FHWA Research and Technology Evaluation

Gusset Plates

Final Report
January 2016

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U.S. Department of Transportation
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Foreword

The Federal Highway Administration (FHWA) Research and Technology Program strives to ensure transparency, accessibility, and responsiveness of RD&T for all stakeholders.

This report examines how FHWA's investment in gusset plate research has affected the design and rating of gusset plates.

This report should be of interest to engineers, practitioners, researchers, and decision makers involved with the research, design, performance, and management of bridges.

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Associate Administrator
Research, Development, and Technology (RD&T)

Notice

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16. Abstract On August 1, 2007, the I–35W Mississippi River Bridge (I–35W Bridge) in Minneapolis, MN, collapsed. The National Transportation Safety Board (NTSB) turned to the Federal Highway Administration (FHWA) to provide technical expertise during their investigation. In response, NTSB issued recommendations to FHWA and the American Association of State Transportation Officials (AASHTO) to prevent similar catastrophic bridge failures. An FHWA research project to assess the performance and design of steel gusset plate connections—referred to in this report as the Gusset Plate Project—facilitated actions that addressed one of the final NTSB recommendations. The main goal of the project was to improve bridge safety by providing research and guidance on gusset plates used to connect main load carrying members. As part of the FHWA Research and Technology (R&T) program evaluation, FHWA decided to evaluate the Gusset Plate Project to better understand how FHWA's investment in gusset plate research has affected the design and rating of gusset plates. This report documents the findings of a summative evaluation of the Gusset Plate Project. The report focuses on outcomes resulting from collaboration between FHWA and NTSB.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
oz	ounces	28.35	grams	g
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
mL	milliliters	0.034	fluid ounces	fl oz
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
g	grams	0.035	ounces	oz
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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3	1.2	Draft	8/10/15	SCE	V-322	Draft Review
4	1.3	Draft	8/18/15	AO	V-322	Draft Review
5	1.4	Draft	9/17/15	AO	V-322	Draft Proofread
6	1.5	Draft	11/19/15	AO	V-322	Incorporated changes/edited
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9	1.8	Final	9/19/16	LB	V-321	Prepared for Publication

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Executive Summary

On August 1, 2007, the I–35W Mississippi River Bridge (I–35W Bridge) in Minneapolis, MN, collapsed. In the tragedy, 13 people were killed and 145 were injured. (1) The National Transportation Safety Board (NTSB) turned to the Federal Highway Administration (FHWA) to provide technical expertise during their investigation. In response, NTSB issued recommendations to FHWA and the American Association of State Transportation Officials (AASHTO) to prevent similar catastrophic bridge failures. An FHWA research project to assess the performance and design of steel gusset plate connections—referred to in this report as the Gusset Plate Project—facilitated actions that addressed one of the final NTSB recommendations. The main goal of the project was to improve bridge safety by providing research and guidance on gusset plates used to connect main load carrying members.

As part of the FHWA Research and Technology (R&T) program evaluation, FHWA decided to evaluate the Gusset Plate Project to better understand how FHWA's investment in gusset plate research has affected the design and rating of gusset plates. This report documents the findings of a summative evaluation of the Gusset Plate Project. The report focuses on outcomes resulting from collaboration between FHWA and NTSB. Data collection for the evaluation relied primarily on telephone interviews with stakeholders, as well as document searches and reviews.

This evaluation focused on processes FHWA used to develop the National Cooperative Highway Research Program (NCHRP) Project 12-84 following the I–35W Bridge collapse, and the publication of NCHRP web-only document (WOD) 197. (2) Strong relationships and a commitment to safety among FHWA, NTSB, and AASHTO are apparent in the timeline leading up to the publication of the final report and in discussions the evaluation team held with stakeholders. The evaluation found the following results from FHWA's preliminary research on the performance and design of gusset plate connections:

- Provided vital support to NTSB to determine the cause of the I–35W Bridge collapse.
- Assisted NTSB's process for choosing a final safety recommendation.
- Expedited research underlying NCHRP WOD 197.
- Informed updates to AASHTO specifications.

The Gusset Plate Project provided essential knowledge that led to the rapid development of national safety standards that will help protect Americans from other potential gusset plate bridge design failures.

List of Abbreviations and Acronyms

Abbreviation	Term
AASHTO	American Association of State Highway and Transportation Officials
BDS	Bridge Design Specifications
DOT	Department of Transportation
FHWA	Federal Highway Administration
I–35W Bridge	I–35W Mississippi River Bridge
LRFD	Load and Resistance Factor Design
MBE	Manual for Bridge Evaluation
NCHRP	National Cooperative Highway Research Program
NTSB	National Transportation Safety Board
R&D	Research and Development
R&T	Research and Technology
SCOBS	Subcommittee on Bridges and Structures
TA	Technical Advisory
TFHRC	Turner-Fairbank Highway Research Center
TRB	Transportation Research Board
Volpe	John A. Volpe National Transportation Systems Center
WOD	Web-Only Document

1. Introduction

The Gusset Plate Project was selected for review as part of the FHWA R&T program evaluation. In 2014, FHWA initiated an effort to evaluate its R&T Program, which performs long-term, high-risk research to develop innovative technologies and solutions in areas such as environmental impacts, highway infrastructure, operations, planning, policy, and safety. The R&T program evaluation helps FHWA assess how effectively it is meeting its goals and objectives, and provides data to inform future project selections.

1.1 Evaluation Purpose

The R&T program evaluation seeks to answer questions about the R&T Program's demonstrated benefits, including the following:

1. What research best supports the organization's objectives?
2. Are the organization's research efforts effective?
3. Is the organization's research having the desired impacts, and is the organization effectively disseminating research results?
4. What is the public benefit for research funds being used?

The Gusset Plate Project evaluation aligns with at least three of six R&T Infrastructure Agenda objectives:[a]

- Improve the security of highway infrastructure and reduce the number of fatalities attributable to infrastructure and design characteristics of work zones.
- Improve the management of infrastructure assets and advance the implementation of a performance-based program for the National Highway System (NHS).
- Improve highway condition and performance through increased use of design, materials, construction, and maintenance innovations. (3)

[a] The FHWA R&T Agenda is a website that provides a high-level overview and context of FHWA's R&T projects and shows the cross-cutting work of the Agency's offices. The site is organized around FHWA's strategic R&T objectives, which drive R&T programs in infrastructure, operations, safety, policy, planning and environment, Federal lands, exploratory advanced research, and innovative program delivery.

This evaluation seeks to understand how FHWA's investment in gusset plate research contributed to improvements in the design, inspection, and rating of gusset plate bridges. This report documents FHWA's response to the NTSB recommendations described below—particularly Recommendation H-08-001—by conducting and disseminating key research to improve specifications for gusset plate design and load rating. This evaluation also examines how FHWA research informed AASHTO's revision of its Load and Resistance Factor Design (LRFD) Bridge Design Specifications (BDS) and the Manual for Bridge Evaluation (MBE).[b]

1.2 Project Background

The main span of the I–35W Bridge deck truss in Minneapolis collapsed during the early evening of August 1, 2007. There were approximately 110 vehicles on the collapsed portion; 17 vehicles fell into the water. Thirteen people were killed and 145 were injured. (1)

Soon after the collapse, investigators from NTSB arrived on the scene to determine what caused the bridge to fail. NTSB investigates significant transportation accidents across all modes of transportation—civil aviation, railroad, highway, marine, and pipelines. (4) Seeking technical expertise in bridge design and performance, NTSB turned to FHWA, whose engineers and researchers were on the scene within a day. Before the I–35W Bridge collapse, NTSB and FHWA worked together on numerous investigations helping to forge a strong relationship between the two agencies. This relationship was instrumental in assembling the appropriate staff to efficiently respond to the I–35W Bridge collapse. With technical assistance and guidance from FHWA, the NTSB investigation examined the role of gusset plates in the I–35W Bridge deck truss. A gusset plate is a plate made of steel that is used to join structural components in steel bridges and buildings. Gusset plates are joined to other structural elements using fasteners such as bolts or rivets, or through welding. In this report, a gusset plate refers to the plate element that joins together the main members—the chords, diagonals, and verticals—of a truss bridge.

Before the I–35W Bridge collapse, bridge designers were given considerable discretion in designing gusset plates. There was also no guidance for gusset plate load ratings, as it was commonly presumed that connections such as gusset plates would have been properly designed to be stronger than the members they connect.[c] However, gusset plates should have been load rated for a change in their condition, such as section loss due to corrosion.

