CSA GROUP™

CSA A23.3:19
National Standard of Canada

Design of concrete structures

Standards Council of Canada
Conseil canadien des normes

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.

Standards Update Service

CSA A23.3:19
June 2019

Title: *Design of concrete structures*

To register for e-mail notification about any updates to this publication
- go to **store.csagroup.org**
- click on **CSA Update Service**

The **List ID** that you will need to register for updates to this publication is **2427169**.

If you require assistance, please e-mail **techsupport@csagroup.org** or call 416-747-2233.

Visit CSA Group's policy on privacy at **www.csagroup.org/legal** to find out how we protect your personal information.

Canadian Standards Association (operating as "CSA Group"), under whose auspices this National Standard has been produced, was chartered in 1919 and accredited by the Standards Council of Canada to the National Standards system in 1973. It is a not-for-profit, nonstatutory, voluntary membership association engaged in standards development and certification activities.

CSA Group standards reflect a national consensus of producers and users — including manufacturers, consumers, retailers, unions and professional organizations, and governmental agencies. The standards are used widely by industry and commerce and often adopted by municipal, provincial, and federal governments in their regulations, particularly in the fields of health, safety, building and construction, and the environment.

Individuals, companies, and associations across Canada indicate their support for CSA Group's standards development by volunteering their time and skills to Committee work and supporting CSA Group's objectives through sustaining memberships. The more than 7000 committee volunteers and the 2000 sustaining memberships together form CSA Group's total membership from which its Directors are chosen. Sustaining memberships represent a major source of income for CSA Group's standards development activities.

CSA Group offers certification and testing services in support of and as an extension to its standards development activities. To ensure the integrity of its certification process, CSA Group regularly and continually audits and inspects products that bear the CSA Group Mark.

In addition to its head office and laboratory complex in Toronto, CSA Group has regional branch offices in major centres across Canada and inspection and testing agencies in eight countries. Since 1919, CSA Group has developed the necessary expertise to meet its corporate mission: CSA Group is an independent service organization whose mission is to provide an open and effective forum for activities facilitating the exchange of goods and services through the use of standards, certification and related services to meet national and international needs.

For further information on CSA Group services, write to
CSA Group
178 Rexdale Boulevard
Toronto, Ontario, M9W 1R3
Canada

A National Standard of Canada is a standard developed by a Standards Council of Canada (SCC) accredited Standards Development Organization, in compliance with requirements and guidance set out by SCC. More information on National Standards of Canada can be found at www.scc.ca.

SCC is a Crown corporation within the portfolio of Innovation, Science and Economic Development (ISED) Canada. With the goal of enhancing Canada's economic competitiveness and social well-being, SCC leads and facilitates the development and use of national and international standards. SCC also coordinates Canadian participation in standards development, and identifies strategies to advance Canadian standardization efforts.

Accreditation services are provided by SCC to various customers, including product certifiers, testing laboratories, and standards development organizations. A list of SCC programs and accredited bodies is publicly available at www.scc.ca.

Standards Council of Canada
600-55 Metcalfe Street
Ottawa, Ontario, K1P 6L5
Canada

Standards Council of Canada
Conseil canadien des normes

Cette Norme Nationale du Canada est disponible en versions française et anglaise.

National Standard of Canada

CSA A23.3:19
Design of concrete structures

Published in June 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***
or call toll-free 1-800-463-6727 or 416-747-4044.

ICS 91.080.40
ISBN 978-1-4883-2168-9

Contents

Technical Committee on Reinforced Concrete Design 13

Preface 16

1 Scope 17
1.1 General 17
1.2 Fire resistance 17
1.3 Alternative design procedures 17
1.4 Shells and folded plates 17
1.5 Terminology 17
1.6 Units of measurement 18

2 Reference publications 18

3 Definitions and symbols 20
3.1 Definitions 20
3.2 Symbols 27
3.3 Standard notation and calculations 39
3.3.1 Standard notation for loads and resistances 39
3.3.2 Standard notation for reinforcing bars 40
3.3.3 Bar diameter for calculations 40

4 General requirements 40
4.1 Materials — Reinforcement 40
4.2 Concrete and other materials 40
4.3 Concrete quality, mixing, and placement 41
4.3.1 Quality 41
4.3.2 Mixing and placement 41

