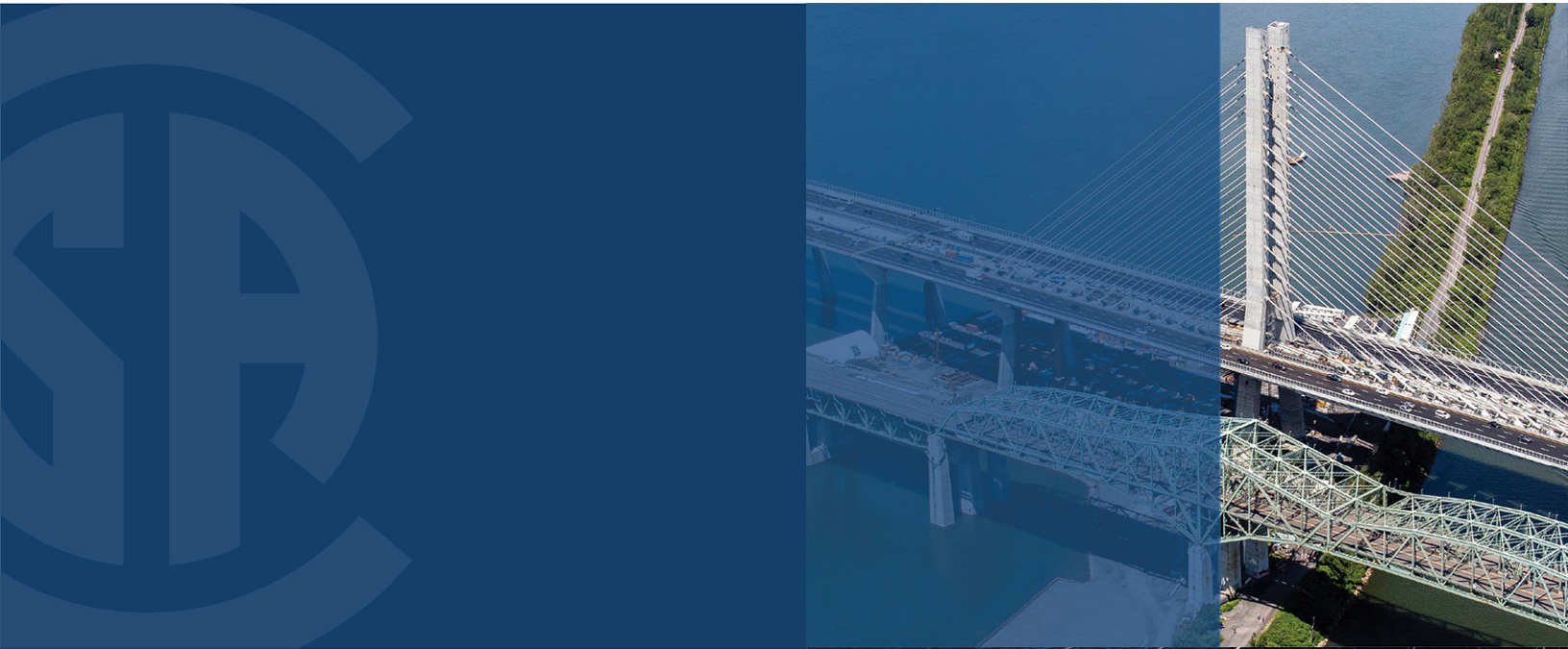


# **Canadian Highway Bridge Design Code**



# Legal Notice for Standards

Canadian Standards Association (operating as “CSA Group”) develops standards through a consensus standards development process approved by the Standards Council of Canada. This process brings together volunteers representing varied viewpoints and interests to achieve consensus and develop a standard. Although CSA Group administers the process and establishes rules to promote fairness in achieving consensus, it does not independently test, evaluate, or verify the content of standards.

## Disclaimer and exclusion of liability

This document is provided without any representations, warranties, or conditions of any kind, express or implied, including, without limitation, implied warranties or conditions concerning this document’s fitness for a particular purpose or use, its merchantability, or its non-infringement of any third party’s intellectual property rights. CSA Group does not warrant the accuracy, completeness, or currency of any of the information published in this document. CSA Group makes no representations or warranties regarding this document’s compliance with any applicable statute, rule, or regulation.

IN NO EVENT SHALL CSA GROUP, ITS VOLUNTEERS, MEMBERS, SUBSIDIARIES, OR AFFILIATED COMPANIES, OR THEIR EMPLOYEES, DIRECTORS, OR OFFICERS, BE LIABLE FOR ANY DIRECT, INDIRECT, OR INCIDENTAL DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES, HOWSOEVER CAUSED, INCLUDING BUT NOT LIMITED TO SPECIAL OR CONSEQUENTIAL DAMAGES, LOST REVENUE, BUSINESS INTERRUPTION, LOST OR DAMAGED DATA, OR ANY OTHER COMMERCIAL OR ECONOMIC LOSS, WHETHER BASED IN CONTRACT, TORT (INCLUDING NEGLIGENCE), OR ANY OTHER THEORY OF LIABILITY, ARISING OUT OF OR RESULTING FROM ACCESS TO OR POSSESSION OR USE OF THIS DOCUMENT, EVEN IF CSA GROUP HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES.

In publishing and making this document available, CSA Group is not undertaking to render professional or other services for or on behalf of any person or entity or to perform any duty owed by any person or entity to another person or entity. The information in this document is directed to those who have the appropriate degree of experience to use and apply its contents, and CSA Group accepts no responsibility whatsoever arising in any way from any and all use of or reliance on the information contained in this document.

CSA Group is a private not-for-profit company that publishes voluntary standards and related documents. CSA Group has no power, nor does it undertake, to enforce compliance with the contents of the standards or other documents it publishes.

## Intellectual property rights and ownership

As between CSA Group and the users of this document (whether it be in printed or electronic form), CSA Group is the owner, or the authorized licensee, of all works contained herein that are protected by copyright, all trade-marks (except as otherwise noted to the contrary), and all inventions and trade secrets that may be contained in this document, whether or not such inventions and trade secrets are protected by patents and applications for patents. Without limitation, the unauthorized use, modification, copying, or disclosure of this document may violate laws that protect CSA Group’s and/or others’ intellectual property and may give rise to a right in CSA Group and/or others to seek legal redress for such use, modification, copying, or disclosure. To the extent permitted by licence or by law, CSA Group reserves all intellectual property rights in this document.

## Patent rights

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights. CSA Group shall not be held responsible for identifying any or all such patent rights. Users of this standard are expressly advised that determination of the validity of any such patent rights is entirely their own responsibility.

## Authorized use of this document

This document is being provided by CSA Group for informational and non-commercial use only. The user of this document is authorized to do only the following:

If this document is in electronic form:

- load this document onto a computer for the sole purpose of reviewing it;
- search and browse this document; and
- print this document if it is in PDF format.

Limited copies of this document in print or paper form may be distributed only to persons who are authorized by CSA Group to have such copies, and only if this Legal Notice appears on each such copy.

In addition, users may not and may not permit others to

- alter this document in any way or remove this Legal Notice from the attached standard;
- sell this document without authorization from CSA Group; or
- make an electronic copy of this document.

If you do not agree with any of the terms and conditions contained in this Legal Notice, you may not load or use this document or make any copies of the contents hereof, and if you do make such copies, you are required to destroy them immediately. Use of this document constitutes your acceptance of the terms and conditions of this Legal Notice.





# CSA S6:19 – Online Training

## Overview of Changes Course

The 2019 edition of *CSA S6, Canadian Highway Bridge Design Code* contains many critical updates and major changes. To get you up to speed quickly, CSA Group has developed an online **Overview of Changes Course** that will provide you with an update on the significant changes contained in the 2019 edition and the impact of those changes on bridge design.

### Training is Available in English or French



To purchase the **CSA S6:19 – Overview of Changes Course**, visit [store.csagroup.org](https://store.csagroup.org)

**This four-hour, self-paced eLearning course covers the changes in the following eight sections of the Code:**

- **Section 2** – Durability and Sustainability
- **Section 3** – Loads
- **Section 4** – Seismic Design
- **Section 5** – Methods of Analysis
- **Section 6** – Foundations and Geotechnical Systems
- **Section 7** – Buried Structures
- **Section 8** – Concrete Structures
- **Section 10** – Steel Structures

# *Standards Update Service*

*CSA S6:19*

*November 2019*

**Title:** *Canadian Highway Bridge Design Code*

To register for e-mail notification about any updates to this publication

- go to [store.csagroup.org](https://store.csagroup.org)
- click on **Product Updates**

The **List ID** that you will need to register for updates to this publication is **2426158**.

If you require assistance, please e-mail [techsupport@csagroup.org](mailto:techsupport@csagroup.org) or call 416-747-2233.

Visit CSA Group's policy on privacy at [www.csagroup.org/legal](https://www.csagroup.org/legal) to find out how we protect your personal information.

*CSA S6:19*  
***Canadian Highway Bridge Design  
Code***



*®A trademark of the Canadian Standards Association, operating as "CSA Group"*

*Published in November 2019 by CSA Group  
A not-for-profit private sector organization  
178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3*

*To purchase standards and related publications, visit our Online Store at [store.csagroup.org](https://store.csagroup.org)  
or call toll-free 1-800-463-6727 or 416-747-4044.*

*ISBN 978-1-4883-1414-8*

*© 2019 Canadian Standards Association  
All rights reserved. No part of this publication may be reproduced in any form whatsoever  
without the prior permission of the publisher.*

# Contents

Technical Committee on the Canadian Highway Bridge Design Code	30
Subcommittee on Section 1 — General	34
Subcommittee on Section 2 — Durability and Sustainability	35
Subcommittee on Section 3 — Loads	36
Subcommittee on Section 4 — Seismic design	37
Subcommittee on Section 5 — Methods of analysis	39
Subcommittee on Section 6 — Foundations and geotechnical systems	40
Subcommittee on Section 7 — Buried structures	42
Subcommittee on Section 8 — Concrete structures	44
Subcommittee on Section 9 — Wood structures	45
Subcommittee on Section 10 — Steel structures	47
Subcommittee on Section 11 — Joints and bearings	49
Subcommittee on Section 12 — Barriers and highway accessory supports	50
Subcommittee on Section 13 — Movable bridges	51
Subcommittee on Section 14 — Evaluation	53
Subcommittee on Section 15 — Rehabilitation and repair	54
Subcommittee on Section 16 — Fibre-reinforced structures	55
Subcommittee on Section 17 — Aluminum structures	57
Code Calibration Task Force	59
Fibre-Reinforced Concrete Task Force	60
French Translation Task Force	62
Regulatory Authority Committee	64
Preface	66
Foreword	71

<b>Section 1 — General</b>	<b>72</b>
1.1	Scope 72
1.1.1	Scope of Code 72
1.1.2	Scope of this Section 72
1.1.3	Terminology 72
1.2	Reference publications 73
1.3	Definitions 86
1.3.1	General 86
1.3.2	General administrative definitions 86
1.3.3	General technical definitions 87
1.3.4	Hydraulic definitions 93
1.4	General requirements 95
1.4.1	Approval 95
1.4.2	Design 95
1.4.3	Evaluation and rehabilitation of existing bridges 97
1.4.4	Construction 97
1.5	Geometry 99
1.5.1	Planning 99
1.5.2	Structure geometry 99
1.6	Barriers 100
1.6.1	Superstructure barriers 100
1.6.2	Roadside substructure barriers 100
1.6.3	Structure protection in waterways 100
1.6.4	Structure protection at railways 100
1.7	Auxiliary components 100
1.7.1	Expansion joints and bearings 100
1.7.2	Approach slabs 100
1.7.3	Utilities on bridges 100
1.8	Durability and maintenance 101
1.8.1	Durability and protection 101
1.8.2	Bridge deck drainage 101
1.8.3	Maintenance 103
1.9	Hydraulic design 105
1.9.1	Design criteria 105
1.9.2	Investigations 106
1.9.3	Location and alignment 106
1.9.4	Estimation of scour 106
1.9.5	Protection against scour 107
1.9.6	Backwater 109
1.9.7	Soffit elevation 110
1.9.8	Approach grade elevation 110
1.9.9	Channel erosion control 111
1.9.10	Stream stabilization works and realignment 111
1.9.11	Culverts 112

**Section 2 — Durability and sustainability 114**

2.1	Scope 114
2.2	Definitions 114
2.3	Design for durability 115

2.3.1	General	115
2.3.2	Environmental condition testing	115
2.3.3	Control of cracking in concrete elements	115
2.3.4	Design for service life	116
2.3.4.2	Non-replaceable components	116
2.3.4.3	Replaceable components	116
2.3.5	Materials	116
2.3.6	Structural details	117
2.4	Design for sustainability	119
2.5	Construction for durability and sustainability	120
2.6	Inspection, monitoring, and maintenance	120
2.6.1	Inspection	120
2.6.2	Monitoring	120
2.6.3	Maintenance	120
2.7	Rehabilitation	120
2.8	Climate and exposure considerations	120

### **Section 3 — Loads** 122

3.1	Scope	122
3.2	Definitions	122
3.3	Abbreviations and symbols	124
3.3.1	Abbreviations	124
3.3.2	Symbols	125
3.4	Limit states criteria	129
3.4.1	General	129
3.4.2	Ultimate limit states	129
3.4.3	Fatigue limit state	129
3.4.4	Serviceability limit states	129
3.5	Load factors and load combinations	130
3.5.1	General	130
3.5.2	Permanent loads	132
3.5.3	Transitory loads	133
3.5.4	Exceptional loads	133
3.6	Dead loads	133
3.7	Earth loads and secondary prestress loads	134
3.7.1	Earth loads	134
3.7.2	Secondary prestress effects	134
3.8	Live loads	134
3.8.1	General	134
3.8.2	Design lanes	135
3.8.3	Traffic loads	135
3.8.4	Application	137
3.8.5	Centrifugal force	140
3.8.6	Braking force	140
3.8.7	Curb load	140
3.8.8	Barrier loads	140
3.8.9	Pedestrian load	141
3.8.10	Maintenance access loads	141
3.8.11	Maintenance vehicle load	141

