Requirements for durability and on-going performance in Canada's objective-based construction codes

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REQUIREMENTS FOR DURABILITY AND ON-GOING PERFORMANCE IN CANADA'S OBJECTIVE-BASED CONSTRUCTION CODES

Durability and Canada's objective-based construction codes

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Abstract
The paper describes the nature of objective-based codes, and describes how performance, prescriptive and functional requirements fit into the structure of Canada's new objective-based construction codes.
Canada's national model codes have for some time included a variety of requirements related to durability and on-going performance. The paper differentiates between the concepts of durability, service life and on-going performance, and indicates how these may be addressed in codes.
The paper reviews a number of approaches for incorporating durability and on-going performance requirements into the objective-based code structure and provides examples of the approach that has been accepted to date. The paper looks ahead to the possible development of more specific durability-related provisions.
Keywords: acceptable solutions, building codes, deterioration, durability, failure, functional requirements, objectives, objective-based codes, performance, service life

Résumé
Ce document décrit la nature des codes axés sur les objectifs ainsi que la façon dont les exigences de performance, normatives et fonctionnelles s'intègrent dans la structure des nouveaux codes canadiens de construction axés sur les objectifs.
Les codes modèles canadiens contiennent depuis un certain temps diverses exigences ayant trait à la durabilité et à la. L'auteure établit une distinction entre les concepts de durabilité, de durée de vie et de performance à long terme, et propose une façon d'aborder ces aspects dans les codes.
On y examine un certain nombre de moyens pour incorporer à la structure des codes axés sur les objectifs des exigences de durabilité et de performance à long terme, et on donne des exemples de l'approche qui a été adoptée à ce jour. Enfin, l'auteure parle de la possibilité d'élaborer des dispositions traitant plus spécifiquement de la durabilité.
Mots clés : solutions acceptables, codes du bâtiment, détérioration, durabilité, défaillance, exigences fonctionnelles, objectifs, codes axés sur les objectifs, performance, durée de vie

1 Introduction – background, present, future

The suitability of addressing durability in the National Building Code of Canada (NBCC) and the issues to be considered in drafting durability-related requirements have been discussed (CCBFC 1995a, Chown 1996). The NBCC and Canada's other national model codes are in the process of evolving into objective-based codes. This evolution has raised questions as to how provisions related to durability and on-going performance will be incorporated into the objective-based structures. This paper describes what an objective based code is, outlines options for including provisions related to durability and on-going performance, identifies the direction that has been adopted, provides an example of code provisions as they may appear in the objective-based NBCC, and describes opportunities for further development of provisions related to durability and on-going performance.

2 Objective-based codes

Objective-based codes are simply codes whose provisions are related to a hierarchical structure of objectives. The complete code structure consists of four types of elements: objectives, functional requirements, quantitative performance criteria and acceptable solutions (see Figure 1.)

2.1 Root and consequential objectives

All regulations have objectives that they are seeking to achieve. In the case of the NBCC, the two most widely recognized and accepted root objectives relate to the provision of healthy and safe conditions for building users. To address these objectives, one may identify a number of consequential objectives.

In the example illustrated in Figure 1, minimizing the risk of unsafe conditions requires protection from fire and structural failure. To minimize the likelihood of structural failure, adequate initial strength and resistance to deterioration are consequential objectives. To reduce the likelihood of inadequate initial strength, the structure must be designed to resist all dead and live loads that might be imposed.

2.2 Functional requirements and quantitative performance criteria

At the bottom of the hierarchy, the objectives become sufficiently specific that they address particular building elements and provide criteria. These objectives are referred to as functional requirements. In theory, these may be qualitative or quantitative. For example, to resist all of the loads that might be expected to be imposed on a floor, a functional requirement might state:

> Floors in residential spaces shall be designed to resist expected live loads imposed by occupants, furnishings and appliances.

The same functional requirement might be stated so as to include a quantitative limit:

> Floors in residential spaces shall be designed to resist 1.9 kPa.

In the Canadian objective-based construction codes, all functional requirements will be stated in qualitative terms. This is intended to minimize the need to revise these requirements over time as new knowledge is developed that might result in changes to quantitative criteria. Related quantitative performance criteria (QPC) are then included as separate elements in the code structure.