5 Drawings and related documents 41

6 Formwork, falsework, embedded pipes, and construction joints 41
6.1 General 41
6.2 Embedded pipes and openings 42
6.3 Construction joints 42

7 Details of reinforcement 42
7.1 Hooks, bends, and headed bars 42
7.1.1 General 42
7.1.2 Stirrups and ties 42
7.1.3 Crossties 42
7.1.4 Headed bars and studs 42
7.2 Placing of reinforcement 42
7.2.1 General 42
7.2.2 Draped fabric 43
7.3 Tolerances 43
7.4 Spacing of reinforcement and tendons 43

7.4.1 Bars *43*
7.4.2 Bundled bars *43*
7.4.3 Pretensioning tendons *44*
7.4.4 Post-tensioning tendons *44*
7.5 Special details for columns and walls *44*
7.5.1 Offset bars *44*
7.5.2 Splices and load transfer in metal cores *44*
7.6 Transverse reinforcement *44*
7.6.1 General *44*
7.6.2 Composite columns *45*
7.6.3 Prestressing tendons *45*
7.6.4 Spirals for compression members *45*
7.6.5 Ties for compression members *45*
7.6.6 Beams and girders — Transverse reinforcement *46*
7.7 Special details for beam-column connections *46*
7.8 Minimum reinforcement in slabs *47*
7.9 Concrete protection for reinforcement *47*

8 Design — Limit states, load combinations, and material properties *47*
8.1 Limit states *47*
8.1.1 Durability *47*
8.1.2 Fire resistance *48*
8.1.3 Ultimate limit states *48*
8.1.4 Serviceability limit states *48*
8.1.5 Structural integrity *48*
8.2 Loading *48*
8.2.1 General *48*
8.2.2 Imposed deformations *49*
8.2.3 Prestress *49*
8.3 Load combinations and load factors *49*
8.3.1 General *49*
8.3.2 Load combinations for ultimate limit states *49*
8.3.3 Load combinations for serviceability limit states *49*
8.4 Factored resistance *49*
8.4.1 General *50*
8.4.2 Factored concrete strength *50*
8.4.3 Factored reinforcement and tendon force *50*
8.5 Reinforcement and tendon properties for design *50*
8.5.1 Design strength for reinforcement *50*
8.5.2 Compression reinforcement *50*
8.5.3 Stress-strain curve for reinforcement *50*
8.5.4 Modulus of elasticity of reinforcement *51*
8.5.5 Coefficient of thermal expansion of reinforcement *51*
8.6 Concrete properties for design *51*
8.6.1 Design strength of concrete *51*
8.6.2 Modulus of elasticity *51*
8.6.3 Concrete stress-strain relationship *52*
8.6.4 Modulus of rupture of concrete *52*
8.6.5 Modification factors for concrete density *52*

8.6.6 Coefficient of thermal expansion of concrete *52*

9 Structural analysis and computation of deflections *53*
9.1 Methods of analysis *53*
9.2 Elastic frame analysis *53*
9.2.1 Stiffness *53*
9.2.2 Span length *53*
9.2.3 Arrangement of loads *54*
9.2.4 Redistribution of moments in continuous flexural members *54*
9.3 Approximate frame analysis *54*
9.3.1 General *54*
9.3.2 Floor and roof loads *54*
9.3.3 Moment and shear coefficients *54*
9.4 Analysis by strut-and-tie models *55*
9.5 Finite element analysis *55*
9.6 Elastic plate analysis *56*
9.7 Plastic analysis *56*
9.8 Control of deflections *56*
9.8.1 General *56*
9.8.2 One-way construction (non-prestressed) *57*
9.8.3 Two-way construction (non-prestressed) *59*
9.8.4 Prestressed concrete construction *59*
9.8.5 Composite construction *59*

