ATTACHMENT 29 – FHWA TURNER-FAIRBANK HIGHWAY RESEARCH CENTER REPORT ASSESSMENT OF THE LOAD RATING RECORDS FOR MINNESOTA BRIDGE NO. 9340 (I-35W OVER THE MISSISSIPPI RIVER) DATED JUNE 30, 2008

(10 pages)

FEDERAL HIGHWAY ADMINISTRATION
TURNER-FAIRBANK HIGHWAY RESEARCH CENTER REPORT

Assessment of the Load Rating Records for Minnesota Bridge No. 9340 (I-35W over the Mississippi River)

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JUNE 30, 2008

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INTRODUCTION

The I-35W Bridge over the Mississippi River in Minneapolis, Minnesota had 14 spans and a total length of 1,907 feet. The primary structure of this bridge was a variable depth steel deck truss of 1,064 feet in length that carried I-35W over the river and gorge. On August 1, 2007 a failure in the river span of the deck truss caused a complete collapse of the entire truss structure and some of the approach spans resulting in the tragic loss of 13 public motorist lives. The National Transportation Safety Board (NTSB) is the primary agency investigating this failure to determine a probable cause. The Federal Highway Administration (FHWA) is assisting and collaborating with both the onsite and broader activities of the NTSB investigators. The FHWA team consists of personnel from the Turner-Fairbank Highway Research Center (TFHRC), the Office of Bridge Technology (HIBT), the Resource Center (RC) and several Division offices. One of the tasks performed by the FHWA team was a review and assessment of the load rating records retained for the I-35W Bridge by the Minnesota Department of Transportation (Mn/DOT). This report will focus on the findings of that assessment.

LOAD RATING OF HIGHWAY BRIDGES

Bridges must have adequate strength, stiffness and toughness to safely operate over their design lives. Highway bridge design specifications are formulated to produce a factor of safety acceptable to the engineering community, and by extension the traveling public, for each of these conditions. In general, proper application of the specifications combined with engineering knowledge and judgment will produce a structure that will conservatively meet the expectant loadings.

The determination of a bridge's load-carrying capacity, also known as a bridge load rating, is similar in overall approach to bridge design. However, design and rating do differ. One difference is that in the design process there is greater uncertainty in the amount of loading the structure will experience over its lifetime and, as a consequence, many assumptions are made with respect to possible future loading conditions. In the load rating process, the actual loading conditions are better known; however, there is some uncertainty due to the variations inherent to the construction process, deterioration resulting from environmental exposure, and repeated application of live load and unusual truck loads or traffic conditions. For this reason, load rating incorporates the results of detailed physical examinations of the structure and significant engineering judgment in the process.

Bridge owners perform three types of load rating: design load rating, legal load rating and permit load rating. A design load rating is the analysis of an existing structure for the vehicle type utilized during its design. It is used to compare the existing condition to the as-designed condition. A legal load rating is the analysis of an existing structure for the vehicle type that more appropriately represents the service load that the structure will experience on a regular basis. This type of rating gives an overall indication of the structures ability to withstand routine heavy loads. A permit load rating is the analysis of specific vehicles that carry loads over the legal limit. This type of analysis is typically

used to provide a safety check for bridges along a route proposed for use by an overload permit vehicle.

Load rating is performed for three main reasons:

(1) Bridges on the current inventory have been designed using an assortment of different live load truck configurations due to the variation in State practices and the requirements of the specifications in effect at the time of their design. Regardless of the live load models used for design, all bridges must be checked against current conditions and standards.

(2) Bridges are typically designed and constructed to last 75 years or more. Even with regular maintenance over its lifetime, the condition of a bridge will inevitably deteriorate to some extent. When this deterioration occurs, the strength or load carrying capacity of the bridge may be affected. Therefore, load rating must be performed whenever bridge conditions change significantly. Typically, condition data are collected for public bridges on a 24 month cycle in accordance with the *National Bridge Inspection Standards* (NBIS) defined in 23 CFR 650, Subpart C.

(3) Lastly, permit load rating must be performed for vehicles carrying loads over the legal limit. These ratings are conducted on a case by case basis prior to approving permit vehicle routes so that permanent structural damage is prevented. If the permit load exceeds the required level of safety for a bridge on the proposed route, the permit truck may be redirected to routes with bridges with ratings that will allow them to safely carry the permit load.

Typically, an initial load rating is conducted for each member of a bridge and the most critical result is used to classify the entire structure. Then, unless inspections uncover deterioration or conditions that would impact the capacity of other members, re-ratings for permits or changing conditions focus on the critical member identified in the initial rating.

