

LRFD Guide Specifications for Bridges Carrying Light Rail Transit Loads, 2nd Edition





American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, DC 20004
202-624-5800 phone/202-624-5806 fax
www.transportation.org

© 2022 by the American Association of State Highway and Transportation Officials. All rights reserved.
Duplication is a violation of applicable law.

ISBN: 978-1-56051-781-8



AASHTO EXECUTIVE COMMITTEE

2021–2022

Voting Members

OFFICERS:

PRESIDENT: Shawn Wilson, Louisiana*

VICE PRESIDENT: Roger Millar, Washington*

SECRETARY-TREASURER: Russell McMurry, Georgia

EXECUTIVE DIRECTOR: Jim Tymon, Washington, DC

Regional Representatives:

REGION I: Marie Therese Dominguez, New York
Nicole Majeski, Delaware

REGION II: Vacant

REGION III: Julie Lorenz, Kansas
Margaret Anderson-Kelliher, Minnesota

REGION IV: Bill Panos, North Dakota
Kristina Swallow, Nevada

IMMEDIATE PAST PRESIDENT: Victoria Sheehan, New Hampshire

*Elected at the 2021 Annual Meeting

This page intentionally left blank.

AASHTO COMMITTEE ON BRIDGES AND STRUCTURES

2021–2022

Carmen Swanwick, Utah, *Chair*
Scot Becker, Wisconsin, *Vice Chair*

Joseph Hartmann, *Liaison*, FHWA
Patricia Bush, *Liaison*, AASHTO

Alabama

Jeffrey Huner
William Tim Colquett
Eric Christie

Alaska

Elmer Marx
Leslie Daugherty
Richard Pratt

Arizona

David Benton
David Eberhart
Pe-Shen Yang

Arkansas

Joe Sartini
Michael Hill
Rick Ellis

California

Gudmund Setberg
Michael Johnson
Thomas Ostrom

Colorado

Jessica Martinez
Michael Collins
Stephen Harelson

Connecticut

Andrew Cardinali
Bart Sweeney
Timothy Fields

Delaware

Craig Stevens
Jason Arndt
Jason Hastings

Dist of Columbia

Konjit Eskender
Richard Kenney
Waseem Dekelbab

Florida

Don Cooney
Sam Fallaha
William Potter

Georgia

Donn Digamon
Douglas Franks
Steve Gaston

Hawaii

James Fu
Nicholas Groves

Idaho

Matt Farrar

Illinois

Ruben Boehler
Tim Armbrrecht

Indiana

Andrew Fitzgerald
Stephanie Wagner
Anne Rearick

Iowa

James Nelson
Michael Nop

Kansas

Calvin Reed
Karen Peterson
Mark Hurt

Kentucky

Michael Carpenter
Royce Meredith

Louisiana

Chris Guidry
Artur DAndrea

Louisiana

Zheng Zheng Jenny Fu

Maine

Jeffrey Folsom
Wayne Frankhauser
Michael Wight

Maryland

Jesse Creel
Maurizio Agostino
Jeffery Robert

Massachusetts

Justin Slack
Matthew Weidele
Alexander Bardow

Michigan

Rebecca Curtis
Richard Liptak
Matthew Chynoweth

Minnesota

Ed Lutgen
Kevin Western
Arielle Ehrlich

Mississippi

Bradnado Turnquest
Scott Westerfield

Missouri

Bryan Hartnagel
Darren Kemna

Montana

Amanda Jackson