10 Flexure and axial loads *60*
10.1 General principles *60*
10.1.1 General *60*
10.1.2 Plane sections assumption *61*
10.1.3 Maximum concrete strain *61*
10.1.4 Balanced strain conditions *61*
10.1.5 Tensile strength of concrete *61*
10.1.6 Concrete stress-strain relationship *61*
10.1.7 Equivalent rectangular concrete stress distribution *61*
10.2 Flexural members — Distance between lateral supports *61*
10.3 Flexural members — T-beams *62*
10.4 Flexural members — Joist construction *62*
10.5 Flexural members — Reinforcement *63*
10.5.1 Minimum reinforcement *63*
10.5.2 Limit of c/d for flexural ductility *63*
10.5.3 Reinforcement in T-beam flanges *63*
10.6 Beams and one-way slabs — Crack control *64*
10.6.1 Crack control parameter *64*
10.6.2 Skin reinforcement *64*
10.7 Deep flexural members *64*
10.8 Design of bearing zones *65*
10.9 Compression members — Reinforcement limits *65*
10.10 Compression members — Resistance *65*
10.11 Columns — Design dimensions *66*
10.11.1 Equivalent circular column *66*

10.11.2 Column built monolithically with wall *66*
10.11.3 Isolated column with interlocking spirals *66*
10.12 Columns — Transmission of loads through floor system *67*
10.13 Slenderness effects — General *67*
10.14 Member properties for computation of slenderness effects *67*
10.14.1 General *67*
10.14.2 Radius of gyration *68*
10.14.3 Unsupported length of compression members *68*
10.14.4 Designation as non-sway *68*
10.14.5 Columns in non-sway frames or storeys *69*
10.14.6 Columns in sway frames or storeys *69*
10.15 Slenderness effects — Non-sway frames *69*
10.15.1 Effective length factor *69*
10.15.2 Non-sway frames *69*
10.15.3 Member stability effect *69*
10.16 Slenderness effects — Sway frames *70*
10.16.1 Effective length factor *70*
10.16.2 End moments *70*
10.16.3 Calculation of $\delta_s M_s$ *71*
10.16.4 Slenderness limit *71*
10.16.5 Strength and stability checks *71*
10.16.6 Moment magnification for flexural members *72*
10.17 Composite columns — General *72*
10.18 Composite column with spiral reinforcement *73*
10.19 Composite column with tie reinforcement *73*

11 Shear and torsion *74*
11.1 General *74*
11.1.1 Flexural regions *74*
11.1.2 Regions near discontinuities *74*
11.1.3 Interface regions *74*
11.1.4 Slabs and footings *74*
11.1.5 Alternative methods *74*
11.2 Design requirements *74*
11.2.1 Tension due to restraint *74*
11.2.2 Variable depth members *74*
11.2.3 Openings *75*
11.2.4 Types of shear reinforcement *75*
11.2.5 Anchorage of shear reinforcement *75*
11.2.6 Types of torsion reinforcement *75*
11.2.7 Anchorage of torsion reinforcement *75*
11.2.8 Minimum shear reinforcement *75*
11.2.9 Consideration of torsion *76*
11.2.10 Effective web width *77*
11.2.11 Reduced prestress in transfer length *77*
11.2.12 Hanger reinforcement for beams supporting other beams *77*
11.2.13 Termination of longitudinal reinforcement in flexural tension zones *78*
11.3 Design for shear and torsion in flexural regions *79*
11.3.1 Required shear resistance *79*

11.3.2 Sections near supports *79*
11.3.3 Factored shear resistance *79*
11.3.4 Determination of V_c *79*
11.3.5 Determination of V_s *79*
11.3.6 Determination of β and θ *80*
11.3.7 Proportioning of transverse reinforcement *82*
11.3.8 Maximum spacing of transverse reinforcement *82*
11.3.9 Proportioning of longitudinal reinforcement *82*
11.3.10 Sections subjected to combined shear and torsion *83*
11.4 Strut-and-tie model *84*
11.4.1 Structural idealization *84*
11.4.2 Proportioning of strut *86*
11.4.3 Proportioning of ties *88*
11.4.4 Proportioning of node regions *89*
11.4.5 Crack control reinforcement *89*
11.5 Interface shear transfer *89*
11.5.1 General *89*
11.5.2 Values of c and μ *90*
11.5.3 Alternative equation for shear stress resistance *90*
11.5.4 Values of σ and ρ_v *90*
11.5.5 Inclined shear friction reinforcement *91*
11.5.6 Anchorage of shear friction reinforcement *91*
11.6 Special provisions for brackets and corbels *91*
11.7 Shear in joints *91*

