U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION:** Inspection of Nonredundant Steel Tension Members

Date: May 9, 2022
In Reply Refer To: HIBS-40

From: Joseph L. Hartmann, Ph.D., P.E.
Director, Office of Bridges and Structures

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Date: 2022.05.09 12:53:43 -04'00'

To: Division Administrators
Federal Lands Highway Division Directors

An update to 23 CFR part 650 Subpart C, National Bridge Inspection Standards (NBIS), was published on May 6, 2022. Section 650.315(f)(2) establishes the requirement for hands-on inspection of Nonredundant Steel Tension Members (NSTMs). State transportation departments, Federal Agencies, and Tribal governments (herein collectively referred to as "Agencies") may choose to develop procedures in accordance with Section 650.313(f)(1)(i) of the NBIS to demonstrate that a member without load path redundancy has system or internal redundancy such that it is not considered an NSTM.

This memorandum replaces and rescinds the June 20, 2012, memorandum "Clarification of Requirements for Fracture Critical Members." Agencies with approved system redundant member procedures must update their procedures to satisfy the requirements of 23 CFR 650.313(f)(1) and submit for FHWA approval by June 6, 2024, pursuant to 23 CFR 650.311(g).

The attached guidance outlines the process and criteria for Agencies to fulfill the requirements of 23 CFR 650.313(f)(1)(i) if they choose to implement procedures to identify members with system or internal redundancy.

Please share this memorandum and its attachment with appropriate staff and with all appropriate Agency officials. Questions on the guidance can be directed to Derek Soden at (202) 493-0341or Derek.Soden@dot.gov, or to Thomas Drda at (919) 747-7011 or Thomas.Drda@dot.gov.

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Directors of Field Services
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Guidance for the Approval of Procedures for Determining System or Internal Redundancy for Steel Tension Members without Load Path Redundancy

Except for any statutes and regulations cited, the contents of this document do not have the force and effect of law and are not meant to bind States or the public in any way. This document is intended only to provide clarity regarding existing requirements under the law or agency policies.

1. **What is the purpose of this guidance?** To update the Federal Highway Administration's (FHWA) guidance on the approval of procedures developed by State transportation departments, Federal agencies, or Tribal governments (herein collectively referred to as "Agencies") to determine that a steel member fully or partially in tension without load path redundancy has system or internal redundancy and does not require Nonredundant Steel Tension Member (NSTM) inspection.
2. **Is this new FHWA guidance?** Yes. This replaces the guidance provided by the FHWA "Clarification of Requirements for Fracture Critical Members" memorandum issued June 20, 2012. This guidance serves as the replacement in all agency materials citing that document.
3. **What authorities govern this guidance?**
    a. Section 144(h) of title 23, United States Code (U.S.C.), National bridge and tunnel inspection standards
    b. 23 CFR part 650, Subpart C, National Bridge Inspection Standards
4. **What is the background of this guidance?**
    a. The National Bridge Inspection Standards (NBIS) require hands-on inspection of NSTMs of in-service bridges (23 CFR 650.313(f)(2)). Bridges with NSTMs are at elevated risk of sudden collapse due to the inability of the system or member(s) to redistribute load and maintain stability in the event of full or partial fracture of the section. This, in turn, leads to a lower tolerance for fatigue cracking that can lead to sudden fracture. Hands-on inspection mitigates this risk by identifying cracks in NSTMs at the early stages of growth so that they are addressed before propagating through, or fracturing, the section.
    b. The NBIS requires that the locations of NSTMs be identified in the bridge files (23 CFR 650.313(f)(1)). This necessitates identification of steel bridges without load path redundancy, system redundancy, or internal redundancy (23 CFR 650.305).
    c. Identification of bridges with load path redundancy is based on the number of primary load-carrying members between points of support (23 CFR 650.305). This is typically determined based on the number of primary load-carrying members observed in the bridge plans and verified by field inspection records.
    d. For bridges without load path redundancy, Agencies may choose to demonstrate that a member has system or internal redundancy such that it is not considered an NSTM (23 CFR 650.313(f)(1)(i)).
    e. System redundancy is a redundancy that exists in a bridge system without load path redundancy, such that fracture of the cross section at one location of a primary member will not cause a portion of or the entire bridge to collapse (23 CFR 650.305). Methods to establish system redundancy typically demonstrate, through refined structural analysis, that in the event of a fracture in a primary load-carrying member, the structural system

redistributes load such that collapse is avoided. Key components of these analyses are the member failure scenarios to be considered, loading, linear and non-linear material properties, boundary conditions, modeling requirements, and member and system performance criteria to be evaluated for each scenario. Previous research efforts[1,2,3,4] have established the physical mechanisms and associated analysis methods that can demonstrate system redundancy in certain structure types. Future research efforts have the potential to refine those methods, as well as establish methods for other structure types.

