

# New Canadian Highway Bridge Design Code design provisions for fibre-reinforced structures<sup>1</sup>

A.A. Mufti, B. Bakht, N. Banthia, B. Benmokrane, G. Desgagné, R. Eden, M.-A. Erki, V. Karbhari, J. Kroman, D. Lai, A. Machida, K. Neale, G. Tadros, and B. Täljsten

**Abstract:** This paper presents a synthesis of the design provisions of the second edition of the *Canadian Highway Bridge Design Code* (CHBDC) for fibre-reinforced structures. New design provisions for applications not covered by the first edition of the CHBDC and the rationale for those that remain unchanged from the first edition are given. Among the new design provisions are those for glass-fibre-reinforced polymer as both primary reinforcement and tendons in concrete; and for the rehabilitation of concrete and timber structures with externally bonded fibre-reinforced-polymer (FRP) systems or near-surface-mounted reinforcement. The provisions for fibre-reinforced concrete deck slabs in the first edition have been reorganized in the second edition to explicitly include deck slabs of both cast-in-place and precast construction and are now referred to as externally restrained deck slabs, whereas deck slabs containing internal FRP reinforcement are referred to as internally restrained deck slabs. Resistance factors in the second edition have been recast from those in the first edition and depend on the condition of use, with a further distinction made between factory- and field-produced FRP. In the second edition, the deformability requirements for FRP-reinforced and FRP-prestressed concrete beams and slabs of the first edition have been split into three subclauses covering the design for deformability, minimum flexural resistance, and crack-control reinforcement. The effect of sustained loads on the strength of FRPs is accounted for in the second edition by limits on stresses in FRP at the serviceability limit state.

**Key words:** beams, bridges, concrete, decks, fibre-reinforced-polymer reinforcement, fibre-reinforced-polymer sheets, prestressing, repair, strengthening, wood.

**Résumé :** Cet article présente une synthèse des dispositions de conception des structures renforcées de fibres telles énoncées dans la seconde édition du Code canadien sur le calcul des ponts routiers. Il aborde les nouvelles dispositions de conception pour les utilisations non couvertes dans la première édition et le raisonnement derrière les changements apportés. Parmi ces nouvelles dispositions se trouvent celles concernant les polymères renforcés de fibres de verre (= GFRP =) comme renforcement primaire et barres dans le béton ainsi que la réhabilitation des structures de béton et de bois d'œuvre au moyen de systèmes en polymère renforcé de fibres (= FRP =) externes ou de renforcement installé près de la surface (= NSMR =). Les dispositions concernant les dalles de tablier en béton renforcé de fibres (= FRC =) dans la première édition ont été réorganisées dans la seconde afin d'isoler explicitement les dalles de tablier des constructions coulées en place et précontraintes et ces dispositions sont maintenant regroupées sous les termes « dalles de tablier à encastrement externe » alors que les dalles de tablier contenant des renforcements « FRC » internes sont regroupées sous l'appellation « dalles de tablier à encastrement interne. » Les facteurs de résistance dans la seconde édition repris à partir de ceux de la première édition et dépendent de la condition d'utilisation; les « FRP » produits en

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A.A. Mufti,<sup>2,3</sup> ISIS Canada Research Network, The University of Manitoba, Winnipeg, MB R3T 2N2, Canada.  
B. Bakht, JMBT Structures Research Inc., 21 Whiteleaf Crescent, Scarborough, ON M1V 3G1, Canada, and ISIS Canada.  
N. Banthia, Department of Civil Engineering, The University of British Columbia, Vancouver, BC V6T 1Z4, Canada.  
B. Benmokrane and K. Neale, Department of Civil Engineering, University of Sherbrooke, Sherbrooke, QC J1K 2R1, Canada.  
G. Desgagné, Structural Design Department, Ministère des Transports du Québec, Québec City, QC J1K 2R1, Canada.  
R. Eden, Design and Contracts, Bridges and Roads, Manitoba Floodway Authority, Winnipeg, MB R3C 3Z1, Canada.  
M.-A. Erki, Royal Military College of Canada, Kingston, ON K3K 5L0, Canada.  
V. Karbhari, Department of Structural Engineering, University of California San Diego, La Jolla, CA 92093-0085, USA.  
J. Kroman, Structural Design, City of Calgary, Calgary, AB T2P 2M5, Canada.  
D. Lai, Ontario Ministry of Transportation, St. Catharines, ON L2R 7R4, Canada.  
A. Machida, Saitama University, Saitama City, Japan.  
G. Tadros, SPECO Engineering Ltd., 43 Schiller Crescent NW, Calgary, AB T3L 1W7, Canada, and ISIS Canada.  
B. Täljsten, Department of Structural Engineering, Luleå University, Luleå, Sweden.

