Feature

Achieving Building Enclosure Durability Using CSA S478

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BACKGROUND

The standards division of the Canadian Standards Association (CSA) develops consensus standards and guideline documents for, among other industries, the design and construction of buildings. Authorized by the Standards Council of Canada, CSA creates technical committees formed of industry experts representing various viewpoints affecting the standards or guidelines. These important documents are vetted by public comment and updated regularly to remain current and relevant. Many have been referenced in the national model and provincial regulatory building codes and thus, as the latter, are the legal minimum requirement.

The origin of CSA S478, *Guideline on Durability in Buildings,* was a guideline document prepared by a committee of experts and published almost 30 years ago as a first attempt at a document to address durability and premature deterioration issues throughout the life of a building. It grew from an industry demand to bring forth a set of recommendations to assist designers in creating durable buildings. CSA S478 was referenced in Part 5 of the *Ontario Building Code* 5.1.4.2(3) Resistance to Deterioration as a potential reference to designers. As a guideline document, it was not encumbered by the formalities of "standards language." Rather, it provided good advice on best practices together with a comprehensive series of appended annexes giving summaries of the then-current research and procedural information directed at durable buildings.

Over the ensuing decades, resistance to build deterioration, in particular, the building elements of the enclosure remained an ongoing concern. Both social and financial costs for what was considered by most experts in the building science community to be premature building repair, costs to litigate, recovery of damages arising from misdirected intentions, poor product selection, inappropriate design, and the growing concern about wasted embodied carbon in building products thrown away too soon, helped spark the desire to revisit the 1995 version of CSA S478. So, in 2017, I co-authored a white paper for CSA[1] on the transformation of the guideline into a standard and eventually became the first chair of that extensive rewrite. A rewrite was considered necessary because the guideline needed both updating and conversion to standards language such that it could be referenced by regulatory codes and design specifications. CSA S478 was first republished in 2019 and that remains the currently available version. It has not yet been adopted by the National model or Provincial building codes but has been on the radar of many design professionals dealing with the challenges of durability and liabilities associated with premature deterioration.

PRIMARY ELEMENTS OF THE STANDARD

The standard deals with Part 5 buildings, that is, buildings that are greater than three stories or greater than 660 m^2 (7,100 ft^2) in building (footprint) area and not a hazardous occupancy. While the standard could be applied to Part 9 small buildings or houses, that has not been its intent. The standard places the primary focus on the building enclosure, members, connections, and components. It applies to both new and retrofit design practices.

As a key design consideration, the standard defines and distinguishes between the design and service life of the building and the components. It also suggests design life and proportionate service life periods but makes those decisions a subject of agreement between the designer and the owner. This distinction between suggested design and service lives provides the fundamental starting point for the selection of materials, geometric considerations, and processes used in the assembly of the building enclosure components. It also allows flexibility in selecting design life and thus component service life which dovetails into a risk management process for designers. More about that later in this paper.

While not a construction standard, CSA S478 provides construction process steps that will assist all parties to a building development or repair, Additionally, the standard gives owner operational steps to ensure the longer-term performance of building enclosure components and systems. Supplementing the design for durability for the building enclosure, these construction and operations initiatives form a full durability plan for the building throughout its design life.

The standard itself is quite short, being only 18 pages of standard requirements content; however, attached to the standard are 77 pages of nonmandatory (informative) Annexes. For example, Annex H gives a deep dive bibliography into available consensus standards and authoritative industry guidelines. That compendium is given as a reference for use by designers to know they are using the best available information on building enclosure design and materials.

