



National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: January 15, 2008

In reply refer to: H-08-1

The Honorable J. Richard Capka
Administrator
Federal Highway Administration
1200 New Jersey Avenue, S.E.
Washington, D.C. 20590

On Wednesday, August 1, 2007, about 6:05 p.m. central daylight time, the Interstate 35W (I-35W) highway bridge over the Mississippi River in north Minneapolis, Minnesota, experienced a failure in the superstructure of the 1,000-foot-long deck truss portion of the 1,900-foot-long bridge. Approximately 456 feet of the center span of the deck truss fell about 108 feet into the 15-foot-deep river. Approximately 110 vehicles were on the portion of the bridge that collapsed, and 17 vehicles fell into the water. As a result of the bridge collapse, 13 people died and 145 people were injured.

Roadway construction was being conducted on the deck truss portion of the bridge, and four of the eight lanes were closed for repaving when the bridge collapsed. Machinery and paving materials were being parked and stockpiled on the center span.

The National Transportation Safety Board dispatched investigators within hours of the collapse and continues to investigate the circumstances of the accident. Although the Safety Board's investigation is ongoing and no determination of probable cause has been reached, investigators have a concern regarding certain elements of the bridge (gusset plates), which has prompted issuance of this safety recommendation.

Bridge

Construction of the bridge (Federal bridge identification number 9340) began in 1964, and it was opened to traffic in 1967. The bridge was designed by Sverdrup & Parcel (subsequently acquired by Jacobs Engineering) and was built by Hurcon Incorporated and Industrial Construction Company. The steel deck truss portion of the bridge consisted of two parallel main trusses (east and west) connected through transverse floor trusses supporting the reinforced concrete deck. The ends of the beams in the main trusses were connected by riveted gusset plates at 112 nodes (joints) along the deck truss portion of the bridge. The bridge was considered to be fracture-critical because the load paths in the structure were nonredundant, meaning that a failure of any one of a number of structural elements in the bridge would cause a complete collapse of the entire bridge. This type of bridge is also referred to as a

non-load-path-redundant bridge. The Federal Highway Administration (FHWA) estimates that there are approximately 465 steel deck truss bridges within the National Bridge Inventory.

Since it was built, the deck truss portion of the bridge has undergone at least two major renovations, one in 1977 and one in 1998. As part of these renovations, the average thickness of the concrete deck was increased from 6.5 inches to 8.5 inches, and the center median barrier and outside barrier walls were increased in size. These changes added significantly to the overall weight of the structure.

Gusset Plates

Physical examination of the recovered bridge structure showed that the gusset plates at the east and west nodes U10, U10', L11, and L11' were fractured.¹ The other major gusset plates in the main trusses were intact. Design methodology for gusset plates is normally very conservative, with the result that a properly designed gusset plate should generally be stronger than the beams it connects. Accordingly, one would not expect to find fractured gusset plates. However, the damage patterns and fracture features uncovered in the investigation to date suggest that the collapse of the deck truss portion of the bridge was related to the fractured gusset plates and, in particular, may have originated with the failure of the U10 gusset plates. Materials testing performed to date has found no deficiencies in the quality of the steel or concrete used in the bridge. Therefore, the Safety Board, with the FHWA, conducted a thorough review of the design of the bridge, with an emphasis on the design of the gusset plates.

Gusset Plate Design Process Error

The investigation discovered that the original design process led to a serious error in sizing of some of the gusset plates in the main trusses. Engineers working in the investigation used generally accepted calculation methodologies to recalculate the stresses in these gusset plates. Their results indicate that some of the gusset plates were undersized and did not provide the margin of safety expected in a properly designed bridge. These undersized gusset plates were found at 8 (of the 112) nodes on the main trusses of the bridge (east and west upper nodes U10 and U10', and east and west lower nodes L11 and L11'). These gusset plates were roughly half the thickness required. The results of the calculations are documented in the FHWA's interim report, [*Adequacy of the U10 & L11 Gusset Plate Designs for the Minneapolis Bridge No. 9340 \(I-35W over the Mississippi River\)*](#).

Bridge Design Documentation

The Safety Board obtained copies of the original design and fabrication drawings, as well as a partial set of design calculations from both Jacobs Engineering and the Minnesota Department of Transportation (Mn/DOT), and compared the design documents with the actual bridge structure. So far, this comparison has indicated that the superstructure of the bridge was generally built as specified in the design, with no significant discrepancies identified between the design documents and the as-built condition of the bridge. The gusset plates that were undersized on the bridge were undersized on the drawings.

¹ The symbol ' is pronounced "prime" and indicates the corresponding node on the opposite end of the bridge.