Nathan Haddick
Stephanie Brandenberger

Nebraska

Fouad Jaber
Mark Ahlman

Nevada

David Chase
Jessen Mortensen

New Hampshire

Loretta Doughty
David Scott

New Jersey

Xiaohua Cheng

New Mexico

Kathy Crowell
Shane Kuhlman
Jeff Vigil

New York

Brenda Crudele
Ernest Holmberg
James Flynn

North Carolina

Brian Hanks
Girchuru Muchane
Scott Hidden

North Dakota

Jason Thorenson
Jon Ketterling

Ohio

Alexander Dettloff
Jeffrey Syar
Timothy Keller

Oklahoma

Justin Hernandez
Tim Tegeler
Walter Peters

Oregon

Albert Nako
Raymond Mabey
Tanarat Potisuk

Pennsylvania

Richard Runyen

Shane Szalankiewicz
Thomas Macioce

Rhode Island

Mary Vittoria-Bertrand
Keith Gaulin

South Carolina

Hongfen Li
Terry Koon
Jeff Sizemore

South Dakota

Steve Johnson
Dave Madden
Todd Thompson

Tennessee

Ted Kniazewycz

Texas

Bernie Carrasco
Graham Bettis
Jamie Farris

Utah

Mark Daniels
Rebecca Nix
Cheryl Hersh Simmons
Carmen Swanwick

Vermont

Carolyn Cota
Jim Lacroix
Robert Klinefelter
Kristin Higgins

Virginia

Andrew Zickler
Kendal Walus

Washington State

Mark Gaines
Bijan Khaleghi
Tony Allen

West Virginia

Chad Robinson
Tracy Brown

Wisconsin

Aaron Bonk
Josh Dietsche
Scot Becker
William Oliva

Wyoming

Jeff Booher
Michael Menghini
Paul Cortez

This page intentionally left blank.

TABLE OF CONTENTS

1—GENERAL.....	1
1.1—SCOPE	1
1.2—NOTATION.....	1
1.3—DEFINITIONS.....	2
2—DESIGN PHILOSOPHY.....	5
2.1—GENERAL.....	5
2.2—LIMIT STATES.....	5
2.2.1—SERVICE LIMIT STATE	6
2.2.2—STRENGTH LIMIT STATE.....	6
2.2.3—EXTREME EVENT LIMIT STATE.....	6
2.2.4—FATIGUE LIMIT STATE	7
2.3—LOAD FACTORS AND COMBINATIONS	7
2.4—USER COMFORT CRITERIA.....	8
2.4.1—BRIDGE DEFLECTION.....	8
2.4.2—PEDESTRIAN AND PASSENGER COMFORT.....	8
3—LOADS.....	11
3.1—PERMANENT LOADS.....	11
3.1.1—DEAD LOADS: DC, DW, AND EV	11
3.1.2—EARTH LOADS: EH, ES, AND DD	11
3.2—LIVE LOADS	11
3.2.1—GRAVITY LOADS: LL AND PL.....	11
3.2.1.1—General.....	11
3.2.1.1.1—Number of Design Tracks	11
3.2.1.1.2—Multiple Presence of Live Load	11
3.2.1.2—Design Light Rail Transit Load.....	11
3.2.1.3—Pedestrian Loads	12
3.2.2—APPLICATION OF DESIGN LIVE LOAD	15
3.2.3—DYNAMIC LOAD ALLOWANCE: IM	16
3.2.4—DERAILMENT LOAD: DE.....	17
3.2.5—CENTRIFUGAL FORCE: CE	18
3.2.6—BRAKING FORCE: BR.....	18
3.2.7—WIND LOADS: WS AND WL	18
3.2.7.1—Wind Load on Structures: WS	18
3.2.7.2—Wind Load on Trains: WL	18
3.2.8—EARTHQUAKE EFFECTS: EQ.....	19
3.3—LOAD EFFECTS.....	19
3.3.1—LOADS DUE TO SUPERIMPOSED DEFORMATIONS	19
3.3.2—THERMAL LOADING.....	19
3.3.3—RAIL-STRUCTURE INTERACTION.....	20
3.3.4—RAIL BREAK	20



