U.S. Department of Transportation
Federal Highway Administration

2008 Michigan Bridge Conference

March 19, 2008
Mount Pleasant, MI

Update from the Federal Highway Administration

Jon Nekritz, P.E.
Division Bridge Engineer
FHWA, Michigan Division

Presentation outline & handouts

- **Minnesota Bridge Collapse – August 1, 2007**
  - Resulting Federal Investigations
    - National Transportation Safety Board (NTSB) [Interim safety recommendation – http://www.ntsb.gov/Recs/letters/2008/H08_1.pdf]
    - USDOT Office of Inspector General (OIG) [2006 Report – http://www.oig.dot.gov/StreamFile?file=/data/pdfdocs/mh2006043.pdf]
    - Government Accountability Office (GAO) [http://www.gao.gov/]
    - Congressional investigations/hearings
  - FHWA Technical Advisories
    - Technical Advisory 5140.27 - Immediate Inspection of Deck Truss Bridges Containing Fracture Critical Members (FCM) [handout]
    - Technical Advisory 5140.28 - Construction Loads on Bridges [handout]
    - Technical Advisory 5140.29 - Load-carrying Capacity Considerations of Gusset Plates in Non-load-path-redundant Steel Truss Bridges [handout]
      - DRAFT Part – A Gusset Plate Resistance in Accordance with the Load and Resistance Factor Rating Method (LRFR) released 2/28/08 [handout]

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- **Scour Evaluation & POA's**
  - FHWA 1/4/08 memorandum [memo available at http://www.fhwa.dot.gov/engineering/hydraulics/policymemo/20080104.cfm]
  - Scour Status as of January 2008

Bridges over Waterways	Evaluation Complete	Unknown Foundations	Evaluation Required
MDOT owned bridges	1,331	106	**91**
County owned bridges	3,233	553	**1,769**
City owned bridges	410	26	**287**
Other owned bridges	2	0	**4**
Totals	6,984	685	**2,151**

  - Scour Critical Bridge POA Status as of January 2008

Scour Critical Highway Bridges	
MDOT owned bridges	**377**
County owned bridges	**153**
City owned bridges	**21**
Other owned bridges	**0**
Total	**551**

  - FHWA Michigan Division 2/14/08 letter to MDOT [handout]

- **NBIS Quality Requirements**
  - § 650.313 (g) Quality control and quality assurance [NBIS available at http://www.fhwa.dot.gov/bridge/nbis.htm]

Memorandum

U.S. Department of Transportation
Federal Highway Administration

Subject: Technical Advisory 5140.27 - Immediate Inspection of Deck Truss Bridges Containing Fracture Critical Members (FCM)

Date: August 2, 2007

From: Frederick G. Wright (Bud)
Executive Director (HOA-3)

To: Division Administrators
Directors of Field Services
Federal Land Highway Division
Engineers

PURPOSE
In light of the uncertainty surrounding the cause of the I-35 W Bridge collapse in Minneapolis, Minnesota, we strongly advise that all State Transportation Agencies and other bridge owners immediately re-inspect all steel deck truss bridges with fracture critical members. At a minimum, State Transportation Agencies and other bridge owners should review inspection reports, including those for routine, in-depth, fracture critical, and underwater, to determine whether more detailed inspections are warranted.

BACKROUND
At 6:05 P.M. EST on Wednesday, August 1, 2007, the bridge over the Mississippi River between University Avenue and Washington Avenue on highway I-35 W in Minneapolis, MN, collapsed. Numerous vehicles were on the bridge at the time.

To assist with this undertaking we are attaching the Structural Inventory and Assessment. We will provide State Transportation Agencies with additional information as it becomes available.

Please refer any question to Benjamin Tang at 202-366-4592 or benjamin.tang@dot.gov.

Attachment

MOVING THE AMERICAN ECONOMY

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: Technical Advisory 5140.28 - Construction Loads on Bridges   Date: August 8, 2007

From: Frederick G. Wright (Bud)
Executive Director (HOA-3)

To: Division Administrators
Directors of Field Services
Federal Land Highway Division
Engineers

PURPOSE
In the ongoing investigation of the collapse of the I-35W Bridge in Minneapolis, the National Transportation Safety Board has identified construction equipment and materials loading on the bridge as part of their review. While no conclusions have been reached, in an abundance of caution, we strongly advise the State Transportation Agencies and other bridge owners who are engaged in or contemplating any construction operation on their bridges to ensure that any construction loading and stockpiled raw materials placed on a structure do not overload its members.

For more discussion on this issue, please refer to the AASHTO Standard Specifications for Highway Bridges, 17th Edition, Division II, Section 8.15 or the AASHTO Load Resistance and Factor Design Bridge Design Specifications, 4th Edition, Section 3.

