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November 7, 2008

Mr. Carl R. Schultheisz, Ph. D.
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, D.C. 20594

Mr. Mark Bagnard
National Transportation Safety Board
624 Six Flags Drive, Suite 150
Arlington TX 76011

James F. Wildey II
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, D.C. 20594

Mr. Dan Walsh, P.E.
National Transportation Safety Board
624 Six Flags Drive, Suite 150
Arlington, Texas

Re: I-35W Bridge Collapse Investigation

Gentlemen:

As I have reported previously to Mark, Jacobs has been working on a set of safety recommendations that we believe are important in light of the information that has been acquired in the course of the investigation into the I-35W Bridge collapse. A copy of our final report on these recommendations is attached. The recommendations are the product of an extensive joint working effort between Jacobs' engineers (Bob Niemietz and myself) and three outside engineers with national reputations in the bridge design community and longtime members of the American Society of Civil Engineers, whose review of investigation materials was limited to publicly available information. The names of the authors of the safety recommendations and a brief summary of their credentials is set forth below:

John Finke, P.E., S.E. Mr. Finke is a structural bridge engineer with 20 years of experience. His bridge experience includes long, medium and short spans of new construction, strengthening, widening, and rehabilitating, bridge condition inspections, evaluations, and ratings. Mr. Finke is actively involved in industry technical organizations including ASCE, where he is a member of the Methods of Analysis committee and former Co-Chair of the 2006 Structures Congress. Mr. Finke is a member of and currently past-president of the Structural Engineers Association of Kansas and Missouri (SEAKM). He has also served as the past president of the St. Louis Chapter of SEAKM He is also a member of the Seismological Society of America (SSA). Mr. Finke is a lecturer in Civil Engineering and is a manuscript reviewer for several peer reviewed publications such as ASCE's Bridge Engineering Journal and the Journal of Structural

Engineering and Elsevier Science Publication, Engineering Structures. Mr. Finke is the Structural Department Manager for the Jacobs' St. Louis Office, a position he has held since 2005.

C. Stewart Gloyd, P.E., S.E. Mr. Gloyd has been employed as a bridge engineer since 1958, when he began work as a bridge designer for the State of Washington Department of Transportation. Until 1972, he was a bridge designer and then design supervisor. Mr. Gloyd became Chief Bridge & Structures Engineer for the State of Washington DOT in 1972, a position he held until 1989, when he became Senior Engineering Manager for Parson Brinckerhoff from 1989 to 2003. From January 2004 to the present, Mr. Gloyd has performed on-call services for PBS&J. Throughout his long career, he has directly supervised the design of over 100 bridges and has reviewed the designs of hundreds more.

Arthur W. Hedgren, Jr., Ph.D., P.E. Dr. Hedgren worked as a bridge engineer for HDR Engineering, Inc. from 1965 to 2001, where he attained the position of Senior Vice President and Structures Section Manager of HDR Engineering's Pittsburgh office. He has continued to work as a consultant since 2001. In the course of his career, Dr. Hedgren has directed the design of many types of bridges, including long-span steel truss bridges. He is the author of many publications. Among his awards, Dr. Hedgren was named Engineer of the Year in 1999 by the Pittsburgh Section of the American Society of Civil Engineers.

Robert D. Niemietz, P.E., S.E. Mr. Niemietz has more than 30 years' experience in all types of bridges including studies, criteria, preliminary surveys, specifications, cost estimates, designs, and field inspection of construction for steel welded and bolted, and continuous girder, truss, and concrete bridges. He has participated in the design or rehabilitation of numerous highway and railway truss bridges of all types. He has worked on major rehabilitation projects and those requiring staged construction to allow uninterrupted use by the traveling public. Mr. Niemietz is a member of AREMA Committee 8, Concrete Structures and Foundations, of the American Railway Engineering and Maintenance-of-Way Association (AREMA).

Charles Seim, P.E., F.ASCE. Mr. Seim has worked in bridge engineering since 1954, when he joined the California Public Works Department. He was involved in numerous bridge design/maintenance/inspection matters during his employment with the State of California from 1954 to 1980. From 1980 to 2004 Mr. Seim was a Vice President and Senior Bridge Engineer with T.Y. Lin International. He has worked as an independent consulting engineer from 2004 to the present. Mr. Seim has authored numerous publications and papers. Among the awards he has received for his many years of experience is the John A. Roebling Medal for "Lifetime Contributions to the Advancement of Bridge Engineering," which he received in 2006.

Jacobs believes that the enclosed safety recommendations, which collectively are based on nearly 200 years of experience, are an important contribution to the bridge design and ownership community and to the investigation into the I-35W Bridge collapse. It is our understanding that one of the purposes of the NTSB' investigation is to make safety recommendations based on lessons learned from the tragic collapse on August 1, 2007. It is our hope that that the enclosed recommendations will receive serious consideration by the NTSB as it prepares to make its own recommendations to the public and the bridge community.

