Fostering climate resilience through northern standards: Shaping a resilient future

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ABSTRACT

Climate-resilient standards and guidelines – those that consider a future-looking climate and account for associated risks – can be powerful resources for professionals, practitioners, and governments in designing and implementing sustainable solutions. By standardizing best practices, National Standards of Canada (NSCs) can streamline and harmonize the field of climate resilience while playing an integral role in improving the overall health and safety of Canadians, and of their environment. The Standards Council of Canada (SCC) is leading the development of climate-resilient standards that can be implemented to adapt communities to climate change and extreme natural events.

Since 2011, SCC has been working with communities, standards development organizations, and experts from across northern Canada to lead the development of standards that consider climate change impacts in northern infrastructure design, planning and management. This paper will cover the development of standards and guidelines that support the design of foundations and infrastructure in permafrost regions, namely:

- CSA S500:21 Thermosyphon foundations for buildings in permafrost regions
- CSA S501:21 Moderating the effects of permafrost degradation on existing building foundations
- BNQ 9701-500 Risk-based approach for community planning in northern region
- CSA PLUS 4011:19 Technical guide: Infrastructure in permafrost: A guideline for climate change adaptation

The purpose of this study is to highlight standards that will help building owners and operators, as well as those responsible for public and community infrastructure, build and maintain infrastructure in a changing climate in permafrost regions. Further, it is meant to inform northern practitioners on the benefit of building and designing infrastructure with guidance that goes “beyond the building code” under a changing climate.

1 INTRODUCTION

1.1 Standards and climate change

Communities worldwide are facing negative impacts from climate change and extreme weather events. Canada's Northern Region is particularly vulnerable, experiencing temperatures rising three times faster than the global average (Bush and Lemmen 2019). This has led to more intense storms, higher precipitation, melting sea ice, and coastal erosion. Further, changing permafrost conditions pose a significant challenge, as most buildings were historically designed to account for frozen ground. Climate change has disrupted this norm, leaving older structures unprepared for shifting permafrost and thus more susceptible to damage like sinking and cracking. Given the high costs and challenges of building in remote regions of the North, it is important that buildings are made to be resilient. Climate-informed standards can play a crucial role in ensuring this durability and adaptability (Standards Council of Canada 2023a).

1.2 Standards as part of a toolbox

Standards outline accepted practices, guidelines, and technical criteria for diverse sectors and areas. Engineers, asset owners and planners rely on standards to ensure developed products and services meet a minimum level of performance and provide assurance to the owner and user of the product or service. Standards are voluntary by default but become mandatory when referenced in codes, acts or regulations.

Building standards, that consider a future looking climate, are an integral part of a community’s adaptation strategy and provide a concrete framework on how to address the challenges presented by climate change by assessing the risks and impacts to infrastructure.

With climate-informed infrastructure standards, communities will be able to adapt and adjust for future impacts to deliver reliable, equitable, and sustainable services to all of society by factoring in climate change adaptation into their operational practices (Environment and Natural Resources Canada 2023).

1.3 The Standards Council of Canada (SCC) and the Northern Infrastructure Standardization Initiative (NISI)

SCC is a federal crown corporation with the mandate to promote efficient and effective voluntary standardization in Canada.

A significant initiative under SCC is the Standards to Support Resilience in Infrastructure Program (SSRIP). Collaborating with Canada’s national standardization network, academia, industry, and all levels of government, SSRIP spearheads the creation and application of standardized solutions to enhance infrastructure resilience,

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thus fostering more resilient communities for the people of Canada. The primary goal of SSRIP is to advance technical guidance that empowers Canadian households, businesses, and communities to adapt to the challenges posed by climate change and extreme weather events. The program envisions a built environment in Canada that is not only sustainable but also capable of withstanding the impacts of climate change. Currently in its second phase (2021–2028), SSRIP has successfully developed over 41 standardization solutions geared towards strengthening the climate resilience of Canadian infrastructure and communities.