[b]A variety of staff within FHWA were involved in the Gusset Plate Project. This was truly a collaborative effort with staff at FHWA Headquarters, the Resource Center, and Turner-Fairbank Highway Research Center (TFHRC) all contributing. This report does not distinguish the work performed by different offices within FHWA, but rather collectively refers to any and all work involving Headquarters, the Resource Center, and/or TFHRC, as "FHWA". See appendix A for more information on the different players involved in FHWA's infrastructure research.

[c]Load rating refers to the periodic evaluation of a structure to determine the safe level of live load it can carry relative to that for which it was designed. Load rating is typically performed when there is a change of use (e.g., lanes were added to the bridge) or a change in condition (e.g., deterioration from corrosion).

Within months of the collapse, NTSB issued its first recommendation—H-08-001—to FHWA, requiring that bridge owners conduct load-capacity calculations to verify stress levels in all structural elements, including gusset plates. [5],[d] FHWA responded with a technical advisory (TA), TA 5140.29, to formally respond to the NTSB recommendation. [6] This TA provided AASHTO with recommendations to supplement procedures for load rating steel truss bridges to ensure consideration of gusset plate capacity.

A second round of recommendations concerning the design, construction, inspection, and rating of gusset plate bridges followed in November 2008, addressed to FHWA and AASHTO.

A number of FHWA projects sought to address those recommendations. They included projects that investigated:

- Novel ways to inspect gusset plate connections that did not rely on strictly visual inspection (H-08-018). [7]
- Develop quality assurance and quality control standards for bridge design (H-08-017). [8]
- Modifications to bridge inspector training specific to truss gusset plates (H-08-019). [9]

About one year after FHWA released TA 5140.29, the agency issued publication FHWA-IF-09-014, "Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges." [10] As draft versions of that document were being reviewed, it was clear that more research was needed to rigorously validate several criteria suggested in the document. It was decided internally that FHWA would conduct a gusset plate research project. The project culminated in NCHRP WOD 197, which was used to develop new AASHTO LRFD specifications for the design and rating of gusset plate bridges. [2] Figure 1 on the next page provides a visual timeline of significant events and responsible parties, beginning with the collapse of the I–35W Bridge and concluding with the official close of NTSB's recommendation H-08-001.[e]

[d] Safety recommendations result from NTSB's investigative process and are essential to NTSB's mandate. In order to urgently address safety issues, NTSB often provides recommendations before the formal completion of its investigations. This was the case for I–35W investigation and the issuance of recommendation H-08-001. Recommendations draw upon the results of an investigation and may pertain to safety deficiencies beyond what is determined to be the probable cause of the accident. [13]

[e] The official close out process for an NTSB recommendation involves formal responses from the addressee, or the entity responsible for addressing the recommendation, documenting the action or actions taken to comply with the recommendation. NTSB's board is responsible for approving recommendation status changes, including formally closing out a recommendation. NTSB can close a recommendation for a number of reasons, depending on the action or inaction of the assignee. H-08-001 was classified as "Closed-Acceptable Alternate Action" by NTSB on November 14, 2013. NTSB defines this closed status as a response by the recipient that indicates an alternate course of action has been completed that meets the objective of the safety recommendation.[15, 16]

Figure 1. Example I–35 deck truss connection showing gusset plate and truss member it connects. (1)

1.3 Report Structure

The next chapter of this report, **Evaluation Design**, describes the evaluation methodology and key hypotheses, and provides a logic model for the Gusset Plate Project. Evaluation Design is followed by **Evaluation Findings**, which delves into the findings and results of this evaluation, followed by **Recommendations**, which offers recommendations for FHWA based on the results of this evaluation.

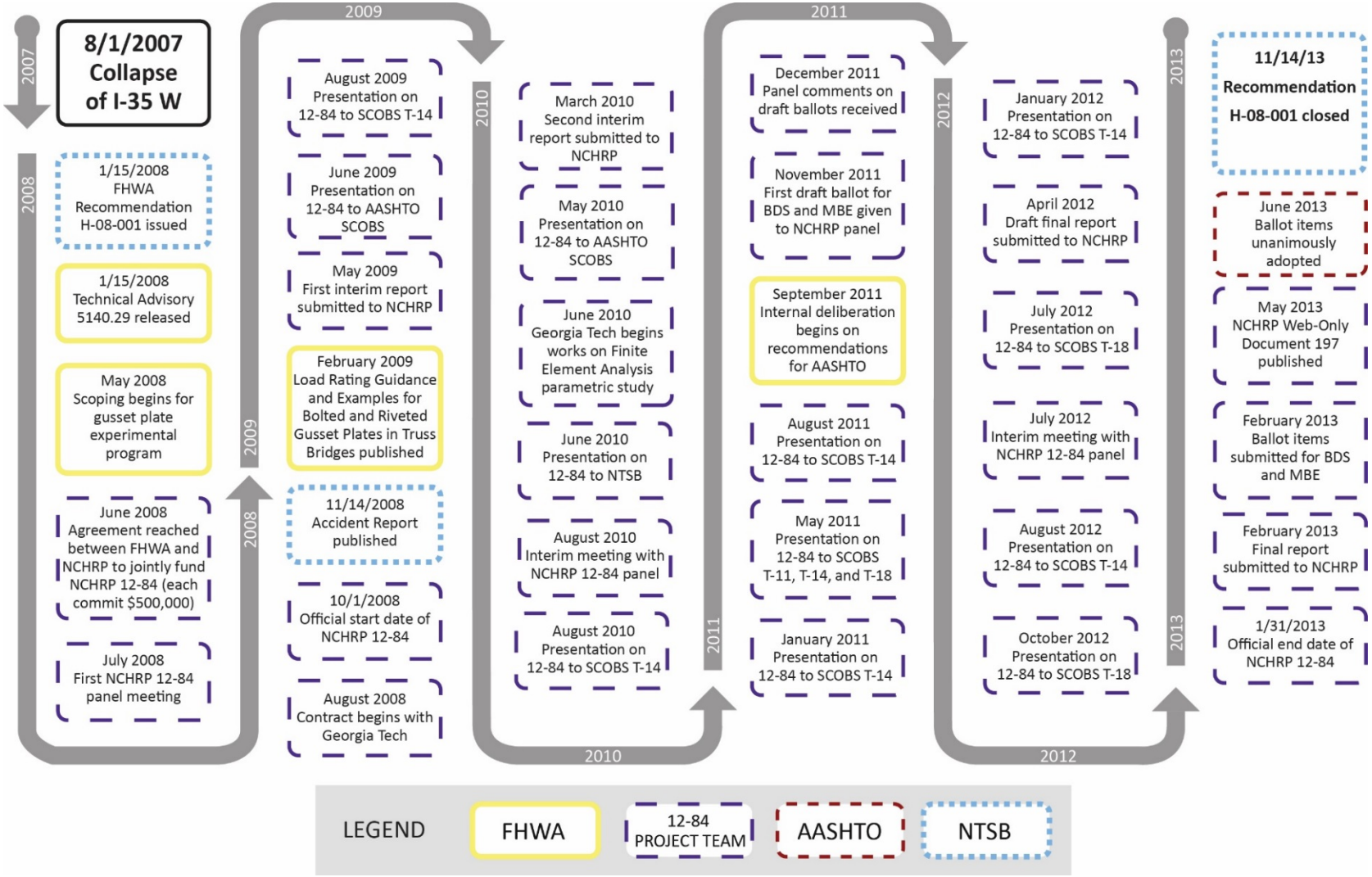


Figure 2. Timeline of gusset plate research activities.[f]

[f] Figure based on information from interviews with project staff.

2. Evaluation Design

This evaluation sought to understand how FHWA's investment in gusset plate research improved the design and rating of gusset plate bridges. The evaluation team's primary hypothesis was that FHWA's R&T activities led to the development, adoption, and application of improved design standards and guidelines for rating gusset plate bridges. A secondary related hypothesis was that FHWA's R&T activities led to new knowledge of the design and load rating of gusset plates diffused throughout the industry. These hypotheses are discussed in greater length in the **Evaluation Findings** chapter.