Design Calculation Methodology

Because the investigation has determined that some of the gusset plates were undersized, the Safety Board examined the design calculation methodology used at the time the bridge was designed, in the 1960s, to verify that the methodology was sound. The design documents reviewed included detailed calculations for the beams in the main trusses and detailed calculations for the welded gusset plates joining the beams in the floor trusses, both of which indicate sound calculation methodology. However, because the detailed calculations for the main truss gusset plates could not be located, the Safety Board was unable to verify the calculation methodology used for those gusset plates. As a result, the Safety Board has not yet determined whether the error was due to a calculation mistake, a drafting error, or some other error in the design process.

Design Review Process

The design error was not detected during the internal review process conducted by Sverdrup & Parcel when the drawings were developed. The Safety Board is still evaluating this review process but notes that any effective review should be sufficient to detect and correct design errors such as the one that resulted in the undersized gusset plates. Nevertheless, the review process in place at the time of the design failed to detect the error.

For the most part, State departments of transportation rely on bridge designers to perform accurate calculations and to check their work. Thus, beyond the designer's internal review, there does not appear to be a process in place to identify original design errors in bridges.

In addition, gusset plate design calculations are not usually reviewed during major modifications on bridges. Generally, the weakest point of a bridge is evaluated to determine if the additional loads or stresses can be accommodated, with the assumption that the remaining portions of the bridge can withstand the change. For example, as previously mentioned, the accident bridge underwent two major renovations, which added significantly to the overall weight of the structure. Information obtained from Mn/DOT indicates that Mn/DOT engineers followed generally accepted practice and recalculated the anticipated stress levels in what they believed at the time were the weakest members of the bridge. Normally, there would be no reason for them to question the strength of the gusset plates relative to these weaker structural members.

In summary, the gusset plate design error identified during this ongoing investigation was not detected by any of the internal review procedures used by Sverdrup & Parcel during the original bridge design, nor was there a reasonable expectation that it would be detected during any review associated with the original submission of the design or any subsequent modifications to the bridge.

Bridge Load Rating Calculations

The error in the design of the gusset plates would not have been identified by routine load rating calculations because gusset plate stresses are not normally part of these calculations. Bridge load rating calculations are used by bridge owners to determine if their bridge can accommodate heavy vehicles and to make critical load posting and permitting decisions. A

number of States use specialized bridge load rating computer programs—BARS or its successor Virtis—to calculate load ratings. Mn/DOT currently uses the BARS program but is in the process of switching to the Virtis software program. Although these two computer programs can be used to evaluate the stresses in the truss beams for a specified load case, they do not consider any aspect of the gusset plates connecting the truss beams. In summary, periodic recalculations of the load ratings of bridges are not intended to verify or confirm the adequacy of gusset plate designs.

Bridge Inspections

Bridge inspections would also not have identified the error in the design of the gusset plates. The National Bridge Inspection Standards (NBIS) are aimed at detecting conditions such as cracks or corrosion that degrade the strength of the existing structure; they do not, and are not intended to, address errors in the original design. Although inspections of the accident bridge identified and tracked some areas of cracking and corrosion, at this point in the investigation, there is no indication that any of those areas played a significant role in the collapse of the bridge.

Summary

The Safety Board is concerned that, for at least this bridge, there was a breakdown in the design review procedures that allowed a serious design error to be incorporated into the construction of the I-35W bridge. The bridge was designed with gusset plates that were undersized, and the design firm did not detect the design error when the plans were created. Because of this design error, the riveted gusset plates became the weakest member of this fracture-critical bridge, whereas normally gusset plates are expected to be stronger than the beams they connect. Further, there are few, if any, recalculations after the design stage that would detect design errors in gusset plates. Finally, other programs to ensure the safety of our Nation's bridges, such as the methods used in calculating load ratings and the inspections conducted through the NBIS program, are not designed or expected to uncover original mistakes in gusset plate designs or calculations.

It is important to note that the Safety Board has no evidence to suggest that the deficiencies in the various design review procedures associated with this bridge are widespread or even go beyond this particular bridge. In fact, this is the only bridge failure of this type of which the Safety Board is aware. However, because of this accident, the Safety Board cannot dismiss the possibility that other steel truss bridges with nonredundant load paths may have similar undetected design errors. Consequently, the Safety Board believes that bridge owners should ensure that the original design calculations for this type of bridge have been made correctly before any future major modifications or operational changes are contemplated.

Therefore, the National Transportation Safety Board makes the following recommendation to the Federal Highway Administration:

For all non-load-path-redundant steel truss bridges within the National Bridge Inventory, require that bridge owners conduct load capacity calculations to verify that the stress levels in all structural elements, including gusset plates, remain within applicable requirements whenever planned modifications or operational changes may significantly increase stresses. (H-08-1)

Please refer to Safety Recommendation H-08-1 in your reply. If you need additional information, you may call (202) 314-6177.

Chairman ROSENKER, Vice Chairman SUMWALT, and Members HERSMAN, HIGGINS, and CHEALANDER concurred in this recommendation.

Original Signed By:

By: Mark V. Rosenker
Chairman