A considerable focus of these efforts lies within Canada's Northern Region, which faces heightened vulnerability due to ongoing climate change threats. This area experiences unique impacts (such as permafrost thaw), necessitating specific strategies to mitigate them. NISI, a subprogram of SSRIP, is designed to assist infrastructure owners, operators, and custodians of public and community facilities in adapting to a changing climate. This initiative is tailor-made for the North, and all standards produced under NISI are carefully curated by a Northern Advisory Committee. The Northern Advisory Committee comprises representatives from Nunavut, the Northwest Territories, Yukon, and Nunavik, ensuring that the standards cater to the unique needs of these regions. Additionally, Crown-Indigenous Relations and Northern Affairs Canada has been a steadfast supporter of NISI since its inception.

A vital aspect of this process involves collaboration with Standards Development Organizations (SDOs) to ensure that the standards are crafted by experts with Northern experience or those residing in the North. This approach guarantees that the resultant standards genuinely address the requirements of northern communities. To date, nearly a dozen standards have been formulated to assist in constructing structures on permafrost, dealing with extreme weather conditions like high winds and heavy snowfall, planning community systems including wastewater facilities, and adopting a forward-looking approach to design that considers climate change risks.

For a standard to achieve recognition as a National Standard of Canada (NSC) that has been formulated by an SCC-accredited SDO, it must adhere to the following:

- Consensus Development: The standard should be formulated through consensus among a well-balanced assembly of stakeholders;
- Transparency: The standard must undergo public scrutiny, ensuring transparency and inclusivity in its development;
- Language Accessibility: Publication of the standard in both of Canada’s official languages is essential;
- Alignment with International Standards: The standard should either be consistent with or incorporate existing relevant international and foreign standards;
- Trade Facilitation: The standard should not act as a trade barrier; and
- Ongoing Maintenance: Regular maintenance, typically through periodic reviews (usually on a five-year cycle) or as necessary due to changes, is crucial.

The distinctiveness of NSCs lies in their consensus-based and interdisciplinary approach. This sets them apart from industry or professional standards that are specific to certain sectors or industries and do not necessarily require a balanced consensus methodology. The collaborative and diverse development process ensures their robustness and relevance across a broader spectrum of applications and scenarios.

The maintenance cycle of NSCs means that every five years, the standard must either be updated, confirmed as is, or withdrawn. As a result, the standards are continuously reviewed to include the latest knowledge and technology, making them a strong tool for northern communities.

2 METHODOLOGY

In crafting this article, we've adopted a case study approach.

Our selection of the case study strategy is rooted in its appropriateness for cultivating a deep understanding of the significance, application, and worth of standards in assisting northern communities to navigate climate change and foster climate resilient infrastructure through the implementation of northern standards.

This report presents a comprehensive overview of four NSCs dedicated to facilitating the planning, creation, and maintenance of foundations and infrastructure within permafrost regions. The analysis of these standards encompasses an assessment of their impact, the extent of their practical application, and their utilization as points of reference. Their potential to aid communities in adjusting to the challenges posed by climate change and climate hazards remains a focal point throughout the assessment.

3 RESULTS; CANADIAN STANDARDS AND GUIDANCE ON PERMAFROST

What follows is an overview of four technical guidance documents that were prioritized by SCC’s Northern Advisory Committee and are now available for use. These standards go “beyond the building code” and are meant to support a climate-resilient future. Several communities across Canada’s north have begun implementation of:

- CSA S500:21 Thermosyphon foundations for buildings in permafrost regions;
- CSA S501:21 Moderating the effects of permafrost degradation on existing building foundations;
- BNQ 9701-500 Risk-based approach for community planning in northern region; and
- CSA PLUS 4011:19 Technical guide: Infrastructure in permafrost: A guideline for climate change adaptation

3.1 CSA S500:21 Thermosyphon foundations for buildings in permafrost regions

3.1.1 Project description

Shifting climate conditions across northern Canada have led to documented changes in temperature, precipitation, and typical weather patterns. These alterations hold the potential to induce significant impacts on permafrost conditions and hydrogeological attributes of specific construction sites, consequently affecting both the infrastructure in the northern regions and the local inhabitants.