Figure 2 on the next page shows the logic model for the Gusset Plate Project and illustrates the links between key inputs, activities, outputs, outcomes, and impacts.[g] The main outcome was the adoption of revised AASHTO design specifications as part of the LRFD BDS and MBE. A secondary outcome was that new knowledge on the design and load rating of gusset plates was diffused to pertinent stakeholders. These outcomes were directly informed by three key FHWA outputs: NCHRP WOD 197, TA 5140, and *Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges* (FHWA-IF-09-014). NCHRP Project 12-84 was the main effort that led to NCHRP WOD 197. Other key activities included developing technical advisories and guidelines, giving presentations at important conferences and AASHTO meetings to encourage buy-in, and FHWA's ongoing coordination and collaboration with NTSB.[h]

[g] A logic model is a visual depiction of program components—including inputs, activities, outputs, outcomes, and impacts—that are linked in a chain of causality. It describes the relationship between program resources, planned activities, and expected results. It is not meant to be a comprehensive or linear description of all program processes and activities, but rather it explains the theories of change that drive the design of a program and provides relevant hypotheses that can be tested in an evaluation.

[h] These activities were led by different offices within FHWA.

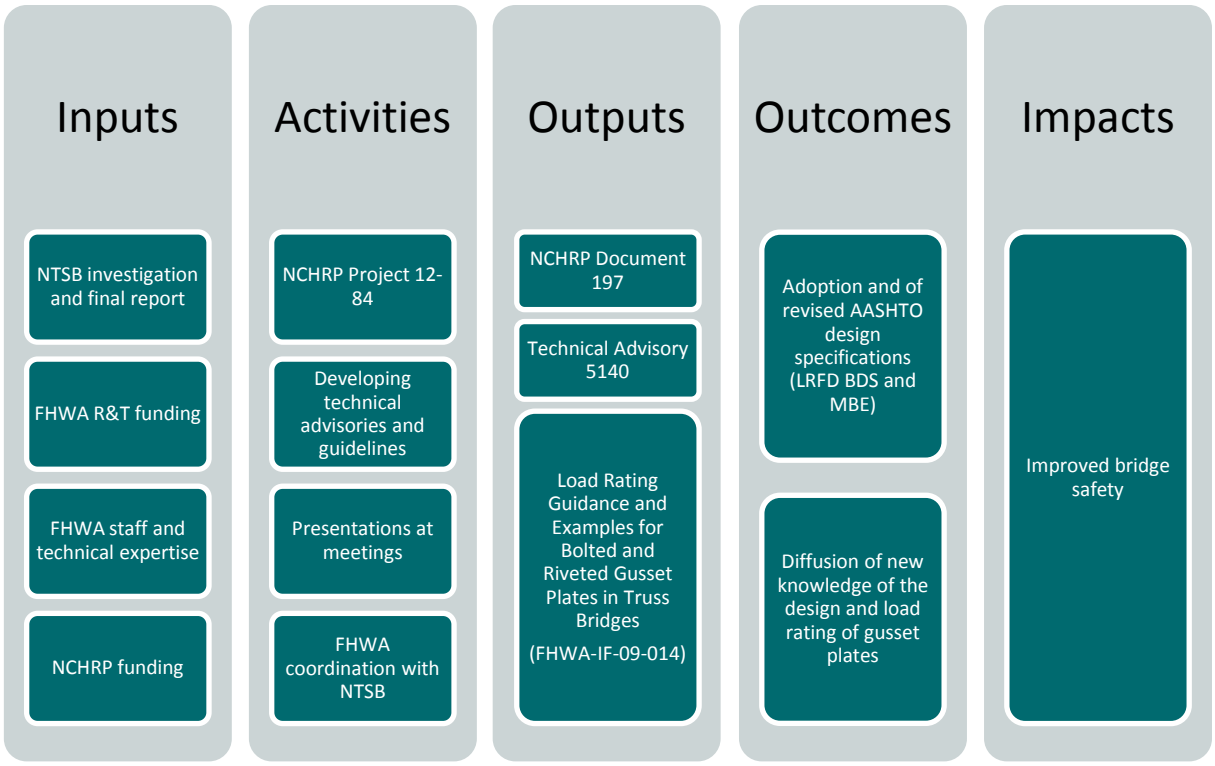


Figure 3. High-level logic model.

2.1 Evaluation Scope and Feasibility

The evaluation focused on FHWA R&T gusset plate investigations, including testing and research done in response to NTSB Recommendation H-08-001, which culminated in 2013 in the adoption of AASHTO standards on gusset plate design and load rating.

NTSB's Recommendation H-08-001 for FHWA, issued in January 2008, reads:

> *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.* (5)

NTSB's November 2008 recommendations for FHWA—H-08-017, H-08-018, and H-08-019—address separate issues, including the development of a bridge design quality assurance and quality control program, requiring that bridge owners assess truss bridges using nondestructive evaluation technologies where appropriate, and updating bridge inspector training courses and materials. (7,8,9);[i]

[i] See appendix D for a full description of NTSB's written recommendations for FHWA.

Initiated in 2009, FHWA conducted research on proper methods to measure corrosion and section loss in inspections of single- and multi-plate gusset plate designs. That research is currently in publication. However, that work is not part of the scope of this evaluation, as preliminary interviews with State department of transportation (DOT) bridge personnel and AASHTO Subcommittee on Bridges and Structures (SCOBS) members indicated it is too early to measure the meaningful effects of this research.[j] State DOTs have varying schedules for bridge inspections and data was unavailable for the evaluation team to gather on recent State bridge inspections and changes resulting from updates to the MBE.

The scope of this evaluation is limited to the efforts that led to the eventual adoption of AASHTO's revised standards for the design and rating of gusset plate bridges. This scope includes a description of how FHWA research helped NTSB identify the cause of the bridge collapse and allowed swift responses from FHWA, NCHRP, and AASHTO to the NTSB recommendations, as shown in figure 4 on the next page.

[j] A list of stakeholder interviews, including these preliminary discussions with State DOT bridge personnel and AASHTO SCOBS members, is in appendix E.

