Bridge Description and Collapse

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Presentations

1. Bridge description and collapse
2. Construction activities on bridge at time of collapse
3. Gusset plate inadequacy
4. Finite element modeling analysis
5. Design and review process
6. Bridge load rating and bridge load analysis
7. Bridge inspections
8. Gusset plate inspections
Bridge Description and Collapse

1. General description of bridge
   - Structural elements
   - Bridge modifications

2. Sequence of collapse
   - Initiation location
   - Secondary damage and fractures

3. Factors excluded
Bridge Description and Collapse

North Approach  Deck Truss  South Approach

Spans 9 - 14  Spans 6 - 8  Spans 1 - 5

North  South
North Deck truss
North approach
South approach
Deck truss
General Description of the Bridge
General Description of Bridge

• Deck truss original weight: 18.3 million pounds

• 1977 Modification
  – Deck thickness increased
  – Added over 3 million pounds

• 1998 Modification
  – Barriers / deicing system
  – Added 1.2 million pounds
Sequence of Collapse

- Deck truss
- Camera
Video Evidence

Pre-Collapse

North

South
Video Evidence

LWR4

18:01:38 08/01/2007
Video Evidence

Pre-Collapse

North

South
Video Evidence

Collapse Video - Frame #1

North

South

L11W
Video Evidence

Collapse Video - Frame #3

North

South

L11W
Video Evidence

Collapse Video - Frame #5

North

South
Video Evidence

Collapse Video - Frame #6

North

South
Video Evidence

Collapse Video - Frame #7

North

South
Video Evidence

Collapse Video - Frame #8
Video Evidence

Collapse Video - Frame #11

North

South
Video Evidence

North

Pre-collapse

South
Video Evidence

• No initiation in center section or north section
• Collapse initiated south of node L11
• Node L11W remained intact after collapse initiated
• Deck lifted from stringers above node L11 and further to the south
Basis of Collapse Sequence

- Video evidence
- Fracture and damage patterns
- Finite element analysis
Fracture and Deformation

North

Upper chord

Lower chords

Upper chord

U10W

U10E
Sequence of Collapse Methodology

• Initiating event occurs from forces acting along the members
  – Buckling under compression
Sequence of Collapse Methodology

- Initiating event occurs from forces acting along the members
  - Buckling under compression
  - Tension fracture without bending
Sequence of Collapse Methodology

• Deformation adjacent to fracture
  – Occurs during fracture process
  – Not from subsequent collision or ground impact
Sequence of Collapse Methodology

• Documentation
  – Fractures
  – Deformation patterns
  – Impact marks

• Damage evaluation
  – Early in collapse process?
  – From subsequent ground or riverbed impact?
Sequence of Collapse Methodology

• Methodology used in other investigations
  – TWA Flight 800
  – Rail from Baltimore railroad tunnel fire
Sequence of Collapse Results

- Main trusses fractured between nodes 9 and 10
- Fractures in node U10 gusset plates met initial event criteria
Drawing of Fractures in Node U10E
West Gusset Plate

Initial compression failure

Initial tension fracture
Initial Tension Fracture U10 West

L9/U10W

North

Up

1 2 3 4 5 6
Folded gusset plate tips on compression diagonal at node U10 west.
2003 Photo

Compression diagonal
Collapse Initiation

• Initial failure in U10 gusset plates
  – Compression failure above compression diagonal
  – Tension fracture

• Collapse was unavoidable once gusset plates failed at node U10
Secondary Damage - Bent and Fractured Member
1. Gusset plates at nodes U10 failed, compression diagonals translated to the west, and remaining portions of nodes U10 were pulled down and through diagonals.
Sequence of Collapse

2. Dropping of center span created tension loading in main truss lower chords and secondary structural members. This loading pulled south portion of deck truss to the north, off pier 5, causing loss of support for south approach spans.
Sequence of Collapse

3. Other main truss members fractured in bending
Sequence of Collapse

4. Lower chord L7/L8 east fractured from its nodes, allowing south portion of truss to topple to the east
South Portion Toppled to the East

Center section
Sequence of Collapse

5. Gusset plates at node U10′ failed, and additional secondary failures in this portion of the truss completely separated the center section of the center span from remainder of deck truss.
6. Deck truss collapsed above pier 8, causing loss of support for north approach spans, and this collapse spread southward toward pier 7.
Factors That Did Not Contribute

- Corrosion damage
- Fracture of a floor truss
- Pre-existing cracking
- Bearings and piers
Corrosion Damage

• Some corrosion present
  – Secondary members
  – Lower chord gusset plates

• Inspection records documented corrosion
Corrosion Did Not Contribute

L11 gusset plates
failure eliminated
as factor as shown by:

- Fracture and
deformation patterns
- Video recording
- Finite element
analysis
Fracture of a Floor Truss

- Fracture of a Floor Truss
- Floor truss 10 upper chord
- West
Fracture of a Floor Truss

Floor Truss 10

Cut

West
Floor truss 10 – secondary damage
Preexisting Cracking

- Primarily in approach spans
- Main truss welds
  - Near node U14
  - Near node U7’
- No fatigue cracking in fractured pieces
- U10 gusset plates
  - Ductile overstress tension, shear, and bending fractures
• Rollers were moving
• Wear in center of contact plates
• No horizontal shifting of piers
Pier Movement

Pier 7
Overall Summary

• Collapse initiated with failure of gusset plates at nodes U10
• Complete collapse was unavoidable once these gusset plates failed
• Other possible initiation locations and factors were ruled out
• All findings were supported by
  – Fracture and deformation patterns
  – Video evidence
  – Finite element analysis