Please refer any questions to Benjamin Tang at 202-366-4592 or benjamin.tang@dot.gov.

MOVING THE AMERICAN ECONOMY

U.S. Department of Transportation
Federal Highway Administration

Technical Advisory

Subject
Load-carrying Capacity Considerations of Gusset Plates in Non-load-path-redundant Steel Truss Bridges

Classification Code	Date	Office of Primary Interest
T 5140.29	**January 15, 2008**	**HIBT**

Par.

1. **What is the purpose of this Technical Advisory?** The purpose of this Technical Advisory is to provide recommendations for supplementing the American Association of State Highway and Transportation Officials (AASHTO) procedures for load rating steel truss bridges with respect to gusset plate considerations.

2. **Does this Technical Advisory supersede another Technical Advisory?** No. This is a new Technical Advisory.

3. **What is this background of this Technical Advisory?**

   a. On August 1, 2007, the I-35W Interstate highway bridge over the Mississippi River in north Minneapolis, Minnesota, experienced a failure in the superstructure of the steel deck truss center portion of the 1,900-foot- long bridge. Approximately 1,000 feet of the deck truss portion collapsed with approximately 456 feet of the main span falling about 108 feet into the 15-foot-deep river. There were approximately 110 vehicles on the collapsed portion, with 17 vehicles falling into the water. Roadway construction was occurring on the deck truss portion of the bridge, and four of the eight lanes were closed for re-paving when the bridge collapsed. Machinery and paving materials were being parked and stockpiled on the center span.

   b. Physical examination of the recovered bridge structure showed that the gusset plates at the east and west joints, identified as U10, U10', L11, and L11', were fractured. The other major structural gusset plates in the main trusses were generally intact. The damage patterns and fracture features uncovered in the investigation to date suggest that the collapse of the deck truss portion of the bridge was related to the fractured gusset plates and, in particular, may have originated with the failure of the joint U10 gusset plates.

   c. So far, the design review has found that the superstructure of the bridge was generally built as designed, with no significant discrepancies between the design documents and the as-built condition of the bridge. Materials testing to-date has found no deficiencies in the quality of steel or concrete used in the bridge.

   d. Examination of the design methodology used at the time was found to be sound. Although no problems were identified with the design methodology used for the bridge, the investigation discovered that the gusset plates on the main trusses of the bridge at the east and west joints U10, U10', L11, and L11' were undersized.

e. The bridge underwent two major renovations, one in 1977 and another one in 1998. The average thickness of the concrete deck was increased from 6.5 inches to 8.5 inches, and the center median barrier and outside barrier walls were increased in size. These changes added to the dead weight of the structure. At this point in the investigation, it is not clear whether the general practice in the industry would include recalculating the capacity of gusset plates as part of the renovations.

f. As a result of this accident, the National Transportation Safety Board (NTSB) recommends that bridge owners conduct load capacity calculations for all non-load path-redundant steel truss bridges 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.

4. **What are the recommendations?**

a. Currently, per the National Bridge Inspection Standards (Title 23, Code of Federal Regulations, Section 650.313(c)), bridge owners are required to load rate each bridge as to its safe load-carrying capacity in accordance with the AASHTO Manual for Condition Evaluation of Bridges. As stated in the AASHTO Manual, bridge load rating calculations provide a basis for determining the safe load capacity of a bridge. A load rating result is used to maintain the safe use of a bridge and arrive at posting and permit decisions. The AASHTO Manual further states that bridge load ratings should be reviewed and updated to reflect any relevant changes in condition or dead load noted during inspections of existing bridges.

b. Accordingly, the following actions are recommended to supplement the provisions of the AASHTO Manual.

(1) **New or replaced non-load-path-redundant steel truss bridges.** Bridge owners are strongly encouraged to check the capacity of gusset plates as part of the initial load ratings.

(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.

(3) **Previous load ratings for non-load-path-redundant steel truss bridges.** Bridge owners are recommended to review past load rating calculations of bridges which have been subjected to significant changes in stress levels, either temporary or permanent, to ensure that the capacities of gusset plates were adequately considered.

King W. Gee
Associate Administrator
for Infrastructure

FHWA Bridge Design Guidance No. 1

Revision Date: February 28, 2008

Load Rating Evaluation of Gusset Plates in Truss Bridges

By Firas I. Sheikh Ibrahim, PhD, PE

Part – A
Gusset Plate Resistance in Accordance with the Load and Resistance Factor Rating Method (LRFR)

Gusset connections of non-load-path-redundant steel truss bridges shall be evaluated during a bridge load rating analysis. Non-load-path-redundant bridges are those with no alternate load paths and whose failure of a main component is expected to result in the collapse of the bridge.