f. Internal redundancy is a redundancy that exists within a primary member cross-section without load path redundancy such that fracture of one component will not propagate through the entire member, is discoverable by the applicable inspection procedures, and will not cause a portion of or the entire bridge to collapse (23 CFR 650.305). Typically, methods to establish internal redundancy demonstrate that the remaining structural section of the member will continue to safely carry dead and live load until the fracture is discovered, presumably at the next inspection event. Previous research efforts[5,6] have demonstrated the ability of sections built up from mechanically fastened components in certain structure types to prevent fracture of one element from propagating to connected elements and to redistribute stress within the section. Future research efforts have the potential to establish this capability in other structure types.

5. What is FHWA's guidance concerning the review and approval of procedures to determine that a steel member fully or partially in tension has system or internal redundancy?

a. For the purposes of NSTM identification, FHWA considers bridges with three or more primary load-carrying members to be load path redundant. A determination of system or internal redundancy is not required for load path redundant members.

b. FHWA will use Table 1 to determine if procedures developed by Agencies to determine that a steel member fully or partially in tension has system or internal redundancy are consistent with the requirements of 23 CFR 650.313(f)(1)(i).

c. FHWA considers the American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications for Analysis and Identification of Fracture Critical Members and System Redundant Members* and AASHTO *Guide Specification for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* to be nationally recognized methods to determine that a steel member has system or internal redundancy (23 CFR 650.313(f)(1)(i)(B)).

d. A method to determine system or internal redundancy other than those in Paragraph 5.c can be established as a nationally recognized method by meeting either of two criteria (23 CFR 650.313(f)(1)(i)(B):

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[1] J.H. Daniels, W. Kim, and J.L. Wilson: *Recommended Guidelines for Redundancy Design and Rating of Two-Girder Steel Bridges,* NCHRP Report 319, Transportation Research Board, Washington DC, 1989.
[2] R.J. Connor, F.J. Bonachera Martin, A. Varma, Z. Lai, and C. Korkmaz: *Fracture Critical Systems Analysis for Steel Bridges,* NCHRP Report 883, Transportation Research Board, Washington DC, 2018.
[3] Connor, R. J., Digglemann, L. M., and R. J. Sherman: *Evaluation of Member and Load Path Redundancy on the US-421 Bridge over the Ohio River,* FHWA-HRT-13-105. Federal Highway Administration, McLean, VA, 2013.
[4] Barnard, T. et. al.: *Modeling the Response of Fracture Critical Steel Box-Girder Bridges,* FHWA/TX-10/9-5498-1, Texas Department of Transportation. Austin, TX. (https://ctr.utexas.edu/wp-content/uploads/pubs/9_5498_1.pdf).
[5] M. H. Hebdon, C. Korkmaz, Martin, F.J., and R. J. Connor: *Member-level Redundancy of Built-up Steel Girders Subjected to Flexure*, Purdue University, West Lafayette, Indiana, 2015.
[6] Lloyd, J. B., Bonachera Martin, F.J., Korkmaz, C., and R. J. Connor: *Member-level Redundancy of Built-up Steel Axially-Loaded Members*, Purdue University, West Lafayette, Indiana, 2018.

(1) Developed, endorsed, and disseminated by a national organization with affiliates based in two or more States. AASHTO would be one such organization.

(2) Currently adopted for use by one or more State governments or by the Federal government. Methods recognized by FHWA and adopted by State transportation departments between 2012 and 2022 would satisfy this criterion.

e. System and internal redundancy established though analysis relies on the continued ability of the elements and members in the alternate load path to carry the loads identified in the analysis of the faulted state. Procedures developed by Agencies to determine that a steel member fully or partially in tension has system or internal redundancy must include procedures for routine inspection that identify the elements and members in the alternate load path. (23 CFR 650.313(f)(1)(i)(E)). Those procedures must also include criteria establishing when damage to, or deterioration of, those members will require reevaluation to ensure that the steel member fully or partially in tension still has system or internal redundancy (23 CFR 650.313(f)(1)(i)(G)).