The results of a load rating can determine whether a bridge remains open to legal loads, is posted to restrict loads to a particular level, can accommodate a specified permit load, or is closed. These actions are the responsibility of the bridge owner who uses the engineering analysis of a load rating to implement policy. Enforcement of posted loads is typically left to the local law enforcement agency with appropriate jurisdiction.

Until 2007, Federal-aid bridges could have been designed in accordance with the *AASHTO Standard Specifications for Highway Bridges* (Standard Specifications) using either the Allowable Stress Design (ASD) method or the Load Factor Design (LFD) method. The ASD method compares the stresses caused by the actual loadings on a structure to stress limits, or allowable stresses, determined by dividing the yield strength of a material by an appropriate factor of safety for a specific application. The ASD method has been included in Standard Specifications since the first edition in 1931. The ASD method for bridge rating, herein referred to as Allowable Stress Rating (ASR), was

included in the first edition (1970) of the *AASHTO Manual for Maintenance Inspection of Bridges* (Maintenance Inspection Manual) and its successor the *AASHTO Manual for Condition Evaluation of Bridges* (Condition Evaluation Manual) first published in 1994.

The LFD method for steel bridge design was first included in the Standard Specifications in 1971. For this design method, bridge loadings are factored up individually to account for the varying levels of uncertainty inherent in their determination. These factored loads are then compared to capacities based on the yield strength of a material that have been reduced to produce the desired factor of safety for the application. Rating with the LFD method, herein referred to as Load Factor Rating (LFR), was first included in the 1978 edition of the Maintenance Inspection Manual and was also included in the first edition of the Condition Evaluation Manual in 1994.

As stated earlier, regardless of the rating method used, bridge ratings rely on the results of a thorough bridge inspection that documents significant changes in bridge condition in a bridge inspection report. This report should emphasize quantitatively all changes in the structural conditions of the bridge including damage and deterioration to load carrying components, permanent loads added to the bridge, and the currently permitted live load weight. In addition to the bridge inspection report, a complete set of as-built plans for the existing structure is needed.

Bridges are often rated by licensed engineers that have experience designing the specific type of structure being considered. However, qualification requirements for bridge raters have varied. Neither FHWA nor AASHTO identified any qualifications for engineers performing bridge ratings prior to publication of the Condition Evaluation Manual in 1994. Language in that document suggests that individuals responsible for the rating of bridges have a minimum of appropriate experience. However, in 2004, the FHWA updated the *National Bridge Inspection Standards* (NBIS) regulation to require the individual with overall responsibility for rating bridges to be a registered professional engineer.

A bridge has both a design life and a service life. Meeting the design life requirements of the specifications insures that the strength and reliability of a bridge is not degraded below a minimum level due to the expected frequency of design load application over a specified period of time. The specifications also have requirements intended to extend the service life of a bridge. However, a bridge service life is much more dependent on the materials used and the quality of construction, the environmental conditions at the site and on the level of maintenance the structure receives.

The average age for bridges currently in the National Bridge Inventory (NBI) is approximately 42 years. A significant number of these bridges are expected to be in service for many more years. The service life of bridges can easily outlast the careers of the engineers inspecting and rating these structures. Therefore, maintaining complete and detailed documentation on the history of a structure is necessary to insure accurate load ratings through changes in administration.

The Maintenance Inspection Manual required a bridge history to include calculations substantiating the current operating load limits. The Condition Evaluation Manual recommends that load ratings "be completely documented in writing including all background information such as field inspection reports, material and load test data, all supporting computations, and a clear statement of all assumptions used in calculating the load rating." The 2004 revisions to the NBIS regulation incorporated the Condition Evaluation Manual by reference, thereby making the content of the manual regulatory.

LOAD RATING RECORDS FOR THE I-35W BRIDGE

The NTSB supplied FHWA with a copy of all the rating documents identified for the I-35W Bridge by Mn/DOT. These documents addressed ratings that were conducted by Mn/DOT in 1979, 1995 and 1997. Below is an inventory of the items received for each of these ratings. The documents supplied also included a complete set of the influence lines generated for the structure during the creation of the original design plans.