3.8.12	Multiple-use structures	142
3.9	Superimposed deformations	142
3.9.1	General	142
3.9.2	Movements and load effects	143
3.9.3	Superstructure types	143
3.9.4	Temperature effects	143
3.10	Wind loads	145
3.10.1	General	145
3.10.2	Design of the superstructure	147
3.10.3	Design of the substructure	148
3.10.4	Aeroelastic instability	149
3.10.5	Wind tunnel tests	150
3.11	Water loads	150
3.11.1	General	150
3.11.2	Static pressure	150
3.11.3	Buoyancy	150
3.11.4	Stream pressure	150
3.11.5	Wave action	151
3.11.6	Scour action	151
3.11.7	Debris torrents	151
3.12	Ice loads	152
3.12.1	General	152
3.12.2	Dynamic ice forces	152
3.12.3	Static ice forces	155
3.12.4	Ice jams	155
3.12.5	Ice adhesion forces	155
3.12.6	Ice accretion	155
3.13	Earthquake effects	156
3.14	Vessel collisions	156
3.15	Vehicle collision load	156
3.16	Construction loads and loads on temporary structures	156
3.16.1	General	156
3.16.2	Dead loads	156
3.16.3	Live loads	156
3.16.4	Segmental construction	157
3.16.5	Falsework	157
Annex A3.1	(normative) — Climatic and environmental data	158
Annex A3.2	(normative) — Wind loads on highway accessory supports and slender structural elements	176
Annex A3.3	(normative) — Vessel collision	185
Annex A3.4	(normative) — CL-625-ONT live loading	195
<b>Section 4</b>	<b>— Seismic design</b>	<b>196</b>
4.1	Scope	196
4.2	Definitions	196

4.3	Abbreviation and symbols	199
4.3.1	Abbreviations	199
4.3.2	Symbols	199
4.4	Earthquake effects	204
4.4.1	General	204
4.4.2	Importance categories	204
4.4.3	Seismic hazard	204
4.4.4	Seismic performance category	210
4.4.5	Analysis and design approach	210
4.4.6	Performance-based design	213
4.4.7	Force-based design	217
4.4.8	Seismic force effects	219
4.4.9	Load factors and load combinations	219
4.4.10	Design forces and support lengths	219
4.5	Analysis	224
4.5.1	General	224
4.5.2	Single-span bridges	224
4.5.3	Multi-span bridges	224
4.6	Foundations	226
4.7	Concrete structures	226
4.7.1	General	226
4.7.2	Flexural resistances for design	226
4.7.3	Seismic performance category 1	227
4.7.4	Seismic performance category 2	227
4.7.5	Seismic performance category 3	227
4.7.6	Piles	230
4.8	Steel structures	232
4.8.1	General	232
4.8.2	Permitted materials	232
4.8.3	Sway stability effects	233
4.8.4	Steel substructures	233
4.8.5	Ductile diaphragms	238
4.8.6	Other systems	239
4.9	Joints and bearings	239
4.9.1	General	239
4.9.2	Seismic design forces	239
4.9.3	Displacements	239
4.10	Seismic base isolation and supplemental damping	239
4.10.1	General	239
4.10.2	Seismic hazard acceleration and displacement spectral values	240
4.10.3	Seismic performance category	240
4.10.4	Performance based design	240
4.10.5	Analysis procedures	241
4.10.6	Design displacements for seismic and other effects	244
4.10.7	Design forces and ductile detailing requirements for substructures	244
4.10.8	Other requirements	244
4.10.9	Required tests of isolation system	245
4.10.10	Elastomeric bearings used in isolation systems	249
4.10.11	Sliding bearings used in isolation systems	249

4.10.12	Supplemental dampers	250
4.10.13	Shock transmission units	252
4.11	Seismic evaluation of existing bridges	254
4.11.1	General	254
4.11.2	Bridge classification	254
4.11.3	Seismic hazard and evaluation	254
4.11.4	Performance criteria for performance-based design approach	254
4.11.5	Performance criteria for force-based design approach	255
4.11.6	Load factors and load combinations for seismic evaluation	255
4.11.7	Minimum support length	255
4.11.8	Member capacities	255
4.11.9	Required response modification factor for force-based design	256
4.11.10	Response modification factor of existing substructure elements	256
4.11.11	Evaluation acceptance criteria	256
4.11.12	Bridge access	257
4.11.13	Liquefaction of foundation soils	257
4.11.14	Soil-structure interaction	257
4.12	Seismic rehabilitation	257
4.12.1	Performance criteria	257
4.12.2	Response modification factor for force-based design approach	258
4.12.3	Seismic rehabilitation	258
4.12.4	Seismic rehabilitation techniques	259

## **Section 5 — Methods of analysis** 260

5.1	Scope	260
5.2	Definitions	260
5.3	Abbreviations and symbols	262
5.3.1	Abbreviations	262
5.3.2	Symbols	262
5.4	General requirements	265
5.4.1	Application	265
5.4.2	Modelling requirements	265
5.4.3	Material properties	265
5.4.4	Traffic load application	266
5.4.5	Structural responses	266
5.4.6	Selection of a method of analysis	266
5.4.7	Construction sequence	267
5.4.8	Support conditions other than line support	267
5.4.9	Diaphragms and cross-frames	267
5.4.10	Horizontal and wind bracing	267
5.4.11	Traffic barriers	267
5.4.12	Effects of deformations	268
5.4.13	Stability effects	268
5.5	Requirements for specific bridge types	268
5.5.1	General	268
5.5.2	Slab bridges with tapered free edges	268
5.5.3	Voided slab	268
5.5.4	Deck-on-girder	268
5.5.5	Longitudinally connected beams	269

5.5.6	Truss and arch	269
5.5.7	Rigid frame and integral abutment types	270
5.5.8	Laminated wood decks spanning transversely	270
5.5.9	Multi-cell and multi-spine box girders	270
5.5.10	Single-cell box girder	270
5.6	Simplified method of analysis for longitudinal load effects	271
5.6.1	Applicability	271
5.6.2	Conditions for use for the analysis of dead and traffic loads	271
5.6.3	Analysis for dead load	272
5.6.4	General requirements for traffic load analysis	273
5.6.5	Traffic load analysis of slab and voided slab bridges	276
5.6.6	Traffic load analysis of slab-on-girder bridges	277
5.6.7	Traffic load analysis of girder bridges incorporating steel grid decks, aluminum decks, and wood decks	282
5.6.8	Traffic load analysis of multi-spine box girder bridges	285
5.6.9	Traffic load analysis of longitudinally connected box beam bridges	286
5.7	Analysis of decks	287
5.7.1	Load effects in deck slabs supported on longitudinal girders	287
5.7.2	Load effects in steel grid decks	292
5.7.3	Load effects in wood decks	292
5.7.4	Transverse vertical shear in longitudinally connected concrete box beam bridges	293
5.7.5	Analysis of floor systems in truss and arch bridges	295
5.7.6	Analysis of orthotropic steel decks	295
5.8	Effective flange widths for bending	295
5.8.1	Concrete slab-on-girders	295
5.8.2	Orthotropic steel decks	296
5.9	Refined methods of analysis for short- and medium-span bridges	297
5.9.1	General	297
5.9.2	Methods of analysis	297
5.9.3	Structural model	297
5.9.4	Requirements for specific bridge types	298
5.10	Long-span bridges	302
5.10.1	General	302
5.10.2	Cable-stayed bridges	302
5.10.3	Suspension bridges	302
5.11	Dynamic analysis	302
5.11.1	General requirements of structural analysis	302
5.11.2	Elastic dynamic responses	303
5.11.3	Inelastic-dynamic responses	303
5.11.4	Analysis for collision loads	304
5.11.5	Seismic analysis	304
5.12	Stability and magnification of force effects	304
5.12.1	General	304
5.12.2	Member stability analysis for magnification of member bending moments	304
5.12.3	Structural stability analysis for lateral sway	304
5.12.4	Structural stability analysis for assemblies of individual members	305
Annex A5.1 (normative) — Simplified methods of analysis for curved bridges		306

Annex A5.2 (normative) — Simplified analysis pony-truss bridges	310
Annex A5.3 (normative) — Simplified analysis of bridges for Class C and Class D highways	316
Annex A5.4 (informative) — Two-dimensional grillage analysis of steel, concrete, and aluminum superstructures	323
Annex A5.5 (informative) — Two-dimensional grillage analysis of wood superstructures	332
Annex A5.6 (informative) — Yield-line analysis of barrier walls due to vehicle impact	337

## **Section 6 — Foundations and geotechnical systems** 340

6.1	Scope	340
6.2	Definitions	340
6.3	Symbols and abbreviations	344
6.3.1	Symbols	344
6.3.2	Abbreviations	348
6.4	Design requirements	349
6.4.1	Limit states	349
6.4.2	Effects on surroundings	350
6.4.3	Effects on supported structure	350
6.4.4	Structural components	350
6.4.5	Consultation	350
6.4.6	Quality assurance and quality control	350
6.5	Consequence and site understanding classification	351
6.5.1	Consequence classification	351
6.5.2	Consequence factor	351
6.5.3	Degree of site and prediction model understanding	351
6.5.4	Performance prediction models	352
6.6	Geotechnical engineering services	352
6.6.1	General	352
6.6.2	Site understanding and geotechnical investigation	352
6.6.3	Characteristic geotechnical parameters	352
6.7	Geotechnical report	353
6.7.1	General	353
6.7.2	Investigation information	353
6.7.3	Design information	353
6.8	Design liaison, contract documentation, and support during construction	354
6.9	Geotechnical resistance	354
6.9.1	General	354
6.9.2	Ultimate limit state	356
6.9.3	Serviceability limit state	357
6.10	Shallow foundations	358
6.10.1	General	358
6.10.2	Ultimate geotechnical bearing resistance	359
6.10.3	Serviceability geotechnical resistance	363
6.10.4	Ultimate geotechnical horizontal resistance	363
6.10.5	Structural design of shallow foundations	363
6.11	Deep foundations	366

6.11.1	General	366
6.11.2	Individual pile behaviour	367
6.11.3	Pile group behaviour	369
6.11.4	System design and construction considerations	370
6.12	Ground pressures	372
6.12.1	General	372
6.12.2	Lateral ground pressure resistance	373
6.12.3	Compaction surcharge	373
6.12.4	Effects of loads	374
6.12.5	Surcharge	374
6.12.6	Wheel load distribution through fill	374
6.13	Integral and semi-integral abutments	375
6.13.1	Application	375
6.13.2	Geotechnical investigation	375
6.13.3	Design requirements	375
6.14	Seismic design	377
6.14.1	General	377
6.14.2	Seismic design and performance requirements	377
6.14.3	Geotechnical investigation	378
6.14.4	Geotechnical resistance factors and analysis	378
6.14.5	Shallow foundations	379
6.14.6	Deep foundations	380
6.14.7	Abutments and retaining walls	381
6.14.8	Liquefaction	382
6.14.9	Associated seismic hazards	384
6.15	Ground anchors	385
6.15.1	Application	385
6.15.2	Design	385
6.15.3	Materials and installation	386
6.15.4	Anchor testing	386
6.16	Sheet pile structures	387
6.16.1	Application	387
6.16.2	Design	387
6.16.3	Ties and anchors	387
6.16.4	Cellular sheet pile structures	387
6.17	Pole foundations	388
6.17.1	Application	388
6.17.2	Design	388
6.18	Permafrost design	388
6.18.1	General	388
6.18.2	Site screening and design for climate change	389
6.18.3	Foundation strategy	389
6.18.4	Qualifications	389
6.18.5	Effect on surroundings and sustainability	389
6.18.6	Altered permafrost conditions	389
6.18.7	Geotechnical site investigation in permafrost zones	390
6.18.8	Thermosyphons	391
6.19	Mechanically stabilized earth (MSE) wall systems	391
6.19.1	Application	391

6.19.2	Design	391
6.19.3	Structure dimensions	392
6.19.4	Reinforced soil material	394
6.19.5	Reinforcement elements	394
6.19.6	Loading, load factors, and resistance factors	395
6.19.7	Vertical and lateral displacements	395
6.19.8	Active lateral earth pressure coefficient	395
6.19.9	External stability	396
6.19.10	Internal stability	399
6.19.11	Seismic design of MSE walls	414
6.19.12	Drainage	414
6.19.13	Special loading conditions	414
6.19.14	MSE abutments	416
6.19.15	Other considerations	417

**Section 7 — Buried structures** 419

7.1	Scope	419
7.2	Definitions	419
7.3	Abbreviation and symbols	422
7.3.1	Abbreviation	422
7.3.2	Symbols	422
7.4	Hydraulic design	427
7.5	Design	427
7.5.1	Sustainability and durability	427
7.5.2	Limit states	428
7.5.3	Load factors	429
7.5.4	Material resistance factors	429
7.5.5	Refined methods of analysis for buried structures	430
7.5.6	Minimum height of cover	431
7.5.7	Geotechnical considerations	433
7.5.8	Seismic requirements	440
7.5.9	Minimum clear spacing between buried structures	441
7.5.10	Structures in cold regions	442
7.5.11	Transverse connections	442
7.5.12	End design	442
7.5.13	Handling, storage, transportation, and installation of precast concrete components	444
7.5.14	Site supervision and construction control	444
7.6	Soil-metal structures	444
7.6.1	General	444
7.6.2	Structural materials	446
7.6.3	Design criteria	446
7.6.4	Foundation material treatment for pipe-arches	451
7.6.5	Construction	452
7.6.6	Special features	454
7.6.7	Footing loads	454
7.7	Metal box structures	454
7.7.1	General	454
7.7.2	Structural materials	455
7.7.3	Design criteria	455