6. What are the responsibilities of FHWA Division and Federal Lands Highway Division offices in the review and approval of procedures to determine that a steel member fully or partially in tension has system or internal redundancy?

a. Reviewing procedures developed by Agencies and providing comments and recommendations to the FHWA Office of Bridges and Structures (HIBS) for consideration in the review.

b. Coordinating with the Agency the resolution of FHWA comments on the procedure prior to approval.

c. With the concurrence of HIBS, communicating to the Agency via letter FHWA's approval of the procedures.

d. Monitoring the implementation of FHWA-approved procedures by the Agency including:

(1) Identification of bridges determined to have system or internally redundant members,

(2) Documentation of the finding of system or internal redundancy in the bridge file, and associated inspection and condition criteria, and

(3) Verification that the Agency is applying the inspection and condition criteria documented in the approved procedure.

7. What are the responsibilities of the FHWA Office of Bridges and Structures, in the review and approval of procedures to determine that a steel member fully or partially in tension has system or internal redundancy?

a. Reviewing procedures developed by Agencies and providing comments and recommendations for consideration in the review.

b. Coordinating with the FHWA Division or Federal Lands Highway Division office in the resolution of comments on the procedure prior to approval.

c. Providing concurrence via memorandum to the FHWA Division or Federal Lands Highway Division office to the approval of procedures.

d. Maintaining liaisons with AASHTO, Transportation Research Board, and industry committees that might develop, endorse, or disseminate new or updated methods to determine system or internal redundancy.

e. Ensuring consistency by maintaining a record of nationally recognized methods and approved procedures to determine system or internal redundancy.

Table 1. NSTM Procedure Elements

Required Procedure Component	**Indicators that NSTM reclassification procedure meets component requirements in 23 CFR 650.313(f)(1)(i)** (some, but not all review considerations)	**Review Finding** (check if element requirement(s) are met)	**FHWA Review Comments** (provide explanation if requirement(s) not met)
Written policy and procedures for determining system or internal redundancy (23 CFR 650.313(f)(1)(i)(A))	Procedure contains all elements meeting the requirements of 23 CFR 650.313(f)(1)(i)(B) through (G)		
Identification of the nationally recognized method used to determine system or internal redundancy (23 CFR 650.313(f)(1)(i)(B))	Method contains all elements meeting the requirements of 23 CFR 650.313(f)(1)(i)(B). Considerations: • Consult available information from Office of Bridges and Structures on currently recognized methods • Factors that might affect applicability of the method to structures addressed in the procedure • For journal-published methods, details of the journal's editorial practice, editorial board, and journal impact factor citation		
Baseline condition of the bridge(s) to which the policy is being applied (23 CFR 650.313(f)(1)(i)(C))	Conditions that might affect applicability of the method to establish redundancy: • Presence of fatigue cracks • Fatigue life considerations • Severity and extent of corrosion • Impact damage		

Table 1. NSTM Procedure Elements

Description of design and construction details on the member(s) that may affect the system or internal redundancy (23 CFR 650.313(f)(1)(i)(D))	Details that might affect applicability of the method to establish redundancy or that factor into the redundancy determination: System Redundancy that relies on: • Absence of pin and hanger connections • Absence of nonredundant eyebars • Absence of plug welds or discontinuous back-up bar splices • Absence of constraint induced fracture prone, other fracture prone, or stress concentrating details Internal Redundancy that relies on: • Section proportions and connections • Ability to identify a faulted member during a routine inspection • Determination that the faulted member has sufficient capacity in the faulted state • Determination that the faulted member can function in service until the next inspection without further damage to intact components		

Table 1. NSTM Procedure Elements

Routine inspection requirements for bridges with system or internally redundant members (23 CFR 650.313(f)(1)(i)(E))	• Inspection interval • Access methods • Focus areas and conditions to monitor		
Special inspection requirements for the members with system or internal redundancy (23 CFR 650.313(f)(1)(i)(F))	• Visual inspection of interior members and connections (i.e., box girders) at some prescribed interval • Inspection interval for internally redundant members		
Evaluation criteria for when members should be reviewed to ensure they still have system and internal redundancy (23 CFR 650.313(f)(1)(i)(G))	• Defects that reduce structural capacity or stability, such as section loss from corrosion • Impact or fire damage • After repair/retrofits		