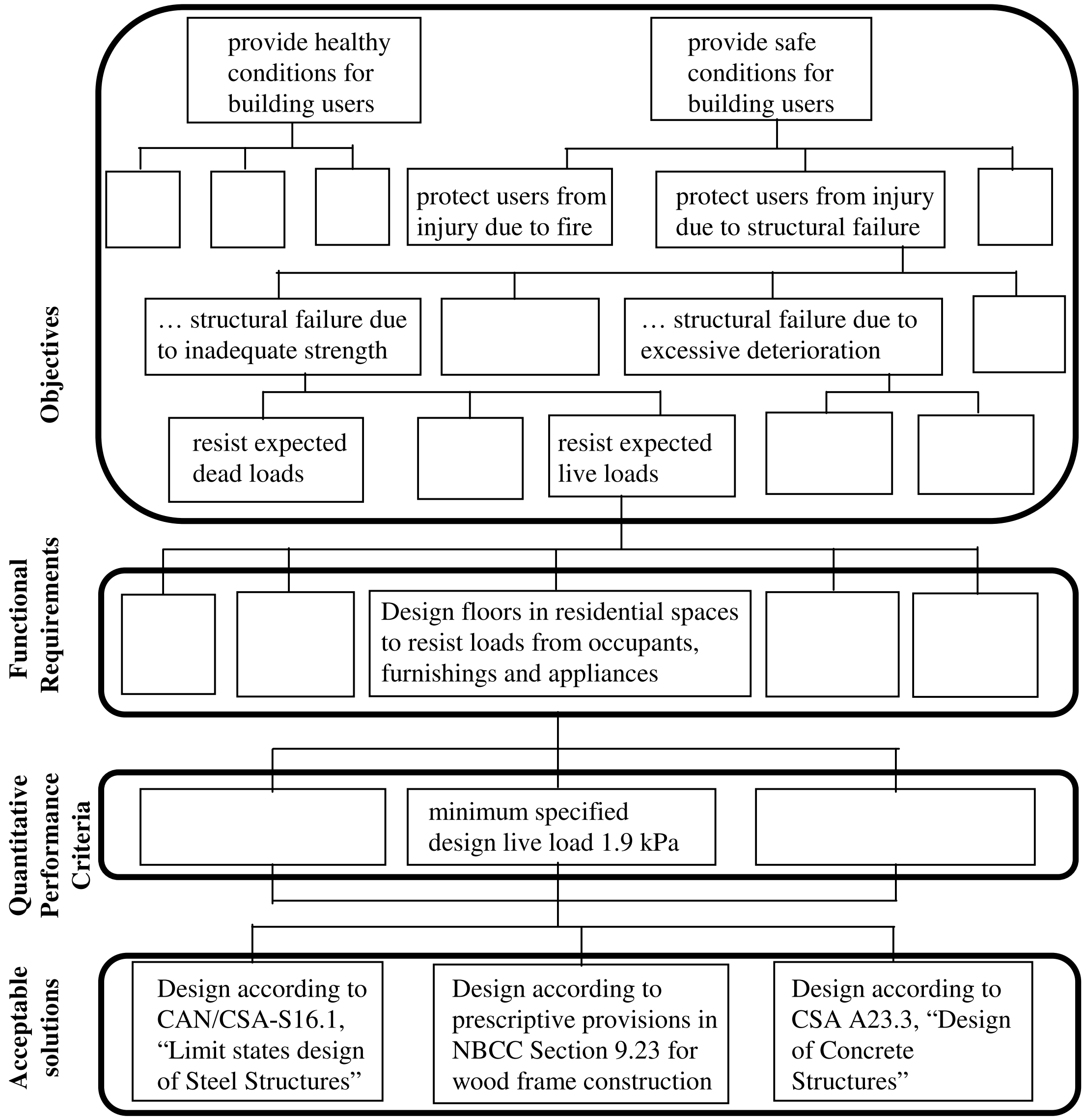
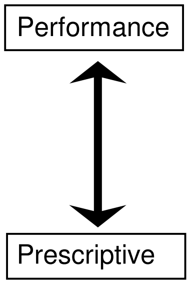


Fig. 1: Example of hierarchy of objectives with related functional requirements and acceptable solutions

2.3 Acceptable solutions

To comply with a functional requirement and its related QPC, a variety of solutions may be developed. These are referred to as acceptable solutions and may be performance- or prescriptive-based. Figure 2 lists possible acceptable solutions to a functional requirement concerned with protection from corrosion, illustrating a continuum from performance to prescriptive. Consequently, an objective-based code is not a solely performance-based code or a prescriptive-based code, but allows for the development of numerous solutions, described in performance or prescriptive terms, to meet the functional requirements and achieve the stated objectives.



- treat component as necessary to ensure acceptable performance over the service live of the assembly in which the component is a part.
- treat component to limit rate of material loss to Y % by mass over the service live of the assembly in which the component is a part.
- treat component to limit rate of material loss to X g/kg over 5 years
- apply galvanizing to component to limit rate of material loss to X g/kg over 5 years
- apply 305 g galvanizing per m^2 surface area of component

Fig. 2: Example of continuum of acceptable solutions from performance to prescriptive

Construction that satisfies the provisions of the current codes represent one set of acceptable solutions. For example, the prescriptive requirements currently provided in the NBCC for wood-frame construction of floors would constitute an acceptable solution for fulfilling the functional requirements provided above. Alternative solutions may also be provided by various consensus-based standards.