The evaluation of gusset connections shall include the evaluation of the connecting plates and fasteners. The resistance of a gusset connection is determined as the smaller resistance of the fasteners or gusset plates.

The following guidance is intended to provide for life safety and thus the resistance of the connection is required to be checked at the strength limit state only. Owners may require that connections be checked at other limit states such as the service limit state to minimize serviceability problems.

<u>THE RESISTANCE OF FASTENERS:</u>

For concentrically loaded bolted and riveted gusset connections, the axial load in each connected member may be assumed to be distributed equally to all fasteners at the strength limit state.

The bolts in bolted gusset connections shall be evaluated to prevent bolt shear and plate bearing failures at the strength limit state. At the strength limit state, the provisions of AASHTO LRFD Article 6.13.2.7 and 6.13.2.9 shall apply for determining the bolts' resistance to prevent bolt shear and plate bearing failures.

The rivets in riveted gusset connections shall be evaluated to prevent rivet shear and plate bearing failures at the strength limit state. The plate bearing resistance for riveted connections shall be in accordance with AASHTO LRFD Article 6.13.2.9 for bearing at bolt holes.

The factored shear resistance of one rivet shall be taken as:

$$\phi R = \phi F m A_r \quad (1)$$

where:

ϕF = Factored shear strength of rivet. The values in the table below may be used for ϕF

Rivet Type or Year of Construction	ϕF ksi
Constructed prior to 1936 or of unknown origin	18
Constructed after 1936 but of unknown origin	21
ASTM A 502 Grade I	25
ASTM A 502 Grade II	30

m = The number of shear planes
A_r = Cross-sectional area of the rivet before driving

The shear resistance of a rivet in connections greater than 50.0 in. in length shall be taken as 0.80 times the value given in Eq. 1.

THE RESISTANCE OF GUSSET PLATES:

The resistance of a gusset plate shall be determined as the plate's least resistance in shear, tension including block shear, compression, and combined flexural and axial loads.

GUSSET PLATES IN TENSION

Gusset plates subjected to axial tension shall be investigated for three conditions:

- Yield on the gross section,
- Fracture on the net section, and
- Block shear rupture

The factored resistance, R_r, for gusset plates in tension shall be taken as the least of the values given by either yielding, fracture, or the block shear rupture resistance.

Gross Section Yielding Resistance

$$P_r = \phi_y P_{ny} = \phi_y F_y A_g \qquad (2)$$

Net Section Fracture Resistance

$$P_r = \phi_u P_{nu} = \phi_u F_u A_n U \qquad (3)$$

where:

ϕ_y = resistance factor for tension yielding = 0.95
ϕ_u = resistance factor for tension fracture = 0.80
P_{ny} = nominal tensile resistance for yielding in gross section
A_g = gross cross-sectional area of the member
A_n = net area of the member as specified in AASHTO LRFD Article 6.8.3. The effective width shall be determined by the Whitmore method explained in this Guidance.

P_{nu}	=	nominal tensile resistance for fracture in net section
F_y	=	specified minimum yield strength
F_u	=	tensile strength
U	=	reduction factor to account for shear lag = 1.0 for gusset plates

When determining the gross and net section areas, the effective width of the gusset plate in tension should be determined by the Whitmore method. In it, the effective width is located through the last row of fasteners and bound by the closer of the nearest plate edges or the lines constructed from the external fasteners of the first row of fasteners and at 30 degrees with respect to the line of action of the axial load. Figures 1 and 2 provide examples for determining the effective width in tension in accordance with the Whitmore method.

