American Association of State Highway and Transportation Officials
AASHTO

GSBSM-1-UL
ISBN: 978-1-56051-724-5

Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members

2018
First Edition

American Association of State Highway and Transportation Officials
444 North Capitol Street, NW, Suite 249
Washington, DC 20001
202-624-5800 phone/202-624-5806 fax
www.transportation.org

Cover photos: Left: Blue Water Bridge, Port Huron, MI. The M&M-designed Blue Water Bridge carries I-69/94 over the St. Clair River between Michigan and Canada. The original bridge is a continuous steel cantilever through truss with an 871-ft main span. The twin bridge is a 922-ft tied arch bridge. Courtesy of Thomas Murphy, Modjeski & Masters, Inc. **Right:** Point Marion Bridge, Point Marion, PA. Courtesy of Anthony Ream, HDR, Inc.

ISBN: 978-1-56051-724-5

Pub Code: GSBSM-1

AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO

GSBSM-1-UL
ISBN: 978-1-56051-724-5

Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members

2018
First Edition

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
444 North Capitol Street, N.W. Suite 249
Washington, D.C. 20001

EXECUTIVE COMMITTEE
2018-2019

OFFICERS:

PRESIDENT: Carlos Braceras, Utah*

VICE PRESIDENT: Patrick McKenna, Missouri*

SECRETARY-TREASURER: Scott Bennett, Arkansas*

EXECUTIVE DIRECTOR: Bud Wright, Washington, D. C.

REGIONAL REPRESENTATIVES:

REGION I:	Jennifer Cohan, Delaware Victoria Sheehan, New Hampshire
REGION II:	Russell McMurry, Georgia
REGION III:	Joe McGuinness, Indiana Mark Lowe, Iowa
REGION IV:	Roger Millar, Washington Marc Luiken, Alaska

IMMEDIATE PAST PRESIDENT: John Schroer, Tennessee

***Elected at the 2018 Annual Meeting in Atlanta, Georgia**

AASHTO Committee on Bridges and Structures, 2018

GREGG FREDRICK, *Chair*
BRUCE V. JOHNSON, *Vice Chair*
JOSEPH L. HARTMANN, Federal Highway Administration, *Secretary*
PATRICIA J. BUSH, *AASHTO Liaison*