3 Code provisions for durability and on-going performance

The NBCC has over time included a variety of durability-related requirements and it is agreed that "... requirements for quality and durability that affect health and safety are appropriate" (CCBFC 1995a). It has been agreed that "durability is a factor appropriate for codes provided the concern is related to the objectives of the particular code and any requirements are clear, explicit and enforceable at the time of construction" (CCBFC 1996). In the context of construction codes, it is important to differentiate between durability, service life and on-going performance.

3.1 Durability

For the purpose of this paper, durability of a building material, component, assembly or system is defined as that element's

> ability, at a single point in time and measured in terms of time, to resist or accommodate agents and mechanisms of deterioration in the service environment, and thereby perform the required functions.

Durability depends on initial properties and rate of deterioration in a particular service environment; that is, on initial performance and the rate of deterioration of performance in the service environment. As durability reflects a snapshot in time, it can be considered independent of maintenance. Carrying out maintenance will alter the properties of the building element or its service environment; consequently, durability after maintenance will be different from that before maintenance. (See Figure 3.)

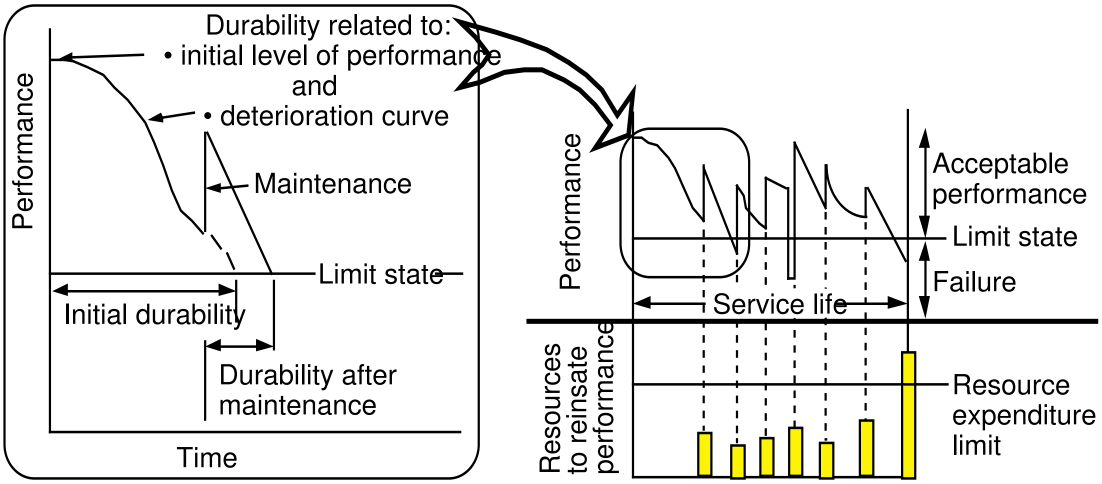


Fig. 3: Durability, deterioration and service life (Chown and Oleszkiewicz 1997)

3.2 Service life

Durability and maintenance together determine service life.

> Service life is the period after installation during which all properties of a material, component, assembly or system essential to its required functions meet or exceed minimum acceptable levels without major costs or disruption for major maintenance, repair or replacement.

That is, service life depends on maintenance and the resources necessary to carry out that maintenance. When cost for maintenance or repair exceeds an acceptable level or when replacement is required, service life has ended.

In a building clad with face-sealed precast concrete panels, deterioration of sealant between the panels will allow water entry. Where this indicates performance below the limit state, the cladding system, in effect, fails. Although the sealant has reached the end of its service life, likely the whole cladding system has not. If the sealant can be replaced for reasonable cost, the assembly will continue to function.

Obsolescence, or physical damage or deterioration of the cladding components themselves, may require, to re-establish performance, expenditure of resources that exceeds a certain limit. At this point, the end of the service life of the cladding has been reached. If resources are expended to repair or replace the cladding components, the cladding system would acquire a new service life.

3.3 Addressing durability in building codes

Durability, because it refers to the characteristics of an element at a particular point in time and the expected deterioration curve after that time, may be addressed relatively easily in building codes, such as the NBCC, that only comes into force up until and at the time of hand-over of the building. It may, for example, be expressed prescriptively in terms of material properties required when the element is installed in a particular assembly or exposed to a particular climate.

3.4 Addressing service life and on-going performance in codes

Service life, as it depends on maintenance, is difficult to address in a building code. It may be addressed in regulations that consider on-going operation of a building and its elements. The National Fire Code of Canada (NFCC) (CCBFC 1995b) is an example of a code that addresses on-going performance with respect to fire safety.

