

# **Technical Guide: Design and construction considerations for foundations in permafrost regions**



# 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 treaty 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 PLUS 4011.1:19 November 2019***

**Title:** *Technical Guide: Design and construction considerations for foundations in permafrost regions*

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

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

The **List ID** that you will need to register for updates to this publication is **127-90**.

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](http://www.csagroup.org/legal) to find out how we protect your personal information.

*CSA PLUS 4011.1:19*  
***Technical Guide: Design and  
construction considerations for  
foundations in permafrost regions***



*®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 978-1-4883-2343-0*

*© 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 Northern Built Infrastructure	4
Subcommittee on Foundations in Permafrost Technical Guide	6
Preface	7
<b>1 Introduction</b>	<b>8</b>
1.1 Background	8
1.2 Purpose	8
1.3 Document structure	8
<b>2 Permafrost distribution and conditions</b>	<b>9</b>
2.1 Distribution of permafrost	9
2.2 Permafrost ground temperature ranges	10
2.3 Physical features of permafrost terrain	12
2.4 Ice content	15
2.5 Salinity and other contamination	16
2.6 Ground thermal regime	17
2.7 Terrain sensitivity	18
2.8 Surface hydrology	19
2.9 Climate change effects	19
2.10 Physiographic effects on ground thermal regime and foundations	20
<b>3 Permafrost considerations for foundation design</b>	<b>21</b>
3.1 General	21
3.2 Ground temperature	22
3.3 Strength of frozen soil and creep	22
3.3.1 Strength of frozen soil	22
3.3.2 Creep	26
3.4 Effect of salinity	28
3.5 Physiographic considerations	28
3.6 Potential impacts of buildings on ground thermal regime	29
3.7 Climate change considerations	29
3.8 Geotechnical investigation	29
3.9 Geothermal modelling	30
3.10 Site preparation	31
3.11 Foundation selection — Flowchart	31
3.12 Bearing capacity/Adfreeze bond capacity	33
3.13 Thaw settlement	33
3.14 Frost heave	34
3.15 Frost jacking	35
3.16 Adaptive foundation design	35
3.17 Mitigation techniques to reduce the effects of heat transfer	36
<b>4 Resource and logistical considerations — Northern-specific constraints and construction planning consideration</b>	<b>36</b>
4.1 General	36

4.2	Local availability of resources	38
4.2.1	General	38
4.2.2	Material	39
4.2.3	Equipment	39
4.2.4	Labour market	39
4.3	Logistics and transportation	40
4.3.1	General	40
4.3.2	Air transport	40
4.3.3	Land transport	40
4.3.4	Water transport	41
4.3.5	Rail transport	41
4.3.6	Site accommodation	41
4.3.7	Storage	42
4.4	Climate consideration	42
4.5	Social consideration	42
<b>5</b>	<b>Shallow foundations</b>	<b>42</b>
5.1	General	42
5.2	Pads and wedges	46
5.3	Timber sills	47
5.4	Post and pad	49
5.5	Spaceframe foundations	50
5.6	Slabs on grade	52
5.7	Footings in or on permafrost	53
5.8	Footings on rock	55
5.9	Strip footings on grade	56
5.10	Thermosyphon	57
5.11	Basements	59
<b>6</b>	<b>Deep foundations</b>	<b>59</b>
6.1	General	59
6.2	Driven piles	63
6.3	Slurry backfilled adfreeze piles	64
6.3.1	Slurry backfilled adfreeze pile installation	64
6.3.2	Freezeback of slurry backfilled adfreeze piles	65
6.3.3	Slurry backfilled adfreeze pile design considerations	68
6.4	Modified slurry piles	69
6.5	Screw piles	70
6.6	End-bearing piles	70
6.6.1	General	70
6.6.2	Presence of competent end-bearing stratum	70
6.6.3	Rock socketed piles	70
6.7	Thimopiles	70
6.8	Frost jacking of piles	73
<b>7</b>	<b>Insulation materials</b>	<b>74</b>
7.1	General	74
7.2	Types of insulation	75
7.2.1	General	75