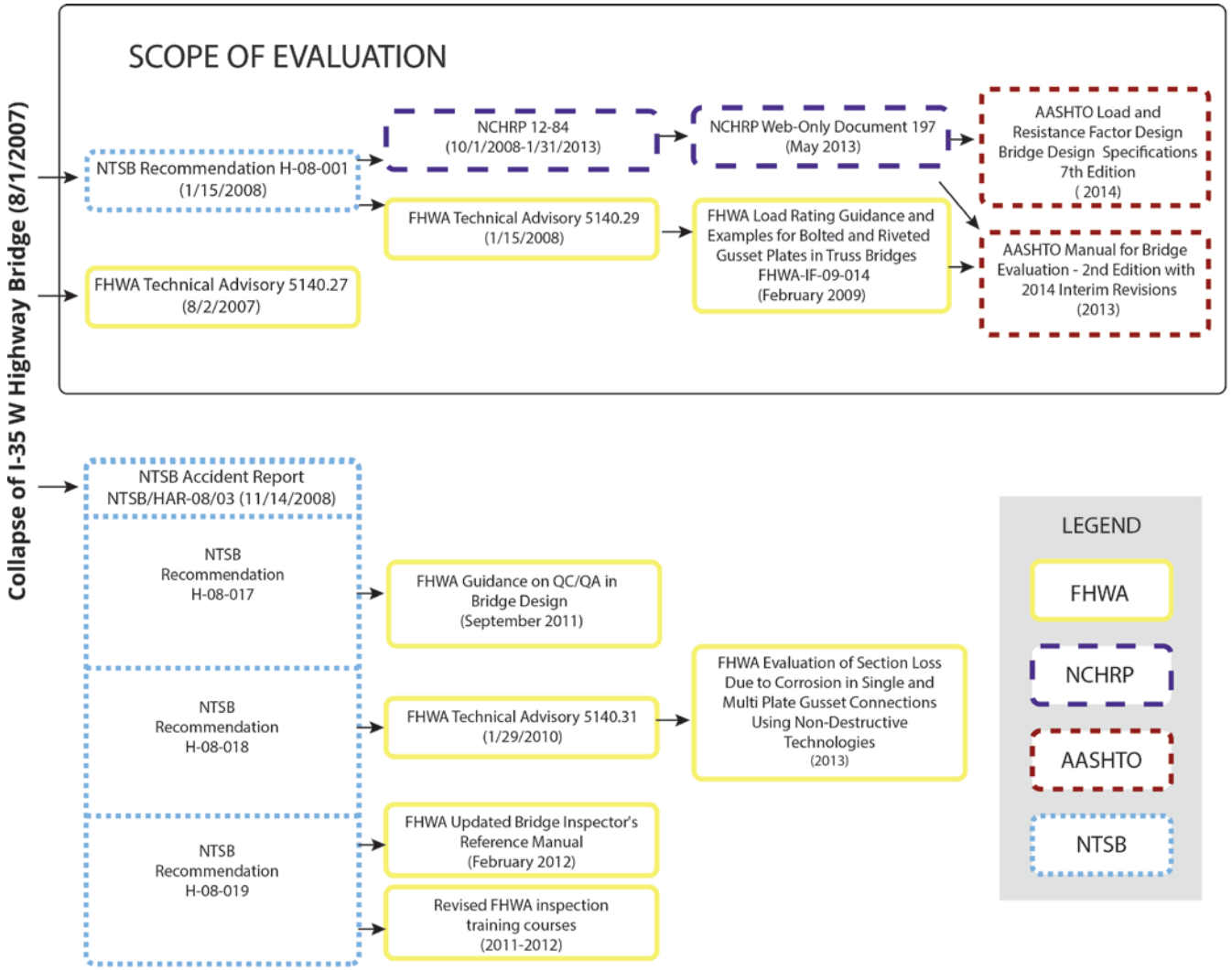


Figure 4. Flow diagram of project outputs by organization.[k]

[k] Figure generated by research team.

2.2 Evaluation Methodology

To collect evaluation data, the Volpe team conducted in-depth interviews with key stakeholders and reviewed and analyzed documents from FHWA, NTSB, and a selection of States.

Evaluation Participants and Key Questions

Volpe interviewed NTSB investigators on the I–35W Bridge investigation, FHWA engineers, and members and leaders of various Technical Committees of the AASHTO Subcommittee on Bridges and Structures (SCOBS). A list of major stakeholders is included in table 1 below.

Table 1. Stakeholders

Stakeholder	Role
FHWA Office of Corporate Research, Technology, and Innovation Management	Evaluation Program Leader
FHWA Office of Infrastructure Research & Development (R&D)	Technical Program Leader
National Transportation Safety Board	NCHRP Project 12-84 Principal Investigators
AASHTO Subcommittee on Bridges and Structures	I–35W Bridge collapse investigators and staff
Transportation Research Board National Cooperative Highway Research Program	Decision makers who worked on updates to AASHTO's LRFD Bridge Design Specifications and the Manual for Bridge Evaluation; chairs and former chairs of Technical Committee T-14 (Structural Steel Design); representatives responsible for disseminating information to AASHTO member agencies
Volpe	Research Cosponsor

The Volpe team interviewed:

- Three NTSB staff who worked on the I–35W Bridge investigation.
- Two FHWA staff who worked on the I–35W Bridge investigation and NCHRP Project 12-84.
- Four current and former members of the AASHTO Committee on Structural Steel Design.

See appendix B for a complete list of stakeholder interviews and their relevance.[l]

[l] Stakeholders at four State DOTs were also interviewed prior to a change in the scope of the evaluation. These stakeholders are listed in appendix B.

These interviews sought to document:

- How FHWA assisted NTSB with the I–35W Bridge investigation.
- The extent to which FHWA's forensic engineering on gusset plates informed NTSB's recommendations to FHWA and AASHTO in November 2008.
- How FHWA's research and calculations led AASHTO to adopt revisions to LRFD BDS on gusset plate designs and MBE specifications for the load rating of gusset plates.

Table 2 provides general questions Volpe asked during interviews with FHWA and NTSB stakeholders.

Table 2. General Questions for Stakeholder Interviews

Agency	Question
FHWA	What was your interaction with NTSB leading up to its first set of recommendations, H-08-001, during and following the onsite investigation?
FHWA	What was the timeline, from idea generation through implementation, for conducting research and eventually publishing the NCHRP report?
FHWA	What expertise and activities did FHWA contribute to NCHRP Project 12-84 and the final NCHRP WOD 197 report?
NTSB	After FHWA fulfilled its particular role with the onsite investigation, how did your agencies continue to work together? What were the next steps in the process that eventually led to the NCHRP Project 12-84?
NTSB	What is the process for bridge and highway investigations? Why, when, and how did you involve FHWA in the process?
NTSB	How did you involve FHWA in the process for developing your recommendations following the I–35W Bridge investigation?
NTSB	Describe the technical expertise and resources FHWA provided during and after the I–35W Bridge investigation.

Table 3. Most Important Documents from Review

Document	Affiliated Agency	Relevant Information
Accident Report NTSB/HAR-08-03 Collapse of I–35W Highway Bridge Minneapolis, Minnesota August 1, 2007	NTSB	Final report presenting the conclusion of the NTSB's investigation of the I–35W Bridge in Minneapolis.
Safety Recommendation H-08-001	NTSB	First recommendation from NTSB to FHWA following I–35W Bridge collapse, before the investigation was closed.
Safety Recommendation H-08-001 Correspondence between NTSB and FHWA	NTSB, FHWA	Correspondence between the two agencies regarding the recommendation that FHWA encouraged bridge owners to rate gusset plate load capacity.
FHWA Technical Advisory (TA) 5140.29	FHWA	Strongly encouraged owners to include gusset plates as part of a load rating, and ensure gusset plate capacity is adequately considered for prior ratings.
FHWA-IF-09-014 Load Rating Guidance and Examples For Bolted and Riveted Gusset Plates In Truss Bridges	FHWA	First publication from FHWA providing specific guidelines to bridge owners in meeting the requirements of FHWA TA 5140.29.
NCHRP Web-Only Document 197 Guidelines for the Load and Resistance Factor Design and Rating of Riveted and Bolted Gusset-Plate Connections for Steel Bridges	NCHRP	Final document with gusset plate load rating specifications that FHWA developed for AASHTO; served to close out NCHRP Project 12-84.
Accident Report NTSB/HAR-08-03 Collapse of I–35W Highway Bridge Minneapolis, Minnesota August 1, 2007	NTSB	Final report presenting the conclusion of the NTSB's investigation of the I–35W Bridge in Minneapolis.

Document Review

Table 3 highlights documents that informed the Volpe's evaluation. The Volpe team obtained these documents through web searches and correspondence with stakeholders. See appendix C for a complete list of documents the team reviewed.

3. Evaluation Findings

This section discusses key findings, framed by the hypotheses mentioned in the previous chapter and detailed below. The findings illustrate the two key roles FHWA played leading to the adoption of revised AASHTO standards:

1. Working with NTSB from the initial collapse and providing vital technical expertise.
2. Working with NCHRP to advance Project 12-84 and collaborating with AASHTO to ensure the results included in NCHRP WOD 197 (the document that served to close out NCHRP Project 12-84) informed the changes to AASHTO standards (LRFD BDS and MBE).

3.1 Improved Specifications for the Design and Load Rating of Gusset Plates

Hypothesis: FHWA's R&T activities led to the development, adoption, and application of improved specifications for the design and load rating of gusset plates.

There are many administrative details and approvals associated with starting a federally-funded research program. It can take years for an idea to grow into a refined topic and approach.

However, for the Gusset Plate Project FHWA was well-positioned to lead the initial research effort on gusset plate design and load ratings and ensure the research was conducted swiftly.

Finding: FHWA's technical expertise in bridge infrastructure and its prior history of working with NTSB was critical during the bridge investigation.

Immediately following the collapse, NTSB investigators called FHWA engineers to assist on scene. Before the I–35W Bridge collapse, NTSB and FHWA worked together on numerous investigations going back to 1967, with two investigations in the recent past. One investigated an overpass collapse in Golden, CO, in 2004, and the other investigated a tunnel ceiling panel collapse on I–90 in Boston, MA, in 2006. During these investigations, NTSB and FHWA worked hand-in-hand and developed a good working relationship.

For the Golden, CO, overpass collapse, NTSB sought FHWA's assistance performing structural testing and to provide specialized knowledge of bridge behavior. Following the I–90 tunnel collapse, FHWA was quickly on scene and conducted research on parameters that affect the behavior and performance of ceiling anchors. This ongoing relationship was instrumental in assembling the appropriate staff to efficiently respond to the I–35W Bridge collapse. Immediately after the collapse, NTSB got in touch with technical experts at FHWA and had structural engineers on site within a day.