12 Development and splices of reinforcement *92*
12.1 Development of reinforcement — General *92*
12.2 Development of deformed bars and deformed wire in tension *92*
12.2.1 Minimum development length *92*
12.2.2 General development length equation *92*
12.2.3 Simplified development length equations *92*
12.2.4 Modification factors *93*
12.2.5 Excess reinforcement *93*
12.3 Development of deformed bars in compression *93*
12.3.1 Development length *93*
12.3.2 Basic development length *93*
12.3.3 Modification factors *93*
12.4 Development of bundled bars *94*
12.5 Development of standard hooks in tension *94*
12.5.1 Tension development length *94*
12.5.2 Basic development length *94*
12.5.3 Factors modifying hook development length *94*
12.5.4 Confinement of hooks *94*
12.5.5 Development of bars in compression *94*
12.6 Mechanical anchorage *95*
12.7 Development of welded deformed wire fabric in tension *95*
12.8 Development of welded smooth wire fabric in tension *95*
12.9 Development of pretensioned strand *96*
12.10 Development of flexural reinforcement — General *96*

12.11 Development of positive moment reinforcement *97*
12.12 Development of negative moment reinforcement *97*
12.13 Anchorage of shear reinforcement *97*
12.14 Splices of reinforcement — General *98*
12.14.1 Limitations on use *98*
12.14.2 Lap splices *98*
12.14.3 Welded splices and mechanical connections *99*
12.15 Splices of deformed bars and deformed wire in tension *99*
12.16 Splices of deformed bars in compression *100*
12.16.1 Minimum lap length *100*
12.16.2 Lap length for bars of different sizes *100*
12.16.3 Welded splices or mechanical connections *100*
12.16.4 End-bearing splices *100*
12.17 Special splice requirements for columns *101*
12.17.1 General *101*
12.17.2 Reinforcement *101*
12.17.3 Lap splices in columns *101*
12.17.4 Welded splices or mechanical connections in columns *101*
12.17.5 End-bearing splices in columns *102*
12.18 Splices of welded deformed wire fabric in tension *102*
12.19 Splices of welded smooth wire fabric in tension *102*

13 Two-way slab systems *102*
13.1 General *102*
13.2 Minimum slab thickness *103*
13.2.1 General *103*
13.2.2 Two-way slab systems *103*
13.2.3 Slabs without drop panels *103*
13.2.4 Slabs with drop panels *103*
13.2.5 Slabs with beams between all supports *104*
13.2.6 Slab bands *104*
13.2.7 Computation of slab deflections *104*
13.3 Design procedures for shear for slabs without beams *104*
13.3.1 General *104*
13.3.2 One-way and two-way shear *104*
13.3.3 Critical shear section for two-way action *105*
13.3.4 Maximum shear stress resistance without shear reinforcement *105*
13.3.5 Factored shear stress *106*
13.3.6 Alternative analysis for corner columns *107*
13.3.7 Shear reinforcement for two-way slabs without beams *107*
13.3.8 Headed shear reinforcement *108*
13.3.9 Stirrup reinforcement *109*
13.4 Shear in slab systems with beams *109*
13.5 Design procedures for flexure *109*
13.6 Elastic plate theory *110*
13.7 Theorems of plasticity *111*
13.8 Slab systems as elastic frames *111*
13.8.1 Definition of frame geometry *111*
13.8.2 Non-prismatic modelling of member stiffness *112*

13.8.3 Prismatic modelling of member stiffness *113*
13.8.4 Arrangement of live load *114*
13.8.5 Critical sections *114*
13.9 Direct design method *115*
13.9.1 Limitations *115*
13.9.2 Total factored static moment for a span *115*
13.9.3 Negative and positive factored moments *116*
13.9.4 Unbalanced factored moments in columns and walls *117*
13.9.5 Selection of reinforcement *117*
13.10 Slab reinforcement *117*
13.10.1 General *117*
13.10.2 Shear and moment transfer *117*
13.10.3 Exterior columns *117*
13.10.4 Spacing *117*
13.10.5 Anchorage *118*
13.10.6 Structural integrity reinforcement *118*
13.10.7 Effective depth at drop panels *119*
13.10.8 Curtailment of reinforcement *119*
13.10.9 Top reinforcement at slab edges *120*
13.10.10 Openings *121*
13.11 Lateral distribution of moments for slabs without interior beams *121*
13.11.1 General *121*
13.11.2 Factored moments in column strip *121*
13.11.3 Factored moments in middle strips *122*
13.12 Reinforcement for slabs with beams between all supports *123*
13.12.1 General *123*
13.12.2 Factored moments in beams *123*
13.12.3 Slab reinforcement for positive moment *123*
13.12.4 Slab reinforcement for negative moment *123*
13.12.5 Corner reinforcement *124*