Additional Annex References:

- **Annex A:** How to Use the Standard together with a sample form for recording design and maintenance options forming part of a durability plan.
- **Annex B:** Life Cycle Costs of Buildings, which refers to ISO 15686-5 2017 *Buildings and constructed assets—Service life planning—Part 5: Life-cycle costing.*
- **Annex C:** Assessment of Environmental Conditions, discussing macro and micro environments, agents causing environmental actions (air, moisture, contaminants, soil, biological agents, temperature, solar radiation, and chemical incompatibility) as well as a discussion of the parameters affecting the structure environment such as driving rain index, the acidity of precipitation, time of wetness, exposure, freeze-thaw and severity classification for various materials of the assessed environmental conditions.
- **Annex D:** Degradation Mechanisms and Mitigation Strategies for Building Materials, which incorporates a comprehensive table describing the mechanism and effect of failure, the necessary conditions for occurrence, mitigation methodologies, and selected reference material for various materials.
- **Annex E:** Climate Change Effects on Durability of Building Materials and Building Elements, which gives an overview of the impact that climate change has as stated in research on climate change and describes the anticipated influence of degradation mechanisms for various materials and in various areas of Canada.
- **Annex F:** The Building Envelope, which is an overview of good design practices for the various building enclosure components, walls above and below ground, roofs, windows and doors, soffits and cantilevered floors, and joints between these elements.
- **Annex G:** Designer Considerations for Design Alternatives and the Quality Management Program, which describes risk areas and construction issues affecting quality management along with how designers can integrate quality management steps into the construction process.

CONTENTS OF THE STANDARD

The body of the standard lays out a simple yet effective process to arrive at a building enclosure design that results in a durable but cost-effective. Sections, in the standard are:

1 Scope: to describe the purpose and what building elements are included and not included.

2 Reference publications and bibliography: to list the numerous CSA, ASTM, EN, and ISO Standards specifically cited in the standard.

3 Definitions: to identify the meaning of terms used in the standard.

These first three are standard clauses in all CSA standards tailored to suit the subject of the standard. The bespoke clauses set out for the standard follow. They are:

4 Fundamental durability requirements: This section sets out the mandatory obligations for compliance with the standard in the following subsections:

4.1 Durability and design service life: This requires that buildings and their elements be conceptualized, designed, constructed, maintained, and operated in such a way that they will maintain the required resistance to the structure environment defined at the time of the design. This allows designers to incorporate design resilience in a manner to address their interpretation of the future environmental and physical loads under which the building must perform for the chosen design service life agreed to with the owner.

4.2 Basic service life requirement: The predicted service life shall meet its design service life. That is, no building is to be designed to fail before its intended useful life.

4.3 Satisfying service life requirements—Agents and degradation: The basic service life requirements are to be satisfied by taking into consideration all reasonably foreseeable agents and mechanisms of degradation and durability. A list of applicable clauses and Annex references are given. This direction requires that the designer knowledgeably consider the loads that are reasonably expected to affect the longevity of the elements proposed to form the building enclosure.

4.4 Design compliance: Options are given for determining the basic service life of the building. These are:

a. By designing protective mitigation to defend against loads and the consequences of those loads;
b. By specifying building elements that, without maintenance, will not degrade to failure during the design service life;
c. By specifying building elements that with scheduled and condition-dependent maintenance will not degrade to failure during the design service life; or
d. By providing a design such that degradation will not fail in the design service life.

4.5 Fabrication and construction: This leads the designer to Clause 9 which talks about the role of contractors, fabricators, and suppliers in the execution of the designer's overall quality management plan.

4.6 Maintenance, repair, and renovation: This tells designers that they shall provide a plan for execution by others to employ later in the life of the building to maintain the original durability plan developed by the architect.

5 Quality management during design, construction, maintenance, and operation: This clause mandates that the designer is to determine and specify the quality management requirements to achieve durability for design, construction, operation and maintenance, and renovation and repair. It mandates that action items and documentation are necessary.

6 Design service life of buildings and building elements: These clauses describe design service life for the building and for building elements.

6.1 Buildings: At this time, the design service life for the building is set out in a table which suggests the appropriate life for different building categories with life spans ranging from 25 to more than 100 years (**Table 1**).

The range of life spans allows owners and designers to make rational choices concerning the durability of the building and focuses on the intended use as a metric. For example, the minimum life span for a small office building may reasonably be 25 years whereas the minimum lifespan for a residential building may be 50 years. Longer life spans may be chosen.