ALABAMA, Eric J. Christie, William "Tim" Colquett, Randall B. Mullins
ALASKA, Leslie Daughtery, Elmer E. Marx, Richard A. Pratt
ARIZONA, David B. Benton, David L. Eberhart, Pe-Shen Yang
ARKANSAS, Charles "Rick" Ellis, Mike Hill, Joe Santini
CALIFORNIA, Thomas A. Ostrom, Gedmund Setberg, Dolores Valls
COLORADO, Behrooz Far, Stephen Harelson, Jessica Martinez
CONNECTICUT, Mary E. Baker, Timothy D. Fields
DELAWARE, Jason Arndt, Jason Hastings, Craig A. Stevens
DISTRICT OF COLUMBIA, Donald L. Cooney, Konjit C. "Connie" Eskender, Richard Kenney
FLORIDA, Sam Fallaha, William Potter, Jeff Pouliotte
GEORGIA, Clayton Bennett, Bill DuVall, Steve Gaston
HAWAII, James Fu, Kevin Murata, John Williams
IDAHO, Matthew Farrar
ILLINOIS, Tim A. Armbrecht, Carl Puzey, Jayme Schiff
INDIANA, Andrew Fitzgerald, Jeremy Hunter, Anne M. Rearick
IOWA, Ahmad Abu-Hawash, James S. Nelson
KANSAS, Mark E. Hoppe, John P. Jones, Kurt F. Niehaus
KENTUCKY, Bart Asher, Andy Barber, Marvin Wolfe
LOUISIANA, Arthur D'Andrea, Paul Fossier, Zhengzheng "Jenny" Fu
MAINE, Jeffrey S. Folsom, Wayne Frankhauser, Michael Wight
MARYLAND, Maurice Agostino, Jesse Creel, Jeffrey L. Robert
MASSACHUSETTS, Alexander K. Bardow, Thomas Donald, Joseph Rigney
MICHIGAN, Matthew Chynoweth, Rebecca Curtis, Richard E. Liptak
MINNESOTA, Arielle Ehrlich, Ed Lutgen, Kevin Western
MISSISSIPPI, Aaron Cagle, Justin Walker, Scott Westerfield
MISSOURI, Dennis Heckman, Greg E. Sanders, Scott Stotlemeyer
MONTANA, Amanda Jackson, Dustin E. Rouse
NEBRASKA, Mark Ahlman, Fouad Jaber, Mark J. Traynowicz
NEVADA, Troy Martin, Jessen Mortensen
NEW HAMPSHIRE, Robert Landry, David L. Scott
NEW JERSEY, Xiaohua "Hannah" Cheng, Eddy Germain, Dave D. Lambert
NEW MEXICO, Kathy Crowell, Jeff C. Vigil
NEW YORK, Brenda Crudele, Ernest Holmberg, Richard Marchione
NORTH CAROLINA, Brian Hanks, Scott Hidden, Girchuru Muchane
NORTH DAKOTA, Jon D. Ketterling, Jason R. Thorenson
OHIO, Alexander B.C. Dettloff, Timothy J. Keller, Jeffrey Syar
OKLAHOMA, Steven Jacobi, Walter Peters, Tim Tegeler
OREGON, Bruce V. Johnson, Albert Nako, Tanarat Potisuk
PENNSYLVANIA, James M. Long, Thomas P. Macioce, Lou Ruzzi
PUERTO RICO, (Vacant)
RHODE ISLAND, Georgette Chahine, Keith Gaulin
SOUTH CAROLINA, Terry B. Koon, Jeff Sizemore
SOUTH DAKOTA, Steve Johnson, Dave Madden, Todd S. Thompson
TENNESSEE, John S. Hastings, Ted A. Kniazewycz
TEXAS, Bernie Carrasco, Jamie F. Farris, Gregg A. Freeby
U.S. DOT, Joseph L. Hartmann
UTAH, Rebecca Nix, Carmen Swanwick, Cheryl Hersh Simmons
VERMONT, Kristin M. Higgins, Jim Lacroix
VIRGINIA, Prasad L. Nallapaneni, Kendal R. Walus, Andrew M. Zickler
WASHINGTON, Tony M. Allen, Mark A. Gaines, Bijan Khaleghi
WEST VIRGINIA, Ahmed Mongi, William Varney
WISCONSIN, Scot Becker, William C. Dreher
WYOMING, Jeff R. Booher, Paul G. Cortez, Gregg C. Frederick, Michael E. Menghini

DELAWARE RIVER AND BAY AUTHORITY, Shoukry Elnahal
MDTA, Dan Williams
MULTNOMAH COUNTY TRANSPORTATION DIVISION, Jon Henrichsen
N.Y. STATE BRIDGE AUTHORITY, William Moreau
U.S. ARMY CORPS OF ENGINEERS—DEPARTMENT OF THE ARMY, Phillip W. Sauser

FOREWORD

While there is variability in the definitions found in US specifications, fracture-critical members (FCMs) are generally considered to be steel primary members or portions thereof, subject to tension, whose failure would probably cause a portion of, or the entire bridge to collapse. The decision to define members as FCMs has been made without considering internal redundancy; in other words, the redundancy within an individual member built-up from multiple components that provides mechanical separation of elements to limit crack propagation across the entire member cross-section. Prior to the development of these Guide Specifications, no standards existed on how to establish whether adequate internal redundancy exists in a mechanically-fastened built-up steel member. Transportation Pooled Fund Project TPF-5(253) "Evaluation of Member Level Redundancy in Built-up Steel Members" was intended to address issues in performing a "credible" analysis, identifying members with adequate internal redundancy to resist complete cross-section failure should one component suddenly fail (Hebdon et al., 2015; Lloyd et al., 2018). The resistance to such a failure mode is referred to as cross-boundary fracture resistance (CBFR). Existing and newly designed members satisfying the provisions of these Guide Specifications need not be classified as FCMs, but rather may be classified as Internally Redundant Members (IRMs).

These provisions also include a methodology to establish the interval for inspections specifically intended to identify whether any of the tension components have failed. In the context of this Guide Specification, this inspection is referred to as a Special Inspection for IRMs and must be of sufficient depth to reliably detect a severed component. This is a major departure from the current calendar-based approach to setting inspection intervals, and is a first step toward the development of an integrated fracture control plan by AASHTO. It is also important to note that the primary objective of the in-service special inspections of IRMs is to detect fully severed components in a built-up member rather than very small fatigue cracks emanating from any one of thousands of fastener holes. Probability of detection (POD) studies suggest that it is unrealistic to assume that such small cracks can be identified with a high level of reliability using traditional visual inspection techniques. Considering the sheer number of possible locations where a crack can initiate in a built-up member (i.e., at each fastener), this finding is not very surprising. In contrast, the likelihood of detecting a severed component in a built-up member is much higher.