14 Walls *124*
14.1 General requirements for all walls *124*
14.1.1 Application *124*
14.1.2 Lateral support of walls *124*
14.1.3 Design length of wall for the distribution of concentrated vertical loads *124*
14.1.4 Columns built integrally with walls *125*
14.1.5 Transfer of vertical wall loads through floor *125*
14.1.6 Transfer of horizontal wall forces across construction joints *125*
14.1.7 Minimum thickness of walls *125*
14.1.8 Details of wall reinforcement *126*
14.1.9 Opening in walls *127*
14.2 Structural design of bearing walls *127*
14.2.1 General *127*
14.2.2 Bearing walls designed under Clause 14 *128*
14.3 Structural design of non-bearing walls *128*
14.4 Structural design of shear walls *128*
14.4.1 General *128*
14.4.2 Design of flexural shear walls *128*

14.4.3 Design of squat shear walls *129*
14.4.4 Assemblies of interconnected shear walls *130*
14.4.5 Horizontal reinforcement in shear walls *130*
14.4.6 Weak axis bending *130*

15 Foundations *130*
15.1 General *130*
15.2 Loads and reactions *130*
15.3 Footings and pile caps supporting circular or regular polygonal columns or pedestals *131*
15.4 Flexural design of footings *131*
15.5 Shear design of footings and pile caps *132*
15.6 Development of reinforcement in footings and pile caps *132*
15.7 Minimum depth of footings *133*
15.8 Piles *133*
15.8.1 Design of piles *133*
15.8.2 Special requirements for piles *133*
15.8.3 Minimum depth of pile caps *133*
15.9 Transfer of force at base of column, pile cap, wall, or pedestal *133*
15.9.1 General *133*
15.9.2 Cast-in-place construction *134*
15.9.3 Precast concrete construction *134*
15.10 Sloped or stepped footings *135*
15.11 Combined footings and mats *135*
15.12 Plain concrete footings and deep foundations *135*

16 Precast concrete *135*
16.1 General *135*
16.2 Prequalification of manufacturer *136*
16.3 Drawings *136*
16.4 Design *136*
16.4.1 General *136*
16.4.2 Distribution of forces among elements *137*
16.4.3 Reinforcement of precast concrete elements *137*
16.4.4 Joints and connections *137*
16.4.5 Bearing *138*
16.5 Structural integrity *138*

17 Composite concrete flexural members *140*
17.1 General *140*
17.2 Shoring *141*
17.3 Transverse shear resistance *141*
17.4 Longitudinal shear resistance *141*
17.5 Ties for longitudinal shear *142*

18 Prestressed concrete *143*
18.1 General *143*
18.2 Design assumptions for flexure and axial load *144*
18.3 Permissible stresses in concrete flexural members *144*
18.4 Permissible stresses in tendons *145*

18.5 Loss of prestress *146*
18.6 Flexural resistance *146*
18.7 Minimum factored flexural resistance *147*
18.8 Minimum bonded reinforcement *147*
18.9 Minimum length of bonded reinforcement *148*
18.10 Frames and continuous construction *148*
18.11 Compression members — Combined flexure and axial loads *148*
18.11.1 General *148*
18.11.2 Limits for reinforcement of prestressed compression members *149*
18.12 Two-way slab systems *149*
18.12.1 General *149*
18.12.2 Stresses under specified loads *149*
18.12.3 Shear resistance *149*
18.12.4 Shear and moment transfer *150*
18.12.5 Minimum bonded non-prestressed reinforcement *150*
18.12.6 Spacing of tendons *150*
18.13 Tendon anchorage zones *151*

