S304-14
(reaffirmed 2019)

Design of masonry structures

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 printed 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 thereof, 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.

Update No. 1
S304-14
February 2015

Note: *For information about the **Standards Update Service**, go to **shop.csa.ca** or e-mail **techsupport@csagroup.org**.*

Title: *Design of masonry structures* — originally published August 2014

The following revisions have been formally approved and are marked by the symbol delta (Δ) in the margin on the attached replacement pages:

Revised	Clause 7.10.3
New	None
Deleted	None

- Update your copy by inserting these revised pages.
- Keep the pages you remove for reference.

v_m = shear strength attributed to the masonry, given in Clause 7.10.2.3, MPa

d_v = effective depth for shear calculations, which need not be taken as less than $0.8\ell_w$ for walls, mm

γ_g = factor to account for partially grouted or ungrouted walls that are constructed of hollow or semi-solid units as follows:

(a) equal to 1 for fully grouted masonry, fully solid concrete block masonry, or solid brick masonry; or

(b) equal to A_e/A_g, but not greater than 0.5, for other types of masonry

A_g = gross cross-sectional area, mm^2

P_d = axial compressive load on the section under consideration, based on 0.9 times dead load including any axial load arising from bending in coupling beams, N

7.10.2.2 Low-aspect-ratio (squat) shear walls

The upper limit on the factored shear resistance of low-aspect-ratio walls ($h_w/\ell_w < 1$) is greater than that given in Clause 7.10.2.1; however, care shall be taken that the shear input to the wall is distributed along the entire length of the wall and will not lead to failure of a portion of the wall. If such care is taken, then the maximum factored shear resistance may be increased to

$$0.4\phi_m\sqrt{f'_m}\,b_w d_v \gamma_g \left[2-\left(h_w/\ell_w\right)\right]$$

where

h_w = total wall height, mm

ℓ_w = wall length, mm

h_w/ℓ_w = shall be taken as not less than 0.5 nor more than 1

7.10.2.3 Masonry shear strength

Shear strength contributed by masonry, v_m, shall be as given by

$$v_m = 0.16\left(2-\frac{M_f}{V_f d_v}\right)\sqrt{f'_m}$$

where

M_f = factored moment at the section under consideration

V_f = factored shear at the section under consideration

$\frac{M_f}{V_f d_v}$ = shall be taken as not less than 0.25 nor more than 1

Δ

7.10.3 Factored out-of-plane shear resistance for walls and columns

The factored out-of-plane shear resistance, V_r, shall be taken as

$$V_r = \phi_m\left[0.16\sqrt{f'_m}A_e + 0.25P_d\right]$$

but not greater than

$$0.4\phi_m\sqrt{f'_m}\,A_e$$

Note: *The effective cross-sectional area, A_e, is defined in Clause 7.3.*

7.10.4 Stack pattern factored shear resistance

The maximum factored vertical in-plane shear resistance in stack pattern walls shall not exceed that corresponding to the shear friction resistance of the continuous horizontal reinforcing used to tie the wall together at the continuous head joints. Such reinforcing shall be spaced at not more than 800 mm for bond beam reinforcing and 400 mm for wire joint reinforcing. Shear friction resistance shall be taken as

$$V_r = \phi_m \mu C_h$$

where

μ = 0.7

C_h = compressive force in the masonry acting normal to the head joint, normally taken as the factored tensile force at yield of the horizontal reinforcement that crosses the vertical joint and has been detailed to develop yield strength on both sides of the vertical joint, N

7.10.5 Factored sliding shear resistance

7.10.5.1 Factored in-plane sliding shear resistance

The factored in-plane sliding shear resistance, V_r, shall be taken as

$V_r = 0.16\phi_m\sqrt{f'_m}A_{uc} + \phi_m\mu P_1$ for shear along bed joints between courses of masonry

and

$V_r = \phi_m\mu C$ for shear along bed joint between the support and the first course of masonry

where

A_{uc} = the uncracked portion of the effective cross-sectional area of the wall that provides shear bond capacity (applied out-of-plane loads in addition to the applied in-plane loads can cause cracking of the masonry wall), mm