6.2 Building Elements: Clearly, some of the component parts referred to in this standard as building elements will have shorter service lives than the building. The standard addresses the life of building elements and the replacement or repair as factors to consider in the design and use of those elements. Factors to be considered include:

a. The environmental and physical loads,
b. The intended quality management procedures in the durability plan,
c. The difficulty and expense of maintenance,
d. The consequences of failure considering costs, disruption, and hazard to users,
e. The availability of replacement components.

The life of the building elements is set out in terms of the replacement as a percentage of the life of the building. **Table 2** sets out various categories of failure in terms of the consequences ranging from minor to a risk to health and safety of users, injury, loss of life, loss of the asset, or a prohibitive repair cost. If an element falls into more than one category, the higher or highest category should be used. Where not possible to comply with the table, a life cycle analysis is to be conducted for the durability plan.

6.3 Specification of design service life: While a range of design life is given in Table 1, the designer is expected to establish the minimum design service life for the building under design. The designer does that through consideration of the environmental and physical loads, proposed maintenance, and exposure conditions.

TABLE 1. Categories of design service life for buildings (see Clauses 6.1.2, 11.2, A.1, and A.2.2)

Design service life category	Building type	Minimum design service life for building, years	Range of design service life, years
Short life	❑ Bunkhouses, sales offices ❑ Minor storage buildings	–	Up to 10
Medium life	❑ Low-hazard industrial ❑ Temporary buildings	10	10 to 25
	❑ Mercantile ❑ Medium-hazard industrial ❑ Business and personal services occupancies ❑ School portables	25	25 to 50
	❑ Low-rise commercial and office buildings ❑ Stand-alone parking structures* ❑ High-hazard industrial	25	25 to 99
Long life	❑ Single-unit residential ❑ Multi-unit residential ❑ Mid- and high-rise commercial and office buildings ❑ Post-disaster buildings (e g., hospitals, power generating stations, public water treatment facilities, and emergency response facilities) ❑ Performing arts buildings, arenas, schools and colleges, and other assembly occupancies ❑ Detention, care, and treatment occupancy	50	50 to 99
Permanent	❑ Monumental and heritage buildings	100	100 to 300

** Parking structures shall have a design service life at least equal to the building they serve, except that parking structure serving long-life category buildings may be designed for medium life, provided that (a) they are not integral to the long-life superstructure; and (b) degradation of the parking structure will not adversely affect the building served. See CSA S413.*

7 Predicted service life of building elements: The designer is to employ one or a combination of the following approaches, as applicable.

a. Demonstrated effectiveness based on documented records of successful performance in the same or more severe environment and on information on degradation in literature (Annexes D and H).
b. Modelling applied where
   i) a similar building element has been used in a similar or more severe environment has been successfully used,
   ii) a proven building element has been successfully used in a moderately different environment, or
   iii) an innovative building element is proposed to be used in a significantly different environment combined with laboratory or field testing for durability.

8 Design considerations: Innovative designs, systems, and materials are possible if they comply with applicable regulations. Materials are to be compatible physically and chemically considering environmental and physical loads. Detailing is to be clear, concise,