19 Structural diaphragms *151*
19.1 General *151*
19.2 Design forces *151*
19.3 Analysis and design of structural diaphragms *152*
19.4 Diaphragm systems *152*
19.5 Reinforcement *152*
19.6 Monolithic concrete systems *153*
19.6.4 Reinforcement splices *153*
19.7 Precast systems *153*
19.8 Composite systems *154*
19.9 Construction joints *154*

20 Strength evaluation procedures *155*
20.1 General *155*
20.2 Analytical investigation *155*
20.3 Load tests *155*
20.3.1 General *155*
20.3.2 Load tests of flexural systems or members for moment resistance *157*

21 Special provisions for seismic design *157*
21.1 Scope *157*
21.2 General *158*
21.2.1 Capacity design *158*
21.2.2 Seismic-force-resisting systems *158*
21.2.3 Design based on nonlinear dynamic analysis *158*
21.2.4 Applicable clauses *159*
21.2.5 Analysis and proportioning of structural members *159*
21.2.6 Concrete in members resisting earthquake-induced forces *160*
21.2.7 Reinforcement in members resisting earthquake-induced forces *160*
21.2.8 Special ties for compression members *161*
21.3 Ductile moment-resisting frames (R_d = 4.0) *162*

21.3.1 Ductile moment-resisting frame members subjected to predominant flexure *162*
21.3.2 Ductile moment-resisting frame members subjected to flexure and significant axial load *164*
21.3.3 Joints of ductile moment-resisting frames *167*
21.4 Moderately ductile moment-resisting frames (R_d = 2.5) *169*
21.4.1 General *169*
21.4.2 Dimensional limitations *169*
21.4.3 Detailing of beams *170*
21.4.4 Detailing of columns *170*
21.4.5 Shear in frames *171*
21.4.6 Joints in frames *171*
21.5 Ductile and moderately ductile shear walls (R_d = 2.0, 2.5, 3.5, or 4.0) *172*
21.5.1 General *172*
21.5.2 Requirements for strength and ductility over height *173*
21.5.3 Minimum wall thickness *176*
21.5.4 Reinforcement *176*
21.5.5 Distributed reinforcement *177*
21.5.6 Concentrated vertical reinforcement *178*
21.5.7 Ductility of walls *179*
21.5.8 Additional requirements for coupled shear walls (R_d = 2.5 or 4.0) and partially coupled shear walls (R_d = 2.0 or 3.5) *180*
21.5.9 Shear resistance of flexural shear walls *184*
21.5.10 Moderately ductile squat shear walls (R_d = 2.0) *186*
21.6 Conventional construction (R_d = 1.3 or 1.5) *187*
21.6.1 General *187*
21.6.2 Moment-resisting frames (R_d = 1.5) *187*
21.6.3 Shear walls (R_d = 1.5) *188*
21.6.4 Two-way slabs without beams (R_d = 1.3) *190*
21.7 Tilt-up construction (R_d = 1.5 or 2.0) *191*
21.7.1 General *191*
21.7.2 Seismic force demands *192*
21.7.3 Design requirements *193*
21.7.4 Design of tilt-up frames *194*
21.7.5 Additional requirements for moderately ductile wall panels (R_d = 2.0) *195*
21.8 Precast concrete *196*
21.8.1 General *196*
21.8.2 Ductile moment-resisting frames constructed using precast concrete (R_d = 4.0) *196*
21.8.3 Ductile shear walls constructed using precast concrete (R_d = 3.5 or 4.0) *197*
21.8.4 Moderately ductile shear walls constructed using precast concrete (R_d = 2.0) *197*
21.9 Structural diaphragms (R_d > 1.5) *197*
21.9.1 General *197*
21.9.2 Design forces *197*
21.9.3 Concrete compression forces *197*
21.9.4 Reinforcement splices *197*
21.9.5 Minimum reinforcement *198*
21.9.6 Precast and composite systems *198*
21.10 Foundations (R_d > 1.0) *198*
21.10.1 General *198*
21.10.2 Design of foundations restrained against rotation *198*
21.10.3 Design of foundations — General method *199*