In November 2012, the SCC entrusted CSA Group with the task of developing four standards as part of NISI. The inaugural standard in this series pertains to thermosyphon foundations for buildings in permafrost regions. The development of this standard emerged from the cooperative efforts of representatives from territorial and federal governments, universities, the private sector, and local community governance organizations. A second edition, published in 2021, supersedes the earlier 2014 version and fills the void that previously existed – the absence of guidelines or standards for designing, constructing, and maintaining thermosyphon-supported foundations.

CSA S500: Thermosyphon foundations for buildings in permafrost regions is designed to enable northern Canadians to adapt to the evolving environment through the utilization of thermosyphon foundations. Functioning by transferring heat from the ground to the air during appropriate temperature differences, thermosyphons effectively sustain frozen and stable ground in cold climates. Notably, structures constructed on permafrost without such mitigative systems can trigger permafrost degradation and compromise a structure's foundational integrity (SCC.2014).

The standard's scope encompasses all phases of a thermosyphon foundation's life cycle for new buildings on permafrost, covering site assessment, design, installation, commissioning, monitoring, and maintenance. It is strategically designed to ensure the enduring performance of thermosyphon-supported foundation systems under changing environmental circumstances.

Intended for designers, contractors, building proprietors, and operators, the standard offers insight into the design and construction processes required to guarantee the implementation of adequate measures during these phases. Furthermore, the standard outlines expectations for monitoring and maintenance for building operators.

Primarily targeting new buildings on permafrost sites, particularly those employing materials sensitive to thawing, the standard furnishes guidance regarding geotechnical investigations and advises on foundation conditions that either support or challenge the use of thermosyphons as a foundational system. The standard underscores the importance of preserving permafrost to uphold building support and design integrity before its implementation (CSA Group 2021a).

3.1.2 Impact

Since the first edition was published, several northern infrastructure projects have implemented the standard. Further, the standard has been referenced in the Société d'habitation du Québec's Housing Construction in Nunavik – Guide to Good Practices (Société d'habitation du Québec 2018), as well as in the Northwest Territories Good Building Practice for Northern Facilities requirements (Government of Northwest Territories 2021). As such, it is being recognized as being a best practice in these regions.

Arctic Foundations, a leading manufacturer of thermosyphons in Canada, ensures that CSA S500:14 (the first edition) is followed on every building related installation they have performed since 2014 (adherence is specific to their portion of the work, i.e., final review, modelling, design, manufacturing, and installation). Further, the first edition of this standard is referenced in CSA S6:19 Canadian Highway Bridge Design Code (CSA Group 2019b), CSA S6.1-2019 Commentary on CSA S6:19 Canadian Highway Bridge Design Code (CSA Group 2019c), and in the new Yukon Government Design Standards Manual (Government of Yukon 2023).

Moreover, the standard was used in the following projects:

- Qikiqtani Correctional Healing Centre Expansion – Iqaluit, NU;
- Arctic Bay Fire Hall – Arctic Bay, NU;
- Kugaaruk Fire Hall – Kugaaruk, NU;
- Heath centre and housing project – Old Crow, YT;
- Rankin Inlet Airport Maintenance Garage – Rankin Inlet, NU ;
- Igloolik High School – Igloolik, NU; and
- Tununuk Apartments (Thermopiles) – Inuvik, NT.

The establishment of this standard serves as a crucial stride towards safeguarding the stability of existing and forthcoming infrastructure within northern communities and showcases how standards serve to harmonize and streamline best practices across jurisdictions, regulatory frameworks, and guidelines.

