

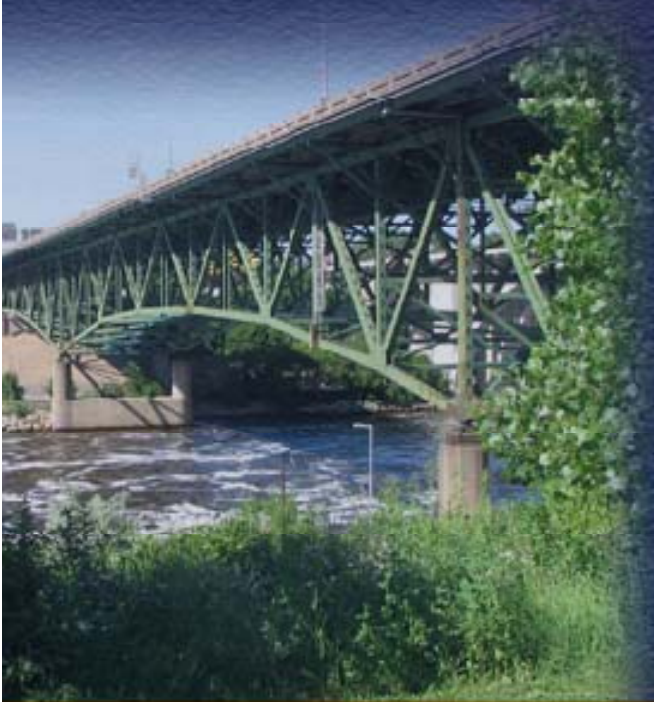


NTSB National Transportation Safety Board

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

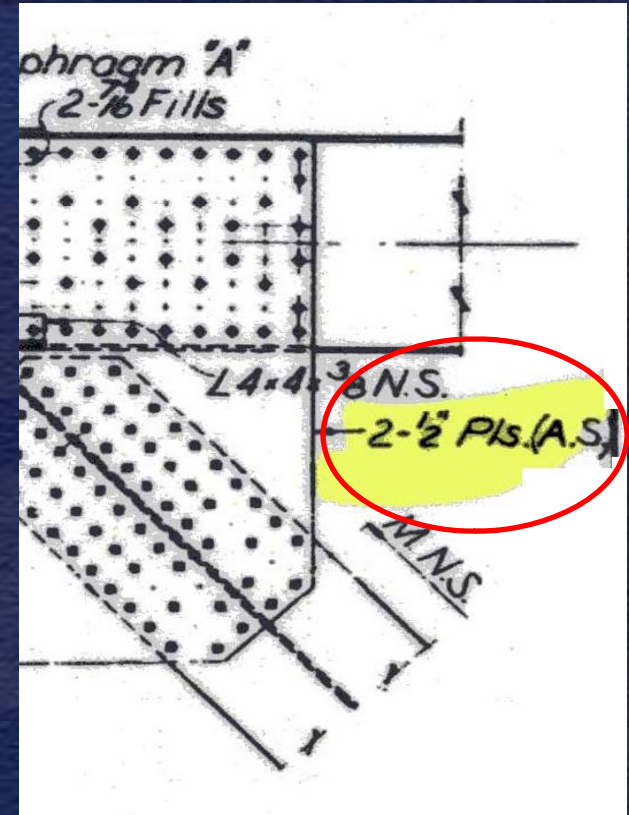
- October 22, 1962
- Sverdrup & Parcel (S&P) was contracted to design I-35W bridge
 - Preliminary engineering report
 - Completed and checked final plans
 - Checked design computations

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 ½” gusset plates been the correct design, stiffeners would have been required
- Use of stiffeners would not have made the ½” 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 CHKD

Member: L5-U6 1259 T U22-L23 1197 T
 (1265T) U12-L13 1233 T
 (1256T) L15-U16 1207 T
 (1230T)

A441	Gr Area		Holes	Net Area	
2 Pls. 22x1/8	49.50	8	39.37	8x9x1/8 = 10.13	
1 Pl. 18 3/4 x 7/16	8.20	0	8.20		
	57.70		47.57		

$L = 55.02'$ (L5U6 & U22L23) $L = 52.35'$ (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