21.10.4 Footings, foundation mats, and pile caps *202*
21.10.5 Grade beams and slabs on grade *202*
21.10.6 Piles *203*
21.11 Members not considered part of the seismic-force-resisting system (R_d = 1.5, 2.0, 2.5, 3.5, or 4.0) *204*
21.11.1 General *204*
21.11.2 Seismic demands *204*
21.11.3 Design of members in gravity-load resisting frames *206*
21.11.4 Design of slab-column connections for seismic drift demands *209*

22 Plain concrete *210*
22.1 General *210*
22.2 Control joints *210*
22.3 Design *211*
22.4 Walls *211*
22.5 Pedestals *212*
22.6 Footings *212*
22.6.1 Base area of footing *212*
22.6.2 Minimum thickness *212*
22.6.3 Minimum thickness for calculations *212*
22.6.4 Critical sections *213*
22.6.5 Strength in bending *213*
22.6.6 Shear resistance *213*
22.7 Slabs on grade *214*
22.8 Drilled piles *214*

23 Tilt-up wall panels *215*
23.1 General *215*
23.2 Design requirements *215*
23.2.1 Effective panel height *215*
23.2.2 Minimum panel thickness *215*
23.2.3 Maximum height-to-thickness ratio *215*
23.2.4 Minimum reinforcement *215*
23.2.5 Concrete cover and tolerances *215*
23.2.6 Thermal effects *216*
23.2.7 Sandwich panels *216*
23.2.8 Connections *216*
23.2.9 Structural integrity *216*
23.2.10 Effective reinforcement *216*
23.3 Analysis and design *217*
23.3.1 Flexure and axial load interaction and slenderness effects *217*
23.3.2 Deflection limitations *218*
23.4 Effects of openings *218*
23.4.1 Design width *218*
23.4.2 Tributary width *219*
23.4.3 Ratio of tributary width to design width *219*
23.5 Concentrated loads or reactions *219*
23.5.1 Design width *219*
23.5.2 Bearing *221*

23.5.3 Lateral and vertical components *221*
23.5.4 Tributary width for vertical and lateral loads *221*
23.5.5 Concentrated loads or reactions *221*
23.6 Shear *221*
23.6.1 In-plane shear *221*
23.6.2 Out-of-plane shear *221*
23.7 Lifting stresses *221*
23.7.1 General *221*
23.7.2 Elastic — Uncracked analysis *221*

Annex A (informative) — Excerpts from CSA A23.1:19, Concrete materials and methods of concrete construction *222*
Annex B (informative) — Rectangular two-way slab systems with stiff supports on four sides *235*
Annex C (informative) — Load combinations and load factors in the National Building Code of Canada, 2020 *241*
Annex D (normative) — Anchorage *246*
Annex E (normative) — Shells and folded plates *293*

Technical Committee on Reinforced Concrete Design

R.J. McGrath	Cement Association of Canada (CAC), Ottawa, Ontario, Canada *Category: Producer Interest*	*Chair*
P. Adebar	University of British Columbia, Vancouver, British Columbia, Canada *Category: General Interest*	*Vice-Chair*
Hélène Dutrisac	University of Ottawa, Ottawa, Ontario, Canada	*Committee Secretary/ Non-voting*
S.D. Alexander	COWI North America, Ltd., Edmonton, Alberta, Canada *Category: User Interest*	
C.M. Allen	Adjeleian Allen Rubeli Limited, Ottawa, Ontario, Canada *Category: User Interest*	
A. Attar	National Research Council of Canada, Ottawa, Ontario, Canada *Category: Regulatory Authority*	
F.M. Bartlett	University of Western Ontario, London, Ontario, Canada *Category: General Interest*	
E. Buzimkic	Rebar Enterprises Inc., Oakville, Ontario, Canada *Category: Producer Interest*	
M.P. Collins	University of Toronto, Toronto, Ontario, Canada *Category: General Interest*	
M.P. Comeau	Campbell Comeau Engineering Limited, Halifax, Nova Scotia, Canada *Category: User Interest*	