Furthermore, by being referenced in territorial building and design guides, the territorial governments are endorsing the use of the standard and in many cases, they design publicly funded infrastructure in accordance with these guidelines.

3.2 CSA S501:21 Moderating the effects of permafrost degradation on existing building foundations

3.2.1 Project description

In the northern regions of Canada, the foundations of buildings are anchored deeply into the permafrost, the persistently frozen layers of soil and sediment. Building designs factor in the cyclic thawing and freezing of the active layer – the topsoil – during summers and winters. However, as the northern climate undergoes change, this active layer expands, resulting in permafrost degradation that poses a threat to the foundations of vital infrastructure.

CSA S501 Moderating the effects of permafrost degradation on existing was developed by CSA Group under NISI. Inputs from SCC's Northern Advisory Committee helped to shape the scope and need for the standard. The standard encompasses a range of strategies for preserving permafrost or mitigating its degradation concerning existing structures, including:

- Site techniques, such as site grading and drainage, snow management, and shading or albedo alteration; and
- Foundation techniques, such as encompassing ventilation, ground insulation, foundation adjustment and leveling, mechanized refrigeration, thermosyphons, and foundation replacement.

Additionally, the standard accommodates responses like site abandonment or structure demolition due to permafrost degradation. Monitoring holds a central role within this framework.

The standard's intended users encompass a diverse group:

- Building Owners and Operators: Responsible for structures susceptible to permafrost degradation;
- Community Infrastructure Managers: Overseeing infrastructure like drainage systems, necessitating permafrost maintenance or degradation remediation;
- Building Contractors: Engaging in engineering interventions;
- Design Professionals and Reviewers: Including consulting engineers, architects, and technical services staff, engaged in designing, assessing, approving, and supervising engineering interventions;
- Educators: For knowledge transfer; and
- Regulators: Such as building inspectors (CSA Group 2021b).

The standard complements existing building codes by offering guidance on conserving permafrost beneath established structures. It also provides methodologies for addressing buildings impacted by permafrost degradation, evaluates engineering approaches for preserving permafrost, and furnishes best practices to minimize the effects of permafrost deterioration on standing buildings. In essence, this standard not only addresses the pressing issue of permafrost degradation in northern communities but also provides a comprehensive guide for various stakeholders to ensure the stability and longevity of existing structures in the face of changing climatic conditions.

3.2.2 Impact

The standard has been widely referenced and used across the north. For instance, it has been referenced in the Société d'habitation du Québec's Housing Construction in Nunavik – Guide to Good Practices (Société d'habitation du Québec 2018), as well as in the Northwest Territories Good Building Practice for Northern Facilities requirements (Government of Northwest Territories 2021). Further, it has been referenced in the Yukon's 2022 Design Requirements and Technical Standards Manual which provides standards, strategies, and technical requirements for the planning, design and construction of new buildings (Government of Yukon 2023).

It's also referenced in the NWT Association of Communities' Climate Toolkit (Northwest Territories Association of Communities 2014). Further, the standard, as with many other NISI standards, has been referenced as a resilience measure in funding applications, such as funding under Infrastructure Canada (Infrastructure Canada 2021). Lastly, it was referenced in a review of climate impacts to infrastructure in Ross River, Yukon (Northern Climate Exchange 2021)

This standard's widespread application in territorial design guidelines, climate impact assessments, and federal funding applications exemplifies its significance and the way in which it harmonizes the field of climate resilience with the support of territorial and federal government.

3.3. BNQ 9701-500 Risk-based approach for community planning in northern region

3.3.1 Project description

When determining optimal locations for new community infrastructure, it's crucial to assess potential construction areas for hazards, vulnerabilities, and future climate risks. This standard serves to guide communities in understanding the advantages and disadvantages of infrastructure development across various zones (Standards Council of Canada 2023b). It outlines the minimum requisites for generating Land Development Suitability (LDS) maps, focusing on climate change within a risk management framework.