As always, please do not hesitate to call if you have any questions.

Very Truly Yours,

(R) [redacted]

John Finke, P.E., S.E.

PROPOSED SAFETY RECOMMENDATIONS DRAWN FROM THE I-35W BRIDGE COLLAPSE

November 7, 2008

By:

John E. Finke, P.E., S.E.
Charles Stewart Gloyd, P.E., S.E.
Arthur W. Hedgren, Jr., Ph.D, P.E.
Robert D. Niemietz, P.E., S.E.
Charles Seim, P.E., F.ASCE

INTRODUCTION

The National Transportation Safety Board's public emphasis on a rare design flaw and an unreasonable concentration of construction loads on the I-35W Bridge, without addressing the many opportunities for discovery and correction of both conditions by public and private entities, fails to seize the chance to implement important safety procedures and policies that could have prevented the I-35W Bridge collapse and that could prevent future similar catastrophic truss failures. The history of bridge inspection and recording procedures, unfortunately, has been forged far too often from the debris of collapsed structures. Failing to extract all useful guidance from the I-35W catastrophe does a disservice to all those who design, construct, maintain, manage, and use our bridges. Among the lessons from the I-35W Bridge failure is the need for heightened awareness of conditions that foreshadowed the collapse, the diligent enforcement of current inspection standards, and the prompt implementation of repair protocols to correct such conditions.

To that end, we offer the following Safety Recommendations, that we propose be incorporated into the Safety Board's Final Report. Between us we possess well over one hundred years of professional experience in the design, construction, maintenance, and repair of truss structures as well as the public administration of those services. We believe this experience qualifies us to make these recommendations.

THE SAFETY RECOMMENDATIONS

1 Inspections & Ratings

1.1 Inspections of truss structures must include the entire truss system, including joints. The inspection process must evaluate the effective existing load path mechanism of the entire structure, which necessitates a physical examination of the gusset plates and fasteners that make up the joint. The inspection evaluation of the load path mechanism requires that professional engineers, knowledgeable in the assessment of these mechanisms, be an integral part of the inspection team.

Inspection of truss structures must address the entire structure, including the deck, railings, bearings, expansion joints, floor system, lateral bracing, sway bracing, portals, and the main truss members, gusset plates and fasteners. Since most truss bridges, including the I-35W Bridge, are non-redundant structures,

it is particularly important to inspect main members and gusset plates for evidence of deficiencies. The gusset plates should be given a "hands on" inspection for evidence of bowing/buckling, section loss due to corrosion, cracking, loose or missing bolts or rivets, and other deficiencies. Any significant defect should be carefully documented and reported to supervisory engineers and the owner for further action including an analysis and rating which could result in posting or closing the bridge prior to repair or strengthening. Critical defects, those that in the opinion of the inspector compromise the bridge's ability to perform its intended functions, should be reported immediately.

1.2 When truss members and joints show evidence of distress (e.g., corrosion, deformation or cracking), then each truss component evidencing such distress must be individually analyzed, and the rating of the structure must be determined based upon the results of each component's analysis.

Since most trusses, including the I-35W Bridge, are non-redundant structures, an analysis of any distressed component should be made in order to determine if the bridge can safely carry required loads. This analysis should include gusset plates as well as main members since gusset plates can be Fracture Critical Members and are on the critical load path. If an insufficient rating is obtained, the owner and his engineers must determine if posting or closing the bridge or repairing the distressed components is warranted.

When the members framing into a joint are loaded greater than the original design load, the joint, including gusset plates and fasteners must be analyzed. Since AASHTO specifies that truss joints (and connections in general) be designed for the average of the applied load and the member capacity but not less than 75% of the capacity of the connected members, the assumption that joints are always stronger than the connected members is incorrect.

2 Adding Dead Load to a Truss Structure

2.1 Before significantly increasing the dead load on a truss structure, a stress analysis of the entire structure should be performed, including the truss system, gusset plates and fasteners.

It is generally accepted practice to reanalyze a bridge when it is rehabilitated and a significant change is made to its dead load and/or its traffic loading or use. This presents the opportunity to strengthen members and joints that do not have the capacity to carry the increased loads. AASHTO specifies that truss joints be designed for the average of the applied load and the member capacity but not less than 75% of the capacity of the connected members. This re-analysis should obviously be performed before the field work commences.

Any modification to a truss bridge that increases its dead load appreciably must be considered a significant modification to the truss structure necessitating re-analyzing the entire structure including the truss system, gusset plates and fasteners. In the case of the I-35W Bridge, such an analysis would have presented an opportunity to discover the undersized gusset plates and could have prevented the failure.