- 7.7.4 Additional design considerations 457
- 7.7.5 Construction 457
- 7.7.6 Special features 458
- 7.8 Reinforced concrete pipe, boxes, and three-sided buried structures 458
  - 7.8.1 General 458
  - 7.8.2 Standards for structural components 458
  - 7.8.3 Standards for joint gaskets for precast concrete units 459
  - 7.8.4 Installation criteria 459
  - 7.8.5 Loads and load combinations 466
  - 7.8.6 Earth pressure distribution from loads 467
  - 7.8.7 Analysis 471
  - 7.8.8 Ultimate limit state 471
  - 7.8.9 Strength design 472
  - 7.8.10 Serviceability limit state 475
  - 7.8.11 Fatigue limit state 476
  - 7.8.12 Minimum reinforcement 476
  - 7.8.13 Distribution reinforcement 477
  - 7.8.14 Details of the reinforcement 477
  - 7.8.15 Joint shear for top slab of precast concrete box structures and other structures with flat top slabs and height of cover less than 600 mm 477
  - 7.8.16 Construction 477
- 7.9 Reinforced concrete buried arches 481
  - 7.9.1 General 481
  - 7.9.2 Loading and analysis 481
  - 7.9.3 Structural design 482
  - 7.9.4 Construction 482

## **Section 8 — Concrete structures 484**

- 8.1 Scope 484
- 8.2 Definitions 484
- 8.3 Symbols 487
- 8.4 Materials 495
  - 8.4.1 Concrete 495
  - 8.4.2 Reinforcing bars and deformed wire 499
  - 8.4.3 Tendons 500
  - 8.4.4 Anchorages, mechanical connections, and ducts 500
  - 8.4.5 Grout 502
  - 8.4.6 Material resistance factors 502
- 8.5 Limit states 503
  - 8.5.1 General 503
  - 8.5.2 Serviceability limit states 503
  - 8.5.3 Fatigue limit state 503
  - 8.5.4 Ultimate limit states 504
- 8.6 Design considerations 504
  - 8.6.1 General 504
  - 8.6.2 Design 505
  - 8.6.3 Buckling 507
- 8.7 Prestressing 507
  - 8.7.1 Stress limitations for tendons 507

- 8.7.2 Concrete strength at transfer 508
- 8.7.3 Grouting 508
- 8.7.4 Loss of prestress 508
- 8.8 Flexure and axial loads 511
  - 8.8.1 General 511
  - 8.8.2 Assumptions for the serviceability and fatigue limit states 511
  - 8.8.3 Assumptions for the ultimate limit states 512
  - 8.8.4 Flexural components 512
  - 8.8.5 Compression components 513
  - 8.8.6 Tension components 517
  - 8.8.7 Bearing 517
- 8.9 Shear and torsion 517
  - 8.9.1 General 517
  - 8.9.2 Design procedures 518
  - 8.9.3 Sectional design model 519
  - 8.9.4 Slabs, walls, and footings 524
  - 8.9.5 Interface shear transfer 525
- 8.10 Strut-and-tie model 526
  - 8.10.1 General 526
  - 8.10.2 Structural idealization 526
  - 8.10.3 Proportioning of a compressive strut 526
  - 8.10.4 Proportioning of a tension tie 528
  - 8.10.5 Proportioning of node regions 528
  - 8.10.6 Crack control reinforcement 528
- 8.11 Durability 529
  - 8.11.1 Deterioration mechanisms 529
  - 8.11.2 Protective measures 530
  - 8.11.3 Detailing for durability 533
- 8.12 Control of cracking 533
  - 8.12.1 General 533
  - 8.12.2 Crack control reinforcement 534
  - 8.12.3 Crack control reinforcement in zones of computed tensile stress 534
  - 8.12.4 Proportioning and distribution of reinforcement in the side faces of beams 535
  - 8.12.5 Proportioning and distribution of reinforcement near concrete surfaces exposed to daily temperature changes and near surfaces of mass concrete 535
- 8.13 Deformation 536
  - 8.13.1 General 536
  - 8.13.2 Dimensional changes 536
  - 8.13.3 Deflections and rotations 536
- 8.14 Details of reinforcement and special detailing requirements 537
  - 8.14.1 Hooks and bends 537
  - 8.14.2 Spacing of reinforcement 538
  - 8.14.3 Transverse reinforcement for flexural components 539
  - 8.14.4 Transverse reinforcement for compression components 540
  - 8.14.5 Reinforcement for shear and torsion 541
  - 8.14.6 Maximum spacing of reinforcement for shear and torsion 541
  - 8.14.7 Bundled bars 541
- 8.15 Development and splices 542
  - 8.15.1 Development 542

- 8.15.2 Development of reinforcing bars and deformed wire in tension 543
- 8.15.3 Development of reinforcing bars in compression 544
- 8.15.4 Development of pretensioning strand 545
- 8.15.5 Development of bundled bars 545
- 8.15.6 Development of standard hooks in tension 545
- 8.15.7 Combination development length 546
- 8.15.8 Development of welded wire reinforcement in tension 546
- 8.15.9 Mechanical anchorages 547
- 8.15.10 Splicing of reinforcement 547
- 8.16 Anchorage zone reinforcement 549
  - 8.16.1 General 549
  - 8.16.2 Post-tensioning anchorage zones 549
  - 8.16.3 Pretensioning anchorage zones 552
  - 8.16.4 Inclined anchorages 553
  - 8.16.5 Intermediate anchorages 553
  - 8.16.6 Anchorage blisters 553
  - 8.16.7 Anchorage of attachments 554
- 8.17 Seismic design and detailing 557
- 8.18 Special provisions for deck slabs 557
  - 8.18.1 Applicability 557
  - 8.18.2 General 558
  - 8.18.3 Empirical design method 558
  - 8.18.4 Diaphragms 563
  - 8.18.5 Edge stiffening 563
  - 8.18.6 Distribution reinforcement 563
- 8.19 Composite construction 565
  - 8.19.1 General 565
  - 8.19.2 Flexure 565
  - 8.19.3 Shear 565
  - 8.19.4 Semi-continuous structures 565
- 8.20 Concrete girders 566
  - 8.20.1 General 566
  - 8.20.2 Effective flange width for T- and box girders 566
  - 8.20.3 Flange thickness for T- and box girders 566
  - 8.20.4 Isolated girders 567
  - 8.20.5 Top and bottom flange reinforcement for cast-in-place T- and box girders 567
  - 8.20.6 Post-tensioning tendons 567
  - 8.20.7 Diaphragms 567
- 8.21 Multi-beam decks 567
- 8.22 Segmental construction 568
  - 8.22.1 General 568
  - 8.22.2 Additional ducts and anchorages 568
  - 8.22.3 Diaphragms 568
  - 8.22.4 Deviators for external tendons 568
  - 8.22.5 Coupling of post-tensioning tendons 569
  - 8.22.6 Special provisions for various bridge types 569
  - 8.22.7 Precast segmental beam bridges 571
- 8.23 Concrete piles 572
  - 8.23.1 General 572

- 8.23.2 Specified concrete strength 572
- 8.23.3 Handling 572
- 8.23.4 Splices 572
- 8.23.5 Pile dimensions 572
- 8.23.6 Non-prestressed concrete piles 572
- 8.23.7 Prestressed concrete piles 573

Annex A8.1 (informative) — Fibre-reinforced concrete (FRC) 575

**Section 9 — Wood structures 605**

- 9.1 Scope 605
- 9.2 Definitions 605
- 9.3 Symbols 607
- 9.4 Limit states 610
  - 9.4.1 General 610
  - 9.4.2 Serviceability limit states 610
  - 9.4.3 Ultimate limit states 610
  - 9.4.4 Resistance factor 610
- 9.5 General design 611
  - 9.5.1 Design assumption 611
  - 9.5.2 Spans 611
  - 9.5.3 Load-duration factor 611
  - 9.5.4 Size-effect factors 611
  - 9.5.5 Service condition 611
  - 9.5.6 Load-sharing factor 613
  - 9.5.7 Notched components 613
  - 9.5.8 Butt joint stiffness factor 614
  - 9.5.9 Treatment factor 614
- 9.6 Flexure 614
  - 9.6.1 Flexural resistance 614
  - 9.6.2 Size effect 615
  - 9.6.3 Lateral stability 615
- 9.7 Shear 617
  - 9.7.1 Shear resistance 617
  - 9.7.2 Size effect 617
  - 9.7.3 Shear force and shear load 617
  - 9.7.4 Shear modulus 617
  - 9.7.5 Vertically laminated decks 617
- 9.8 Compression members 617
  - 9.8.1 General 617
  - 9.8.2 Compressive resistance parallel to grain 618
  - 9.8.3 Slenderness effect 618
  - 9.8.4 Amplified moments 620
  - 9.8.5 Rigorous evaluation of amplified moments 620
  - 9.8.6 Approximate evaluation of amplified moments 622
- 9.9 Tension members 624
- 9.10 Compression at an angle to grain 625
- 9.11 Sawn wood 625
  - 9.11.1 Materials 625

9.11.2	Specified strengths and moduli of elasticity	626
9.12	Glued-laminated timber	631
9.12.1	Materials	631
9.12.2	Specified strengths and moduli of elasticity	631
9.12.3	Vertically laminated beams	633
9.12.4	Camber	633
9.12.5	Varying depth	633
9.12.6	Curved members	633
9.13	Structural composite lumber	633
9.13.1	Materials	633
9.13.2	Specified strengths and moduli of elasticity	633
9.14	Wood piles	633
9.14.1	Materials	633
9.14.2	Splicing	633
9.14.3	Specified strengths and moduli of elasticity	633
9.14.4	Design	634
9.15	Connections	634
9.15.1	General	634
9.15.2	Design	635
9.15.3	Construction	635
9.16	Hardware and metalwork	635
9.17	Durability	635
9.17.1	General	635
9.17.2	Pedestrian contact	636
9.17.3	Incising	636
9.17.4	Fabrication	636
9.17.5	Pressure preservative treatment of laminated veneer lumber	636
9.17.6	Pressure preservative treatment of parallel strand lumber	636
9.17.7	Field treatment	637
9.17.8	Treated round wood piles	637
9.17.9	Untreated round wood piles	637
9.17.10	Pile heads	637
9.17.11	Protective treatment of hardware and metalwork	637
9.17.12	Stress-laminated timber decking	637
9.18	Wood cribs	638
9.18.1	General	638
9.18.2	Member sizes and assembly	638
9.18.3	Fastening	638
9.18.4	Load transfer to cribs	638
9.19	Wood trestles	638
9.19.1	General	638
9.19.2	Pile bents	638
9.19.3	Framed bents	639
9.19.4	Caps	639
9.19.5	Bracing	639
9.20	Stringers and girders	639
9.20.1	Design details	639
9.20.2	Diaphragms	639
9.21	Nail-laminated wood decks	640

- 9.21.1 General 640
- 9.21.2 Transversely laminated wood decks 640
- 9.21.3 Longitudinal nail-laminated wood decks 641
- 9.22 Wood-concrete composite decks 641
  - 9.22.1 General 641
  - 9.22.2 Wood base 641
  - 9.22.3 Concrete slab 642
  - 9.22.4 Wood-concrete interface 643
  - 9.22.5 Factored moment resistance 645
- 9.23 Stress-laminated wood decks 646
  - 9.23.1 General 646
  - 9.23.2 Post-tensioning materials 646
  - 9.23.3 Design of post-tensioning system 646
  - 9.23.4 Design of distribution bulkhead 648
  - 9.23.5 Laminated decks 650
  - 9.23.6 Net section 651
  - 9.23.7 Hardware durability 652
  - 9.23.8 Design details 652
- 9.24 Glued-laminated decks 653
  - 9.24.1 General 653
  - 9.24.2 Materials 653
  - 9.24.3 Interconnected decks 653
  - 9.24.4 Non-interconnected decks 653
- 9.25 Wearing course 653
- 9.26 Drainage 653
  - 9.26.1 General 653
  - 9.26.2 Deck 654

## **Section 10 — Steel structures 655**

- 10.1 Scope 655
- 10.2 Definitions 655
- 10.3 Abbreviations and symbols 657
  - 10.3.1 Abbreviations 657
  - 10.3.2 Symbols 657
- 10.4 Materials 667
  - 10.4.1 General 667
  - 10.4.2 Structural steel 667
  - 10.4.3 Cast steel 667
  - 10.4.4 Stainless steel 667
  - 10.4.5 Bolts 668
  - 10.4.6 Welding electrodes 668
  - 10.4.7 Stud shear connectors 668
  - 10.4.8 Cables 668
  - 10.4.9 High-strength bars 668
  - 10.4.10 Galvanizing and metallizing 668
  - 10.4.11 Identification 668
  - 10.4.12 Coefficient of thermal expansion 669
  - 10.4.13 Pins and rollers 669
- 10.5 Design theory and assumptions 669

10.5.1	General	669
10.5.2	Ultimate limit states	669
10.5.3	Serviceability limit states	669
10.5.4	Fatigue limit state	670
10.5.5	Fracture control	670
10.5.6	Seismic requirements	670
10.5.7	Resistance factors	670
10.5.8	Analysis	670
10.5.9	Design lengths of members	670
10.6	Durability	671
10.6.1	General	671
10.6.2	Corrosion as a deterioration mechanism	671
10.6.3	Corrosion protection	671
10.6.4	Superstructure components	672
10.6.5	Other components	672
10.6.6	Areas inaccessible after erection	676
10.6.7	Detailing for durability	676
10.7	Design details	676
10.7.1	General	676
10.7.2	Minimum thickness of steel	676
10.7.3	Floor beams and diaphragms at piers and abutments	677
10.7.4	Camber	677
10.7.5	Welded attachments	678
10.8	Tension members	678
10.8.1	General	678
10.8.2	Axial tensile resistance	680
10.8.3	Axial tension and bending	681
10.8.4	Tensile resistance of cables	681
10.9	Compression members	681
10.9.1	General	681
10.9.2	Width-to-thickness ratio of elements in compression	682
10.9.3	Axial compressive resistance	685
10.9.4	Axial compression and bending	686
10.9.5	Composite columns	688
10.10	Beams and girders	691
10.10.1	General	691
10.10.2	Classes 1 and 2 sections	692
10.10.3	Class 3 sections	694
10.10.4	Stiffened plate girders	695
10.10.5	Shear resistance	695
10.10.6	Intermediate transverse stiffeners	697
10.10.7	Longitudinal web stiffeners	698
10.10.8	Bearing stiffeners	699
10.10.9	Lateral bracing, cross-frames, and diaphragms	700
10.11	Composite beams and girders	700
10.11.1	General	700
10.11.2	Proportioning	701
10.11.3	Effects of creep and shrinkage	701
10.11.4	Control of permanent deflections	701