Written discussion of this article is welcomed and will be received by the Editor until 31 July 2007.

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<sup>2</sup>Canadian Highway Bridge Design Code's Technical Subcommittee for Fibre Reinforced Structures, chaired by A.A. Mufti.

<sup>3</sup>Corresponding author (e-mail: [muftia@cc.umanitoba.ca](mailto:muftia@cc.umanitoba.ca)).

# Ontario Bridge Design Code And Manual

**Patrick Arnold, Gordon A.  
Fenton, Michael A. Hicks, Timo  
Schweckendiek, Brian Simpson**

## **Ontario Bridge Design Code And Manual:**

**Handbook of International Bridge Engineering** Wai-Fah Chen, Lian Duan, 2013-10-11 This comprehensive and up to date reference work and resource book covers state of the art and state of the practice for bridge engineering worldwide Countries covered include Canada and the United States in North America Argentina and Brazil in South America Bosnia Bulgaria Croatia Czech Republic Denmark Finland France Greece Macedonia Poland Russia Serbia Slovakia and Ukraine in the European continent China Indonesia Japan Chinese Taipei and Thailand in Asia and Egypt Iran and Turkey in the Middle East The book examines the use of different materials for each region including stone timber concrete steel and composite It examines various bridge types including slab girder segmental truss arch suspension and cable stayed A color insert illustrates select landmark bridges It also presents ten benchmark comparisons for highway composite girder design from different countries the highest bridges the top 100 longest bridges and the top 20 longest bridge spans for various bridge types including suspension cable stayed extradosed arch girder movable bridges vertical lift swing and bascule floating stress ribbon and timber and bridge construction methods Innovative Bridge Design Handbook Alessio

Pipinato, 2021-09-08 Innovative Bridge Design Handbook Construction Rehabilitation and Maintenance Second Edition brings together the essentials of bridge engineering across design assessment research and construction Written by an international group of experts each chapter is divided into two parts the first covers design issues while the second presents current research into the innovative design approaches used across the world This new edition includes new topics such as foot bridges new materials in bridge engineering and soil foundation structure interaction All chapters have been updated to include the latest concepts in design construction and maintenance to reduce project cost increase structural safety and maximize durability Code and standard references have been updated Completely revised and updated with the latest in bridge engineering and design Provides detailed design procedures for specific bridges with solved examples Presents structural analysis including numerical methods FEM dynamics risk and reliability and innovative structural typologies

*Modern Geotechnical Design Codes of Practice* Patrick Arnold, Gordon A. Fenton, Michael A. Hicks, Timo Schweckendiek, Brian Simpson, 2013 The ground is one of the most highly variable of engineering materials It is therefore not surprising that geotechnical designs depend on local site conditions and local engineering experience Engineering practices relating to investigation and design methods site understanding and to safety levels acceptable to society will therefore vary between different regions The challenge in geotechnical engineering is to make use of worldwide geotechnical experience established over many years to aid in the development and harmonization of geotechnical design codes Given the significant uncertainties involved empiricism and engineering judgment will undoubtedly always be an essential element of geotechnical design However rigorous and scientific approaches based on probability theory are finding increased attention in the calibration of modern geotechnical codes of practice and these codes can and should be used to aid fundamental engineering

judgment Containing contributions on Code Implementation Code Application and Code Development this book provides a single resource that code developers practitioners and researchers can use to understand the different choices made by national code developers around the world Furthermore the book highlights some of the key challenges faced worldwide concerning the ongoing process of harmonizing geotechnical design code specifications Inelastic Rating Procedures for Steel Beam and Girder Bridges Theodore V. Galambos, National Research Council (U.S.). Transportation Research Board, National Cooperative Highway Research Program, 1993

**Foundation Design Codes and Soil Investigation in View of International Harmonization and Performance Based Design** Y. Honjo, O. Kusakabe, K. Matsui, M. Koda, G. Pokharel, 2002-01-01 The contributions contained in these proceedings are divided into three main sections theme lectures presented during the pre workshop lecture series keynote lectures and other contributed papers and a translation of the Japanese geotechnical design code

**Bridge Engineering Handbook** Wai-Fah Chen, Lian Duan, 2023-01-27 First Published in 1999 The Bridge Engineering Handbook is a unique comprehensive and state of the art reference work and resource book covering the major areas of bridge engineering with the theme bridge to the 21st century This second volume includes sections covering substructure design and seismic design

*Computational Analysis and Design of Bridge Structures* Chung C. Fu, Shuqing Wang, 2014-12-11 Gain Confidence in Modeling Techniques Used for Complicated Bridge Structures Bridge structures vary considerably in form size complexity and importance The methods for their computational analysis and design range from approximate to refined analyses and rapidly improving computer technology has made the more refined and complex methods of ana

