Engineering Ethics: The Minnesota I-35W Bridge Collapse

An Online Continuing Education Course for Engineers

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Prologue: Recollections of survivors

Nina Jenkins

Twelve year old Nina Jenkins, who was on the school bus that was on the bridge when it collapsed:

"It was scary. It was terrifying. It was lucky because everybody survived." She said the bus shook violently. After it came to a stop, a man opened the back door and helped the children escape. Nina called her mother on her cell phone and told her the bridge had "broken."

"I was like, 'It broke?'" Christy Jenkins, Nina's mother said. Nina responded, "Yeah, mom, it broke in half."[i]

Chuck Hoffman

"I was going southbound at six o'clock, and I felt my car going up and down. Traffic was about 20 miles per hour. It was strange, like being on a diving board or something, and I thought 'What is going on?' I had no idea.

"And I glance in my rear view mirror, and I saw the bridge collapse right behind me. It just disappeared.

"(I'm thinking) 'Wow, this is a tragedy.' I'm right at the edge, I just gotta keep going and hope I make it off of here. I didn't know if more bridge was going to collapse, so I look forward, and I saw the bridge ahead of me undulating up and down, and I thought, this could collapse too.

"I'm nervous. I feel very lucky. I feel badly for all the people who didn't make it. I saw people going down — it was kind of over the brink from where I was. You could see cars on the other side going down. You could see the rest of the cars and the concrete deck as it was sloping down.

"It was very quick, but they just gradually dropped, about five or ten seconds or so."[ii]

Synopsis

On August 1, 2007, the I-35W Bridge over the Mississippi River in Minneapolis, Minnesota collapsed during evening rush hour, plummeting into the river and onto the concrete embankment below. At the time of the collapse, traffic was congested from normal rush hour traffic and fans headed to the Twins game. In some places the cars were bumper to bumper, their progress constrained by two lanes closed for construction. In all, 111 vehicles were on the collapsed part of the bridge, along with members of the construction crew working on the bridge, their equipment, and supplies.

Survivors recall the bridge swaying for a few seconds, followed by a rumbling sound and a succession of two to three free falls. Approximately 1,000 feet of the bridge deck – which extends over the Mississippi — separated from the approach spans and fell. Cars drove or slid off of the roadway into 15 feet of river water below, some falling on top of their predecessors. A number of motorists survived by applying their brakes, and some cars were restrained from the edge by construction barriers or debris. Some survivors managed to exit their cars and walk to safety, while passersby or emergency response teams successfully rescued others.

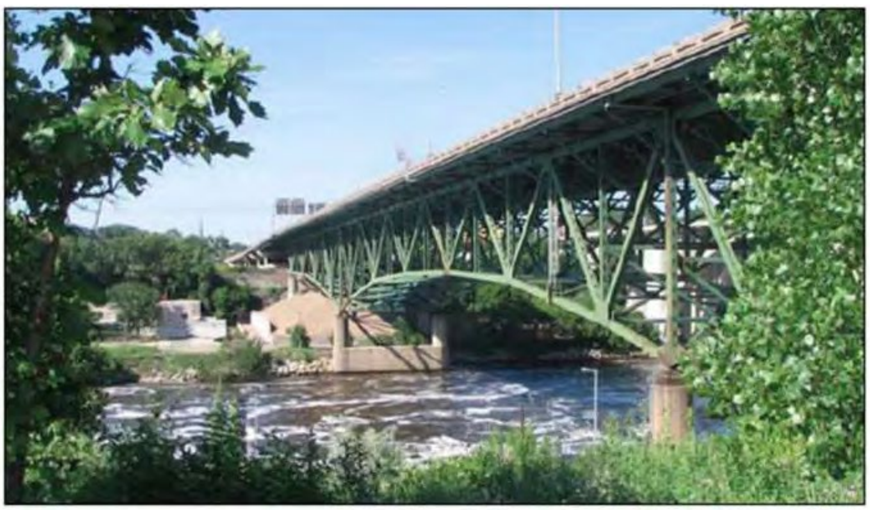

Figure 1: Center span of I-35W Bridge prior to the accident, looking northeast. (Source: NTSB.)

A school bus filled with 52 children and nine adults returning from a recreational daytrip fell amid the bridge debris, landing on its tires on the concrete embankment. Miraculously, the bus driver and aides, with assistance from rescuers, managed to open the rear door and evacuate the passengers. While several were treated for injuries, all survived.