10.11.5	Class 1 and Class 2 sections	701
10.11.6	Class 3 sections	704
10.11.7	Stiffened plate girders	706
10.11.8	Shear connectors	707
10.11.9	Lateral bracing, cross-frames, and diaphragms	709
10.12	Composite box girders	709
10.12.1	General	709
10.12.2	Effective width of tension flanges	709
10.12.3	Web plates	709
10.12.4	Flange-to-web welds	710
10.12.5	Moment resistance	710
10.12.6	Diaphragms, cross-frames, and lateral bracing	713
10.12.7	Multiple box girders	713
10.12.8	Single box girders	714
10.13	Horizontally curved girders	715
10.13.1	General	715
10.13.2	Special considerations	715
10.13.3	Design theory	715
10.13.4	Bearings	715
10.13.5	Diaphragms, cross-frames, and lateral bracing	715
10.13.6	Steel I-girders	716
10.13.7	Composite box girders	719
10.13.8	Camber	720
10.14	Trusses	721
10.14.1	General	721
10.14.2	Built-up members	721
10.14.3	Bracing	722
10.15	Arches	723
10.15.1	General	723
10.15.2	Width-to-thickness ratios	723
10.15.3	Longitudinal web stiffeners	723
10.15.4	Flange stability	723
10.15.5	Arch ties	724
10.16	Orthotropic decks	724
10.16.1	General	724
10.16.2	Serviceability limit states	724
10.16.3	Ultimate limit states	724
10.16.4	Fatigue limit states	724
10.17	Structural fatigue	724
10.17.1	General	724
10.17.2	Live-load-induced fatigue	724
10.17.3	Distortion-induced fatigue	739
10.18	Splices and connections	740
10.18.1	General	740
10.18.2	Bolted connections	740
10.18.3	Welds	743
10.18.4	Detailing of bolted connections	745
10.18.5	Connection reinforcement and stiffening	748
10.19	Anchor rods	749

10.19.1	General	749
10.19.2	Anchor rod resistance	749
10.20	Pins, rollers, and rockers	750
10.20.1	Bearing resistance	750
10.20.2	Pins	750
10.21	Torsion	751
10.21.1	General	751
10.21.2	Members of closed cross-section	751
10.21.3	Members of open cross-section	752
10.22	Steel piles	753
10.22.1	General	753
10.22.2	Resistance factors	753
10.22.3	Compressive resistance	753
10.22.4	Unsupported length	754
10.22.5	Effective length factor	754
10.22.6	Splices	754
10.22.7	Welding	754
10.22.8	Composite tube piles	754
10.23	Fracture control	754
10.23.1	General	754
10.23.2	Identification	754
10.23.3	Materials	754
10.23.4	Fracture toughness	755
10.23.5	Welding of fracture-critical and primary tension members	759
10.23.6	Welding corrections and repairs to fracture-critical members	760
10.23.7	Radiographic inspection of fracture-critical members	762
10.23.8	Inspection records	763
Annex A10.1	(normative) — Construction requirements for structural steel	764
Annex A10.2	(normative) — Hybrid girders	781
<b>Section 11</b>	<b>— Joints and bearings</b>	<b>784</b>
11.1	Scope	784
11.2	Definitions	784
11.3	Abbreviations and symbols	785
11.3.1	Abbreviations	785
11.3.2	Symbols	785
11.4	Common requirements	787
11.4.1	General	787
11.4.2	Design requirements	788
11.5	Deck joints	788
11.5.1	General requirements	788
11.5.2	Selection	790
11.5.3	Design	791
11.5.4	Fabrication	792
11.5.5	Installation	792
11.5.6	Joint seals	792
11.5.7	Sealed joint drainage	792

11.5.8	Open joint drainage	792
11.5.9	Volume control joint	792
11.6	Bridge bearings	793
11.6.1	General	793
11.6.2	Metal back, roller, and spherical bearings	794
11.6.3	Sliding surfaces	795
11.6.4	Spherical bearings	800
11.6.5	Pot bearings	800
11.6.6	Elastomeric bearings	803
11.6.7	Disc bearings	809
11.6.8	Guides for lateral restraints	810
11.6.9	Load plates and attachment for bearings	811
11.6.10	Required tests for sliding interface	811
11.6.11	Required tests for laminated, spherical, pot, and disc bearings	816

## **Section 12 — Barriers and highway accessory supports 817**

12.1	Scope	817
12.2	Definitions	817
12.3	Abbreviations and symbols	819
12.3.1	Abbreviations	819
12.3.2	Symbols	819
12.4	Barriers	820
12.4.1	General	820
12.4.2	Barrier joints	821
12.4.3	Traffic barriers	821
12.4.4	Pedestrian barriers	831
12.4.5	Bicycle barriers	833
12.4.6	Combination barriers	834
12.4.7	Noise barriers	834
12.5	Highway accessory supports	836
12.5.1	General	836
12.5.2	Vertical clearances	836
12.5.3	Maintenance	836
12.5.4	Aesthetics	836
12.5.5	Design	836
12.5.6	Breakaway supports	859
12.5.7	Foundations	860
12.5.8	Corrosion protection	861
12.5.9	Minimum thicknesses	861
12.5.10	Connections — Bolts	861
12.5.11	Damping devices	861

## **Section 13 — Movable bridges 863**

13.1	Scope	863
13.2	Definitions	863
13.3	Abbreviations and symbols	869
13.3.1	Abbreviations	869
13.3.2	Symbols	869
13.4	Materials	872

- 13.4.1 General 872
- 13.4.2 Structural steel 872
- 13.4.3 Concrete 872
- 13.4.4 Timber 872
- 13.4.5 Carbon steel 872
- 13.4.6 Forged steel 872
- 13.4.7 Cast steel or iron 872
- 13.4.8 Bronze 872
- 13.4.9 Bolts 873
- 13.4.10 Aluminum 873
- 13.5 General 873
- 13.5.1 Safety 873
- 13.5.2 Type of deck 873
- 13.5.3 Piers and abutments 873
- 13.5.4 Navigation requirements 873
- 13.5.5 Vessel collision 873
- 13.5.6 Protection of traffic and pedestrians 873
- 13.5.7 Time of operation 874
- 13.5.8 Houses for machinery, electrical equipment, and operators 874
- 13.5.9 New devices 875
- 13.5.10 Interlocking 875
- 13.5.11 Position indicator 875
- 13.5.12 Inspection, evaluation, maintenance, and repair 875
- 13.6 Structural analysis and design 875
- 13.6.1 General 875
- 13.6.2 Access for routine maintenance 876
- 13.6.3 Durability 876
- 13.6.4 Wind loads 876
- 13.6.5 Seismic loads 877
- 13.6.6 Reaction due to temperature differential 878
- 13.6.7 Hydraulic cylinder connections 878
- 13.6.8 Loads on end floor beams and stringer brackets 878
- 13.6.9 Swing bridges — Ultimate limit states 878
- 13.6.10 Bascule (including rolling lift) bridges — Ultimate limit states 879
- 13.6.11 Vertical lift bridges — Ultimate limit states 880
- 13.6.12 Dead load factor 880
- 13.6.13 All movable bridges — Ultimate limit states 881
- 13.6.14 Special types of movable bridges 881
- 13.6.15 Load effects 881
- 13.6.16 Fatigue limit state 881
- 13.6.17 Friction 881
- 13.6.18 Machinery supports 881
- 13.6.19 Vertical lift bridge towers 881
- 13.6.20 Transitory loads 882
- 13.6.21 Counterweights 882
- 13.7 Mechanical system design 884
- 13.7.1 General 884
- 13.7.2 General design 884
- 13.7.3 Allowable stresses for machinery 884

- 13.7.4 Frictional resistance 891
- 13.7.5 Fits and tolerances 892
- 13.7.6 Surface finishes 894
- 13.7.7 Swing bridge components 894
- 13.7.8 Bascule bridge components 898
- 13.7.9 Rolling lift bridge components 900
- 13.7.10 Vertical lift bridge components 901
- 13.7.11 Bridge stops and buffers 904
- 13.7.12 Aligning and locking devices 905
- 13.7.13 Equalizing devices 905
- 13.7.14 Prime mover 906
- 13.7.15 Brakes 913
- 13.7.16 Shafting 919
- 13.7.17 Shaft keys and friction couplings 921
- 13.7.18 Bearings 923
- 13.7.19 Gearing 927
- 13.7.20 Wire ropes 931
- 13.7.21 Welded parts 939
- 13.7.22 Bolts and nuts 940
- 13.7.23 Set screws 941
- 13.7.24 Dust covers 941
- 13.7.25 Drain holes 941
- 13.7.26 Cams 942
- 13.7.27 Lubrication 942
- 13.8 Hydraulic systems 943
  - 13.8.1 General 943
  - 13.8.2 Design objectives 943
  - 13.8.3 Hydraulic systems and components 943
  - 13.8.4 Design loading criteria 944
  - 13.8.5 Hydraulic system limit states 945
  - 13.8.6 Hydraulic fluid 946
  - 13.8.7 Electric motors 946
  - 13.8.8 Internal combustion engines 947
  - 13.8.9 Couplings 947
  - 13.8.10 Pumps 947
  - 13.8.11 Control valves 948
  - 13.8.12 Accumulators 948
  - 13.8.13 Fluid reservoirs 948
  - 13.8.14 Hydraulic power unit accessories 949
  - 13.8.15 Filters 949
  - 13.8.16 Hydraulic motors 949
  - 13.8.17 Pressure indicators 952
  - 13.8.18 Controls 952
  - 13.8.19 Hydraulic system detailing 954
  - 13.8.20 Fabrication and construction 955
  - 13.8.21 Materials — Hydraulic piping 956
- 13.9 Electrical system design 957
  - 13.9.1 General 957
  - 13.9.2 General requirements for electrical installations 957

- 13.9.3 Electrical supply and power service 958
- 13.9.4 Circuit breakers 958
- 13.9.5 Enclosures, junction boxes, and terminal cabinets 958
- 13.9.6 Fuses 958
- 13.9.7 Disconnect switches 959
- 13.9.8 Transformers 959
- 13.9.9 Medium voltage switchgears (600 V and above) 959
- 13.9.10 Transfer switches 959
- 13.9.11 Electrical control systems 960
- 13.9.12 Electric motors 968
- 13.9.13 Electric motor controls 970
- 13.9.14 Lights and signals 972
- 13.9.15 Grounding 973
- 13.9.16 Lightning and surge protection 974
- 13.9.17 Fire detection 975

## **Section 14 — Evaluation 976**

- 14.1 Scope 976
- 14.2 Definitions 976
- 14.3 Symbols 976
- 14.4 General requirements 980
  - 14.4.1 Exclusions 980
  - 14.4.2 Expertise 980
  - 14.4.3 Future growth of traffic or future deterioration 980
  - 14.4.4 Scope of evaluation 980
- 14.5 Evaluation procedures 980
  - 14.5.1 General 980
  - 14.5.2 Limit states 981
  - 14.5.3 Evaluation methodology 981
  - 14.5.4 Bridge posting 982
- 14.6 Condition inspection 982
  - 14.6.1 General 982
  - 14.6.2 Plans 982
  - 14.6.3 Physical features 982
  - 14.6.4 Deterioration 982
- 14.7 Material strengths 982
  - 14.7.1 General 982
  - 14.7.2 Review of original construction documents 983
  - 14.7.3 Analysis of tests of samples 983
  - 14.7.4 Strengths based on date of construction 984
  - 14.7.5 Deteriorated material 985
- 14.8 Permanent loads 985
  - 14.8.1 General 985
  - 14.8.2 Dead load 986
  - 14.8.3 Earth pressure and hydrostatic pressure 986
  - 14.8.4 Shrinkage, creep, differential settlement, and bearing friction 986
  - 14.8.5 Secondary effects from prestressing 986
- 14.9 Transitory loads 986
  - 14.9.1 Normal traffic 986

14.9.2	Permit — Vehicle loads	989
14.9.3	Dynamic load allowance for permit vehicle loads and alternative loading	991
14.9.4	Multiple-lane loading	991
14.9.5	Loads other than traffic	992
14.10	Exceptional loads	992
14.11	Lateral distribution categories for live load	993
14.11.1	General	993
14.11.2	Statically determinate method	993
14.11.3	Sophisticated method	993
14.11.4	Simplified method	993
14.12	Target reliability index	993
14.12.1	General	993
14.12.2	System behaviour	993
14.12.3	Element behaviour	994
14.12.4	Inspection level	994
14.12.5	Important structures	994
14.13	Load factors	995
14.13.1	General	995
14.13.2	Permanent loads	995
14.13.3	Transitory loads	996
14.14	Resistance	997
14.14.1	General	997
14.14.2	Resistance adjustment factor	1006
14.14.3	Effects of defects and deterioration	1006
14.15	Live load capacity factor	1007
14.15.1	General	1007
14.15.2	Ultimate limit states	1007
14.15.3	Serviceability limit states	1009
14.15.4	Combined load effects	1009
14.16	Load testing	1009
14.16.1	General	1009
14.16.2	Instrumentation	1009
14.16.3	Test load	1009
14.16.4	Application of load test results	1010
14.17	Bridge posting	1010
14.17.1	General	1010
14.17.2	Calculation of posting loads	1010
14.17.3	Posting signs	1012
14.18	Fatigue	1013
Annex A14.1 (normative) — Equivalent material strengths from tests of samples		1014
Annex A14.2 (normative) — Evaluation levels in Ontario		1016
<b>Section 15 — Rehabilitation and repair</b>		<b>1019</b>
15.1	Scope	1019
15.2	Definitions and symbols	1019
15.2.1	Definitions	1019
15.2.2	Symbols	1019