TABLE 2. Categories of failure

Category of Failure	Consequences of failure	Description	Examples	Minimum Design Service Life of Building Element
1	Minor	Building element repair can be readily accommodated within routine maintenance	❑ Worn weatherstripping	Owner defined
2	Reduction in Serviceability State	Reduction in building element serviceability state without risk of failure of the building element, an adjacent building element, or the system in which it is included.	❑ Mortar joint degradation ❑ Sealant crazing ❑ Aesthetic degradation	
3	Reduction in Resistance Capacity Or Moderate Repair Cost	Reduction in the building element resistance capacity or performance without posing an unacceptable risk of failure of the building element, an adjacent building element, or of the system in which it is included. Or Repair to the building or building element could be moderately difficult in execution or accessibility (e.g. accessible from balconies, roofs, non-engineered scaffolding).	❑ Isolated roof leak in a conventional roof ❑ Leaking roof termination flashings ❑ Accessible thin membrane waterproofing on suspended slab ❑ Paint or coatings on serviceable elements (e.g., visible cladding surfaces)	20% of building design service life
4	Loss of Resistance Capacity Or High Repair Cost	Loss of building element resistance capacity or function. Or Repair to the building or building element could be costly because of difficulty in execution or accessibility issues (e.g. specialized equipment, engineered scaffolding, swing-stage use), or repair could require extensive use of materials or component replacements	❑ Roof replacement; ❑ Isolated roof leak in a protected roof membrane system that is difficult to access ❑ Concealed cladding attachments or guard elements that are easily accessible for inspection and repair ❑ Inner seal of a two-stage joint ❑ Insulating Glass Unit failure; ❑ Protective coatings on unserviceable elements (Ie.g., long-span roof over a pool)	50% of building design life
5	Risk to health and safety of building users	Unacceptable risk for building users or the public (e.g., personal injury, biological growth potentially affecting human health, release of toxic chemical substances)	❑ Cladding falling hazards ❑ Examples shown for categories 6 and 7 that also pose a risk to health	100% of building design service life
6	Injury, loss of life, or loss of asset	Unacceptable risk of injury, loss of human life, or loss of building; building elements are hidden or not readily inspected	❑ Cladding primary support members and infill structural wall systems ❑ Cladding connectors and secondary support framing members ❑ Guard elements that are difficult to access for inspection and repair	100% of building design service life
7	Prohibitive repair cost	Extensive reconstruction require	❑ Waterproofing system below overburden ❑ Through-wall flashings and inaccessible drainage ❑ Elements of the building or building enclosure that are difficult or costly to access for inspection and repair on mid- and high-rise buildings ❑ Concealed sheathing, air barriers, and insulation ❑ Foundation wall waterproofing and dampproofing ❑ Corrosion of unserviceable elements	100% of building design service life

and complete using drawings and specifications.

Buildability is required to achieve the necessary level of performance and reliability. For example, early input from contractors, fabricators, and suppliers, considering the sequence of construction, seeking input from building maintenance staff, and construction of mock-ups can provide important input.

Access for inspection throughout the service life and identification of building elements that require special care should be part of the durability plan.

9 **Construction considerations:** The designer's role during construction includes review of the contractor's proposed changes to maintain compliance with the durability plan and confirmation that the quality assurance plan is maintained.

The contractors, fabricators, and suppliers also have a role. They are to review the design for execution of the durability plan and communicate concerns to the designer. They are to develop their quality control procedures as set out in the durability plan, submit a quality assurance plan to the designer, and assign appropriate resources to implement that plan.

10 **Operation, maintenance, and inspection:** The operation and maintenance of the building shall not conflict with the durability plan. While it is acknowledged that designers do not control this portion of the life of a building, the premise of consistency in the purpose of the durability plan is important to the designer's chosen service life.

11 **Repair work:** Designers for repair work also have obligations under the durability plan. All repairs are to be based on an accurate diagnosis of the cause of degradation and the scope of repairs considering the extent of degradation on failure, impact on immediate and long-term use of the building, design service life of the repairs, and disruption of the use of the building during repairs. Work is to be done considering the scheduled design service life in the original durability plan with a revised durability plan created following Tables 1 and 2, where relevant.

12 **Renovation:** Buildings that are repurposed and renovated will require a revised durability plan which is to consider the revised use, environment changes and the impact of new work on other building elements.

SUMMARY OF THE PURPOSE OF CSA S478

In addition to the steps a designer can take to understand and develop designs that achieve a level of durability that aligns with the building's intended function, the basic intent of the standard is to provide a coherent framework for designers to develop a durability plan that can be applied from the early design stages through the life of the building. Once the design for durability is complete, the durability plan a designer is to create includes:

a) a maintenance plan,
b) a quality assurance plan,
c) an operation and maintenance manual,
d) reference documentation supporting the chosen service life,
e) a framework for compliance with the plan during renovation or repair, and
f) quality control framework for construction in support of the overall plan.

CLIMATE CHANGE AND DESIGN LOADS

A key input to the design for durability is the prediction of design loads, both physical and environmental. The current design practice is to employ design tables included in supplements to the NBCC or applicable regulations. The physical loads on structural elements are those applied through use and are controlled through that use. The environmental loads are subject to the effects of climate change and are not established in model codes or applicable regulations. The impact of climate on building loads is discussed in Annex E. That reference would assist designers in selecting appropriate environmental loads but with the proviso that there is no guarantee that those loads will be accurate.