"I recall free falling three times and hitting whatever was left of the bridge," recalled Julie Graves, the youth program manager for the agency that sponsored the children's trip.[iii]

A total of 190 people were on or near the bridge when it failed. The eventual death toll was 13. An additional 145 people were treated at 12 area hospitals. Seventeen cars were recovered from the water.

The bridge collapsed at 6:05 p.m., and the Minnesota State Patrol was notified immediately. The first Minneapolis police arrived at 6:10, followed by the fire department, county sheriff's office, and watercraft from 12 public safety agencies. By 7:27 p.m., the search was shifted from a rescue to recovery mode. On the following day, command of the site was transferred to the Minneapolis Police Department because of concerns that the disaster might have been the result of a terrorist act.

The Coast Guard, the FBI underwater search and rescue team, and the US Naval Sea Systems Command (NAVSEA) mobile diving and salvage teams later joined the state and local authorities.

Introduction

Engineers are well familiar with load-path redundant structures. These are structures in which multiple critical members carry load paths, so that if any single main member fails, others compensate for its failure. Similarly, a properly designed and implemented quality control and oversight process may be thought of as load-path redundant. Human beings make mistakes, but validation procedures, crosschecking, guidelines, regulations, and inspections are designed to prevent and detect the mistakes and to correct and compensate for errors.

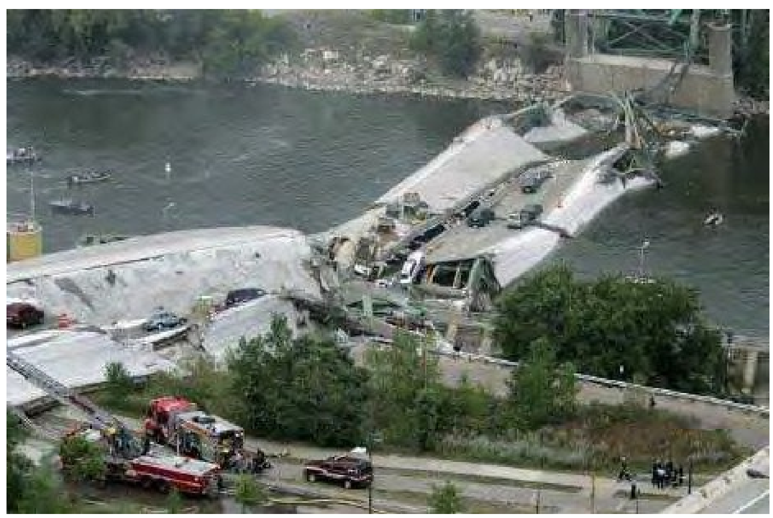

Figure 2: Collapsed north section of bridge. (Source: NTSB.)

Perhaps one of the most striking things about the Minneapolis I-35W bridge collapse is that an engineer made a critical error in the design of a steel truss bridge more than 40 years before the disaster and for more than 40 years the error and the symptoms of the impending failure of the bridge component were never properly identified or addressed. Not one member of a quality control team or any safety system in place at the time addressed the source of the error or heeded the warning signs of the impending disaster. Despite state and federal guidelines and regulations, the Minnesota Department of Transportation (Mn/DOT); Mn/DOT inspectors; and engineering groups hired to inspect the bridge all failed to act.

Some of the deficiencies could perhaps be attributed to simple lapses, a failure to attend to detail, or perhaps a lack of knowledge. But the investigation and analysis of the National Transportation and

Safety Board (NTSB) also shows evidence of complacency or the reliance on conventional wisdom that caused everyone involved to assume that all was right, even in the face of evidence to the contrary.

Over the years, the design and load bearing capacity of the ill-fated connector (gusset) plates were never questioned, based on the prevailing wisdom that gusset plates are very conservatively designed and are considered the strongest part of the truss unit. (Figure 3 below.) For some reason, the original design was apparently never checked; the American Society of State Highway and Transportation Officials (AASHTO) and state guidelines overlooked the load-bearing capacity of gusset plates; the load bearing capacity of the plates was not considered when the load rating was recalculated during bridge modifications; and multiple inspectors ignored bows and significant distortion in the aging plates.