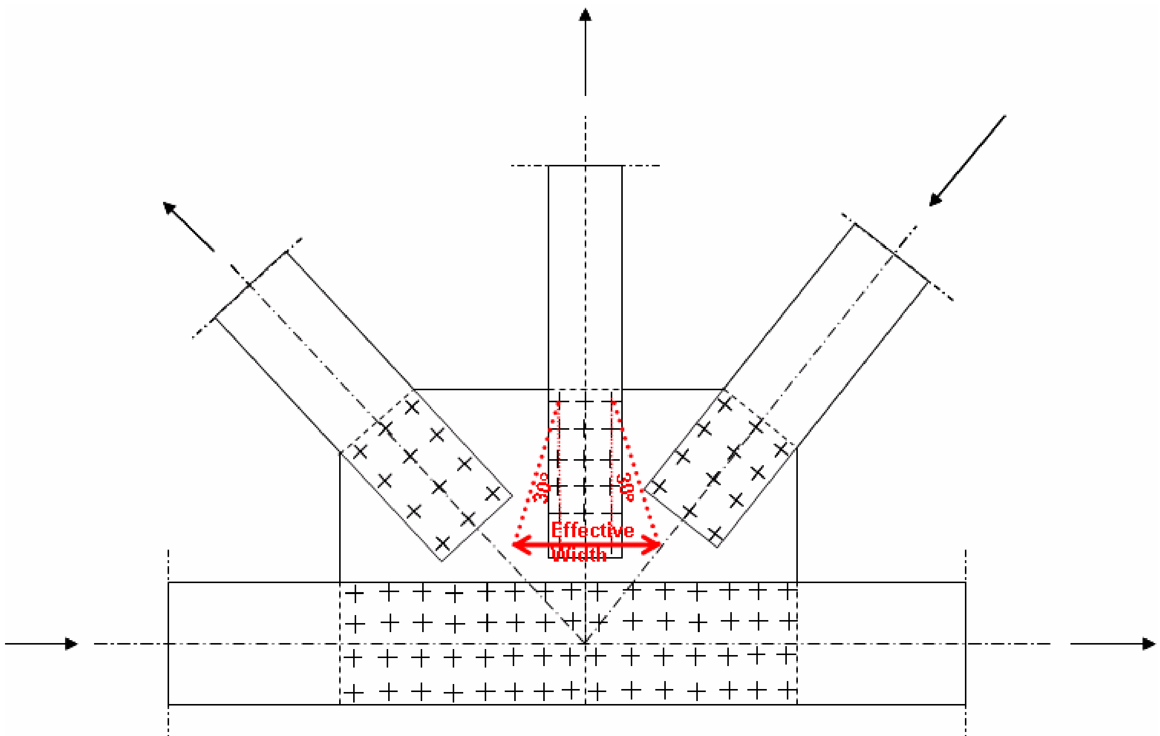

Figure 1 – Example 1 for using the Whitmore method to determine the effective width in tension

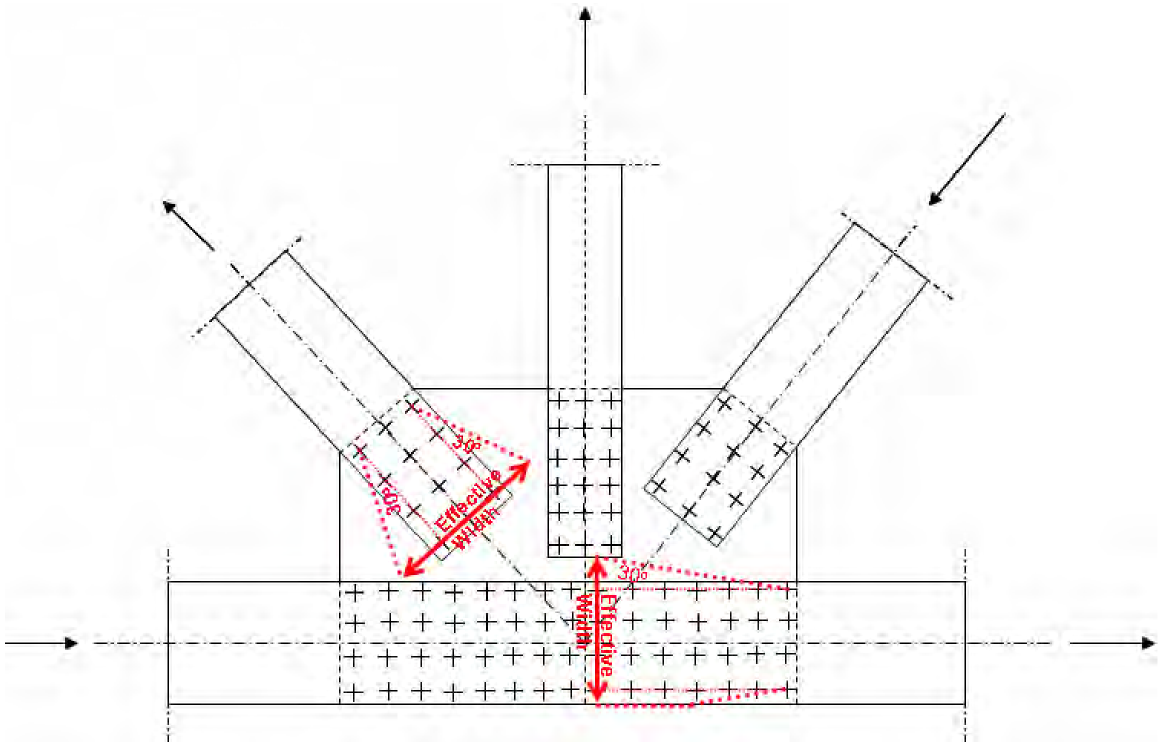

Figure 2 – Example 2 for using the Whitmore method to determine the effective width in tension

When using the Whitmore method, proximity of the connected members can affect the resistance of gusset plates in tension. Therefore, special attention must be exercised in congested areas to evaluate all possible failure modes of gusset connections.