FHWA staff expertise on gusset plate design and load ratings informed NTSB's specific load rating calculations, as well as further research in its materials lab. FHWA provided the knowledge and expertise on gusset plate performance that led NTSB to conclude a gusset plate design error caused the collapse. The following quotes from NTSB staff who worked with FHWA during the investigation show that NTSB depended on FHWA for infrastructure-related domain expertise.[m]

> *We wanted them to assist in bringing their technical expertise in bridges into the investigation. We worked very closely with FHWA in the early on-scene phase, even while the structure was still in the river. – NTSB staff*

> *Those are the guys who do research there who could provide us with expertise, which is what we want, we want the experts. – NTSB staff*

> *Early on they were on scene. They did bring in their knowledge of bridge inspection practices and bridge design. Somebody from FHWA sat down and did the initial calculations based on the information to apply that to gusset plates and to the nodes on the superstructure, so they were doing a lot of work either for us or in conjunction with our folks in the materials lab to make the early-on assessment of what was going on. – NTSB staff*

NTSB uses a party system to conduct investigations. A party system investigation relies on multiple stakeholders who contribute expertise across all phases of the investigation, from onscene to the feasibility and adoptability of final recommendations. The following quotes highlight FHWA's knowledge of gusset plate design and performance that made its experts indispensable to NTSB, particularly in formulating the second set of recommendations for FHWA and AASHTO.

> *We want to have enough dialogue with them to accurately portray what the problem is and where we think we can go with a potential solution. I know FHWA was very much involved in that. We had numerous meetings throughout the course of the investigation to sit down and discuss our findings and concerns…It was through the course of those meetings we collectively had in our minds, here's where we need to move forward and the best way to approach how to make those changes, and FHWA was involved quite a bit in that process. – NTSB staff*

> *It was probably the summer…when we came down to saying there's an issue with the inspection process, and that gusset plates aren't being looked at to the degree we think they should be. That's when we first started having the dialogue with Federal Highway saying, "Here's some additional work to be done." Prior to that, the focus of the case was what can we do to prevent having design errors make their way through the initial phase of a planned construction project, to the fact that they can remain in there to the point where they're being built. – NTSB staff*

[m] Please refer to appendix E for further information.

As indicated in the final quote above, NTSB stakeholders initially said they considered what should be done to prevent gusset plate design errors from becoming part of planned construction projects. During the investigation, FHWA and NTSB determined that fewer truss bridges are being constructed, as they are a less popular option, but many such bridges will exist in States' inventories for a long time to come. The focus of the recommendations turned to how States should maintain existing structures to prevent another collapse like the one that happened in Minnesota. While NTSB continued to develop its recommendations, FHWA conducted full-scale gusset plate load testing and continued to evaluate the state of practice for gusset plate design. This action from FHWA, to begin testing and to take a leadership role in gusset plate research, was unique and vitally important, as illustrated by the following quote:

> *When I found out how much work they were doing I was actually kind of surprised they really went after it. That was a substantial investment on their part. I give them a lot of credit for going after it. – NTSB staff*

Finding: FHWA's coordination with key stakeholders contributed to an accelerated timeline leading to the close of NTSB recommendations.

AASHTO, FHWA, and NTSB stakeholders all reported that NTSB and FHWA frequently communicated while NTSB developed the final safety recommendations. NTSB wanted to accurately portray the problem identified in the bridge collapse investigation and to provide actionable recommendations, especially since AASHTO and FHWA would be responsible for fulfilling them.

Minnesota DOT and the engineering firm that designed and constructed the bridge were involved in discussions with NTSB, but FHWA was a main participant in NTSB meetings about the gusset plate problem and potential solutions. It became clear during the investigation that the gusset plate design problem had national implications, and FHWA was in a position to provide support on a far-reaching solution because of their unique expertise and Federal role. As one NTSB stakeholder explained in the quote below, FHWA's close collaboration and coordination with NTSB was a major contributing factor to closing out NTSB's recommendations.

> *Our dealings with FHWA have for several years been very good and strong with open dialogue, compared with our relationship with [another Federal agency]—you can see the number of our recommendations still open for that agency, compared to FHWA. – NTSB staff*

Additionally, several NTSB staff members noted FHWA's willingness to engage with NTSB. FHWA's time and resource investments toward the NTSB investigation and recommendations process meant FHWA-specific recommendations were closed relatively quickly.

> *All recommendations for the Minneapolis bridge were closed within 5 years, which is perfect—we expect (the timeline) to be about 5–7 years. That is our average rate, 5–7 years, and we try to stick to that. And we're trying to stick to that even more than we have in the past. Some agencies take much longer, some recipients take much longer. – NTSB staff*

> *Our relationship with FHWA has allowed us to have good collaboration and led to recommendations that can be strong and meaningful and enacted in a short amount of time. – NTSB staff*

Finding: FHWA's commitment to bridge research and the decision to jointly fund the NCHRP effort accelerated the research timeline from initiation to conclusion.

Initial scoping efforts began in May 2008 for what would eventually become NCHRP Project 12-84. Within 2 months FHWA and NCHRP reached an agreement to jointly fund the research, and the first meeting of NCHRP Panel 12-84 was convened. The project kicked off in October 2008, less than 1 year from initial scoping. The quick initiation of the research project was integral in helping FHWA accelerate the research timeline and move closer to the desired outcome of updating AASHTO's specifications (LRFD BDS and MBE).

> *It was about manpower and funding, the idea that you could pool the resources and deliver the product so much faster, competently, which was in this case serving the needs of the industry because this was a safety issue that needed to be addressed in the near term…It was the fact that we had the ability to reprioritize and be more nimble in our processes and the work we had ongoing that allowed us to react that way. – FHWA staff*

AASHTO SCOBS commissioned an NCHRP report in response to the NTSB investigation. Because FHWA released interim recommendations on gusset plate design shortly after the I–35W Bridge collapse, AASHTO stakeholders selected FHWA to be the Principal Investigator on the NCHRP report on gusset plate performance and design. In addition to providing expertise, FHWA offered matching funds to conduct the research and develop the NCHRP report. FHWA was able to redirect funds regarding steel bridge research to the Gusset Plate Project.[n] The typical life of an NCHRP project concludes about 6–7 years after funding is approved. In the case of 12-84, answers were needed much faster for gusset plates than this typical time range. FHWA was able to hit the ground running without going through the development of a request for proposal (RFP) and contractor selection that usually takes approximately two years.

> *[FHWA] was already working on the subject, on the analysis of the bridge that failed. So, they were, if you will, already miles down the road looking for the answer as opposed to the normal process to put out the RFP, wait for anybody interested in doing that work to submit a proposal, evaluate the proposals and on and on. By using FHWA, they were already working on the subject, so whatever they were doing was chargeable to FHWA until such time as the NCHRP project contract was signed. But from then on AASHTO, through NCHRP, was sharing in the cost. In many ways it was a no-brainer in this instance to go to FHWA as the contractor. Because of the exigency of the situation it was decided, ok let's pool the money and let FHWA be the Primary Investigator. – Former AASHTO representative*

[n] Stakeholders provided this information in interviews with the evaluation team. Please refer to appendix B for a list of persons interviewed.

FHWA invested funds to initiate research and provided vital technical expertise, led and carried out various research approaches, and managed contractors. Combined, those elements sped up the research timeline and more rapidly led to the development of revised specifications for load rating and gusset plate design.

3.2 Diffusion of Knowledge about Design and Load Rating of Gusset Plates

Hypothesis: New knowledge about the design and load rating of gusset plates was diffused among stakeholders because of FHWA's R&T activities.

In addition to carrying out the initial research that developed into the work of NCHRP Project 12-84, and coordinating the contracts falling under that project, FHWA actively spearheaded efforts to inform and engage pertinent stakeholders. FHWA staff provided ongoing updates to AASHTO SCOBS and its technical committees, and led extensive efforts to reach stakeholders by presenting at conferences, universities, workshops, and industry group meetings.

Finding: FHWA's active and ongoing engagement of transportation stakeholders expedited delivery of new information regarding the design and load rating of gusset plates.

Correspondence between NTSB and FHWA regarding NTSB Safety Recommendation H-08-001 demonstrates the depth, breadth, and speed of communication on gusset plate performance and rating in the transportation community in the months and years following the I–35W Bridge collapse (see appendices D and E). A review of correspondence between NTSB and FHWA (see appendix E) concerning Recommendation H-08-001 shows that FHWA embarked on internal and external outreach efforts related to gusset plate research.