4—STRUCTURAL ANALYSIS..... 21

4.1—ACCEPTABLE METHOD OF STRUCTURAL ANALYSIS..... 21

4.2—STRUCTURAL MATERIAL BEHAVIOR 21

4.3—MODELING GEOMETRY AND BOUNDARY CONDITIONS 21

4.4—APPROXIMATE METHOD OF ANALYSIS 21

 4.4.1—INFLUENCE OF PLAN GEOMETRY..... 21

 4.4.2—DECKS 21

 4.4.3—DISTRIBUTION FACTOR METHOD FOR MOMENT AND SHEAR..... 22

 4.4.4—SKEWED BRIDGES 28

 4.4.5—CURVED BRIDGES 29

4.5—REFINED METHOD OF ANALYSIS 29

4.6—DYNAMIC ANALYSIS 29

4.7—ANALYSIS BY PHYSICAL MODELS 29

5—REFERENCES..... 31

SECTION 1

GENERAL

1.1—SCOPE

C1.1

These guide specifications (LRT Guide Specifications) are a supplement to the *AASHTO LRFD Bridge Design Specifications* (LRFD Bridge Design Specifications) that address the design of bridges subjected to light rail transit (LRT) loadings, or both LRT and conventional highway traffic loadings. The LRT Guide Specifications state only the minimum requirements necessary to provide for public safety and are not intended to supplant proper training or the exercise of judgment by the Designer. The Owner or the Designer may require levels of sophistication for design and quality of materials and construction to be higher than the minimum requirements.

Except as superseded herein, the *LRFD Bridge Design Specifications* and the *AASHTO LRFD Bridge Construction Specifications* shall govern the design and construction of bridges subjected to LRT loadings, or LRT and conventional highway loadings. Seismic design shall be in accordance with either the provisions in the appropriate sections of the *LRFD Bridge Design Specifications* or the provisions in the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*.

This document is largely dedicated to LRT load cases and load effects, and analysis of bridges subjected to LRT loadings. The following subjects are not covered: mechanical and electrical components of light rail trains, track materials and configurations, public utilities, transit signal work, and the maintenance of transit systems.

The commentary is not intended to provide a detailed summary of the studies and research data reviewed in formulating the provisions of the LRT Guide Specifications. However, technical discussions are provided as required.

Light rail transit is defined as an electric railway system characterized by its ability to operate single or multiple cars along exclusive rights-of-way at ground level, on aerial structures, in subways, or on streets; able to board and discharge passengers at station platforms or at street, track, or car-floor level; and normally powered by overhead electrical wires.

Article 1.1 provides the scope of the LRT Guide Specifications, their applicability, and their limitations. The commentary directs attention to other documents when necessary, which provide guidance for carrying out the requirements and intent of these LRT Guide Specifications. However, the commentary and references herein are not part of the LRT Guide Specifications.

The design provisions of these LRT Guide Specifications employ the load and resistance factor design (LRFD) methodology. The load factors relevant to light rail transit loading have been developed from the theory of reliability based on current statistical knowledge of loads and structural performance.

1.2—NOTATION

A	=	cross-sectional area of rail (in. ²) (C3.3.4)
a_h	=	centrifugal acceleration (ft/sec ²) (C3.2.5)
C	=	centrifugal force multiplier for a curved bridge superstructure (3.2.5)
c_l	=	parameter for skewed supports (Table 4.4.4-1)
d	=	depth of member (ft) (4.4.3)
d_e	=	horizontal distance from the centerline of the exterior web of exterior beam at the deck level to the interior edge of curb or traffic barrier (ft) (4.4.3)
E	=	elastic modulus of rail (psi) (C3.3.4)
e	=	correction factor for distribution (Table 4.4.3-1)
f'_c	=	specified concrete strength in compression (ksi) (3.1.1)
G_{max}	=	rail break gap (in.) (C3.3.4)
g	=	gravitational acceleration (ft/sec ²) (3.2.5); live load distribution factor representing the number of lanes (Table 4.4.3-1)
H	=	height of the retarding surface above the ground surface (ft) (3.2.7.2)
K_g	=	longitudinal stiffness parameter (in. ⁴) (4.4.3)
L	=	bridge span length (ft) (4.4.3)
N_b	=	number of beams, stringers, or girders (4.4.3)
N_c	=	number of cells in a concrete box girder (4.4.3)
N_{clip}	=	number of rail clips on fastener (C3.3.4)
n	=	number of loaded tracks (3.2.5)