Block Shear Rupture Resistance

The resistance of block shear rupture is that of combination of parallel and perpendicular planes, one in axial tension and the remainder under shear. The factored resistance of the plate for block shear rupture shall be taken as:

- If $A_{tn} \geq 0.58A_{vn}$, then: $R_r = \phi_{bs}\left(0.58F_y A_{vg} + F_u A_{tn}\right)$ (4)
- Otherwise: $R_r = \phi_{bs}\left(0.58F_u A_{vn} + F_y A_{tg}\right)$ (5)

where:

ϕ_{bs}	=	resistance factor for block shear = 0.80
A_{vg}	=	gross area along the plane resisting shear stress
A_{tg}	=	gross area along the plane resisting tension stress
A_{vn}	=	net area along the plane resisting shear stress
A_{tn}	=	net area along the plane resisting tension stress
F_y	=	specified minimum yield strength of the plate
F_u	=	specified minimum tensile strength of the plate

The analysis of block shear rupture involves the evaluation of several patterns of planes to arrive at the governing pattern. Figure 3 provides some examples of block shear rupture planes in gusset plates in tension.

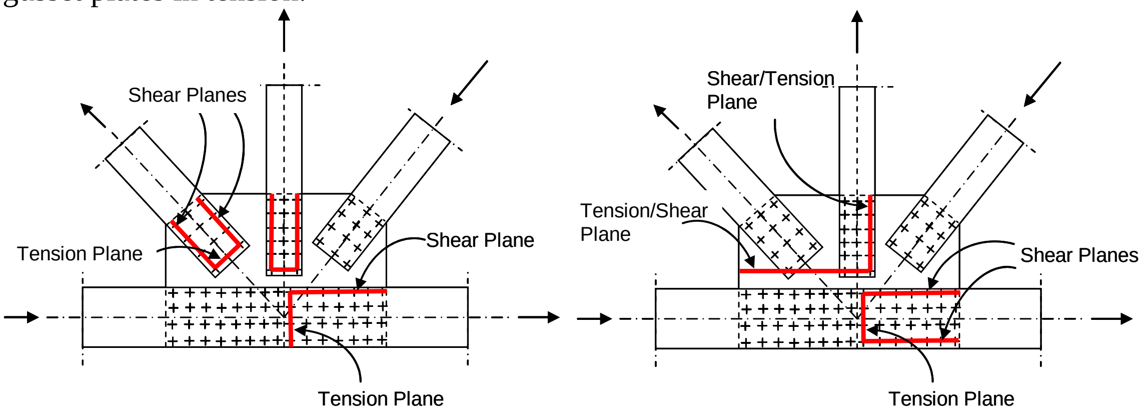

Figure 3 – Examples of block shear rupture planes in gusset plates in tension

GUSSET PLATES IN SHEAR

The factored shear resistance, R_r, for gusset plates in shear shall be taken as the least resistance against shear yielding and net section fracture specified in Equations 6, and 7:

$$R_r = \phi_v R_n = \phi_{vy} \times 0.58 A_g F_y \times 0.74 \quad (6)$$

$$R_r = \phi_v R_n = \phi_{vu} \times 0.58 A_n F_u \times 0.74 \quad (7)$$

where:

ϕ_{vy}	=	resistance factor for shear yielding on the gross section = 0.95
ϕ_{vu}	=	resistance factor for shear fracture on the net section = 0.80
R_n	=	nominal resistance in shear
A_g	=	gross area of the plates resisting shear
A_n	=	net area of the plates resisting shear
F_y	=	specified minimum yield strength of the plates
F_u	=	specified minimum tensile strength of the plates
0.74	=	reduction factor used for determining the flexural shear resistance of gusset connections.

The analysis of gusset plates for shear involves the evaluation of several shear sections to arrive at the governing section. Figures 4 and 5 provide examples of shear sections to be evaluated in gusset plates in gross section shear yielding and net section shear fracture.

