I-35 BRIDGE COLLAPSE

How an Unchecked Assumption Brought Down a Bridge

Assumptions are made to simplify analyses. When these assumptions aren't verified, they can result in a compounded error. In this case, an assumption of a part's strength meant it was never rechecked or inspected, and resulted in the collapse of a bridge.

"Bridge designers, builders, owners, and inspectors will never look at gusset plates quite the same again"
- NTSB Acting Chairman Mark V. Rosenker

Cause Mapping is a Root Cause Analysis method that captures basic cause-and-effect relationships supported with evidence.

CAUSE MAPPING ™
Problem Solving • Incident Investigation • Root Cause Analysis

Step 1 **Problem** — What's the Problem?
Step 2 **Analysis** — Why did it happen?
Step 3 **Solutions** — What will be done?

1 Problem

What	Problem(s)	Bridge collapse
When	Date	August 1, 2007
	Time	6:05 p.m.
	Differences	Evening rush hour, roadwork underway
Where	Physical location	Minneapolis, Minnesota

Impact to Goals

Safety	13 people killed
	145 people injured
Service	Loss of major transportation route
Property	Replacement of bridge ($234 M)

2 Analysis

Basic Level Cause Map - Start with simple Why questions.

Why? Why? Why? Why?

Safety Goal Impacted ← 13 people killed ← Main span of bridge collapsed ← Fracture of gusset plate ← Insufficient load capacity of gusset plate

Basic Cause-and-Effect
The safety goal was impacted because 13 people were killed when the bridge collapsed. The bridge collapsed due to a fractured gusset plate, which was designed with insufficient load capacity.

More Detailed Cause Map - Add detail as information becomes available.

Safety Goal Impacted ← 13 people killed
Safety Goal Impacted ← 145 people injured
← Vehicles fell into river
Service Goal Impacted ← Loss of major transportation route
Property Goal Impacted ← Replacement of bridge (~$234 M)

← Main span of bridge collapsed ← Fracture of gusset plate ← Strength of gusset less than load on gusset

← Insufficient thickness of gusset plate
Evidence: 1/2" thick plates should have been 1". NTSB Calculations.

← Shear calculations not performed ← Preliminary design
Solution 1: Mark preliminary designs clearly.

AND

← Design firm review process not followed ← No procedure for ensuring all calculations performed
Solution 2: Checklist to make sure all calculations have been performed.

AND

← Insufficient review, oversight of design

← Lack of government design oversight ← Design review did not apply to gusset plates
Solution 3: Add gusset plates to design review.

AND

← No evaluation of gusset plate capacity in load rating ← Gusset plates considered not important to load rating
Solution 4: Analyze capacity of gusset plates.
Solution 5: Educate on the importance of gusset plates.

AND

← Inadequate inspection of gusset plates
Solution 7: List gusset plates as a specific, separate inspection element.

← Gusset plates not listed as separate inspection elements ← Assumed gusset plates stronger than the members
Solution 6: Verify strength of gusset plates is greater than strength of members.

AND

← Lack of training on gusset plate inspection
Solution 8: Add specific training on gusset plate inspections.

AND

← Increased load on gusset

← Construction material over gusset plate ← No policy requiring permission to stage materials
Solution 11: Limit weight concentration of construction materials.
Solution 10: Require written permission for staging materials on bridges.

AND

← Increased dead load (weight of structure)
Solution 12: Recheck strength analyses after dead weight increases.

← Increased concrete overlay (~2") ← Protect rebar from corrosion
Evidence: >3 M pounds additional weight (13.4% dead load increase)

AND

← Upgrades to median barrier, railings ← Did not meet updated safety standards
Evidence: >1 M pounds additional weight (6.1% dead load increase)

AND

← High volume of traffic on bridge

More Detail
The gusset plate was under-designed because shear calculations were not performed. The error wasn't noticed during the firm's review process, by the government, or during load rating evaluations and inspections over the service of the bridge. Why? Because gusset plates just weren't considered to be that important. When correctly designed, they are stronger than the members they connect and so can be omitted from the analysis.

More Detail
The gusset plate had been under designed from the time the bridge opened. So why did it fail in 2007? The volume of the traffic had increased greatly since the bridge opening, and traffic was particularly high at the time of the collapse thanks to rush hour and road work. The construction materials for the road work were concentrated over the gusset plate, with no oversight. On top of all this, the dead load, or weight of the bridge, had increased by more than 4 million pounds from roadway improvements.

3 Solutions

Corrective actions for this incident and their corresponding cause.

No.	Action Item	Cause	Owner	Due Date
1	Mark preliminary designs clearly	Meant to be a preliminary design		
2	Checklist to make sure all calculations have been performed	No procedure for ensuring all calculations performed		
3	Add gusset plates to design review	Design review did not apply to gusset plates		
4	Analyze capacity of gusset plates	No evaluation of gusset plate capacity		
5	Educate on the importance of gusset plates	Gusset plates considered not important to load rating		
6	Verify strength of gusset plates > strengh of members	Assumed gusset plates stronger than the members they connect		
7	List gusset plates as a specific, separate inspection element	Gusset plates not listed as separate inspection elements		
8	Add specific training on gusset plate inspections	Lack of training on gusset plate inspection		
9	Limit weight concentration of construction materials	Construction material concentrated over gusset plate		
10	Require written permission for staging materials on bridges	No policy requiring permission to stage materials		
11	Recheck strength analyses after dead weight increases	Increased dead load (weight of structure)		

Effect ← Cause
Solution:
Evidence:

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