In fact, even the 17 most popular bridge design modeling programs evaluated after the disaster were not designed to address the design flaw that caused the Minneapolis bridge failure. According to the NTSB:

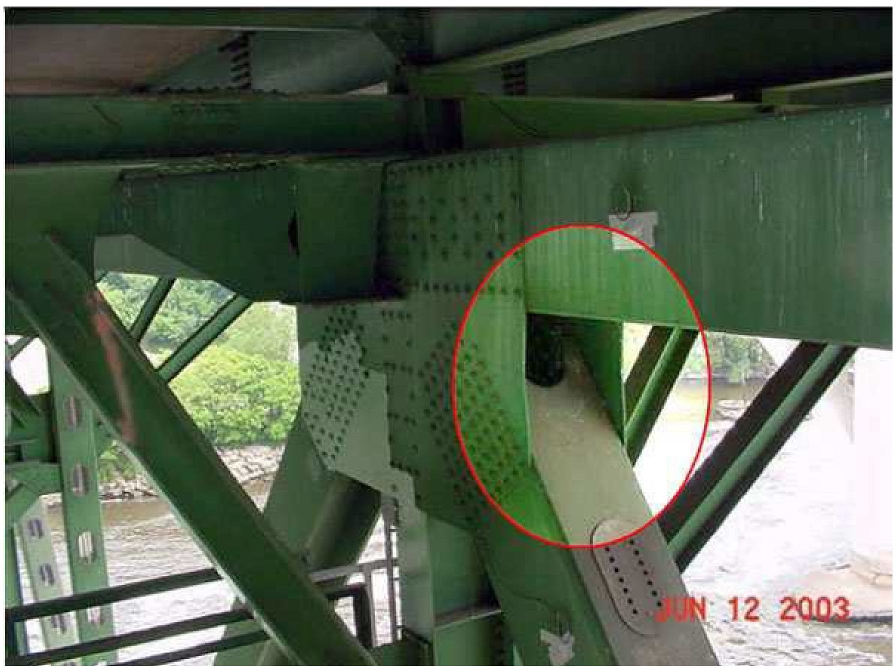

Figure 3: Bowed and significantly distorted gusset plate. (Source: NTSB.)

"The assumption that gusset plates are stronger than their members appears to prevail despite the fact that, as indicated in the problem statement to the proposed (Federal Highway Administration) FHWA–AASHTO joint study of gusset plates, the complex geometry and stress in those connections present bridge engineers with special analytical and design challenges that have not previously been adequately addressed."[iv]

The disaster killed 13 people and injured 145 more, and the loss of an important interstate bridge had a major impact on the Minneapolis economy. It also portended enormous liability issues for the engineering design and inspection firms, the construction company working on the bridge at the time of collapse, and the State on Minnesota. The 40 year time lapse and the fact that the original design firm had merged or changed hands since the time of its work on the bridge did not diminish liability problems for the corporate owners of record at the time of collapse.

In the years following the collapse, the engineering firm contracted to inspect and assess the condition of the bridge agreed to a $52.4 million settlement with victims' families and survivors and a $5 million settlement with the State of Minnesota. The construction firm that was working on the bridge at the time of collapse settled with victims' families and survivors for $10.15 million and with the state for $1 million. Negligence lawsuits against the State are in nebulous legal territory, but the Minnesota Legislature allocated $36.64 million for victims' families and survivors. As of this writing, the current corporate owner of record for the original engineering design firm is still involved in litigation, having lost a critical legal battle at the Minnesota Supreme Court.

Course objectives

This course will draw extensively from the NTS[…]alysis and other sourc[…] to familiarize the reader with the design errors that led to the d[…] We w[…] failures of the quality control process; insufficien[…] […]n the state and federal spec[…] […]ridge connectors to be overlo[…]
40 years afte[…]

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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[…]35W Mississippi River Bridge. Bridge

- Insufficient b[…] design firm q[…] control proce[…] for designing bridges, and insufficient Federal and State procedures for reviewing and approving bridge design plans and calculations.
- Lack of guidance for bridge owners with regard to the placement of construction loads on bridges during repair or maintenance activities.
- Exclusion of gusset plates in bridge load rating guidance.
- Lack of inspection guidance for conditions of gusset plate distortion.
- Inadequate use of technologies for accurately assessing the condition of gusset plates on deck truss bridges. [v]