**Planning and Design of Bridges** M. S. Troitsky, 1994-10-28 Timely authoritative extremely practical an exhaustive guide to the nontheoretical aspects of bridge planning and design This book addresses virtually all practical problems associated with the planning and design of steel and concrete bridge superstructures and substructures Drawing on its author's nearly half century as a bridge designer and engineer it offers in depth coverage of such crucial considerations as selecting the optimum location and layout traffic flow aesthetics design analysis construction current codes and government regulations maintenance and rehabilitation and much more Offers in depth coverage of all the steps involved in performing proper planning and design with comparative analyses of alternative solutions Includes numerous examples and case studies of existing bridges and important projects underway around the world Features a time line history of bridge building from pre Roman times to the present Summarizes key technical data essential to bridge engineering Supplemented with 200 line drawings and photos vividly illustrating all concepts presented Comprehensive coverage of CAD planning design and analysis techniques and technologies

Advances in Steel Structures ICASS '96 S.L. Chan, J.G. Teng, 1996-12-06 These two volumes of proceedings contain 11 invited keynote papers and 172 contributed papers presented at the International Conference on Advances in Steel Structures held on 11-14 December 1996 in Hong Kong The papers cover a wide spectrum of topics and have been contributed from over 20 countries

around the world The conference the first ever of its kind in Hong Kong provided a forum for discussion and dissemination by researchers and designers of recent advances in the analysis behaviour design and construction of steel structures The papers in the proceedings report the current state of the art and point to the future directions of structural steel research Volume I contains 93 papers on the analysis behaviour design and construction of framed structures and bridges with 90 papers in Volume II dealing with plates shells analysis optimization and computer applications dynamics and seismic design fatigue and soil structure interaction **Advances in Steel Structures** S.L. Chan,J.G. Teng,1996-12-06 Volumes and section headings Volume I Keynote Papers Beams and Columns Frames and Trusses Space Structures Connections Composite Construction Bridges Design and Construction Volume II Keynote Papers Plates Shells Analysis Optimization and Computer Applications Dynamics and Seismic Design Fatigue Soil Structure Interaction *Analysis and Design of Geotechnical Structures* Manuel Matos Fernandes,2020-08-27 Analysis and design of geotechnical structures combines in a single endeavor a textbook to assist students in understanding the behavior of the main geotechnical works and a guide for practising geotechnical engineers designers and consultants The subjects are treated in line with limit state design which underpins the Eurocodes and most North America design codes Instructors and students will value innovative approaches to numerous issues refined by the experience of the author in teaching generations of enthusiastic students Professionals will gain from its comprehensive treatment of the topics covered in each chapter supplemented by a plethora of informative material used by consultants and designers For the benefit of both academics and professionals conceptual exercises and practical geotechnical design problems are proposed at the end of most chapters A final annex includes detailed resolutions of the exercises and problems **Highway Vehicle-bridge Coupled Vibrations: Numerical Simulations And Applications** Steve C S Cai,Deng Lu,2020-09-23 Vehicle bridge interaction happens all the time on roadway bridges and this interaction performance carries much useful information On one hand while vehicles are traditionally viewed as loads for bridges they can also be deemed as sensors for bridges structural response On the other hand while bridges are traditionally viewed as carriers for vehicle weight they can also be deemed as scales that can weigh the vehicle loads Based on these observations a broad area of studies based on the vehicle bridge interaction have been conducted in the authors research group Understanding the vehicle and bridge interaction can help develop strategies for bridge condition assessment bridge design and bridge maintenance as well as develop insight for new research needs This book documents fundamental knowledge new developments and state of the art applications related to vehicle bridge interactions It thus provides useful information for graduate students and researchers and therefore straddles the gap between theoretical research and practical applications *Design of Highway Bridges* Richard M. Barker,Jay A. Puckett,2021-03-23 The latest in bridge design and analysis revised to reflect the eighth edition of the AASHTO LRFD specifications *Design of Highway Bridges An LRFD Approach* 4th Edition offers up to date coverage of engineering fundamentals for the design of short and medium span