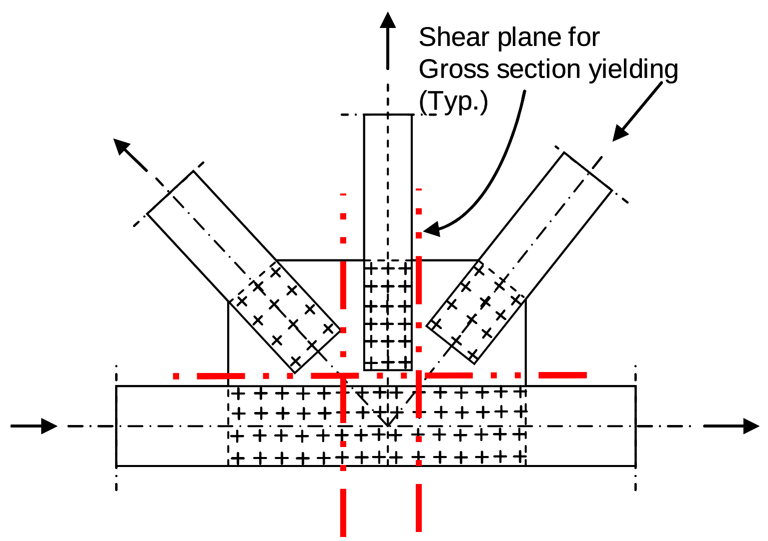

Figure 4 – Examples of gross section shear yielding planes

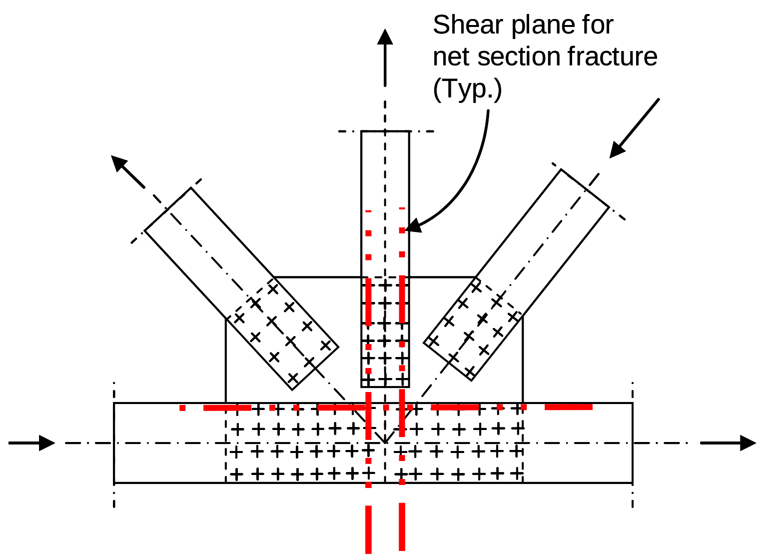

Figure 5 – Examples of net section shear fracture planes

GUSSET PLATES IN COMPRESSION

The resistance of gusset plates in compression shall be determined as that of idealized members in compression in accordance with the provisions of AASHTO LRFD Articles 6.9.2.1 and 6.9.4

The compression member's effective width shall be determined in accordance with the Whitmore method as shown in Figure 6. The unsupported length shall be determined as the distance between the last row of fasteners on one end of the connection to the first row of fasteners on the opposite end of the connection, in the direction of the applied load. Figure 6 provides an example of determining the unsupported length for a gusset plate in compression.

The proximity of connected members may affect the resistance of gusset plates in compression. Therefore, special care must be exercised to properly assess the buckling coefficients and compressive resistance of gusset plates in compression.