15.3	General requirements	1019
15.3.1	General	1019
15.3.2	Limit states	1019
15.3.3	Condition data	1020
15.3.4	Remaining service life and rehabilitation design life	1020
15.3.5	Inspection and maintenance	1020
15.3.6	Rehabilitation loads and load factors	1020
15.3.7	Analysis	1020
15.3.8	Factored resistances	1020
15.3.9	Fatigue and imposed deformations	1020
15.3.10	Bridge posting	1020
15.3.11	Seismic upgrading	1021
15.4	Particular considerations	1021
15.4.1	General	1021
15.4.2	Existing information	1021
15.4.3	Required remaining service life	1021
15.4.4	Capacity	1021
15.4.5	Environmental factors	1021
15.4.6	Stakeholder consultation	1022
15.4.7	Aesthetics	1022
15.4.8	Economics	1022
15.5	Rehabilitation loads and load factors	1022
15.5.1	Loads	1022
15.5.2	Load factors and load combinations	1024
15.6	Analysis	1025
15.7	Resistance	1025
15.7.1	Existing members	1025
15.7.2	Strengthening of existing members	1025
15.7.3	New members and connections	1026
15.8	Structural steel	1026
15.8.1	Member and connection repair and strengthening	1026
15.8.2	Member and connection replacement	1027
15.8.3	Welding effects and procedures	1027
15.8.4	Combining fasteners and welds	1027
15.8.5	Crevice corrosion and rust jacking	1028
15.8.6	Fatigue and fracture	1028
<b>Section 16 — Fibre-reinforced structures</b>		<b>1029</b>
16.1	Scope	1029
16.1.1	Components	1029
16.1.2	Fibres	1029
16.1.3	Matrices	1029
16.1.4	Uses requiring approval	1029
16.2	Definitions	1029
16.3	Abbreviations and symbols	1031
16.3.1	Abbreviations	1031
16.3.2	Symbols	1032
16.4	Durability	1036
16.4.1	General	1036

16.4.2	FRP tendons, primary reinforcement, and strengthening systems	1036
16.4.3	FRP secondary reinforcement	1037
16.4.4	Fibres in FRC	1037
16.4.5	Cover to reinforcement	1038
16.4.6	Protective measures	1038
16.4.7	Allowance for wear in deck slabs	1038
16.4.8	Detailing of concrete components for durability	1038
16.4.9	Handling, storage, and installation of fibre tendons and primary reinforcement	1038
16.5	Fibre-reinforced polymers	1038
16.5.1	FRP bars and grids	1038
16.5.2	FRP strengthening systems	1039
16.5.3	FRP tendons	1039
16.5.4	Material properties	1039
16.5.5	Confirmation of the specified tensile strength	1039
16.5.6	Resistance factor	1039
16.5.7	Minimum bend-radius-to-bar-diameter ratio of bent FRP bars	1040
16.6	Fibre-reinforced concrete	1040
16.6.1	General	1040
16.6.2	Fibre volume fraction	1040
16.6.3	Fibre dispersion in concrete	1041
16.7	Externally restrained deck slabs	1041
16.7.1	General	1041
16.7.2	Full-depth cast-in-place deck slabs	1042
16.7.3	Cast-in-place deck slabs on stay-in-place formwork	1043
16.7.4	Full-depth precast concrete deck slabs	1044
16.8	Concrete beams, slabs, and columns	1047
16.8.1	General	1047
16.8.2	Deformability and minimum reinforcement	1047
16.8.3	Non-prestressed reinforcement	1048
16.8.4	Development length for FRP bars and tendons	1048
16.8.5	Development of headed FRP bars and grids	1050
16.8.6	Tendons	1050
16.8.7	Design for shear and torsion	1051
16.8.8	Internally restrained cast-in-place deck slabs	1055
16.8.9	Compression components	1055
16.8.10	Cast-in-place deck slabs with FRP stay-in-place structural forms	1056
16.8.11	Strut-and-tie model for deep beams, corbels, and short walls	1057
16.9	Stressed wood decks	1059
16.9.1	General	1059
16.9.2	Post-tensioning materials	1059
16.9.3	Stressing procedure	1060
16.9.4	Design of bulkheads	1060
16.9.5	Stressed log bridges	1060
16.10	Barrier walls	1062
16.10.1	FRC barrier wall design details	1062
16.10.2	Barrier wall design details with front and back reinforcement	1062
16.10.3	Test Level 1, 2, 4, and 5 barrier wall design details	1062
16.10.4	Factored punching shear resistance of concrete barrier to transverse traffic	1063
16.11	Repair of damaged bridge barrier walls, curbs, and slabs reinforced with FRP bars	1064

16.12	Rehabilitation of existing concrete structures with FRP	1064
16.12.1	General	1064
16.12.2	Flexural and axial load rehabilitation	1065
16.12.3	Shear rehabilitation with externally bonded FRP systems	1068
16.12.4	Retrofit for enhancement of concrete confinement	1069
16.12.5	Retrofit for lap splice clamping	1071
16.13	Rehabilitation of timber bridges	1071
16.13.1	General	1071
16.13.2	Strengthening for flexure	1072
16.13.3	Strengthening for shear	1073
Annex A16.1	(informative) — Installation of FRP strengthening systems	1076
Annex A16.2	(normative) — Quality control for FRP strengthening systems	1079
Annex A16.3	(informative) — GFRP composite bridges	1081
<b>Section 17</b>	<b>— Aluminum structures</b>	<b>1085</b>
17.1	Scope	1085
17.2	Definitions	1085
17.3	Abbreviations and symbols	1087
17.3.1	Abbreviations	1087
17.3.2	Symbols	1088
17.4	Materials	1094
17.4.1	General	1094
17.4.2	Wrought products	1095
17.4.3	Castings	1096
17.4.4	Bolts	1096
17.4.5	Welding electrodes	1096
17.4.6	Stud shear connectors	1097
17.4.7	Identification	1097
17.5	Design theory and assumptions	1097
17.5.1	General	1097
17.5.2	Ultimate limit states	1097
17.5.3	Serviceability limit states	1097
17.5.4	Fatigue limit state	1098
17.5.5	Fracture control	1098
17.5.6	Seismic requirements	1098
17.5.7	Resistance factors	1098
17.5.8	Analysis	1098
17.5.9	Design lengths of members	1098
17.6	Durability	1099
17.6.1	General	1099
17.6.2	Deterioration mechanisms	1099
17.6.3	Corrosion protection	1099
17.6.4	Detailing for durability	1099
17.7	Design details	1100
17.7.1	General	1100
17.7.2	Minimum nominal thickness	1100

17.7.3	Camber	1100
17.7.4	Welded attachments	1101
17.8	Cross-sectional areas, effective section, and effective strength	1101
17.8.1	General	1101
17.8.2	Cross-sectional areas	1101
17.8.3	Effective section	1102
17.8.4	Effective strength	1103
17.9	Local buckling	1104
17.9.1	Flat elements	1104
17.9.2	Curved elements	1108
17.10	Tension members	1109
17.10.1	Limiting slenderness for tension members	1109
17.10.2	Shear lag effect	1109
17.10.3	Axial tensile resistance	1110
17.10.4	Pin-connected tension members	1110
17.10.5	Oblique welds	1111
17.11	Compression members	1111
17.11.1	Limiting slenderness for compression members	1111
17.11.2	Buckling	1111
17.11.3	Members in axial compression	1113
17.12	Flexural members	1115
17.12.1	Classification of members in bending	1115
17.12.2	Moment resistance of members not subject to lateral torsional buckling	1116
17.12.3	Moment resistance of members subject to lateral torsional buckling	1117
17.12.4	Design of members in shear	1119
17.13	Members in torsion	1123
17.13.1	General	1123
17.13.2	Hollow sections	1123
17.13.3	Solid sections	1124
17.13.4	Open sections	1124
17.14	Members with combined axial force and bending moment	1125
17.14.1	Axial tension and bending	1125
17.14.2	Axial compression and bending	1126
17.14.3	Shear force in beam-columns	1128
17.15	Built-up compression members	1129
17.15.1	Spacing of connectors	1129
17.15.2	Multiple-bar members with discrete shear connectors	1129
17.15.3	Double angle struts	1129
17.15.4	Lattice columns and beam-columns	1130
17.16	Composite beams and girders	1131
17.16.1	General	1131
17.16.2	Concrete slab	1132
17.16.3	Proportioning	1132
17.16.4	Effects of creep and shrinkage	1132
17.16.5	Control of permanent deflections	1132
17.16.6	Resistance of composite section	1132
17.16.7	Shear connectors	1135
17.17	Trusses	1136
17.17.1	General	1136

17.17.2	Built-up members	1136
17.17.3	Bracing	1136
17.18	Arches	1137
17.18.1	General	1137
17.18.2	Width-to-thickness ratios	1137
17.18.3	Longitudinal web stiffeners	1137
17.18.4	Axial compression and bending	1138
17.18.5	Arch ties	1138
17.19	Decks	1138
17.20	Structural fatigue	1140
17.20.1	General	1140
17.20.2	Live-load-induced fatigue	1140
17.20.3	Distortion-induced fatigue	1143
17.20.4	Local stress approaches	1151
17.20.5	Fatigue performance improving post-weld treatments	1151
17.20.6	Bridge decks	1152
17.21	Fracture control	1152
17.21.1	General	1152
17.21.2	Identification	1152
17.22	Splices and connections	1152
17.22.1	General	1152
17.22.2	Bolted connections	1153
17.22.3	Welded connections	1157
17.22.4	Gusset plate connections	1164
17.23	Anchors	1164
17.24	Pins, rollers, and rockers	1164
17.24.1	Bearing resistance	1164
17.24.2	Pins	1164
17.25	Construction requirements	1165
17.25.1	Submissions	1165
17.25.2	Materials	1166
17.25.3	Fabrication	1166
17.25.4	Welded construction	1169
17.25.5	Bolted construction	1169
17.25.6	Tolerances	1172
17.25.7	Quality control and welding inspection	1173
17.25.8	Transportation and delivery	1175
17.25.9	Erection	1175
17.26	Testing	1176
17.26.1	General	1176
17.26.2	Test methods	1177
17.26.3	Test procedures	1177

# Preface

This is the twelfth edition of CSA S6, *Canadian Highway Bridge Design Code*. It supersedes the previous editions published in 2014, 2006 (including three supplements published in 2010, 2011, and 2013), 2000, 1988, 1978, 1974, 1966, 1952, 1938, 1929, and 1922.

This Code is based on limit states design principles and defines design loadings, load combinations and load factors, criteria for earthquake resistant design, and detailed design criteria for the various materials. This Code has been written to be applicable in all provinces and territories.

There are 17 Sections in this Code:

Section [1](#) (“General”) specifies general requirements for applying the Code and includes definitions and a reference publications clause applicable throughout this Code. It also specifies geometric requirements, based in part on the Transportation Association of Canada’s *Geometric Design Guide for Canadian Roads* (2017), and hydraulic design requirements, based in part on the Transportation Association of Canada’s *Guide to Bridge Hydraulics* (2004). There are also general provisions covering durability, economics, environmental considerations, aesthetics, safety, maintenance, and maintenance inspection access. The definitions in Clauses [1.3.2](#) to [1.3.4](#) apply to those used specifically in this Section, and new to this edition of the Code, also apply to common definitions used in more than one Section in this Code.

Section [2](#) (“Durability and sustainability”) specifies requirements for durability and sustainability that need to be considered during the design process of bridges, culverts, and other structures located in transportation corridors. The durability requirements are based on principles applicable to service life design that consider the environmental exposure conditions, the deterioration mechanisms, the protective measures, and detailing requirements needed to meet the projected service life of structural components. The concept of sustainability considerations has been introduced to alert owners and designers to undertake design and decision-making practices that will help to achieve the context-specific balance of social, environmental, and economic values, and impacts associated with the investment in building new or rehabilitation of existing bridges and other transportation structures included in the scope of this Code. Similarly, local climate change and exposure conditions are brought to the attention of designers and owners.

Section [3](#) (“Loads”) specifies loading requirements for the design of new bridges, including requirements for permanent loads, live loads including special trucks, and special loads (but excluding seismic loads). The 625 kN truck load model and corresponding lane load model are specified as the minima for interprovincial transportation and are based on current Canadian legal loads. Ship collision provisions are also included. Section 3 does not specify limits on the span lengths for application of the truck and lane loads. Accordingly, long-span requirements have been developed and appear in Section [3](#) and elsewhere in this Code (these requirements, however, should not be considered comprehensive). Section [3](#) addresses wind tunnel testing for aerodynamic effects.

Section [4](#) (“Seismic design”) specifies seismic design requirements for new bridges and evaluation and rehabilitation requirements for existing bridges. In this edition of the Code, performance-based design (PBD) has been maintained using updated values for damage states in ductile substructures. Additional damage and service definitions have been provided. Minimum performance levels have been revised from three to two seismic hazard levels for all bridges requiring PBD. Force-based design (FBD) remains permitted for a refined set of special cases. Requirements for geotechnical and foundation design have been moved to Section [6](#). Some provisions for bearing design have been moved to Section [11](#) with

revisions in Section 4 for consistency. Capacity design has been clarified and encouraged for ductile structures using PBD and FBD. Design forces and material properties for PBD, FBD, and capacity design have been clarified. The shear capacity for ductile concrete columns has been revised upwards. Performance-based design and recommended minimum performance targets have been revised for the evaluation and rehabilitation of existing bridges. FBD approaches for existing bridges are discouraged, while guidance on displacement-based methods has been provided.