μ = 1.0 for a masonry-to-masonry or masonry-to-roughened concrete sliding plane

= 0.7 for a masonry-to-smooth concrete or bare steel sliding plane

C = compressive force in the masonry acting normal to the sliding plane, normally taken as P_d plus the factored tensile force at yield of the vertical dowels that are detailed to develop yield strength on both sides of the sliding plane, N

Note: *When flashings reduce the friction that resists sliding shear, the frictional coefficient would be based on the particular flashing material.*

7.10.5.2 Factored out-of-plane sliding shear resistance

The factored out-of-plane sliding shear resistance, V_r, across a horizontal section shall be calculated as follows:

$V_r = 0.16\phi_m\sqrt{f'_m}A_{uc} + \phi_m\mu P_1$ for shear along bed joints between courses of masonry

and

$V_r = \phi_m\mu C$ for shear along bed joint between the support and the first course of masonry

Note: *When flashings reduce the friction that resists sliding shear, the frictional coefficient μ would be based on the particular flashing material.*

7.11 Intersections

7.11.1 Bonded masonry intersections

Where wall intersections are bonded so that units in alternating courses of one wall are embedded at least 90 mm in the other wall, the factored vertical shear at the intersection shall not exceed the factored shear resistance of the masonry taken as

$V_r = \phi_m\left[0.16\sqrt{f'_m}A_e\right]$

Minimum horizontal reinforcement shall be provided across the vertical intersection. This reinforcement shall be equivalent in area to at least two 3.65 mm diameter steel wires spaced 400 mm vertically.

Note: *For hollow and partially grouted masonry construction, A_e in the above equation may be taken as the effective mortared area of the bed joint. For fully grouted walls, A_e in the above equation may be taken as the gross cross-sectional area, A_g.*

Standards Update Service

S304-14
August 2014

Title: *Design of masonry structures*

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

The **List ID** that you will need to register for updates to this publication is **24231**.

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.

S304-14
Design of masonry structures

Published in August 2014 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.

ISBN 978-1-77139-577-9

Contents

Annexes

Tables

Figures

Technical Committee on Masonry Design

R. Drysdale	Drysdale Engineering & Associates Limited, Ancaster, Ontario	*Chair*
D. Stubbs	Canada Masonry Design Centre, Mississauga, Ontario	*Vice-Chair*
D. Anderson	University of British Columbia, Vancouver, British Columbia	
S. Brzev	British Columbia Institute of Technology, Burnaby, British Columbia	
J. Cowie	J.W. Cowie Engineering Limited, Halifax, Nova Scotia	*Associate*
S. Das	University of Windsor, Windsor, Ontario	*Associate*
H. Dutrisac	Cement Association of Canada, Ottawa, Ontario	
W. El-Dakhakhni	McMaster University, Hamilton, Ontario	
S. Fasullo	Davroc Testing Laboratories Inc., Brampton, Ontario	*Associate*
K. Galal	Concordia University, Montréal, Québec	*Associate*
K. Griffiths	City of Calgary, Calgary, Alberta	
M. Guzman	Canada Masonry Design Centre, Calgary, Alberta	*Associate*
J. Halucha	Hallex Engineering Ltd., Niagara Falls, Ontario	
M. Hatzinkolas	Fero Corporation, Edmonton, Alberta	
K. Ibrahim	KIB Consultants Inc., Ottawa, Ontario	
R. Jeffreys	Ontario Ministry of Labour, Toronto, Ontario	
H. Keller	Keller Engineering Associates Inc., Ottawa, Ontario	*Associate*