After FHWA released its first technical advisory—TA 5140.29—in January 2008 (following NTSB's first safety recommendation), FHWA and AASHTO provided ongoing technical assistance and guidance to FHWA field offices and bridge owners about load rating and evaluation of gusset plates on steel truss bridges. (6) Additionally, FHWA offered several teleconferences with FHWA field offices and State DOTs to resolve issues and answer questions. In 2009, FHWA published "Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges"—FHWA-IF-09-014—using the load and resistance factor rating and the load factor rating methods, with illustrated examples. (10)

The agency also sponsored several national teleconferences to familiarize FHWA and State bridge engineers with using the FHWA guidance. FHWA also organized a seminar in June 2009 titled, "Load Rating of Gusset Plates of Connections of Steel Truss Bridges" at the International Bridge Conference held in Pittsburgh, PA. (11) FHWA held a subsequent webinar series on the inspection and load rating of gusset plates using the FHWA guidance. All of these activities were vital in ensuring that appropriate stakeholders were continually updated and educated on the evolution of research and findings related to gusset plate design and load rating.

Moreover, FHWA delivered introductory and update presentations to various audiences during the course of NCHRP Project 12-84, and after the 12-84 panel had concluded its activities. The dates and types of outreach activities are included in appendix F.

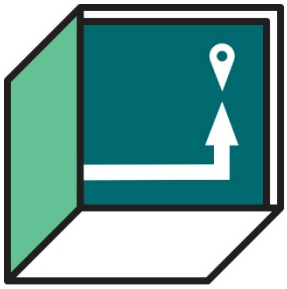
4. Recommendations

The FHWA Infrastructure Program provided important and necessary expertise following the I–35W Bridge collapse in Minneapolis, MN. The office's preliminary research on gusset plate design and performance provided NTSB with needed expertise onsite during the investigation, and while recommendations were being developed. This research capability and technical expertise, along with a willingness to assist with additional onsite and follow-up work, allowed NTSB to quickly finalize its recommendations and let FHWA respond quickly to Recommendation H-08-001 by working collaboratively with AASHTO on NCHRP Project 12-84.

FHWA should remain flexible on how its research funding is used. In this particular case, there were approved projects that FHWA had originally intended to pursue regarding steel bridge research. Given the scale of the emergency and the immediate need for research and information, funds were then redirected into the Gusset Plate Project. FHWA management was flexible with funding, and legislation at the time was also flexible enough to provide this accommodation.

External input oversight from the NCHRP panel ensured the project stayed on track and avoided findings that were not useful. This external oversight is atypical in FHWA research programs and this specific method of comingling resources raises questions about roles and responsibilities, particularly around contracting. Nevertheless, input (and, indeed, funding) from State DOTs was appropriate and helpful. Consequently, FHWA should consider how external input was gathered on this project and how FHWA might improve this approach for future high-profile research projects.

5. Conclusion



The Gusset Plate Project is a noteworthy outcome of FHWA's R&T Program. This evaluation demonstrated the importance of FHWA's preliminary and investigatory research supporting NTSB during the inquiry into the I–35W Bridge collapse. Support from FHWA helped NTSB quickly determine the cause of the collapse and craft recommendations for FHWA and AASHTO, leading to necessary safety precautions established through NCHRP Project 12-84 and summarized in NCHRP WOD 197.

FHWA research and expertise not only informed the NTSB investigation, it also expedited FHWA's own response to the NTSB recommendation. FHWA quickly gathered funding and started working with NCHRP to initiate Project 12-84. FHWA also worked with AASHTO to ensure the results from WOD 197 informed and influenced changes to specifications (LRFD BDS and MBE).

The FHWA R&T research project on gusset plates ensured that bridges across the country that rely on gusset plate connectors will be safer for the remainder of their useful life.

6. References

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Appendix A The FHWA Infrastructure Program

FHWA's infrastructure research supports safety and environmental sustainability while modernizing bridges and roads through better materials, new construction techniques, and consistent quality control. Infrastructure research explores emerging technologies that will improve the safety and reliability, structural integrity, and longevity of the Nation's bridges and roadways.

A.1 Office of Infrastructure Research and Development

Based at the Turner-Fairbank Highway Research Center (TFHRC), the FHWA Office of Infrastructure Research and Development (R&D) conducts and oversees research and development programs and projects that address critical highway infrastructure needs and priorities of national importance. Six teams perform Infrastructure R&D work, including Pavement Materials; Pavement Design and Construction; Long-Term Pavement Performance; Bridge and Foundation Engineering; Infrastructure Management Team; and Hazard Materials and Special Mitigation. FHWA Office of Infrastructure R&D specifically focuses research on the design, materials, construction, operation, and preservation of highway pavements, bridges, culverts, tunnels, and other structures.[12] As laid out in the FHWA R&T Agenda, the FHWA Office of Infrastructure strategic approach to innovation is described in its six objectives:

- **Objective 1:** Improve the security of highway infrastructure and reduce the number of fatalities attributable to infrastructure design characteristics and work zones.
- **Objective 2:** Improve the management of infrastructure assets and advance the implementation of a performance-based program for the National Highway System.
- **Objective 3**: Improve the ability of transportation agencies to deliver projects that meet expectations for timeliness, quality, and cost.
- **Objective 4:** Reduce user delay attributable to infrastructure system performance, maintenance, rehabilitation, and construction.
- **Objective 5:** Improve highway condition and performance through increased use of design, materials, construction, and maintenance innovations.
- **Objective 6:** Reduce the life-cycle environmental impacts of highway infrastructure (design, construction, operation, and maintenance).[3]

A.2 FHWA Office of Infrastructure

The FHWA Office of Infrastructure provides leadership, technical expertise, and program assistance in the areas of Asset Management, Pavements and Construction, Bridges and Structures, Program Administration, and Transportation Performance Management. By collaborating with FHWA R&D, the Office of Infrastructure produces policies and guidance documents, develops and administers training and technology transfers, and provides technical support for State and local transportation agencies.

A.3 Resource Center

The Resource Center helps FHWA advance its strategic goals by providing support in a variety of ways: (13)

- Training and technical assistance to FHWA Division Offices and their State partners.
- Helping FHWA Headquarters disseminate new policies, technologies, and techniques.
- Leading deployment of cutting-edge, market-ready technologies.

Resource Center Technical Service Teams, such as the Structures Team and the Pavement and Materials Team, provide the above services for infrastructure-related topics.

Appendix B Stakeholder Interviews

Stakeholder interviews.

Name	Title	Agency	Interview Date(s)
Justin Ocel	Structural Steel Research Program Manager	FHWA	12/2/14 5/29/15
Anne Rearick*	Director of Bridges	Indiana DOT	4/8/15
Norman McDonald*	Bridge Engineer	Iowa DOT	5/1/15
Timothy Keller*	Administrator - Office of Structural Engineering	Ohio DOT	5/20/15
Tom Macioce*	Bridge Design and Technology Division Chief	Pennsylvania DOT	5/21/15
Ed Wasserman	Senior Engineer	(formerly) AASHTO	6/5/15
Carl Schultheisz	Chief, Vehicle Performance Division, Office of Research and Engineering	NTSB	6/8/15
Julie Perrot	Safety Recommendation Specialist (Highway)	NTSB	6/11/15
Mark Bagnard	Chief of the Investigations Division	NTSB	6/16/15
Joey Hartmann	Director - Office of Bridges and Structures	FHWA	6/22/15

*These preliminary interviews with State DOT bridge personnel and AASHTO SCOBS members indicated that it is too early to measure the meaningful effects of the updated bridge inspection courses and materials. These interviews did not factor into the final evaluation findings and are included here for informational purposes.

Appendix C Documents Reviewed

Documents reviewed.