bridges Fully updated to incorporate the 8th Edition of the AASHTO Load and Resistance Factor Design Specifications this invaluable resource offers civil engineering students and practitioners a comprehensive introduction to the latest construction methods and materials in bridge design including Accelerated Bridge Construction ABC ultra high performance concrete UHPC and Practical 3D Rigorous Analysis This updated Fourth Edition offers Dozens of end of chapter worked problems and design examples based on the latest AASHTO LRFD Specifications Access to a Solutions Manual and multiple bridge plans including cast in place precast concrete and steel multi span available on the Instructor s companion website From gaining base knowledge of the AASHTO LRFD specifications to detailed guidance on highway bridge design Design of Highway Bridges is the one stop reference for civil engineering students and a key study resource for those seeking engineering licensure through the Principles and Practice of Engineering PE exam *Proceedings of the Canadian Society of Civil Engineering Annual Conference 2021* Scott Walbridge,Mazdak Nik-Bakht,Kelvin Tsun Wai Ng,Manas Shome,M. Shahria Alam,Ashraf El Damatty,Gordon Lovegrove,2022-06-16 This book comprises the proceedings of the Annual Conference of the Canadian Society of Civil Engineering 2021 The contents of this volume focus on specialty conferences in construction environmental hydrotechnical materials structures transportation engineering etc This volume will prove a valuable resource for those in academia and industry **Penetrability and Drivability of Piles** ,1986 **Sustainability Issues for the Deep Foundations** Hesham El-Naggar,Khalid Abdel-Rahman,Bengt Fellenius,Hany Shehata,2018-10-29 This volume presents some advances in the analysis and design of deep foundations It contains 21 technical papers covering various aspects of analysis and design of deep foundations based on full scale field testing numerical modeling and analytical solutions They present results and findings from research as well as practical oriented studies on deep foundations that are of interest to civil geotechnical engineering community The topics cover a wide spectrum of applications that include evaluation of the axial and lateral capacity of piles pile group effects evaluation of the increase in pile capacity with time or pile setup influence of excavation on pile capacity study the behavior of pile raft caisson foundations evaluation of the bearing capacity and settlement of piles from cone penetration tests etc The volume is based on the best contributions to the 2nd GeoMEast International Congress and Exhibition on Sustainable Civil Infrastructures Egypt 2018 The official international congress of the Soil Structure Interaction Group in Egypt SSIGE Soil-Steel Bridges Damian Beben,2020-03-04 The primary objective of this book is to provide designers with a set of analysis and design specifications for soil steel bridges and culverts also called flexible structures Brief but informative this guide is based on a quick look up approach to code applications design and analysis methods calculations as well as applications and solved examples The book addresses the unique aspects of soil steel bridges design and analysis as well as examples of applications numerical analysis and modeling techniques corrosion and durability problems service life and maintenance and impact of moving loads

**Bridge Evaluation, Repair and Rehabilitation** A.S. Nowak,2012-12-06 Evaluation repair and rehabilitation of bridges

are increasingly important topics in the effort to deal with the deteriorating infrastructure For example in the United States about 40 percent of the nation s 570 000 bridges are classified according to the Federal Highway Administration s FHW A criteria as deficient and in need of rehabilitation and replacement In other countries the situation is similar FHW A estimates the cost of a bridge replacement and rehabilitation program at 50 billion dollars The major factors that have contributed to the present situation are the age inadequate maintenance increasing load spectra and environmental contamination The deficient bridges are posted repaired or replaced The disposition of bridges involves clear economical and safety implications To avoid high costs of replacement or repair the evaluation must accurately reveal the present load carrying capacity of the structure and predict loads and any further changes in the capacity deterioration in the applicable time span Accuracy of bridge evaluation can be improved by using the recent developments in bridge diagnostics structural tests material tests structural analysis and probabilistic methods There is a need for an international exchange of advanced experience to increase the research efficiency The Workshop is organized on the premise that the exchange of existing American and European experience in the area of bridge evaluation repair and rehabilitation is beneficial for both parties involved

Geotechnical Related Development and Implementation of Load and Resistance Factor Design (LRFD) Methods George G. Goble,1999 This synthesis report will be of interest to geotechnical structural and bridge engineers especially those involved in the development and implementation of the geotechnical aspects of the AASHTO Bridge Code The synthesis documents a review of geotechnical related LRFD specifications and their development worldwide to compare them with the current AASHTO LRFD Bridge Code Design procedures for foundations earth retaining structures and culverts are summarized and compared with the methods specified by the AASHTO code This TRB report provides information designed to assist engineers in implementing the geotechnical features of LRFD methods Information for the synthesis was collected by surveying U S and Canadian transportation agencies and by conducting a literature search using domestic and international sources Interviews were also conducted with selected international experts The limited available experience in the United States and information from international practice are discussed to understand the problems that have arisen in order that solutions may be found Based on the studies reported here suggestions for improving the code are identified

**Civil Engineering for Disaster Risk Reduction** Sreevalsa Kolathayar,Indrajit Pal,Siau Chen Chian,Arpita Mondal,2021-11-21 The book is a comprehensive volume on multi hazards and their management for a sustainable built environment It focuses on the role of civil engineering in building disaster resilient society This book brings together all diverse disciplines of civil engineering and related areas for example geotechnical engineering water resources engineering structural engineering transportation engineering environmental engineering construction management GIS and remote sensing towards a common goal of disaster resilience through an interdisciplinary approach It contains methods and case studies focusing on civil engineering solutions to reduce the disaster risk The book contents are aligned in line with the

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