Truss Bridges and Cause of I-35W Mississippi River Bridge Collapse

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Truss Bridge

Examples of the three common travel surface configurations are shown in the Truss type drawings below. In a Deck configuration, traffic travels on top of the main structure; in a Pony configuration, traffic travels between parallel superstructures which are not cross-braced at the top; in a Through configuration, traffic travels through the superstructure (usually a truss) which is cross-braced above and below the traffic.

William Preston Lane Jr. Memorial (Bay) Bridge (US50/301)

A major dual-span bridge with the original span, opened in 1952 and with a length of 4.3 miles (6.9 km) and the parallel span (westbound) was added in 1973.
- A 3,200-foot (975 m) suspension span over the western channel with a maximum clearance of 186 feet (56.7 m)
- A through-truss cantilever span over the eastern channel with a maximum clearance of 58 feet (18 m)
- Deck truss and steel girder spans flanking the main spans

Francis Scott Key Bridge (I-695)

The bridge was opened in March 1977. The total length is 8,636 feet (2,632 m) and carries an estimated 11.5 million vehicles annually. The main span of 1,200 feet (366 m) is the third longest span of any continuous truss in the world.
Governor Harry W. Nice memorial Bridge (US301) /Thomas J. Hatem Memorial Bridge (US40)

- The Nice bridge opened on December 15, 1940 is a 1.7-mile (2.7 km), two-lane continuous truss bridge that spans the Potomac River between Maryland and Virginia.
- The Hatem bridge is a road bridge crosses the Susquehanna River opened to traffic on August 28, 1940. Total length is 7,624 feet (2,324 m) with the longest span 456 ft (139 m)

Thomas J. Hatem Memorial Bridge (US40)
The Millard E. Tydings Memorial Bridge carries Interstate 95 (I-95) over the Susquehanna River. The toll bridge opened in 1963 carries 29 million vehicles annually. Total span length is 1,542 m (5,061 ft), 6 suspended spans of 245' each and 5 anchored spans for a center span length of 214" - 4½" each with 122' - 6" cantilevered arm on each side. Totally, there are 159 panels

Truss Bridge Parts

- The different parts of a truss bridge are all named. Some of the parts:
  - Top / Upper Chord
  - Vertical (Member)
  - Diagonal (Member)
  - Hip Vertical (Only the verticals that meet the top of the end post)
  - Bottom / Lower Chord
  - Connections
  - End Post
  - Portal Bracing
  - Sway Bracing (Upper-most bar sometimes called a “strut”)
  - Lateral Bracing

Truss Bridge Joint/Member Numbering

- U7U8
- U7L8
- U7L7
- L7L8
- Various numbers and lettering indicating joint and member connections.
I. Truss Bridge Gussets

Background

• Truss Gusset Plates and Connections of Truss Members to the Gusset Plates are Usually Stronger than the Truss Members to which they are Connected.

• Load Ratings of Trusses Have not Usually Included a Check of the Gusset Plate Capacity

• After I-35W Bridge over the Mississippi River in Minneapolis, Minnesota Collapsed in 2007, NTSB Decided on Under-designed Gusset Plate
Load ratings required according to the AASHTO Manual for Condition Evaluation of Bridges. The following supplemental actions are recommended:

- **New or replaced truss bridges** – check gusset plate capacity as part of the initial load rating.
- **Existing truss bridges** – check gusset plate capacity when load rating after condition or load changes of the structure.
- Review previous load rating calculations for truss bridges that have undergone significant changes in stress levels previously in their service life.

### CAUSES of DEAD LOAD INCREASE

- Increased Deck Thickness
- Deck Overlay Increase
- Bridge Deck Widening
- Widening Roadway Width (Curb to Curb, Rail to Rail)
- Addition of Sidewalk Overhang
- Addition of Major Utilities
- Addition of Concrete
CAUSES of LIVE LOAD INCREASE

• Current Live Loading > Design Live Loading
• Increase in Number of Lanes Since Original Construction
• Increase in Deck Roadway Width (Increased LL Distribution to Trusses)
• Known to be in an Area of Increased Overweight Loads

THE RESISTANCE OF FASTENERS

• Fasteners Shear Failure
  – Bolt: AASHTO LRFD Articles 6.13.2.7
  – Rivet: $\phi R = \phi F \times m \times A_r$

• Plate Bearing Failure
  (AASHTO LRFD Articles 6.13.2.9)

THE RESISTANCE OF GUSSET PLATES

The resistance of a gusset plate shall be determined as its least resistance in:

1. Tension including block shear
2. Shear
3. Combined flexural and axial loads
4. Compression.

1. GUSSET PLATES UNDER AXIAL TENSION

Gusset plates subjected to axial tension shall be investigated for three conditions (Whitmore section is adopted):

– Allowable Tensile Force on Gross Section (Yielding Resistance)
  \[ P_y = \phi_y P_{my} = \phi_y F_y A_g \]

– Allowable Tensile Force on Net Section (Fracture Resistance)
  \[ P_r = \phi_r P_{mn} = \phi_r F_y A_n U \]

– Block shear rupture
WHITMORE SECTION
(Effective Width in Tension)

BLOCK SHEAR RUPTURE RESISTANCE

- If \( A_s \geq 0.58A_n \), then: \( R_s = \phi_s \left( 0.58F_y A_y + F_v A_w \right) \)
- Otherwise: \( R_s = \phi_s \left( 0.58F_y A_y + F_v A_w \right) \)

2. GUSSET PLATES IN SHEAR

- Gross Shear Yield Sections: \( R_s = \phi_s R_y = \phi_s \times 0.58A_y F_y \times \Omega \)

GUSSET PLATES IN SHEAR

- Net Shear Fracture Sections: \( R_s = \phi_n R_n = \phi_n \times 0.58A_n F_n \times \Omega \)
3. GUSSET PLATES IN COMPRESSION
- Effective Length Factor, K, varied from 0.65 to 2.1. In most cases, K=1.0 (Pinned-Pinned)

4. GUSSET PLATES UNDER COMBINED FLEXURAL AND AXIAL LOADS
- FHWA Guide: The Maximum Elastic Stress may be taken as $\phi_f F_y$