Document	Affiliated Agency	Relevant Information
Accident Report NTSB/HAR-08-03 Collapse of I–35W Highway Bridge Minneapolis, Minnesota August 1, 2007. (1)	NTSB	Final report presenting the conclusion of the NTSB's investigation of the I–35W Highway Bridge in Minneapolis, MN.
Safety Recommendation H-08-001. (5)	NTSB	First recommendation from NTSB to FHWA following I–35W Bridge collapse.
Safety Recommendation H-08-001 Correspondence between NTSB and FHWA.[o]	NTSB, FHWA	Correspondence between the two agencies regarding the recommendation that FHWA require bridge owners to rate gusset plate load capacity.
FHWA Technical Advisory 5140.29 (Load-carrying Capacity Considerations of Gusset Plates in Non-load-path Redundant Steel Truss Bridges). (6)	FHWA	Provides recommendations for supplementing the AASHTO procedures for load rating steel truss bridges with respect to gusset plates.
FHWA-IF-09-014 Load Rating Guidance and Examples For Bolted and Riveted Gusset Plates In Truss Bridges. (10)	FHWA	First publication from FHWA providing guidelines to bridge owners in meeting the requirements of FHWA Technical Advisory 5140.29.
NCHRP Web-Only Document 197 Guidelines for the Load and Resistance Factor Design and Rating of Riveted and Bolted Gusset-Plate Connections for Steel Bridges. (2)	NCHRP	Final document with gusset plate load rating specifications developed by AASHTO and FHWA; closed out NCHRP Project 12-84.

[o] See appendix E.

Appendix D NTSB's Recommendations for FHWA

NTSB's recommendations for FHWA.

Recommendation No.	Recommendation Text
H-08-001	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. (5)
H-08-017	Develop and implement, in conjunction with the American Association of State Highway and Transportation Officials, a bridge design quality assurance/quality control program, to be used by the States and other bridge owners, that includes procedures to detect and correct bridge design errors before the design plans are made final; and, at a minimum, provides a means for verifying that the appropriate design calculations have been performed, that the calculations are accurate, and that the specifications for the load-carrying members are adequate with regard to the expected service loads of the structure. (8)
H-08-018	Require that bridge owners assess the truss bridges in their inventories to identify locations where visual inspections may not detect gusset plate corrosion and where, therefore, appropriate nondestructive evaluation technologies should be used to assess gusset plate condition. (7)
H-08-019	Modify the approved bridge inspector training as follows: (1) update the National Highway Institute training courses to address inspection techniques and conditions specific to gusset plates, emphasizing issues associated with gusset plate distortion as well as the use of nondestructive evaluation at locations where visual inspections may be inadequate to assess and quantify such conditions as section loss due to corrosion; and, (2) at a minimum, include revisions to reference material, such as the Bridge Inspector's Reference Manual, and address any newly developed gusset plate condition ratings in the American Association of State Highway and Transportation Officials commonly recognized (CoRe) structural elements. (9)

Appendix E Correspondence: NTSB and FHWA—Recommendation H-08-001

The bridge collapse occurred on August 1, 2007. The recommendation was issued January 15, 2008, and it was closed on November 14, 2013. The correspondence below took place between the FHWA and the NTSB as Recommendation H-08-001 was being developed and discussed. This content is taken from the H-08-001 Safety Recommendation History. [5]

Correspondents	Date	Message
From: FHWA To: NTSB	4/30/2008	Letter Mail Controlled 5/5/2008 10:08:10 AM MC# 2080230: - From James D. Ray, Acting Administrator: The FHWA agreed with the safety recommendation and immediately issued Technical Advisory (TA) T5140.29 (Load-Carrying Capacity Considerations of Gusset Plates in Non-Load-Path-Redundant Steel Truss Bridges), dated January 15, 2008. I am enclosing a copy of the TA. Soon after the issuance of the TA, the FHWA Acting Executive Director held a teleconference with our field offices to discuss background information concerning the TA and provide an opportunity for questions and answers. Since then, the FHWA Office of Bridge Technology, in collaboration with the American Association of State Highway and Transportation Officials (AASHTO), has been providing technical assistance and guidance to the FHWA field offices and bridge owners in load rating and evaluation of gusset plates of steel truss bridges. Several teleconferences have been held with FHWA field offices and the State departments of transportation to resolve issues and answer questions. In response to NTSB Safety Recommendation H-08-1 in the Interim Report dated January 15, 2008, FHWA has taken actions within our legal authority. The States are taking positive steps to implement recommendations in the FHWA TA. We will continue to work with AASHTO, our State transportation partners, and other government agencies to assure continued compliance with the recommendation. We will consider any additional recommendations from NTSB when the final report on the investigation is issued and assess the progress of the States to determine whether additional actions are needed. We appreciate the NTSB's efforts to address this safety concern promptly. We believe the issuance of the TA fulfills the intent of Safety Recommendation H-08-1, and recommend that H-08-1 be classified as Closed-Acceptable Action. For additional information, please contact Director Myint Lwin of the Office of Bridge Technology by telephone at 202–366–4589 or e-mail at myint.lwin@dot.gov or Mr. Firas I. Ibrahim of the Office by telephone at 202–366–4598 or e-mail at firas.ibrahim@dot.gov

Correspondents	Date	Message
From: NTSB To: FHWA	7/23/2008	The Safety Board commends the FHWA for its prompt issuance of Technical Advisory (TA) T 5140.29, Load-Carrying Capacity Considerations of Gusset Plates in Non-Load-Path-Redundant Steel Truss Bridges, on January 15, 2008, to supplement the American Association of State Highway and Transportation Officials' (AASHTO's) procedures for load rating steel truss bridges with respect to gusset plate considerations. The Board notes that, since the TA was issued, the FHWA, in collaboration with AASHTO, has been providing technical assistance and guidance to FHWA field offices, bridge owners, and State departments of transportation in load rating and the evaluation of gusset plates of steel-truss bridges. We are pleased that the transportation community is working together to implement this recommendation. Although the FHWA's TA is currently receiving much publicity, resulting in subsequent actions by the States and other transportation agencies, the Safety Board believes that the advisory information should be codified through rulemaking and/or through inclusion in the AASHTO procedures or another appropriate document to ensure that this type of catastrophic accident does not recur. Although this is the only bridge failure of this type of which the Board is aware, we cannot dismiss the possibility that other steel truss bridges having nonredundant load paths may also have similar undetected design errors. By revising FHWA regulations and/or AASHTO procedures to include the advisory information, the FHWA will assist bridge owners in locating information they need to ensure the accuracy of original design calculations for this type of bridge before any future major modifications or operational changes are accomplished. Because AASHTO procedures have the effective force of an FHWA rule, but can be accomplished more quickly, an AASHTO procedure would satisfy the intent of the recommendation in an acceptable alternate manner. Pending final action, Safety Recommendation H-08-1 is classified OPEN -- ACCEPTABLE RESPONSE.

Correspondents	Date	Message
From: NTSB To: FHWA	11/21/2008	On January 15, 2008, the Safety Board issued the following safety recommendation to the FHWA: H-08-1 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. Safety Recommendation H-08-1 is currently classified OPEN -- ACCEPTABLE RESPONSE. Also on January 15, 2008, the FHWA issued Technical Advisory T 5140.29, Load-carrying Capacity Considerations of Gusset Plates in Non-load-path-redundant Steel Truss Bridges, which referenced-08-1 and advised bridge owners to take certain actions to supplement the AASHTO Manual for Condition Evaluation of Bridges. For new or replaced non-load-path-redundant steel truss bridges, bridge owners strongly encouraged to check the capacity of gusset plates as part of the initial load ratings. For non-load-path-redundant steel truss strongly encouraged to check bridges, bridge the capacity of gusset plates when performing load ratings condition or dead load, before making permit or posting decisions, or when necessary to account for bridge alterations that would increase stress levels in the structure. Finally, bridge owners were advised to review previous load rating calculations to ensure that the capacities of gusset plates had been adequately considered. In May 2008, the FHWA and AASHTO proposed a joint study of gusset plates, with the intent, among other things, of further developing and refining the guidance for bridge engineers in the proper design and rating of gusset plates, and guidelines, specifications, of developing and examples for the load and resistance factor design and rating of gusset connections. The Safety Board finds both of these timely responses commendable and takes particular note of the efforts of both the FHWA and AASHTO in providing technical assistance and guidance to FHWA field offices, bridge owners, and State departments of transportation in the load rating and evaluation of gusset plates of steel truss bridges. But while acknowledging the short-term effectiveness of the FHWA technical advisory, the Safety Board is concerned about the long-term implementation of the second action item in the advisory: (2) Future recalculations of load capacity on existing non-load-path-redundant steel truss bridges. Bridge owners are strongly encouraged to check the capacity of gusset plates as part of the load rating calculations conducted to reflect changes in condition or dead load, to make permit or posting decisions, or to account for structural modifications or other alterations that result in significant changes in stress levels. In the view of the Safety Board, this guidance would go further in preventing another gusset-plate-related catastrophic bridge collapse if it were codified through rulemaking or through appropriate guidance documents. Because the National Bridge Inspection Standards incorporate by reference3 the AASHTO Manual for Condition Evaluation of Bridges, in 23 Code of Federal Regulations 650.313©, a provision in that manual would have, for State bridge authorities, the force of a regulation. However, though the Manual for Condition Evaluation of Bridges was current at the time of the bridge collapse, it has since been replaced by the recently adopted Manual for Bridge Evaluation. The Safety Board therefore believes that AASHTO should modify the guidance and procedures in its Manual for Bridge Evaluation to include evaluating the capacity of gusset plates as part of the load rating calculations performed for non-load-path-redundant steel truss bridges. The Safety Board further believes that, when the findings of the FHWA AASHTO joint study on gusset plates become available, AASHTO should update the Manual for Bridge Evaluation accordingly.