LDS maps offer invaluable insights for managing current infrastructure and pinpointing areas susceptible to climate change impacts. For instance, elevated air temperatures and increased precipitation influence ground temperatures, impacting permafrost stability. Consequently, numerous northern communities grapple with issues like land erosion and heightened flooding due to these effects. Incorporating these processes and vulnerabilities into the mapping process is essential for drafting LDS maps that ensure sustainable territorial development (Bureau de normalisation du Québec 2023).

Developed as part of NISI, the standard was shaped by inputs from the Northern Advisory Committee, alongside representatives from territorial governments, the federal government, universities, the private sector, and northern community governance bodies.

Outlined within this standard are the essential prerequisites for planning, preparing, and approving potential construction maps. These maps serve as a crucial resource for community planning decisions in the northern regions, bolstering community expansion in alignment with risk management principles. The primary audience includes land-use planning specialists and northern communities engaged in updating community plans and designing land development projects. It's also intended for use by geotechnical consultants, building designers, and contractors (Standards Council of Canada 2019).

The standard's goal is to establish a consistent and harmonized methodology for constructing potential construction maps, particularly addressing the unique considerations for building in permafrost zones and confronting climate change effects in northern regions (Standards Council of Canada 2019).

Overall, the standard facilitates informed decision-making in the face of evolving climate challenges, aiding in the sustainable growth of northern communities.

3.3.2 Impact

The standard was released in January 2023, and as such SCC does not yet have any use cases. However, discussions with northern communities suggest that funding applications are underway to support implementation of the standard across the territories. Consequently, the endorsement of governments will provide a consistent and coherent risk management approach for community planning across territories.

3.4. CSA PLUS 4011:19 Technical guide: Infrastructure in permafrost: A guideline for climate change adaptation

3.4.1 Project description

Engineering endeavors in northern areas frequently confront the challenge of permafrost within their foundation environments. The load-bearing capacity of frozen ground for supporting structures hinges primarily on local climatic conditions, ground temperatures, soil/rock properties, and ground ice conditions.

Anticipating significant climate warming in northern Canada, it becomes imperative to site community infrastructure in permafrost terrain while accounting for potential shifts in foundation conditions due to permafrost warming and thawing. The scope of analysis for addressing permafrost and climate change-related factors will vary across projects, contingent upon the nature of the infrastructure, its design, location, lifespan, and purpose.

This guideline effectively supports the incorporation of climate change-related considerations during the planning, design, and management phases of various community infrastructure projects in permafrost regions. Its key objectives are as follows:

- To elucidate permafrost as an environmental factor, focusing on its response to climate and environmental changes;
- To provide a broad assessment of trends in climatic and permafrost conditions across northern Canada;
- To outline prevalent foundation types employed in permafrost environments for community infrastructure; and
- To present a systematic approach for integrating climate change effects, as relevant, into the selection of project sites and the design of their foundations.

3.4.2 Impact

This technical guide is referenced in the Government of the Northwest Territories Good Building Practices. Moreover, it is referenced in CSA S6.1:19 Commentary to the Canadian Highway Bridge Design Code (CSA Group 2019c), and will therefore be used as guidance when needed in designing a bridge structure in permafrost conditions.

The first edition of CSA Plus 4011 was mentioned in the Development Assessment Report for the all-weather road to the Prairie CK mine in NWT (where it was used as a screening tool for climate change analysis; Canadian Zinc Corporation Vancouver 2010). It was also referenced in the Société d'habitation du Québec's Housing Construction in Nunavik – Guide to Good Practices (Société d'habitation du Québec 2018*)*. Moreover, it has also been referenced in the Yukon's 2022 Design Requirements and Technical Standards Manual (Government of Yukon 2023).

