



NTSB National Transportation Safety Board

Office of Research and Engineering

Design Error

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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 analysis
5. Design and review process
6. Bridge load rating and bridge load analysis
7. Bridge inspections
8. Gusset plate inspections

Information Reviewed

- Mn/DOT and Jacobs Engineering
- 3,000 documents / 10,000 pages
 - Design plans
 - Shop drawings
 - Contracts
 - Conference notes
 - Inter- and intra-agency communications
 - Computation sheets, checked and unchecked
 - Engineering studies
- Interviews with design firm employees

Chronology of Bridge Project

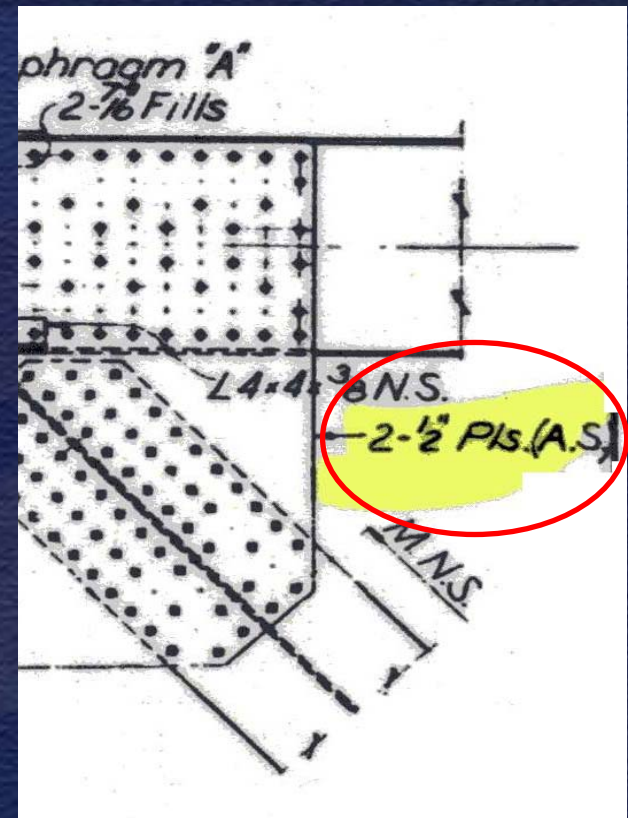
- October 22, 1962
- Sverdrup & Parcel (S&P) was contracted to design I-35W bridge
 - Preliminary engineering report
 - Completed and checked final plans
 - Checked design computations

Chronology of Bridge Project

- 1963 - S&P supplied Mn/DOT with the preliminary engineering report
 - Mn/DOT
 - FHWA
 - Gusset plates not discussed
- 1965 - S&P presented final design plans
 - No gusset plate documents
- 1967 - Bridge opened to public

Potential Sources of Error

- Fabrication
 - ~~– Material mix-up~~
 - ~~– Transcription error~~
 - No shop drawing changes
 - Tests and measurements found correct components installed
- Design firm was source of error



Source of Design Error

- Design error possibilities
 - ~~– Transcription/drafting error~~
 - ~~– Material change error~~
 - Calculation error
 - Omission of calculations
- U10 gusset plates same as in final design plans
- Thickness and material did not change from earliest design

Source of Calculation Error

- Considered design firm calculation error
 - Floor truss gusset plate calculations were present
 - Detailed calculations from Orinoco bridge
 - It was common practice to perform all calculations
 - Documented in Detailing Manual
- S&P knew how to do the proper calculations

Source of Design Error

Design

- ~~– Transcription/drafting error~~
- ~~– Material change error~~
- ~~– Calculation error~~
- Omission of calculations

S&P Detailing Guide

- AASHTO 1961 guidance
 - “resist shear, direct stress, and flexure”
- 1989 S&P Detailing Guide
 - 14-step process that accounted for all stresses
- Unchecked sheets indicated that calculations might have addressed up to 7 steps
- Shear stress calculations not included

Edge Stiffening

- S&P Detailing Guide: additional guidance
 - Add stiffener if length / thickness ratio: >48
 - As built, U10 gusset plates had ratio of 60
- Had $\frac{1}{2}$ " gussets plates been the correct design, stiffeners would have been required
- Use of stiffeners would not have made the $\frac{1}{2}$ " U10 gusset plates adequate
- If the proper 1-inch gusset plates had been used, no stiffening would have been required

Evidence of Omission

- Inadequate capacity in multiple nodes
- Complete documentation of calculations for Orinoco bridge
- Lack of calculation documents for I-35W bridge
- S&P failed to perform these calculations for main truss gusset plates of I-35W bridge

Quality Control / Review

- S&P quality system
- Mn/DOT and FHWA review process
- Other states' reviews

S&P Quality Control / Assurance

Typical Computation Sheet

SVERDRUP & PARCEL

JOB 2083 Minn. Br. #9340 SHEET NO. 60 OF _____

COMPUTATIONS FOR Deck Truss Spans DATE Oct. 1963

BY [Redacted] CHKD [Redacted]

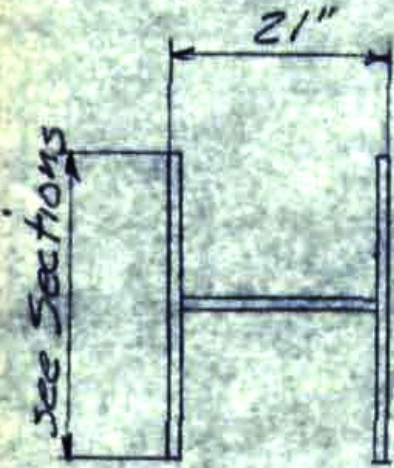
Member: L5-U6 1259 T U22-U23 1197 T
 (1265T) U12-L13 1233 T
 (1256T)

(A441)	Gr. Area.	Holes	Net Area
2 Pls. 22x1/8	49.50	8	39.37
1 Pl. 18 ³ / ₄ x7/8	8.20	0	8.20
	57.70		47.57

L15-U16 1207 T
 (1230T)
 8x98x1/8 = 10.13

$L = 55.02'$ (L5U6 & U22U23) $L = 52.35'$ (U12L13 & L15U16)

$T = 47.57 \times 27 = 1288 \text{ K}$



Quality Control / Assurance

S&P quality assurance process failed to detect omission of necessary gusset plate calculations

Mn/DOT and FHWA Oversight

- Reviewed major items only
- Did not note that some computations had not been provided
- Relied on design firm's QA
- Neither Mn/DOT nor FHWA standard practices included evaluation of gusset plate design in sufficient detail to detect design errors

Federal and State Oversight

- Design errors occur but not common
- Varying state resources and review
- Reliance on design firms
- Review major items
- Professional Engineer's seal
- Current state and federal design review procedures may not be adequate to detect design errors

Summary

- Fabrication and erection not issues
- Source of error in S&P design process
- S&P failed to fully perform necessary computations
- S&P's quality assurance was lacking
- Mn/DOT and FHWA standard practices did not include a review of the design in sufficient detail to detect error
- Current state and federal review procedures may not be adequate