What constitutes an "appreciable" increase in dead load necessitating a re-analysis of the structural capacity of the entire structure varies from bridge to bridge. Reasonable engineering judgment may diverge when it comes to setting a numerical threshold triggering the analysis. Older structures that have been rehabilitated over time must be evaluated in the context of the aggregate of all modifications to the structure and its current condition. Some structures may be in such a condition that no additional increase in dead load may be safely assumed. Notwithstanding, some numerical guideline is useful to

facilitate an efficient yet safe procedure for evaluating the effects of adding dead load to an existing bridge structure. We believe a reasonable threshold increase in dead load that should trigger a re-analysis of the structure is 5%.

3 Sequencing of Rehabilitation Work on Existing Truss Bridges

3.1 The loads and sequencing of rehabilitation construction work on a truss or other complex bridge structure must be carefully analyzed and designed by a professional engineer familiar with such structures. This work plan must be reviewed and approved by the owner's consultant or bridge engineering department, all prior to undertaking the construction work.

The stresses and behavior of trusses and other complex bridge structures are not always clearly evident and require detailed analysis. This is especially important when modifying existing truss structures with deficiencies; and particularly when the structure is open to traffic during the construction project. During the design of a rehabilitation project, the owner or his consultant must check the stresses in the bridge in various conditions. This check should include any added loads, the anticipated construction loads, and the sequence of construction to be sure that the project is feasible and safe. This would include such operations as deck removal, deck rehabilitation, member replacement, and material and equipment loads among others. Members must be analyzed for the proposed loadings and be strengthened if inadequate.

The contract documents must then require the contractor to have a professional engineer prepare a proposed written construction sequence and load analysis for review and approval by the owner. This submittal should show all construction equipment and material loads, sequence of loading and resultant stresses in the truss and other bridge structural members. The goal of this procedure is to avoid overstress of any of the bridge components or a construction failure.

The construction procedures must have written owner approval prior to any field operations that entail anything pertaining to these procedures. The contract documents should specify who should prepare and submit such procedures and who should review and approve them. The owner's field engineer or representative should be responsible for the enforcement of any preapproved procedures in the field. Generally, permission for stockpiling significant amounts of construction materials on a bridge, without an approved procedure, should be refused. In the case if the I-35W Bridge, the large material loading concentrated near one of the suspect joints could have been "the final straw" which caused the bridge to collapse.

4 Bowed/Buckled Gusset Plates

4.1 Always presume that an out-of-plane gusset plate is indicative of an imminent failure.

The purpose of a steel gusset plate is to transfer forces between the main truss members. No gusset plate is intended to accomplish that in a bowed/buckled condition. To the contrary, a bow/buckle in the gusset plate interferes with its function. Indeed, a bowed/buckled plate demands analysis and possible repair.

4.2 The presence of similar bowing/buckling in mirrored joints within the main truss structure indicates that unanticipated additional forces are compromising the original design of the joint, or that the original design of the joint is not adequate to transfer safely the forces in the main truss members.

Minor deformation of a gusset plate may be caused by conditions that do not implicate the structural capacity of the component. Nevertheless, any bowing should be immediately investigated to determine its cause, and to determine that the gusset plate has sufficient residual capacity to perform its design function.

A truss bridge is typically a symmetrically designed structure with two axes of symmetry. Each major joint recurs virtually identically in four locations within the truss span. Generally, two gusset plates are used at each such joint location to sandwich the main members at the joint, totaling eight gusset plates for each numbered joint designation. A serious structural inadequacy is indicated when all eight demonstrate the same type of deformation. Since the gusset plates are critical load carrying components of a non-redundant structure, the load induced failure of any one of them renders the truss span at risk of collapse. Such conditions must never be allowed to remain un-repaired.

5 Section Loss in Truss Members and Joints Caused by Corrosion

5.1 Corrosion section loss in members and joints must be carefully measured and recorded. Section loss should be documented with photographs, accurate measurements, and sketches showing the depth and extent of section loss. Significant section loss necessitates an analysis to determine the residual capacity of the affected components.

Corrosion section loss in members and gusset plates of trusses requires more than a visual inspection and estimate of section loss. It requires accurate measurements, and not merely noting that the condition exists. Major losses affect how and whether the members and/or joints transfer the loads they are intended to carry. A lesson of the I-35W Bridge collapse is the need to re-emphasize existing inspection procedures in the FHWA Bridge Inspectors Training Manual relating to corrosion conditions of gusset plates.

Using the L-11 East gusset plate of the I-35W Bridge as an example, a 3/16'' section loss at a critical location, resulted in a 37% loss of structural capacity. Such a significant section loss should have necessitated an analysis of the gusset plate. An analysis would have indicated whether the gusset plate could carry its current loads or required strengthening. This analysis, in all probability, would have led to the discovery of the under-sized gusset plates at L-11. This in turn should have led to an analysis of all truss gusset plates to determine whether they were properly designed, including U-10.