Section 5 (“Methods of analysis”) specifies requirements for analyzing bridge superstructures. Additional guidance related to longitudinally connected beams and integral abutment bridges are provided. This Section presents new methods for the simplified analysis of longitudinally connected concrete box-beam bridges (previously named shear connected beams), curved steel girder bridges, and steel or aluminum pony-truss bridges. Reductions to limitations for when a curved bridge can be analyzed in the same manner as a straight bridge have been introduced. The robustness and accuracy of the simplified method has been verified by conducting thorough analysis using a large database of simply supported and continuous slab-on-girder bridges. This analysis resulted in shear forces being increased by up to 13% at interior supports for slab-on-girder bridges. In collaboration with Section 3, more specific requirements related to traffic loading are provided with the aim of clarifying the use of refined method of analysis. Revised requirements and guidance for the refined method of analysis have therefore been included. Methods for the design of deck slab cantilever overhang have been updated. Finally, a new simplified method of analysis is provided for determining the factored flexural resistance of steel-reinforced concrete barrier to transverse traffic barrier load.

Section 6 (“Foundations and geotechnical systems”) adopted a risk-based approach to the design of foundations and geotechnical systems (including bridge approach embankments and retaining systems) in the 2014 edition of the Code. The risk-based design approach involves using a resistance factor, which captures our uncertainty in the ground and in our performance predictions, combined with a consequence factor, which adjusts target reliabilities depending on the severity of failure consequences (i.e., depending on the importance of the supported structure), to produce designs which properly account for the level of site understanding and failure consequences. This edition of the Code provides considerable additional changes, adding Code provisions in four design areas, three of which are entirely new to this Section, as follows:

- Clause 6.14, on seismic design, brings the geotechnical seismic design content originally in Section 4 into Section 6 and adds up-to-date content;
- Clause 6.10, on shallow foundations, has been brought up to date and its application is now much clearer;
- Clause 6.18, on permafrost design, provides new specifications for geotechnical design in cold climates; and
- Clause 6.19, on mechanically stabilized earth (MSE) wall systems, provides code requirements for MSE wall systems within the LRFD framework of Section 6 and addresses issues based on Canadian experience with these systems.

Section 7 (“Buried structures”) deals with structures whose design and performance are heavily influenced by soil-structure interaction. The conduit wall of these buried structures can be fabricated from metal, steel or aluminum, or concrete. For metal structures, the conduit wall is made from corrugated plate which fits one of the three industry categories: shallow, deep, or deeper corrugated plate. For concrete structures the wall is reinforced concrete and can be precast or cast-in-place. Section 7 provides for a wide variety of structure shapes from low profile metal boxes or three-sided concrete boxes to large span metal or concrete arches. Section 7 specifies the use of refined methods of analysis for design although some simplified design equations can be used in smaller structures if specific geometric conditions are met. Section 7 also specifies requirements for determining the properties and

dimensions of the engineered soil and non-soil components and addresses construction requirements, geotechnical requirements, and foundation design requirements.

Section [8](#) (“Concrete structures”) covers reinforced, fully prestressed, and partially prestressed concrete components, including deck slabs, made of normal-density, semi-low-density, and high-density concrete of a strength varying from 30 to 80 MPa. Compression field theory is used for proportioning for shear and for torsion combined with flexure. The strut-and-tie approach is used for proportioning regions where the plane sections assumption is not applicable. New to this edition is an informative Annex that provides design provisions for tension softening and tension hardening fibre-reinforced concrete, including ultra-high performance concrete. Other significant changes in this edition include revised provisions relating to the design of slender compression members, the control of cracking, and the use of debonded strands in pretensioned components.

Section [9](#) (“Wood structures”) specifies properties for materials and fastenings that are consistent with *CSA O86 Engineering Design in Wood*. In this edition of the Code, provisions have been reconfigured, and specified strengths revised, to make the application of service condition factors, related to moisture content in members, transparent for the designer. Specified strengths and moduli of elasticity for spruce, lodgepole pine, Jack pine glued-laminated timber have been introduced. Preservative treatments related to durability have been updated to reflect current industry practices, and design values for structural composite lumber have been removed as such products are proprietary and design values can vary between manufacturers. Finally, glued-laminated decks have been introduced.

Section [10](#) (“Steel structures”) specifies the requirements for the design of structural steel bridges and highway accessory supports, including requirements for structural steel components, such as tension and compression members, composite and non-composite straight and horizontally curved girders of I-shape or box shape and their connections. It also covers trusses and arch type bridges. The requirements for structural fatigue and fracture control are outlined in Clauses [10.17](#) and [10.23](#), respectively. The construction requirements for steel bridges are specified in Annex [A10.1](#). Provisions for hybrid girders have been re-introduced into Section [10](#) as Annex [A10.2](#).

Section [11](#) (“Joints and bearings”) specifies the minimum requirements for the design of deck joints and bearings. The design of elastomeric bearings has been updated from previous editions to be consistent with approaches used in other North American and international standards and codes. Alternative sliding materials (as an alternative to PTFE) comprised of ultra-high molecular weight polyethylene are presented. A testing protocol for such materials is also presented.

Section [12](#) (“Barriers and highway accessory supports”) specifies the requirements for the design of permanent bridge barriers and highway accessory supports. New provisions have been added in this edition of the Code to define the extent of the “zone of intrusion” behind barriers and for the design of noise barriers. Also, new provisions have been added for designing highway accessory supports at the serviceability and fatigue limit states.

Section [13](#) (“Movable bridges”) specifies requirements for the design, construction, and operation of conventional movable bridges, i.e., bascule, swing, and vertical lift. Although the structural design aspects are based on the limit states design approach, the mechanical systems design procedures follow the working stress principle used in North American industry. This Section provides special load combinations and load factors that are specific to movable bridges.

Section [14](#) (“Evaluation”) includes provisions concerning the three-level evaluation system, evaluation of deck slabs, detailed evaluation from bridge testing, and load posting of bridges. An optional probability-based mean load method that uses site-specific load and resistance information for more accurate

evaluation is also provided. As in previous editions, an approach to determining material grades from small samples is provided.

Section [15](#) (“Rehabilitation and repair”) specifies minimum design requirements for the rehabilitation of bridges, with particular emphasis on condition assessment, remaining service life, and rehabilitation design life. This Section also provides guidance on the selection of loads and load factors for rehabilitation that is based on the intended use of the bridge following rehabilitation. In this new edition of the Code, this Section introduces a new subsection on rehabilitation of structural steel elements to provide guidance on repair and strengthening of steel components and their connections.

Section [16](#) (“Fibre-reinforced structures”) specifies design requirements for a number of structural components containing high-modulus fibre-reinforced polymers. The high-modulus fibres (aramid, carbon, and glass) are employed in fibre-reinforced polymers (FRPs), which are used for internal reinforcement as replacements for steel bars and tendons or as external reinforcement for retrofit. A new clause also briefly describes the use of the low-modulus fibres which are used for controlling cracks in concrete. This Section covers concrete beams, slabs, columns, concrete deck slabs, barrier walls, and stressed wood decks using FRP. Section [16](#) also includes design provisions for glass-fibre-reinforced polymers to be used as primary reinforcement and as tendons in concrete. An informative annex is now included to provide guidelines for GFRP composite bridges.

Section [17](#) (“Aluminum structures”) specifies the requirements for the design, fabrication, and erection of aluminum highway bridges and pedestrian bridges. Where permitted in Section [12](#), Section [17](#) may now also be applied to highway accessory structures. In this edition of the Code, Clause [17.19](#) on aluminum bridge decks has been simplified and generalized recognizing that aluminum deck products may come in a broad variety of forms. Clause [17.20](#) on fatigue has been updated to add new local stress approaches, and a new Clause [17.26](#) on performance assessment by testing has been added.

CSA Group acknowledges that the development of this Code was made possible, in part, by the financial support of the governments of Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, the Northwest Territories, Nova Scotia, Nunavut, Ontario, Prince Edward Island, Québec, Saskatchewan, and the Yukon, Public Works and Government Services Canada, the Federal Bridge Corporation Limited, and Les Ponts Jacques Cartier et Champlain Incorporée.

This Code was prepared by the Technical Committee on the Canadian Highway Bridge Design Code, under the jurisdiction of the Strategic Steering Committee on Construction and Civil Infrastructure, and has been formally approved by the Technical Committee.

**Notes:**

- 1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*
- 2) *Although the intended primary application of this Code is stated in its Scope, it is important to note that it remains the responsibility of the users of the Code to judge its suitability for their particular purpose.*
- 3) *This Code was developed by consensus, which is defined by CSA Policy governing standardization — Code of good practice for standardization as “substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity”. It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this Code.*
- 4) *To submit a request for interpretation of this Code, please send the following information to [inquiries@csagroup.org](mailto:inquiries@csagroup.org) and include “Request for interpretation” in the subject line:*
  - a) *define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;*
  - b) *provide an explanation of circumstances surrounding the actual field condition; and*
  - c) *where possible, phrase the request in such a way that a specific “yes” or “no” answer will address the issue.*

*Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization and are available on the Current Standards Activities page at [standardsactivities.csa.ca](http://standardsactivities.csa.ca).*

- 5) *This Code is subject to review within five years from the date of publication. Suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to [inquiries@csagroup.org](mailto:inquiries@csagroup.org) and include "Proposal for change" in the subject line:*
- a) *Standard designation (number);*
  - b) *relevant clause, table, and/or figure number;*
  - c) *wording of the proposed change; and*
  - d) *rationale for the change.*

# Foreword

In Canada, the legal mandate for establishing design and construction requirements for highways, including highway bridges, lies with the provincial and territorial governments. All provinces and territories, with the exception of Manitoba, have mandated this Code for use under their jurisdictions.

Among the benefits associated with undertaking the development of this Code is the opportunity to establish safety and reliability levels for highway bridges that are consistent across Canada. Adoption of a single code makes it easier for the consulting and producer industries to respond to calls for proposals and eliminates the need for familiarity with the details of several codes. The adoption of a single code also supports the implementation of a national highway transportation system with agreed minimum standards and loadings for bridges on interprovincial highways, thereby encouraging consistency of vehicle weights across jurisdictions and supporting the objective of more cost-effective transportation of goods.

Designers need to be aware, however, that although this Code establishes CL-625 loading as the minimum for bridges that are part of the national highway system, it is within the mandate of the provinces and territories to adopt a heavier or lighter live loading based on local traffic conditions. For example, Ontario requires (as specified in Annex [A3.4](#)) the use of a CL-625-ONT loading in the design of new bridges; this reflects the higher average regulatory and observed loads for trucks operating in the province. All of the requirements of this Code applicable to CL-W loading also apply to CL-625-ONT loading. Designers should always obtain approval from the regulatory authority when a live loading other than the CL-625 loading is to be used for design, and should check whether any variations from the requirements of this Code are in effect in the jurisdiction, e.g., for evaluation of existing bridges or issuance of overload permits.

This Code was developed by taking into account the different regulatory structures and standards of Canada's provinces and territories. Overall priorities and objectives were established by the Regulatory Authority Committee (RAC), which also monitored the progress of the Code's development. In accordance with CSA procedural requirements, however, responsibility for the technical content of this Code was assigned to the Technical Committee (TC), as were decisions on how to deal with the priorities and objectives identified by the RAC. Because of the breadth and complexity of this Code, subcommittees (which were required to operate and report on a consensus basis) were established to oversee each section. In addition, task forces were established to handle specific aspects of this Code. The subcommittees and task forces reported to the TC through their Chairs. The extensive use of subcommittees permitted the recruitment of experts with the knowledge needed to address the sometimes highly specialized subjects covered by this Code.

This Code is complemented by CSA S6.1:19, *Commentary on CSA S6:19*, Canadian Highway Bridge Design Code, which provides rationale statements and explanatory material for many of the clauses of this Code.

# Section 1

## General

### 1.1 Scope

#### 1.1.1 Scope of Code

This Code applies to the design, evaluation, and structural rehabilitation design of fixed and movable highway bridges in Canada. There is no limit on span length, but this Code does not necessarily cover all aspects of design for every type of long-span bridge. This Code also covers the design of pedestrian bridges, bicycle bridges, retaining walls, barriers, and highway accessory supports of a structural nature, e.g., lighting poles and sign support structures.

This Code does not apply to public utility structures or to bridges used solely for railway or rail transit purposes.

This Code does not specify requirements related to coastal effects (e.g., exposure to sea action and icebergs) or to mountainous terrain effects (e.g., avalanches). For structures that can be subject to such effects, specialists need to be retained to review and advise on the design and to ensure that the applicable requirements of other codes are met.

For bridges not entirely within the scope of this Code, the requirements of this Code apply only when appropriate. Necessary additional or alternative design criteria are subject to the approval by the owner.

#### 1.1.2 Scope of this Section

This Section specifies requirements for applying the Code and requirements of a general nature for bridges, culverts, and related works. These requirements govern basic geometry and hydraulic design. General requirements are also specified for subsidiary components, deck drainage, maintenance, and inspection access. Broad guidelines related to economic, aesthetic, and environmental considerations are also provided.

#### 1.1.3 Terminology

In this Code, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the Code; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the Code.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

# Section 2

## *Durability and sustainability*

### 2.1 Scope

This Section specifies requirements for durability and sustainability that shall be implemented during the design process in addition to this Code's requirements for strength and serviceability. The requirements of this Section apply to the design of new bridges as well as to rehabilitation and replacement work.

### 2.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Durability** — the capability of a component, product, or structure to satisfy, with planned maintenance, the design performance requirements over a specific period of time under the influence of the environmental actions, or as a result of a self-ageing process.