R. DeVall	Read Jones Christoffersen Limited, Vancouver, British Columbia, Canada	*Non-voting*
R. Dozzi	Canadian BBR Inc., Scarborough, Ontario, Canada	*Non-voting*
W. Kassian	Kassian Dyck & Associates, Calgary, Alberta, Canada *Category: Producer Interest*	
T. Kokai	Read Jones Christoffersen Ltd., Toronto, Ontario, Canada *Category: User Interest*	
G. Krsmanovic	City of Toronto, Toronto, Ontario, Canada *Category: Regulatory Authority*	
K.L. Lemieux	Weiler Smith Bowers Consultants, Burnaby, British Columbia, Canada *Category: Producer Interest*	
A. Lubell	Read Jones Christoffersen Limited, Vancouver, British Columbia, Canada	*Non-voting*
K. MacLean	Read Jones Christoffersen Ltd., Toronto, Ontario, Canada	*Non-voting*
D. Mitchell	McGill University, Montréal, Québec, Canada *Category: General Interest*	
J.G. Mutrie	J.G. Mutrie & Associates, Lions Bay, British Columbia, Canada	*Non-voting*
P. Paultre	Université de Sherbrooke, Sherbrooke, Québec, Canada *Category: General Interest*	
M. Razavi	Dialog Design, Vancouver, British Columbia, Canada *Category: User Interest*	

D.M. Rogowsky	Rogowsky Engineering Ltd., Edmonton, Alberta, Canada *Category: User Interest*	
K. Truderung	Tower Engineering Group, Winnipeg, Manitoba, Canada *Category: Producer Interest*	
S. Vézina	Groupe SMi, Montréal, Québec, Canada *Category: User Interest*	
L. Jula Zadeh	CSA Group, Toronto, Ontario, Canada	*Project Manager*

Preface

This is the seventh edition of CSA A23.3, *Design of concrete structures.* It supersedes the previous editions published in 2014, 2004, 1994, 1984, 1977 (metric), and 1973 (imperial), and 1959.

This Standard is intended for use in the design of concrete structures for buildings in conjunction with CSA A23.1/A23.2, *Concrete materials and methods of concrete construction/Methods of test and standard practices for concrete,* and CSA A23.4, *Precast concrete — Materials and construction*.

Changes in this edition include the following:

- Some definitions have been updated.
- Additional information on cover for fire resistance has been provided in Clauses 7 and 8.
- Clause 10 on flexural ductility and slenderness effects has been updated.
- Clause 11 on the Simplified and General method for shear design has been updated.
- A new clause has been added to address punching shear around circular supports or reaction area.
- Clause 14 on walls has been updated.
- A new Clause 19 on structural diaphragms has been added. The previous Clause 19 on shells and folded plates has been moved to mandatory Annex E.
- Numerous updates have been added to Clause 21.
- Annex D is now a mandatory part of the Standard.

This Standard was prepared by the Technical Committee on Reinforced Concrete Design, under the jurisdiction of the Strategic Steering Committee on Construction and Civil Infrastructure, and has been formally approved by the Technical Committee.

This Standard has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

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 Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*
3) *This Standard 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 Standard.*
4) *To submit a request for interpretation of this Standard, please send the following information to 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.*
5) *This Standard 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 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.*

CSA A23.3:19
Design of concrete structures

1 Scope

1.1 General

This Standard specifies requirements, in accordance with the *National Building Code of Canada,* for the design and strength evaluation of

a) structures of reinforced and prestressed concrete; and
b) plain concrete elements.

Notes:

1) *For structures such as blast-resistant structures, tanks, reservoirs, swimming pools, bins, silos, towers, and chimneys, users of this Standard should also refer to applicable codes, standards, or guidelines for additional requirements*
2) *Special requirements for parking structures are specified in CSA S413.*

1.2 Fire resistance

This Standard requires designs to be carried out in accordance with the fire resistance requirements of the applicable building code (see Clause 8.1.2).

Note: *Information on the fire resistance of concrete elements can be found in Appendix D of the* National Building Code of Canada*.*

1.3 Alternative design procedures

Designs that use procedures that are not covered by this Standard but are carried out by a person qualified in the methods applied and provide a level of safety and performance equivalent to designs complying with this Standard are acceptable if carried out by one of the following methods:

a) analysis based on generally established theory;
b) evaluation of a full-scale structure or a prototype by a loading test; or
c) studies of model analogues.

1.4 Shells and folded plates

Design requirements for shells and folded plates can be found in Annex E.

1.5 Terminology

In this Standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the Standard; “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 Standard.

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.