7.2.2	Polystyrene	75
7.2.3	Polyurethane (PUR)	76
7.2.4	Polyisocyanurate (PIR)	77
7.3	R-Value	78
7.4	Advanced thermal insulation materials	79
7.5	Phase change materials (PCMs)	79

<b>8</b>	<b>Inspection and monitoring</b>	<b>80</b>
8.1	General	80
8.2	Inspection protocols	81
8.3	Operational monitoring of foundations	81
8.4	Maintenance	83

---

Annex A (informative)	— Glossary of terms	86
Annex B (informative)	— References	89

# Preface

This is the first edition of CSA PLUS 4011.1, *Technical Guide: Design and construction considerations for foundations in permafrost regions*.

CSA Group received funding for the development of this Guideline from the Standards Council of Canada, as part of the Northern Infrastructure Standardization Initiative (NISI) with input from the Northern Advisory Committee (NAC).

This Guideline was prepared by the Subcommittee on Foundations in Permafrost Technical Guide, under the jurisdiction of the Technical Committee on Northern Built Infrastructure and 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 Guideline is stated in its Scope, it is important to note that it remains the responsibility of the users of the Guideline to judge its suitability for their particular purpose.*
- 3) *This Guideline 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 Guideline.*
- 4) *To submit a request for interpretation of this Guideline, 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(s); 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 Guideline 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) *designation (number);*
  - b) *relevant clause, table, or figure number;*
  - c) *wording of the proposed change; and*
  - d) *rationale for the change.*

# CSA PLUS 4011.1:19

## Technical Guide: Design and construction considerations for foundations in permafrost regions

### 1 Introduction

#### 1.1 Background

In 2010, CSA Group published CSA PLUS 4011, *Technical Guide: Infrastructure in permafrost. A guideline for climate change adaptation*. The intent of that document was to provide stakeholders with information on the potential impacts of climate change on infrastructure in Canada's permafrost regions. It is recognized that climate change might impact permafrost terrain more dramatically than terrain in temperate regions. Those involved in the development, design, procurement, construction, and operations of infrastructure in permafrost terrain would benefit from current knowledge on the potential impacts of a changing climate on those activities.

In 2019, CSA Group published an update to the 2010 edition of CSA PLUS 4011. In making revisions and updates to the 2019 document, it was recognized that stakeholders could gain additional benefit if a supplemental document was developed that provided current information on the issues related to the design and construction of foundations in permafrost regions. It is the foundation of buildings that will be most dramatically impacted by rapid and high-magnitude warming of air temperatures.

#### 1.2 Purpose

While both the 2010 and 2019 versions of CSA PLUS 4011 provide discussions on foundations in permafrost, this Guideline is intended to provide more detailed technical information on the attributes of the various foundation systems, selection criteria, ground conditions, and related issues.

This Guideline is a companion document to CSA PLUS 4011. The CSA Subcommittee made a deliberate decision not to include equations, formulas, and design guidelines in this document. It is not a design manual — it is informative. This Guideline is intended to assist developers, designers, the general public, and other stakeholders understand the permafrost terrain of Canada, as well as the general selection process and choices for permafrost foundations and their limitations.

#### 1.3 Document structure

This Guideline is laid out as follows.

Clause 2 introduces and describes the permafrost of Canada. For this Guideline, permafrost is limited to “northern” permafrost. Topics covered include the distribution of permafrost in Canada, ground temperatures, ice content, salinity, terrain sensitivity, surface hydrology, and the effects of a changing climate on the performance of building foundation.

Clause 3 describes some important considerations for foundation design in permafrost terrain. Topics include ground temperature and its effect on soil strength, creep, effects of pore water salinity, effects of surface disturbance on the thermal regime of the ground, the need for geotechnical investigations,