN LOCATION LOCATIONS MAY VARY
Code evaluation of Member 11/12 deck connection
## Code-calculated capacities

<table>
<thead>
<tr>
<th>Factored Northward Force (kips)</th>
<th>Surface Condition</th>
<th>Factored Resistance</th>
<th>Capacity/Demand Ratio (CDR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>Roughened</td>
<td>2150</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>Not Roughened</td>
<td>1157</td>
<td>0.58</td>
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</table>
FHWA Conclusion: “The evidence indicates that the failure interface coincides with the original cold joint and that the cold joint was not intentionally roughened.”
Interface shear transfer condition testing

Member 11

Member 12

WJE Test Sample

Deck Cutaway Section

Construction
Interface shear transfer condition

<table>
<thead>
<tr>
<th>Laser Scan Data: Standard Deviation (mm)</th>
</tr>
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<tbody>
<tr>
<td>Deck Specimen 1 (recovered by NTSB from site)</td>
</tr>
<tr>
<td>WJE Specimen 3 (as-placed)</td>
</tr>
<tr>
<td>WJE Specimen 4 (intentionally roughened)</td>
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### Summary of Shear-Friction Resistance

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### Interface shear transfer test results

<table>
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<tr>
<th>Specimen</th>
<th>Peak Load (Average)</th>
<th>Member 11 Load at Failure</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Roughened</td>
<td>2,594 kips</td>
<td>1,743 kips</td>
<td>149%</td>
</tr>
<tr>
<td>Non-roughened</td>
<td>1,455 kips</td>
<td>1,743 kips</td>
<td>83%</td>
</tr>
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</table>
FIU Pedestrian Bridge

Conclusion:
If the construction joint were roughened as required by the project specifications, which were reconfirmed by email, the collapse would not have occurred.*

*NTSB attributed cause to design mistakes by FIGG as to the load and capacity of the Member 11/12 deck connection. Had cold joint been roughened, bridge could still have failed.
Causes of Catastrophic Bridge Failures in the U.S.

1. Mianus River
   - Inadequate maintenance

2. Schoharie Creek
   - Scour/undermining of supporting structure

3. Rte 69 - Tennessee River
   - Failure to maintain stability during construction

4. SF/Oakland Bay Bridge to I-580 Connector
   - Vehicular impact

5. I-35W - Mississippi River
   - Design error

6. FIU Prosperity Bridge
   - Construction error
Conclusion:
In all likelihood, the cracking in the weld repairs occurred within hours of their completion but was not detected by any post-weld repair fabrication testing and remained unchanged for a number of years.
Summary

• Design and inspection practices instituted following the Silver Bridge collapse have been successful in eliminating fatigue and brittle fracture as the cause of catastrophic bridge failures.

• Bridge failures during construction and by impact are not addressed by the post-Silver Bridge legislation and require further review.

• Changes to current practices should be deliberate and not reactionary.
Questions?