$P_{longitudinal}$	=	longitudinal rail force associated with rail–structure interaction (lb) (C3.3.4)
P_{TL}	=	individual clip toe load (lb per fastener) (C3.3.4)
R	=	radius of a curvilinear track (ft) (3.2.5)
S	=	spacing of fastener (in.); girder spacing (ft) (C3.3.4) (4.4.3)
t_s	=	depth of concrete slab (in.) (4.4.3)
v	=	moving speed of train (ft/sec) (3.2.5)
W_e	=	half the web spacing plus the total overhang (ft) (4.4.3)
a	=	coefficient of thermal expansion of rail (per degrees Fahrenheit) (C3.3.4)
β	=	reliability index (C2.1)
γ_{EQ}	=	load factor for earthquake (2.3)
γ_{SE}	=	load factor for settlement (2.3)
γ_{TG}	=	load factor for temperature gradient (2.3)
γ_p	=	load factor for permanent loading (2.3)
ΔT	=	temperature variation of rail (°F) (C3.3.4)
θ	=	skew angle (°) (4.4.4)
μ	=	coefficient of friction between rail and rail clip (C3.3.4)

1.3—DEFINITIONS

Definitions and terms related to the design of bridges shall be as stipulated in the *LRFD Bridge Design Specifications*, unless otherwise specified.

Light Rail Train—An electric railway system characterized by its ability to operate single- or multiple-car consists (trains) along exclusive rights-of-way at ground level, on aerial structures, in subways, or on streets; able to board and discharge passengers at station platforms or at street, track, or car-floor level; and normally powered by overhead electrical wires.

Direct Fixation Track—A subset of non-ballasted track systems consisting of a track that is fixed to a concrete pedestal (plinth) leaving the rail fully exposed and isolated for stray current protection.

Ballasted Track—A traditional railway track composed of steel rail, railroad tie, railway fasteners, and ballast bed.

Continuous Welded Rail (CWR)—Also referred to as a continuous rail, “jointless” rail produced by joining rail segments utilizing flash butt welding to form one uninterrupted rail. CWR may contain joints for insulating joints or track switches. CWR has been extensively used since the 1950s and most track may be assumed to be CWR unless stated otherwise.

Ballast Bed—The groundwork onto which a railway track is laid. Also referred to as “trackbed”, a ballast bed is composed of the layers of ballast and sub-ballast above a prepared subgrade and is designed primarily to reduce the stress on the subgrade.

Gauge—Clear minimum perpendicular distance between the inner faces of the two rails.

Guardrail—A rail placed alongside one or both of the main rails to limit lateral excursion of the train in event of a derailment.

Overhead Contact System—A system of overhead wires used to supply electricity to a light rail vehicle that is equipped with a pantograph.

Rail Fasteners—A system for fixing rails to railroad ties or sleepers. The terms rail clip, rail anchors, tie plates, chairs, and track fasteners, are used to refer to parts or all of a rail fastening system.

Rail-Break Force—The deformation-induced forces in a structure because of a rail break.

Rail-Break Gap—In the event of a rail break, the free ends of the rail on either side of the break will contract, forming a gap in the rail.

Rail-Structure Interaction—A complex phenomenon in rail bridges with direct fixation track involving the effects of the forces transmitted between the rail and deck and subsequently to the substructure due to train loadings, temperature, and time-dependent effects.

AW0, AW1, AW2, AW3, AW4—Standard passenger vehicle weight categories that the rail transit industry uses to design rail cars, track, and bridges.

- AW0 (empty load): the weight of the train with all components
- AW1 (fully seated load): AW0 + fully seated passengers and operators
- AW2 (system load): AW1 + 3.3 passengers/yd² in standing areas
- AW3 (crush load): AW1 + 5.0 passengers/yd² in standing areas
- AW4 (structural load): AW1 + 6.7 passengers/yd² in standing areas, to be used for design of bridge structural elements

This page intentionally left blank.