**Glass transition temperature** — the midpoint of the temperature range over which an amorphous material changes from a brittle and vitreous state to a plastic state, or vice versa.

**Inspection** — conformity evaluation by observation and judgment accompanied as appropriate by measurement, testing, or gauging (ISO 9000).

**Maintenance** — a set of activities that are planned to take place during the service life of a structure, in order to fulfil the requirements for durability.

**Major repair** — activities performed to preserve or restore the function of a structure, that fall outside of the definition of planned or reasonably foreseen maintenance or rehabilitation.

**Predicted service life** — an estimated period of time for the service life of a component or system of components based on actual choice of materials, detailing, construction data, environmental characterization, or experience.

**Qualified person** — as a minimum, a person with sufficient experience and credentials as required by the owner based on the requirements of the projects. This should apply to site supervisors, contract administration and inspection staff, contractor's supervisory staff, and anyone responsible for oversight during construction on behalf of the owner or contractor.

**Quality assurance** — as part of quality plan, a set of quality checking and verification procedures applied to confirm engineering design or construction of a structure completed in accordance with relevant codes and standards, and approved project criteria by the owner.

**Quality plan** — the document specifying which procedures and associated resources are to be applied by whom and when to meet the requirements of the specific project.

**Remaining service life** — the remaining period of time for which a structure or a component is to be used for its intended purpose with appropriate maintenance activities and planned rehabilitation, but without major repair. The assessment of the remaining service life of a structure or a component should

# Section 3

## Loads

### 3.1 Scope

This Section specifies loads, load factors, and load combinations to be used in calculating load effects for design. Resistance factors required to check ultimate limit states criteria in accordance with Clause [3.4.2](#) are specified elsewhere in this Code. Loadings provisions for evaluation of existing structures are covered in Section [14](#) and for rehabilitation in Section [15](#).

This Section includes requirements related to the vibration of highway and pedestrian bridges. It also includes requirements related to construction loads and temporary structures; these apply to partially completed structures and structures necessary for construction purposes. Snow loads are not specified because in normal circumstances the occurrence of a considerable snow load will cause a compensating reduction in traffic load.

### 3.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Acceptance criterion** — the acceptable frequency of collapse due to the design vessel collision.

**Axle unit** — any single-axle, tandem, or tridem.

**Buffeting** — the loads induced in a structure by the turbulence in the natural wind.

**Critical or essential bridges** — an operational classification for bridges that must continue to function after a vessel collision.

**Damping** — the dissipation of energy in a structure oscillating in one of its natural modes of vibration. It is normally expressed as a ratio of the actual value of damping to the critical value of damping. The critical value of damping is the lowest value at which an initial motion decays without oscillation.

**Dead load** — the load from material that is supported by the structure and is not subject to movement.

**Debris torrent** — a mass movement that involves water-charged inorganic and organic material flowing rapidly down a steep confined channel.

**Design lane** — a longitudinal strip that is a fraction of the deck width and within which a truck or Lane load is placed for the purpose of design or evaluation.

**Divergence** — an aerodynamic instability in torsion that usually occurs at wind speeds higher than those normally considered in design.

**Drag** — the load in the direction of the wind, induced by an airstream acting on a body.

**Effective temperature** — the temperature that governs the thermally induced expansion and contraction of a superstructure.

# Section 4

## Seismic design

### 4.1 Scope

This Section specifies minimum requirements for

- a) the seismic analysis and design of new bridge structures; and
- b) the seismic evaluation (Clause [4.11](#)) and rehabilitation (Clause [4.12](#)) of existing bridge structures.

### 4.2 Definitions

The following definitions shall apply to this Section of the Code. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Capacity design** — a method of seismic design that allows the designer to prevent damage in certain components by making them strong enough to resist loads generated when adjacent components reach their probable resistance.

**Capacity-protected element** — a structural component that is being protected from damage by designing its capacity to be greater than the loads generated when adjacent ductile or force-limiting elements reach their probable resistance.

**Centrally braced frame with nominal ductility** — a braced frame with concentric bracing designed and detailed to absorb limited amounts of energy through inelastic bending or extension of bracing members.

**Connectors** — mechanical devices, including bearing components and shear keys, that provide transverse or longitudinal restraint of movement of the superstructure relative to the substructure.

**Note:** *Connectors do not include moment connections, monolithic joints, or longitudinal restrainers at expansion bearings (see Clause [4.4.10.4.2](#)).*

**Damping** — the dissipation of energy of a structure oscillating in one of its natural modes of vibration.

**Note:** *It is normally expressed as a ratio of the actual value of damping to the critical value of damping. The critical value of damping is the minimum damping at which an initial motion decays without oscillation.*

**Design displacement** — for bridges without isolation or supplemental damping, the displacement predicted from analysis.

**Note:** *For the design of isolation or supplemental damping, see Clause [4.10.6](#).*

**Ductile concentrically braced frame** — a braced frame with concentric bracing designed and detailed to absorb energy through yielding of the braces.

**Ductile substructure element** — an element of a substructure that is expected to undergo reversed-cyclic inelastic deformations without significant loss of strength and is detailed to develop the appropriate level of ductility while remaining stable.

**Ductility** — the ability of a structural member to deform without significant loss of load-carrying capacity after yielding.

# Section 5

## *Methods of analysis*

### 5.1 Scope

This Section specifies the methods of analysis for the design and evaluation of bridge superstructures.

### 5.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Beam analogy method** — a simplified method applicable to bridges satisfying the requirements of Clause [5.6.2](#) in which the bridge superstructure can be treated as a group of parallel beams equally distributed across the bridge width and on which the longitudinal load effects due to CL-W loading in longitudinal beams are determined using simple statics or prescribed distribution factors.

**Bearing unit** — a group of structural devices forming a line of support on a substructure unit (pier or abutment).

**Bridge width** — the distance between the unsupported edges along a line perpendicular to the centreline of the bridge.

**Cantilever slab** — in the transverse direction, the section of the deck slab that lies outside the centreline of the outermost girder or web; in the longitudinal direction, the section of the deck slab that lies outside the outermost lines of support.

**Cross-frame** — a transverse truss framework connecting adjacent longitudinal flexural components to provide stability to the compression flanges, sometimes synonymous with the term diaphragm.

**Deck-on-girder bridge** — a bridge superstructure made of longitudinal girders supporting a deck that is composite or not with the underlying girders.

**Diaphragm** — transverse structural element that spans between longitudinal main girders to provide lateral stability to these elements while adding to the transverse rigidity of the bridge and to distribute vertical and lateral loads.

**Distortion** — change of the cross-section shape in its own plane due to torsion.

**Divergence** — an aerodynamic instability in torsion that is analogous to column buckling and usually occurs at wind speeds beyond the range normally considered in the design.

**Effective width** — a reduced width of a flange or deck that enables a member to be proportioned on the basis of uniform stress.

**Exterior portion of a slab bridge** —

- a) for a solid slab bridge, the outermost strip of the transverse cross-section on either side of the bridge equal to the slab depth but not less than 0.6 m nor more than 2.0 m; and

# Section 6

## ***Foundations and geotechnical systems***

### **6.1 Scope**

This Section specifies minimum requirements for the design of foundations and geotechnical systems (including highway embankments) under static loading conditions and for requirements pertaining to geotechnical investigations and design reports. This Section includes requirements for investigation to support seismic design, specifies minimum requirements to evaluate seismic resistance of foundations, and provides seismic performance requirements for geotechnical systems. This Section also includes requirements for investigation to support design of buried structures, although design of buried structures falls within the scope of Section [7](#).

Where conflict occurs between requirements in references to other Standards or Codes and Section [6](#), the requirements of Section [6](#) shall take precedence.

### **6.2 Definitions**

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Abutments** — the end foundations upon which the bridge superstructure rests.

**False abutment** — an abutment that consists of a wall where the bridge is actually supported on piles or columns behind the wall face.

**Flexible abutment** — an abutment supported on a single row of steel H-piles or steel tubular unfilled piles not exceeding 302 mm in diameter.

**Integral abutment bridges** — single or multispans continuous deck bridges with the superstructure integrally connected to flexible abutments. A cyclic joint is provided at the end of the approach slabs that are integrally connected to the deck.

**Self-supporting abutment** — an abutment not requiring lateral support from the deck for stability.

**Semi-integral abutment bridges** — single or multispans continuous deck bridges where the superstructure is supported on self-supporting abutments separated by bearings and as such is not integrally connected to the abutments. A cyclic joint is provided at the end of approach slabs that are integrally connected to the deck.

**True abutment** — an abutment that consists of a wall where the bridge is supported directly by the fill through a spread footing.

**Active layer** — the top layer of the ground above the permafrost that is subject to annual thawing and freezing in areas underlain by permafrost.

**Active pressure** — the lateral earth pressure exerted on a structure or geotechnical system, or both, when the system is able to move away from the backfill by an amount sufficient to fully mobilize the ground strength.

# Section 7

## ***Buried structures***

### **7.1 Scope**

This Section specifies requirements for the analysis and design of buried structures of the following types:

- a) soil-metal structures;
- b) metal box structures; and
- c) reinforced concrete structures.

This Section also specifies construction procedures, properties and dimensions of engineered fill components, and requirements for construction supervision.

### **7.2 Definitions**

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Arch** — a soil-metal or reinforced concrete structure in which the structure wall is not continuous around the perimeter of the bridged opening and the structure wall is supported on footings.

**Arching** — the transfer of pressure or load between the soil masses adjacent to and above a buried structure that move relative to one another. Positive arching results in the transfer of loads away from the buried structure; negative arching produces the opposite effect.

**Aufeis** — sheet-like mass of layered ice that forms from successive flows of groundwater during freezing temperatures.

**Backfill** — the fill around and above a buried structure or retained by a structure, including fill approved for use as engineering fill.

**Bedding** — the prepared portion of engineered fill on which the base of a closed buried structure wall is placed.

**Bevel** — the termination of the wall of a buried structure, cut at a plane inclined to the horizontal.

**Buried structure** — a structure that has one or more buried structures and is designed by taking account of the interaction between the structure wall and engineered fill.

**Camber** — a deliberate adjustment required in the longitudinal profile of bedding to compensate for post-construction settlement along the longitudinal axis of the structure.

**Closed buried structure** — a structure with a continuous perimeter.

**Cold region** — those land masses characterized by sub-zero average annual temperatures.

**Note:** *Examples include Yukon, the Northwest Territories, Nunavut, and the northern portions of many Canadian provinces.*

# Section 8

## Concrete structures

### 8.1 Scope

This Section specifies requirements for the design of structural components that are made of precast or cast-in-place normal-density, low-density, or semi-low-density concrete and reinforced with prestressed or non-prestressed steel. The components covered by this Section can be prestressed with pretensioned steel, grouted post-tensioned steel, or both.

### 8.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Adhesive anchor** — an anchor inserted into a hole drilled in hardened concrete and held in place by epoxy resin or another adhesive.

**Anchor** — a bolt, stud, or reinforcing bar embedded in concrete.

**Anchorage** —

- a) in post-tensioning, a device used to anchor a tendon to a concrete member;
- b) in pretensioning, a device used to anchor a tendon until the concrete has reached a predetermined strength; and
- c) for reinforcing bars, a length of reinforcement, mechanical anchor, or hook, or a length of reinforcement combined with a mechanical anchor or a hook.

**Anchorage blister** — a protrusion in a web, flange, or flange-web junction for placement of tendon anchorage fittings.

**Anchorage system** — an anchor or assemblage of anchors.

**At jacking** — at the time of tensioning tendons.

**Attachment** — a structure external to concrete that transmits loads to an anchor.

**At transfer** — at the time immediately after transfer.

**Bonded tendon** — a tendon that is bonded to concrete directly or by grouting.

**Cast-in-place anchor** — an anchor that is in its final location at the time of placing of concrete.

**Closure** — a cast-in-place concrete segment used to complete a span in segmental construction.

**Concrete cover** — the least distance between the surface of reinforcing bars, strands, post-tensioning ducts, anchorages, or connections and the surface of concrete.

**Creep** — time-dependent deformation of concrete under sustained load.

**Deep beam** — a member with a span-to-depth ratio of less than 2.0, where for continuous spans an effective span is taken as the distance between points of contraflexure due to dead load.

# Section 9

## Wood structures

### 9.1 Scope

This Section applies to structural wood components and their connections.

### 9.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Beam and stringer (grading term)** — sawn wood with a smaller dimension of at least 114 mm and a larger dimension more than 51 mm greater than the smaller dimension, graded for use in bending with the load applied to the narrow face.

**Bearing block** — a short wood block with its grain parallel to the applied post-tensioning force, used to distribute the forces in a stress-laminated wood bridge with an external post-tensioning system.

**Butt joint** — the discontinuities in a laminated wood deck where the ends of two laminates meet.

**Crib** — a configuration of horizontal members with alternating layers (usually perpendicular to one another) connected to form a closed box.

**Dimension lumber** — sawn wood 38 to 102 mm thick.

**Direct bearing area** — the area of outside lamination over which the post-tensioning is assumed to be applied.

**Direct bearing pressure** — the average pressure that is assumed to be applied to the direct bearing area by the post-tensioning force.

**Distribution bulkhead** — a steel section used to distribute the post-tensioning force.

**Drift pin** — a steel pin used to connect wood members.

**Duration of load** — a period of continuous application of a specified load or the summation of the time periods of intermittent applications of the same load.

**External post-tensioning system** — a system that transversely post-tensions a longitudinally laminated wood deck using two bars at each anchorage, one above and one below the deck.

**Framed bent** — a line of wood columns suitably braced.

**Glued-laminated timber (Glulam)** — structural wood that is manufactured in accordance with CAN/CSA-O122 and is produced by gluing together a number of laminates with essentially parallel grains.