The user is cautioned and must recognize that traditional hands-on or in-depth inspections may be desirable for other reasons, such as detecting corrosion. Thus, the Owner may wish to consider such inspections at shorter intervals than indicated herein. Further, it is noted that these provisions are not intended to justify leaving a severed component of a member in service for an extended period once discovered. Such damage, once found, should be repaired as quickly as practical.

Throughout these Guide Specifications, the condition during which an individual component of the built-up member is assumed to have severed is referred to as the "faulted state". It is in this condition (i.e., with an assumed severed component) that these Guide Specifications are intended to apply. The provisions are applicable for both evaluating existing members and for use during the design of new members. They are not applicable for ratings or other evaluations when all components are intact.

A new reliability-based load combination used to evaluate internal redundancy of built-up members was developed to achieve a target reliability index in the faulted state. This load combination is based on the research described in NCHRP Report 883 (Connor et al., 2018), which used the same procedures that were previously used to create the various load combinations specified in the *AASHTO LRFD Bridge Design Specifications* (AASHTO, 2017) (referred to as LRFD Design hereafter). Criteria have also been developed for the strength and service limit states to determine if the bridge demonstrates sufficient performance in the faulted state.

The commentary directs attention to other documents that provide references and suggestions for carrying out the requirements and the intent of these Guide Specifications. The commentary is not intended to provide every detail related to the development of these Guide Specifications, nor is it intended to provide a detailed summary of the studies and research data reviewed in formulating these Guide Specifications. Detailed examples showing the application of these Guide Specifications are provided in Appendix B.

Table of Contents

SECTION 1
GENERAL

1.1—GENERAL

These provisions shall be used for the evaluation of internal redundancy in built-up members traditionally designated as Fracture Critical Members (FCM). These provisions shall be used during the design of new members or the evaluation of existing members built-up from plates and rolled shapes that are mechanically fastened using high-strength bolts or rivets and subject to flexure or axial tension.

Members satisfying the requirements of these provisions shall be considered to possess sufficient internal redundancy to provide safety against complete brittle fracture of the entire member, in the event sudden fracture of an individual tension load-carrying component occurs. Such members shall be classified as Internally Redundant Members (IRMs). In new designs, IRMs shall be identified on the contract plans.

A member shall be considered to be in the faulted state when any single tension load-carrying component of the built-up member, e.g., a single angle, cover plate, or an individual component of an axial member, is assumed to be completely severed.

C1.1

These provisions describe a procedure for evaluating the internal redundancy of tension components of built-up flexural members and tension members. Internal redundancy is also often referred to as member level redundancy (MLR). To facilitate implementation, a flowchart describing the overall procedure is provided in Appendix A.

The term Internally Redundant Member (IRM) applies to the entire member if it satisfies the provisions specified herein; i.e., a member cannot have a component designated as a FCM, and another as an IRM.

The term "shall" denotes a requirement for compliance with these Specifications.

The term "should" indicates a strong preference for a given criterion.

The term "may" indicates a criterion that is usable, but other local and suitably documented, verified, and approved criterion may also be used in a manner consistent with the approaches described in the current Guide Specification.

1.2—DEFINITIONS

Bearing Ratio = The maximum allowable ratio of rivet bearing stress to plate tension stress.

Built-up Member = A member in which the plates and angles comprising the portion of the member in tension are mechanically-fastened together with rivets or high-strength bolts.

Collapse = A major change in the geometry of the bridge rendering it unfit for use, as defined in LRFD Design (AASHTO, 2017) and the MBE (AASHTO, 2018).

Component (of a Primary Member) = A portion of a (primary) member with a specific design function; for example, a cover plate attached to the flange of a girder, the web plate of a girder, or an angle used to attach components together.

Cross Boundary Fracture Resistance (CBFR) = The ability of an IRM to resist complete failure of the cross-section should one component suddenly fail.

Faulted State = State of a member in which a single component is assumed to be severed, as opposed to the unfaulted state.

Fracture Critical Member (FCM) = A steel primary member or portion thereof subject to tension whose failure would probably cause a portion of or the entire bridge to collapse.