Correspondents	Date	Message
From: FHWA To: NTSB	9/24/2009	Letter Mail Controlled 10/9/2009 2:43:14 PM MC# 2090631 - From Victor M. Mendez, Administrator: In reference to your Recommendation H-08-1 of the investigation of the failure of the I–35W bridge over the Mississippi River in Minneapolis, Minnesota, we respectfully request that H-08-1 be classified as: "Closed-Acceptable" for the following reasons. We addressed this recommendation in the letter dated April 30, 2008, noting that we had issued Technical Advisory TA 5140.29 in January ("Load-Carrying Capacity Considerations of Gusset Planes in Non-Load-Redundant Steel Truss Bridges) and taken several followup steps to implement the advisory (see enclosure 1). In response, the NTSB classified Recommendation H-08-1 as "Open-Acceptable Response" pending final action (enclosure 2). Since then, FHWA has prepared and published Load Rating Guidance and Examples, for Bolted and Riveted Gusset Plates in Truss Bridges (February 2009, copy enclosed) using both the LRFR (load and resistance factor rating) and the LFR (load factor rating) method with illustrated examples. We also sponsored several national teleconferences to familiarize FHWA and State bridge engineers with the use of the FHWA guidance. In addition, FHWA organized a seminar in June 2009 on "Load Rating of Gusset Plates of Connections of Steel Truss Bridges" at the International Bridge Conference (IBC) held in Pittsburgh, Pennsylvania. The seminar drew the largest crowd of all the seminars held at IBC this year. During the seminar: FHWA discussed the new guidance.* The Pennsylvania Department of Transportation (PennDOT) described its use of the LFR method in load rating of gusset plates. The New York State Department of Transportation explained how it is using LRFR in the load rating of gusset plates, and shared some lessons learned from retrofitting or strengthening connections. A consultant showed how to use finite element analysis to load rate gusset plates.* A software developer demonstrated how his software could be used for load rating of gusset plates. The FHWA is holding a series of Webinars on the inspection and load rating of gusset plates using the FHWA guidance and the methods the States are using. On September 24, 2009, the Webinar will focus on the spreadsheet being used by PennDOT in load rating gusset plates. Further, FHWA is cooperating with the American Association of State Highway and Transportation Officials in a full-scale testing of gusset plates to gain a better understanding of the performance of gusset plates. The goal is to issue guidance and specifications in the design, construction, and evaluation of connections in steel truss bridges. With the above completed activities and the ongoing research, deployment, and education activities, we believe that Recommendation H-08-1 has been put into practice and research. For additional technical information, please contact Mr. Myint Lwin, Director of the Office of Bridge Technology, by telephone at 202–366–4589. If I can provide further information or assistance, please feel free to call me.

Correspondents	Date	Message
From: NTSB To: FHWA	8/19/2010	The NTSB is aware that the FHWA issued Technical Advisory 5140.29008 in January 2009, published Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges in February 2009, organized a seminar on "Load Rating of Gusset Plates of Connections of Steel Truss Bridges" at the International Bridge Conference (IBC) held in Pittsburgh, Pennsylvania, in June 2009, and held a series of webinars on this issue. The NTSB is pleased that, in addition to these actions, the FHWA has been working with the American Association of State Highway and Transportation Officials (AASHTO) to conduct a full-scale testing of gusset plates to gain a better understanding of their performance and, by the end of 2010, will issue guidance and specifications in the design, construction, and evaluation of connections in steel truss bridges. In 2008, the NTSB advised the FHWA that, because issuance of the AASHTO procedures would have the force of the issuance of an FHWA rule, it would satisfy the intent of the recommendation in an acceptable alternate manner. Accordingly, pending publication of the AASHTO procedures, Safety Recommendation H-08-1 remains classified OPEN – ACCEPTABLE RESPONSE.
From: FHWA To: NTSB	9/11/2013	From Victor M. Mendez, Administrator: The Federal Highway Administration worked with the American Association of State Highway Transportation Officials (AASHTO) on this recommendation. In July 2013, voting members of the AASHTO Subcommittee on Bridges and Structures voted unanimously to adopt the following: (1) Ballot Item 25, Make revisions to Articles 6.2,.6.3, 6.5.4.2, 6.7.3, 6.13.6.1.5, 6.14.2.8 and 6.17 of the LRFD Bridge Design specifications to provide comprehensive and more unified design approach for gusset plate designs, and (2) Ballot Item 41, Make revisions to the Manual for Bridge Evaluation: Section 1, Article 1.6; Section 6, Articles C6A.4 & C6A.6; Part B, articles C6B.5.2.1 & C6B.5.3.1; and Appendix L6B to provide specifications for the load rating of gusset plates. Documentation describing these two ballot items is attached. The July 2013 changes to the LRFD Bridge Design specifications and the Manual for Bridge Evaluation direct bridge owners to conduct load capacity calculations to verify the stress levels in structural elements, including gusset plates. These revisions will be included in the next publications of interim specifications or new editions of the AASHTO specifications. Meanwhile, bridge owners may begin to use the AASHTO LRFD Bridge Design Specifications and the Manual of Bridge Evaluation to design and load rate gusset plates, bridge owners may begin to use the AASHTO LRFD Bridge Design Specifications and the Manual of Bridge Evaluation to design and load rate gusset plates. Given the above described actions, we respectfully request that recommendation H-08-01 be classified as "Closed- Acceptable Action."
From: NTSB To: FHWA	11/14/2013	We are pleased that the FHWA worked with the American Association of State Highway and Transportation Officials (AASHTO) to develop gusset plate load rating specifications and improve gusset plate design. We are further pleased that the AASHTO Subcommittee on Bridges and Structures approved revisions, currently available on the AASHTO website, that will be incorporated into the 2014 update of both the LRFD Bridge Design Specifications and the Manual for Bridge Evaluation. These actions have the force of an FHWA rule and satisfy the intent of this recommendation in an acceptable alternate manner. Accordingly, Safety Recommendation H-08-1 is classified CLOSED—ACCEPTABLE ALTERNATE ACTION.

Appendix F FHWA Outreach Activities on Gusset Plates (2010–2013)

The following list represents the outreach activities, including introductory and update presentations, conducted by FHWA pertaining to Gusset Plates for 2010–2013.

- January 2010.
  - Three 12-84-related presentations at the 89th Annual Transportation Research Board (TRB) Meeting.
- September 17, 2010.
  - Overview presentation of 12-84, delivered at University of Missouri.
- September 20, 2010.
  - Overview presentation of 12-84, delivered to a U.S.-Japan Bridge Engineering Workshop.
- January 13, 2011.
  - Presentation on 12-84 at Wiss, Janney, Elstner Associates brown bag lunch.
- January 25, 2011.
  - Update presentation at the 90th Annual TRB Meeting.
- April 2011.
  - Project presentation to American Society of Civil Engineers (ASCE) Young Member Forum.
- June 2011.
  - Paper 11-34 presented at International Bridge Conference.
  - Georgia Tech effectively finishes the parametric finite element analysis study.
- September 2011.
  - Project presentation to Structural Engineering Association of Ohio.
  - Project presentation to ASCE Tennessee Section.
- January 2012.
  - Project presentation for internal FHWA brown bag seminar.
- March 2012.
  - Project presentation to Kansas University Structural Engineering Conference.
- May 2012.
  - Paper 12-102 presented at the 2012 International Bridge Conference.
- August 2013.
  - Overview presentation along with AASHTO adopted recommendations to internal FHWA bridge discipline seminar.
- September 2013.

Overview presentation along with AASHTO adopted recommendations at FHWA webinar on load rating steel trusses.

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