P. Kelly	Hanson Brick, Burlington, Ontario	
Y. Korany	University of Alberta, Edmonton, Alberta	
D. Laird	Halsall Associates Ltd., Toronto, Ontario	
G. Leblanc	GA Masonry, Breslau, Ontario	
S. Lissel	University of Calgary, Calgary, Alberta	*Associate*
Y. Liu	Dalhousie University, Halifax, Nova Scotia	
B. McEwen	Masonry Institute of British Columbia, Vancouver, British Columbia	
R. Pacholok	Building Science Engineering Ltd., St. Albert, Alberta	
M. Picco	Picco Engineering, Concord, Ontario	
S. Sarkhosh	City of Toronto, Toronto, Ontario	
T. Sherwood	Carleton University, Ottawa, Ontario	*Associate*
N. Shrive	University of Calgary, Calgary, Alberta	
B. Sparling	University of Saskatchewan, Saskatoon, Saskatchewan	*Associate*
A. Steen	Ontario Ministry of Municipal Affairs and Housing, Toronto, Ontario	
G. Sturgeon	Canadian Concrete Masonry Producers Association, Millarville, Alberta	
J. Fisher	CSA Group, Mississauga, Ontario	*Project Manager*

Preface

This is the third edition of CSA S304, *Design of masonry structures,* using limit states design principles. It supersedes the previous editions published in 2004, under the designation CSA S304.1, and 1994, under the designation CSA S304.1 and the title *Masonry Design for Buildings (Limit States Design)*. Prior to the limit states design edition in 1994, there were two working stress design editions, CSA S304-M84 and the first edition of CSA S304 issued in 1977 (imperial version) and 1978 (metric version).

Major changes have been made in this edition. The largest changes involve new and revised seismic provisions, including the creation of a separate clause (Clause 16) dedicated to this subject. Clause 16 includes requirements for new and increased seismic ductility-related force-modification factors and the related design limitations. Other new content includes clauses on anchor bolt design and arch design.

The empirical design requirements contained in Annex F have been revised and significant changes to design of dimension cut stone and manufactured stone veneer have been introduced into Annex A. Other major changes include

(a) revised reinforcement provisions for shear walls, including minimum spacing for horizontal reinforcement and continuity requirements for vertical reinforcement;
(b) new strut stiffness provisions for analysis of buildings containing infill shear walls;
(c) revised shear capacity of beams, including the introduction of both a general and a simplified method of calculating shear capacity of beams based on compression field theory;
(d) revised requirements for reinforcing at intersections between walls;
(e) revised requirements for intermediate longitudinal reinforcement in beams; and
(f) revised limit on maximum bar size allowed from 30M down to 25M.

Users of this Standard are advised that many other clauses contain minor technical and editorial changes to correct or clarify previous requirements.

The masonry industry in Canada has provided funding for the development of this Standard through the CMCA Annual Conference sponsorship.

This Standard was prepared by the Technical Committee on Masonry Design, 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 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 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.

S304-14
Design of masonry structures

1 Scope

1.1 General

This Standard specifies requirements for the structural design of unreinforced, reinforced, and prefabricated masonry structures and components in accordance with the limit states design method of the *National Building Code of Canada*. This Standard also provides requirements for the structural design of prestressed masonry beams, walls, and columns in accordance with the limit states design method of the *National Building Code of Canada*. In addition, this Standard provides requirements for the empirical design of unreinforced masonry in Annex F.

Note: *This Standard assumes that review of the structural work designed under this Standard and review of the inspection and test results required by this Standard will be carried out during construction by the designer or another suitably qualified person to determine general conformance with the design.*

1.2 Other masonry standards

Requirements for mortar and grout for unit masonry, masonry connectors, and masonry construction are specified in CSA A179, CSA A370, and CSA A371, respectively. These Standards include requirements that affect the design and are required for use with this Standard.

1.3 Vehicular bridges

This Standard does not apply to the structural design of vehicular bridges.

1.4 Partitions

This Standard applies to the structural design of partitions subject to unusual loads such as wind loads, significant internal air pressure differences, or large eccentric loads mounted to the wall. Where it can be shown that the masonry partitions are not subjected to these unusual loads, the masonry partitions may be designed using Annex F.

1.5 Thin veneers secured by mortar adhesion

This Standard does not apply to the structural design of thin veneers individually secured by mortar adhesion to a structural support or to the structural design of rough stone veneer. See CSA A371 for prescriptive requirements and limitations.

1.6 Rough stone masonry

This Standard does not apply to the structural design of rough (rubble) stone masonry, except as covered in Annex F. See CSA A371 for prescriptive requirements.

1.7 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; “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.

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