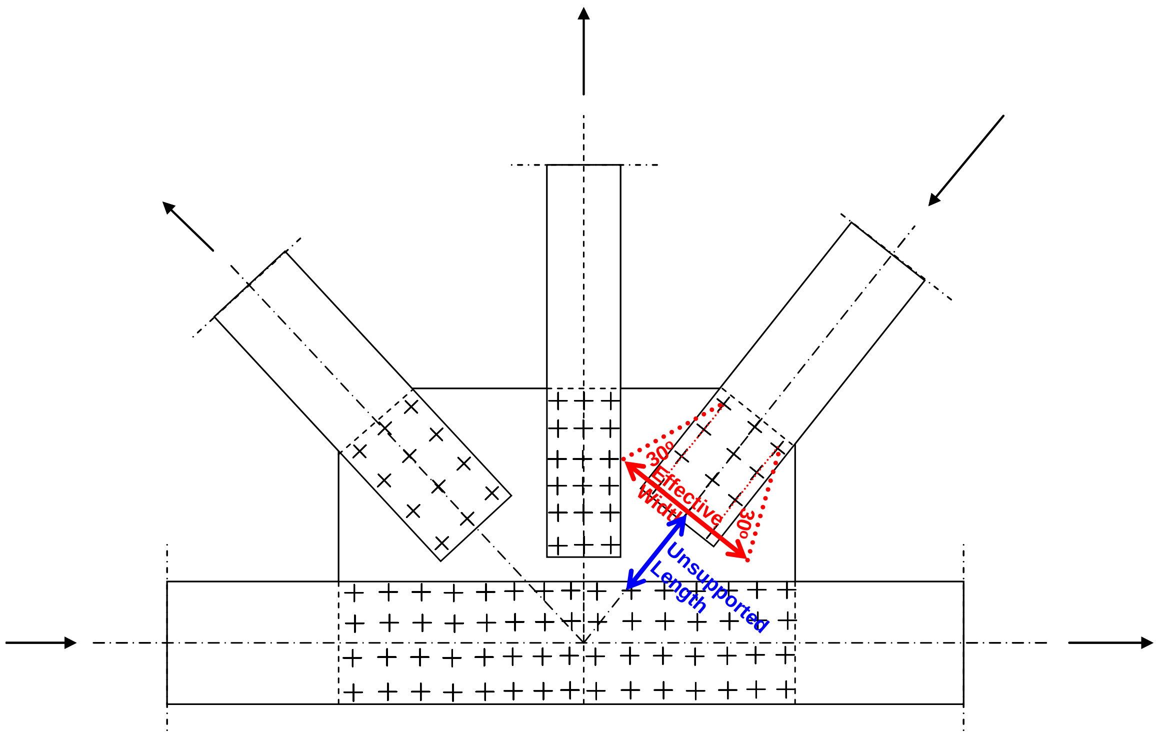

Figure 6 – Example demonstrating the unsupported length and the use of the Whitmore method to determine the effective width for a gusset plate in compression

GUSSET PLATES UNDER COMBINED FLEXURAL AND AXIAL LOADS

The maximum elastic stress from combined factored flexural and axial loads shall not exceed $\phi_f F_y$ based on the gross area of the plate.

where:

ϕ_f	=	resistance factor for flexure = 1.00
F_y	=	specified minimum yield strength of the plate

The analysis of gusset plates for combined flexural and axial loads involves the evaluation of several sections to arrive at the critical section. Figure 7 provides examples of sections to be evaluated in gusset plates under combined flexure and axial loads. Note that the sections in Figure 7 are placed such that the applied eccentricity is maximized.

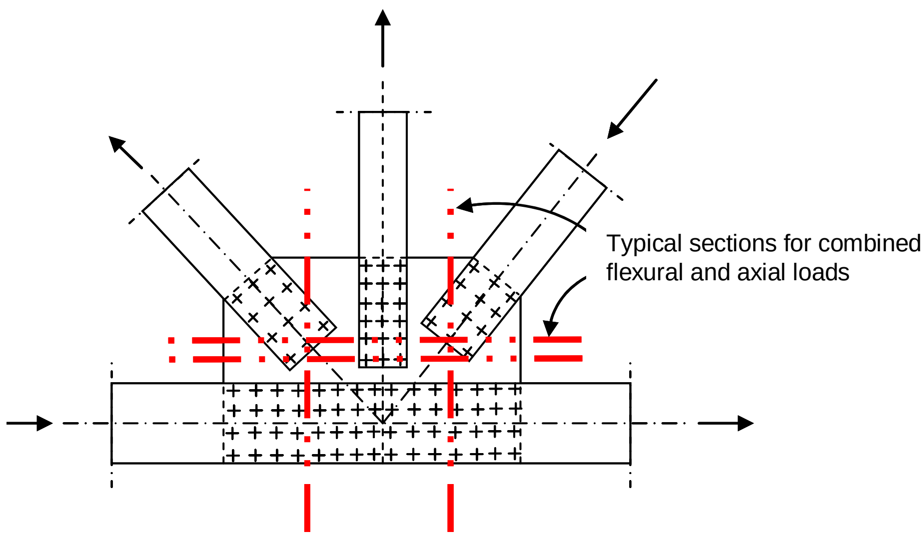

Figure 7 – Examples of combined flexural and axial load planes

U.S. Department
of Transportation
**Federal Highway
Administration**

Michigan Division

315 W. Allegan, Room 201
Lansing, Michigan 48933

February 14, 2008

Mr. Kirk T. Steudle, Director
Michigan Department of Transportation (B450)
Lansing, Michigan

Dear Mr. Steudle:

National Bridge Inspection Standards
<u>Scour Evaluations and Plans of Action for Scour Critical Bridges</u>

Attached is a January 4, 2008, memorandum from our Washington Headquarters office that provides specific direction to the Federal Highway Administration (FHWA) Division offices to ensure that the National Bridge Inspection Standards (NBIS) scour evaluation and Plans of Action (POA) requirements (23 CFR 650.313(e) and 23 CFR 650.313(e)(3)) are met by the States.