Designers must consider that as the building ages, the resistance to environmental loads will probably decrease. Hence the need for routine inspections and maintenance as part of the durability plan. In addition, designers must consider that the conditions that impart environmental loads on the building and elements, will not remain static. Future changes to environmental loads are not currently incorporated into building enclosure design. For buildings with a design life of 25 years or less, that may not be critical. However, if the building is intended to have permanence with a design life of 100 or more years, a greater margin of resistance to degradation and applied environmental loads would be relevant. For example, substantial resistance to wind-driven rain loads in some geographic areas could direct the designer to increase the capacity to shed and drain water from walls and windows. Perhaps the design could choose the alternative approach which would be to increase the adaptive capacity of the building elements such that new components could be interchanged with greater ease than would normally be the case.

Adaptation (or the ability to withstand future loads) and/or adaptive capacity to climate change, meaning the ability to swap in more or perhaps less resistance as may be appropriate, building elements would become among the considerations that a designer would put into the durability plan.

RISK AND LIABILITY CONSIDERATIONS

Failure of the building enclosure, be that through the roof, cladding, windows, doors, below-ground protection systems, or joints between has been a cause of major civil lawsuits for decades. That is a serious concern for both designers and their insurers. While most civil disputes have a conclusion in settlement of the matter through the various mediation and adjudication processes that have taken deep root in the past 30 years, the most appropriate way to manage the risk of failure is to prevent the occurrence of failure in the most rational method available. Until the development of CSA S478 as a standard for fixing the intended durability in time and process controls, the debate about how long specific building elements should last, who was responsible for failure, and what the connections should be between owners, designers, contractors and suppliers, and users was left largely to forensic review of cause and effect.

Liability in terms of compensating for damage has been the result of costly dispute resolution processes that have little to do with the costs for design and construction and much to do with paying for investigation, repair which may conflict with the original design thinking, and zealous advocacy on positions. CSA S478 attempts to redirect the efforts to the design and construction stage. That reduces the uncertain risk and liability associated with alleged premature failure by providing documented support for the intended life and repair timing.

BUILDING CODES AND REGULATIONS

Building codes and regulations state what must be achieved. Those begin with the presumption that persons involved with design and construction will follow applicable statutes, design guides and standards. An omnibus standard for building enclosure durability asserting the obligations of various parties complete with a roadmap of how to achieve the foundational purpose of building codes and regulations has been missing from the landscape. This standard does not assert contractual obligations. That is not the form or purpose of CSA Standards. Rather it establishes various roles with duties that support an overall durability plan.

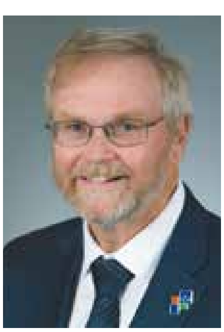
Building codes have historically not dealt with the cradle-to-grave life of buildings. They are largely about creation rather than use. While CSA S478 provides roles and duties to deal with maintenance and repair, fundamentally, the standard is not in conflict with the objective of codes and regulations affecting design nor is it in conflict with the prevalent social imperative to become a more sustainable society. With the current emphasis on building sustainability and reduction in dismissal of embodied carbon, compliance with CSA S478 provides opportunities to reduce the creation of greenhouse gases by minimizing unintended and premature repair and replacement of building elements that should have lasted longer.

As of the writing of this paper, CSA S478 is not referenced in the *National Building Code of Canada.* Further, it has not been incorporated into provincial regulations and therefore is not the minimum legal requirement. Nonetheless, there is no debate that voluntarily following this standard will give all parties that have an interest in the durability of the building enclosure a more-structured, best-practice document on which to base decisions and arguments about durability.

REFERENCE

1. Genge, G. R., and Kerr, D. D., "CSA S478, Durability in Buildings, Transition into a Standard and Importation of Climate Change Issues. Accessed July 11, 2017 (for CSA S478 members only).

ABOUT THE AUTHOR



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