1979 Load Rating (1979 AASHTO Manual for Maintenance Inspection of Bridges)
- Mn/DOT Bridge Rating and Load Posting Report Sheet

1995 Load Rating (1994 AASHTO Manual for Condition Evaluation of Bridges)
- Mn/DOT Bridge Rating and Load Posting Report Sheet
- Mn/DOT Bridge Rating Sheet – South Approach Spans
- Mn/DOT Bridge Rating Sheet – North Approach Steel Beam Composite Spans
- Mn/DOT Bridge Rating Sheet – North Approach Concrete Voided Slab Spans
- Mn/DOT Bridge Rating Sheet – Deck Truss Stringers
- Calculation sheet for revised exterior and median railings
- Bridge Analysis and Rating System (BARS) software input and output files supporting the Mn/DOT Bridge Rating Sheets

1997 Load Rating (1994 AASHTO Manual for Condition Evaluation of Bridges)
- BARS input and output.

FHWA engineers with an appropriate expertise in bridge rating reviewed the supplied records to assess their completeness and their consistency with concurrent policies and procedures. This process primarily consisted of verifying the information found on the supplied records through cross-referencing with other documentation and hand calculations. In order to conduct this assessment, additional information on the I-35W Bridge was downloaded from the Mn/DOT website. In particular, Bridge Inspection Reports and design and construction plans were obtained and utilized in the review. The review was solely focused on the load rating records supplied and does not assess the accuracy or adequacy of the Mn/DOT load rating of the I-35W Bridge.

FINDINGS

This review only considered the documents supplied. That is, where gaps in the information record have been identified, the intent of this report is not to suggest that the missing documents were never produced, but solely that they were not retained or discovered in time to be included in this review.

- No information on load rating of the truss portion of the structure was found in the documentation supplied for any of the load ratings conducted. The load rating file should include an analysis supporting the current load rating for the entire bridge, including the deck truss, either from an initial analysis concluding that the truss was not critical to future ratings or from a rating prompted by a change in conditions or deterioration. The influence lines that were included for all truss members in the original design documents may have been used initially to verify that the rating was controlled by the deck stringer system; however, there is nothing within the documentation provided to support this assumption. A re-rating was performed on the approach spans in 1995, and again in 1997; however, no information was included pertaining to a re-rating of the truss structure. The 1997 rating did consider the deck stringers of the truss structure. The re-rating in 1997 was warranted due to an increase in dead load resulting from the change in bridge barrier type.

- The only document retained from the 1979 load rating was the Rating and Load Posting Report Sheet. The Report Sheet indicates a reduction in capacity of approximately 20% from design values. While no supporting documentation was reviewed, it can be inferred from calculation and other information that the reduction in rating was due to the added weight of the 1977 bridge overlay.

- The retained records for the load ratings conducted in 1995 and in 1997 on the approach spans are incomplete. These ratings were conducted on the interior G13 girder. It is unclear if this is the controlling girder line and unknown whether the engineer considered other girder lines.

- The dead load calculations retained from the 1997 rating contained minor errors. The height for the exterior barrier installed in the 1990's should have been 2'-8" instead of 2'-0" and the width should have been 10 inches instead of 9 inches. Also, diaphragms, lamp posts, and existing metal posts were not included in the dead load calculations. Although the overall significance of these items may be minimal, a load rating analysis should accurately account for all existing dead load conditions applied to the structure and include a narrative describing what assumptions were made in determining the applied dead load.

- The inspection reports indicate that several of the exterior approach span girders, primary truss and floor truss members, and primary truss connections exhibited some section loss due to corrosion that was not addressed in either a narrative summary or in re-rating calculations. A load rating analysis should take into consideration the loss of capacity resulting from deterioration of all load carrying structural elements or

the file should include a discussion detailing the reasons why the deterioration was considered negligible.

- The most recent "Load Rating Summary" sheet is not correct. In the 1997 calculations provided, the girders in the south approach governed with an HS18.9 Inventory Rating and a HS31.5 Operating Rating (ratings in this document are reported in Customary U.S. Units and are based on an HS20 live load rating vehicle and the load factor rating method). The controlling ratings shown on the most recent Load Rating Summary sheet are HS20.0 for Inventory and HS33.0 for Operating. This error seems to have resulted from not appropriately updating the information included on the 1995 load rating summary sheets. It appears that the stringer calculations conducted in 1997 were simply appended to the 1995 Load Rating Summary sheet and no new summary sheet was generated despite the increase in bridge rail dead load which resulted in about a 5% reduction in load carrying capacity.

- According to the 1979 Load Rating Summary sheet, the Inventory Rating was HS15.9 and the Operating Rating was HS30.6. According to the 1995 Load Rating Summary Sheet, the Inventory Rating was HS20 and the Operating Rating was HS33. While it is most likely that the variation in ratings between 1979 and 1995 was the result of transitioning from the ASR method to the LFR method that took place during that time period, no documentation was found that provided that explanation.

It is important to note that despite the omissions and inconsistencies of the documentation, the results for all of the ratings conducted indicate that the I-35W Bridge was capable of safely carrying the live load for which it was designed.

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