Scour is by far the most common cause of the failure of highway bridges. The NBIS defines scour as the erosion of streambed or bank material due to flowing water; often considered as being localized around piers and abutments of bridges. A scour critical bridge is a bridge that has been determined to be unstable for the observed or evaluated scour condition. After long being FHWA Policy and AASHTO guidance, the evaluation of bridges for scour vulnerability and the development and implementation of POAs for those bridges that are evaluated to be scour critical are requirements of the NBIS, revised effective January 13, 2005.

The FHWA Michigan Division has worked closely with the Michigan Department of Transportation (MDOT) to have highway bridges over waterways in Michigan evaluated for scour vulnerability and, more recently, to develop procedures for developing and implementing scour critical bridge POAs. Much progress has been made by your staff in these efforts. However, significant work remains to be done, particularly for the scour evaluation of local agency highway bridges, and for the development and implementation of POAs for all Michigan scour critical highway bridges.

The following table provides an up-to-date count of Michigan highway bridges over waterways that have had evaluations completed, have unknown foundations (making evaluations difficult), and that still require scour evaluations (updated as of January 2008 from data supplied by the MDOT Bridge Operations Unit):

Highway Bridges over Waterways	Scour Evaluation Complete NBI Item 113 = 0-5, 7-9	Unknown Foundations NBI Item 113 = U	Scour Evaluation Required NBI Item 113 = 6,T,or null
MDOT owned bridges	1,331	106	91
County owned bridges	3,233	553	1,769
City owned bridges	410	26	287
Other owned bridges	2	0	4
Totals	6,984	685	2,151

Additionally, the following table provides an up-to-date count of Michigan highway bridges that have been evaluated to be scour critical, and therefore require the development and implementation of POAs (updated as of January 2008 from data supplied by the MDOT Bridge Operations Unit). Note that at least some of the bridges still requiring evaluation in the table above should be expected to be scour critical and will add to the numbers below, and that a small number of scour critical MDOT bridges (< 25) have already had POAs developed:

	Scour Critical Highway Bridges NBI Item 113 = 0, 1, 2, or 3
MDOT owned bridges	377
County owned bridges	153
City owned bridges	21
Other owned bridges	0
Total	551

Summarizing the tables above: (1) there are currently over 2,100 highway bridges that have not yet had scour evaluations performed, and (2) at least 525 highway bridges that have already been determined to be scour critical and have not had POAs developed and implemented. Based on this current status, we have determined that Michigan is not in compliance with the requirements of 23 CFR 650.313(e) and 23 CFR 650.313(e)(3).

In order to avoid the possible suspension of Federal-aid highway funds, we are requesting that MDOT provide the Michigan Division with the following information:

1. A schedule for completing the scour evaluation of all bridges over waterways within the State, including local agency and other owner bridges. We strongly recommend a target date of November 30, 2008, for completing these evaluations, regardless of ownership.

2. A schedule for completing the development and implementation of POAs for all bridges identified as scour critical. We strongly recommend target dates as follow:

    a. State owned bridges: November 30, 2008, for completion of POA development and April 30, 2009, for completion of POA implementation.

    b. Local agency and other owner bridges: November 30, 2009, for completion of POA development, and April 30, 2010, for completion of POA implementation.

The requested schedules should include outlines and descriptions of actions to be taken by MDOT to meet the target dates. Proposed target dates that are later than those recommended will be evaluated for acceptability based on the provided justification. We would appreciate the requested information be provided by Monday, March 10, 2008.

Additionally, we request that MDOT provide regular status reports to the Michigan Division on the progress made towards developing and implementing POAs. The attachment contains specific requirements for status reports; however, we would like to workout tracking and reporting details by working directly with your staff.

We are looking forward to working with you and your staff to restore Michigan's substantial compliance with the NBIS and, therefore; avoid the suspension of Federal-aid highway funds. If you have any questions, please contact Jon Nekritz, Michigan Division Bridge Engineer, at 517-702-1837.

Sincerely,

Original signed by:

James J. Steele
Division Administrator

Attachment

cc: Larry Tibbits, MDOT, Bureau of Highways Operations (B450)
John Friend, MDOT, Bureau of Highway Delivery (B235)
John Polasek, MDOT, Bureau of Highway Development (B450)
David Juntunen, MDOT, C&T (E020)
Kristin Schuster, MDOT, Design (B220)
Mark Harrison, MDOT, Design (B220)

Profile No. S-97506