This guidance document is crafted to aid decision-makers, who might not be permafrost experts, yet play pivotal roles in planning, procuring, developing, or operating community infrastructure in permafrost regions. It ensures that these decision-makers are equipped to address the intricate challenges posed by permafrost conditions and climate change impacts in the context of infrastructure development.

Essentially, the evidence of referencing demonstrates that the technical guide plays a vital role in bringing consistency and efficiency to best practices across different areas such as jurisdictions, regulations, and frameworks through the endorsement of federal and territorial governments.

4 DISCUSSION

Canada's northern regions face the direct impact of climate change, with rising temperatures causing permafrost thaw, severe storms, increased precipitation, melting sea ice, and coastal erosion. Recognizing this reality is fundamental for informed decision-making.

The process of adapting and repairing buildings in the North is financially demanding, especially for smaller communities. Understanding the economic strain is crucial when formulating strategies to bolster infrastructure resilience.

Northern communities require effective tools to minimize infrastructure vulnerability and mitigate climate change impacts. Investing in resources that provide actionable solutions is crucial for long-term resilience.

SCC has been playing a critical role by supporting the creation and dissemination of new resources tailored to northern infrastructure needs. Its involvement signifies a commitment to proactive adaptation strategies.

The success of NISI is rooted in its approach. The success of NISI extends beyond the SCC. Collaboration among territorial governments, federal entities, universities, the private sector, and community organizations is pivotal, showcasing the power of collective efforts. Standards are crafted to cater to the unique requirements of the North, ensuring they genuinely address local challenges. A key aspect of NISI's success is the active engagement of the North. The program's structure fosters ownership,

encouraging northern stakeholders to endorse and advocate for standards adoption within codes and training.

NISI capitalizes on the distinct needs of northern regions, aligning its standards with the region's challenges. This targeted approach ensures that standards are not just relevant but also embraced by the local communities.

Developing standards that cater to northern needs signifies a long-term vision. These standards are not merely quick fixes but serve as foundational tools for resilient infrastructure in the face of ongoing climate change.

Innovative measures found in these standards and highlighted in the previous sections include progressive initiatives that demonstrate value in exceeding code when in high-risk regions. The development of these standards and application in multiple regions demonstrates value in allocating resources beyond code minimums, particularly for new construction. As climate change and extreme natural events continue to influence innovations in adaption and resilience, cost/benefit data will increasingly support federal and local governments, designers, builders and the insurance industry to corroborate what needs to be adapted in existing building practice and what will be deemed an amenity.

In summary, the Northern Infrastructure Standardization Initiative exemplifies the positive impact that tailored standards can have on enhancing the resilience of infrastructure in climate-vulnerable regions. By recognizing local challenges, promoting ownership, and fostering implementation, this initiative serves as a valuable model for proactive climate adaptation strategies.

5 CONCLUSION

In conclusion, the insights garnered and resources harnessed via NISI underscore the vital role that standards play in navigating the challenges posed by climate change and evolving permafrost conditions. The four highlighted standards within this case study exemplify how standards serve as dynamic tools for adapting and mitigating the impacts of climate change on Northern built infrastructure. Crucially, these standards are meticulously designed to genuinely address the specific needs of northern communities, ensuring the creation of sustainable and high-quality infrastructure.

The standards spotlighted within NISI's framework hold the promise of aiding building owners, operators, and custodians of public and community infrastructure. By embracing these standards, stakeholders in permafrost regions are equipped with the knowledge and methodologies to construct and sustain infrastructure amidst the fluctuations of a changing climate. These standards encapsulate a holistic approach, encompassing both adaptation and maintenance, thereby fostering resilience and longevity.

Ultimately, the success of NISI and the associated standards demonstrates how strategic collaboration, and a localized approach can lead to the development of resources that are not just responsive but proactive. The synthesis of knowledge and the creation of purpose-fit tools culminate in the promotion of adaptable, robust, and sustainable infrastructure, which stands as a testament to the capacity of standards to effectively address the challenges of a dynamically changing world.

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