**Grade** — the designation of the quality of a wood element.

# Section 10

## Steel structures

### 10.1 Scope

This Section specifies requirements for the design of structural steel bridges and highway accessory support structures, including requirements for structural steel components, welds, bolts, and other fasteners required in fabrication and erection. Requirements related to the repeated application of loads and to fracture control and fracture toughness for primary tension and fracture-critical members are also specified. Construction requirements for structural steel are also provided.

### 10.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Brittle fracture** — a type of fracture in structural materials without prior plastic deformation that usually occurs suddenly.

**Buckling load** — the load at which a member or element reaches a condition of instability.

**Camber** — the built-in deviation of a bridge member from straight, when viewed in elevation.

**Class** — a designation of structural sections with regard to the width-to-thickness ratios of their constituent elements and their flexural-compressive behaviour.

**Coating** — an owner-approved protective system for steel, e.g., galvanizing, metallizing, a paint system, or coal tar epoxy.

**Composite beam or girder** — a steel beam or girder structurally connected to a concrete slab so that the beam and slab respond to loads as a unit.

**Composite column** — a column consisting of a steel tube filled with concrete, with or without internal reinforcement.

**Connection** — a weld or arrangement of bolts that transfers normal and/or shear stresses from one element to another.

**Critical net area** — the area with the least tensile or tensile-shear resistance.

**Erection diagrams** — drawings that show the layout and dimensions of a steel structure and from which shop details are made. They also correlate the fabricator's piece marks with locations on the structure.

**Fatigue** — initiation of microscopic cracks and propagation of such cracks into macroscopic cracks caused by the repeated application of load.

**Fatigue limit** — the level of stress range below which no fatigue crack growth is assumed to occur.

**Firm contact** — the condition that exists on a faying surface when plies are solidly seated against each other but not necessarily in continuous contact.

# Section 11

## Joints and bearings

### 11.1 Scope

This Section specifies minimum requirements for the design, selection, and detailing of joints and bearings.

### 11.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Armour** — an edging to the deck joint comprising a steel angle or a steel plate permanently attached to the concrete dam corners.

**Bridging plate** — a structurally integral cantilever plate, e.g., a finger plate, that is rigidly fastened to one side of a joint and permits free movement of the joint.

**Concrete dam** — the area adjacent to the joint that anchors the joint assembly or mechanism. It also provides protection against dynamic impact effects resulting from direct wheel traffic loading.

**Cover plate** — a plate that is not necessarily structurally integral with the joint but covers the joint to provide a safe riding surface.

**Deck joint** — a structural discontinuity between two elements, at least one of which is a deck element, that is designed to permit relative translation or rotation, or both, of abutting structural elements.

**Note:** Also called “expansion joint”.

**Disc bearing** — a bearing consisting of a restrained single moulded disc of unreinforced elastomer confined by upper and lower metal-bearing plates and prevented from moving horizontally by a shear-restricting mechanism.

**Effective elastomer thickness** — the sum of the thicknesses of all of the elastomeric layers in a bearing, excluding the outer layers.

**Elastomer** — a compound containing

- a) virgin natural polyisoprene (natural rubber) (when used in pot bearings and plain or laminated elastomeric bearings);
- b) polyether-urethane polymer (when used in disc bearings).

**Elastomeric concrete** — a viscous mixture of elastomer, chemical additives, and aggregates that, after being placed as an end expansion-joint dam and cured, retains the joint assembly while providing a resilient transition in the riding surface.

**Fixed bearing** — a bearing that prevents differential translation while permitting rotation of abutting structural elements.

**Integral abutment bridge** — a bridge whose superstructure and abutments are connected monolithically.

# Section 12

## ***Barriers and highway accessory supports***

### **12.1 Scope**

This Section specifies requirements for the design of permanent bridge barriers and highway accessory supports.

### **12.2 Definitions**

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Anchorage** — a bolt, stud, reinforcing bar, or assembly that is installed in concrete to anchor a structure or a component.

**Barrier clearance** — the clearance between the outside edge of the traffic lanes and the roadway face of a barrier.

**Barrier exposure index** — an index that reflects traffic volumes and bridge site characteristics and is used for determining barrier test levels.

**Barrier joint** — a discontinuity in a barrier that permits relative rotation or translation between barrier components on opposite sides of the discontinuity.

**Bikeway** — part of a highway designated for the movement of bicycles.

**Breakaway support** — a support designed to fail in such a way that, when struck by a vehicle, damage to the vehicle and injury to its occupants does not exceed a specified level.

**Cantilevered support** — a support that cantilevers out over a roadway.

**Crash cushion** — a barrier used for protecting vehicles from a roadside hazard and designed to fail in such a way that, when struck by a vehicle, damage to the vehicle and injury to its occupants does not exceed a specified level.

**Crash test** — a test of a barrier or highway accessory support carried out by crashing a vehicle into it and monitoring the vehicle-barrier or vehicle-highway accessory support interaction.

**Design speed** — the speed for which a highway at a bridge site is designed.

**Double-nut anchor bolt anchorage** — an anchorage consisting of a highway accessory support transverse base plate located above the top of the concrete foundation with the transverse base plate connected to the concrete foundation by anchor bolts having nuts both above and below the transverse base plate.

**Highway accessory** — a component required for the operation of a highway, e.g., a sign, luminaire, traffic signal, surveillance installation, noise barrier, or privacy barrier.

**Highway accessory support** — a structure (including supporting brackets, maintenance walkways, and mechanical devices, where present) that is designed to support highway accessories.

# Section 13

## Movable bridges

### 13.1 Scope

This Section specifies requirements for the design of conventional movable highway bridges, i.e., bascule (including rolling lift), swing, and vertical lift bridges and deals primarily with the components involved in the operation of such bridges. The requirements for fixed span bridges, as given in other sections of the Code, shall apply to movable bridges, except as otherwise provided.

### 13.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Acceleration torque** — torque produced by prime mover at any time between the initial start condition and full load speed.

**Note:** *This is a variable as the torque value will vary with the speed.*

**Accumulator** — an energy storage device for storing hydraulic fluid under pressure.

**Note:** *The energy absorbing mechanism may be a spring, an external weight, or an inert gas with a precharge pressure.*

**Actual speeds** — velocity at which machinery will move or rotate under the actual load or resistance, which is dependent upon the speed versus torque characteristics of the prime mover or the power-limiting settings of a hydraulic pump.

**Addendum** — the portion of gear tooth outside (greater than) the pitch radius.

**Allowable static design stress** — the permissible value of stress for calculations involving components subjected to static loading.

**Average (mean) stress** — one-half of the sum of the maximum and minimum stress.

**Backlash** — the smallest amount of space between the faces of mating gears.

**Beta ratio** — a measure of the effectiveness of filters.

**Bevel gear** — the type of gear that is commonly used when shafts intersect and that utilizes the concept of rolling cones.

**Bridge closed or in closed position or in seated position or in fixed position** — the bridge is in a position that permits highway traffic to use it.

**Bridge open or in open position** — the bridge is in a position that allows navigation to proceed.

**Brittle** —

- a) materials designed against ultimate strength for which failure means fracture; or
- b) easily broken, snapped, or cracked.

# Section 14

## Evaluation

### 14.1 Scope

This Section specifies methods of evaluating an existing bridge to determine whether it will carry a particular load or set of loads.

### 14.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Capacity** — the unfactored nominal resistance of an element or joint.

**Evaluation** — determination of a bridge's capacity to carry traffic loads.

**Evaluation Level 1** — evaluation of a bridge to determine its load-carrying capacity for vehicle trains (in normal traffic).

**Evaluation Level 2** — evaluation of a bridge to determine its load-carrying capacity for two-unit vehicles (in normal traffic).

**Evaluation Level 3** — evaluation of a bridge to determine its load-carrying capacity for single-unit vehicles (in normal traffic).

**Evaluator** — a qualified engineer responsible for evaluating a bridge.

**Posting** — signing of a bridge for load restrictions in accordance with regulations.

**Single-unit vehicles** — trucks, buses, cars, and other vehicles consisting of a single unit.

**Two-unit vehicles** — tractor–semi-trailers, car-trailers, truck-trailers, and other vehicles consisting of two units.

**Vehicle trains** — tractor-trailer-trailers, tractor–semi-trailer–trailers, tractor–semi-trailer–semi-trailers, and other vehicles consisting of three units.

### 14.3 Symbols

The following symbols shall apply in this Section:

$A$  = force effects due to additional loads (including wind, creep, shrinkage, temperature, and differential settlement) that may be considered in the evaluation

$A_r$  = nominal area of a rivet, mm<sup>2</sup>

$A_{sl}$  = area of longitudinal tensile reinforcing steel in the bottom of concrete deck slabs, mm<sup>2</sup>

$A_{st}$  = area of transverse tensile reinforcing steel in the bottom of concrete deck slabs, mm<sup>2</sup>

$A_v$  = area of transverse shear reinforcement perpendicular to the axis of a member within a distance  $s$ , mm<sup>2</sup>

# Section 15

## Rehabilitation and repair

### 15.1 Scope

This Section specifies minimum requirements for the rehabilitation of bridges but is not applicable to the resolution of construction deficiencies of new structures. The requirements specified in this Section relate only to condition assessment, loads, load factors, resistances, and other design criteria relevant to the rehabilitation of bridges, including required remaining service life and assessment of ongoing deterioration and its impact on structural integrity. Material specifications, rehabilitation procedures, and maintenance procedures are not covered in this Section.

### 15.2 Definitions and symbols

#### 15.2.1 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Fastener** — a generic term for bolts, rivets, or other connecting devices, excluding welds.

#### 15.2.2 Symbols

In addition to the symbols listed in this Clause, the symbols in Clause [14.3](#) shall apply in this Section.

$V_{\text{friction}}$  = plate friction resistance component (see Clause [15.8.4.1](#))

$V_{r,\text{bolt}}$  = bolt shear resistance component (see Clause [15.8.4.1](#))

$V_{r,\text{joint}}$  = factored shear resistance of a connection that includes both fasteners and welds in the same shear plane and loaded concentrically

$V_{r,\text{trans}}$  = transverse weld resistance component (see Clause [15.8.4.1](#))

$V_{r,\text{long}}$  = longitudinal weld resistance component (see Clause [15.8.4.1](#))

### 15.3 General requirements

#### 15.3.1 General

The requirements of Section [1](#) shall apply in addition to the content of this Section.

**Note:** See Clause [15.4](#) for particular considerations.

#### 15.3.2 Limit states

Unless otherwise specified by the Owner or required by this Section, all rehabilitated members shall satisfy the ultimate limit state and serviceability limit state requirements specified as part of the design requirements of Sections [1](#) to [13](#) and [16](#) and [17](#), except that if the purpose of the rehabilitation is to allow passage of a controlled vehicle, the only load combination that shall be considered is permanent loads plus the control vehicle, with the load factors specified in Section [14](#).

# Section 16

## *Fibre-reinforced structures*

### 16.1 Scope

#### 16.1.1 Components

The requirements of this Section apply to the following components containing fibre reinforcement:

- a) fully or partially prestressed concrete beams and slabs;
- b) non-prestressed concrete beams, slabs, columns, and deck slabs;
- c) externally and internally restrained deck slabs;
- d) stressed wood decks;
- e) barrier walls;
- f) existing concrete elements with externally bonded fibre-reinforced polymer (FRP) systems and near-surface-mounted reinforcement (NSMR); and
- g) existing timber elements with externally or internally bonded glass-fibre-reinforced polymer systems (GFRP) and NSMR.

A non-mandatory Annex is also included on GFRP composite bridges (see Annex [A16.3](#)).

#### 16.1.2 Fibres

This Section covers fibre reinforcement in which the fibre comprises one or more of the following:

- a) glass;
- b) carbon;
- c) aramid;
- d) a low modulus polymer or polymers; and
- e) steel.

#### 16.1.3 Matrices

This Section covers fibre-reinforced composites in which the matrix comprises one or more of the following:

- a) epoxy resin;
- b) saturated polyester resin;
- c) unsaturated polyester resin;
- d) vinylester resin;
- e) polyurethane; and
- f) Portland-cement-based mortar or concrete.

#### 16.1.4 Uses requiring approval

Uses of fibre-reinforced polymers in structures or strengthening schemes that do not meet the requirements of this Section require approval by the owner.

### 16.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

# Section 17

## Aluminum structures

### 17.1 Scope

This Section specifies requirements for the design, fabrication, and erection of aluminum highway and pedestrian bridges. Where permitted in Section [12](#), the contents of this Section may also be applied to highway accessory structures.

### 17.2 Definitions

The following definitions shall apply in this Section. For common definitions used throughout the Code, refer to Clause [1.3](#).

**Brittle fracture** — a type of fracture in structural materials without prior plastic deformation that usually occurs suddenly.

**Buckling load** — the load at which a member or element reaches a condition of instability.

**Buckling stress,  $F_c$**  — the compressive stress that causes buckling.

**Camber** — the built-in deviation of a bridge member from straight, when viewed in elevation.

**Characteristic resistance,  $R_k$**  — the maximum force, moment, or torque that a component can be assumed to be capable of sustaining.

**Coating** — an owner-approved protective system for aluminum, e.g., galvanizing, metallizing, a paint system, or coal tar epoxy.

**Composite beam or girder** — an aluminum beam or girder structurally connected to a concrete slab so that the beam and slab respond to loads as a unit.

**Critical net area** — the net cross-sectional area with the least tensile or tensile-shear resistance.

**Detail category** — a category that establishes the level of stress range permitted in accordance with the classification of the detail and the number of design stress cycles.

**Effective section** — a section in which elements, because of welding or local buckling, are reduced to their effective thicknesses.

**Effective strength,  $F_m$**  — the reduced strength of an element, at the ultimate limit state, to account for the influence of local buckling or welding.

**Elastic buckling stress,  $F_e$**  — the theoretical stress that initiates elastic buckling.

**Element** — any flat or curved component of a section, such as the web of an I-beam.

**Erection diagrams** — drawings that show the layout and dimensions of an aluminum structure and from which shop details are made. They also correlate the fabricator's piece marks with locations on the structure.