In the code context, the concern is not with service life per se but rather with on-going performance. Service life is related to the resources required for maintenance, but resources are not a primary concern of most codes. The NFCC is not concerned with whether on-going performance is provided by a single durable element with a long life or by an element that is maintained, repaired or replaced regularly.

Regardless of the above, there are instances where the term service life appears in the NBCC. The NBCC does not, however, identify accepted means of establishing service life, and design service life need not recorded in design documents.

4 Durability and on-going performance in an objective structure

Because the development of the objective hierarchy for Canada's national model codes is in progress, it is not possible to describe how any one requirement or a set of requirements will be addressed in the final objective-based documents. A number of options for fitting objectives and provisions related to durability and on-going performance into the structure have been discussed.

4.1 Durability and on-going performance as root objectives

Including durability and on-going performance as root objectives, along with health and safety for example, would suggest that durability and on-going performance are objectives in of themselves and are unrelated to the other identified root objectives. This reflects some public expectations but, as noted, is inconsistent with the decisions related to the strategic development of the national model codes (CCBFC 1996).

4.2 Durability and on-going performance as third dimension to the objective structure

Looking upward through the objective hierarchy from some lower level in the structure, development of the hierarchy is based on answering the question "why?" Durability addresses the question of "how long?" An argument was made that durability can be related to each and every root and consequential objective in the hierarchy. To reflect this, durability could be addressed in a structure that is separate from but parallel to the basic objective tree, or as a parameter that may be attached to every node in the hierarchy. This is theoretically valid but implies an unnecessary degree of complexity. In reality, the issues of durability and on-going performance need only be addressed explicitly at certain levels in the hierarchy.

4.3 Durability and on-going performance within the objective structure

Preliminary efforts to link root objectives with code requirements indicate that the NBCC and NFCC address durability and on-going performance at various levels. In some cases, the existing code provisions directly address the subject. In other instances, the relationship between the provision and durability or on-going performance only becomes evident higher in the objective tree.

The following present small slices of the objective-based hierarchies of the NBCC and NFCC to illustrate how durability and on-going performance might be included in those hierarchies. References to durability, deterioration, service life and on-going performance are in bold type to highlight the various levels at which the issue may be addressed. It is important to note that the current codes do not necessarily provide QPC or acceptable solutions in all cases. This issue is discussed further under Opportunities and Challenges below.

CURRENT CODE PROVISION

NBCC 6.2.9.2. Insulation and Coverings

1) Insulation and coverings on pipes shall be composed of material which will withstand deterioration from softening, melting, mildew and mould at the operating temperature of the system.

OBJECTIVE PROGRESSION 1

- provide HEALTHY CONDITIONS for building users
  - protect users from inadequate air quality
  - protect users from inadequate thermal conditions
    - ...due to **premature failure** of the heating or cooling system

Functional requirement

- **6.2.9.2.(1)** Insulation and coverings on heating and cooling pipes shall be **resistant to thermal and biological deterioration**.

Quantitative performance criteria

- (undefined)

Acceptable solution

- (undefined)

OBJECTIVE PROGRESSION 2

- provide SAFE CONDITIONS for building users
  - protect users from injury due to fire
  - protect users from injury due to structural failure
  - reduce probability of user injury due to burning
    - ...due to **premature failure** of protective material over exposed hot elements

Functional requirement

- **6.2.9.2.(1)** Insulation and coverings on heating and cooling pipes shall be **resistant to thermal and biological deterioration**.

Quantitative performance criteria

- (undefined)

Acceptable solution

- (undefined)

CURRENT CODE PROVISION

NBCC 9.20.9.5. Ties for Masonry Veneer

1) Masonry veneer 75 mm or more in thickness and resting on a bearing support shall be tied to masonry back-up or to wood framing members with straps that are a) corrosion-resistant, ….

Objectives

- provide SAFE CONDITIONS for building users
    - protect users from injury due to fire
    - protect users from injury due to structural failure
        - ...structural failure resulting from inadequate strength
        - ...structural failure resulting from excessive rate of deterioration
            - ... **excessive rate of deterioration** due to corrosion
                - control temperatures in the assembly
                - control moisture levels in the assembly
                - provide protection of corrosion-prone materials

Functional Requirement

- **9.20.9.5.(1)(a)** Masonry ties shall be **corrosion resistant**.

Quantitative performance criteria

- (undefined)

Acceptable solution (or part thereof)

- 9.20.16.1. Corrosion Resistance of Connectors, Table 9.20.16.1. provides **minimum prescriptive galvanizing criteria**.

CURRENT CODE PROVISION

NFCC 2.3.2.2. Flame Retardant Treatment

1) Flame retardant treatments shall be renewed as often as required to ensure that the material will pass the match flame test in NFPA 701, "Fire Tests for Flame-Resistant Textiles and Films."

Objectives

- provide SAFE CONDITIONS for building users
    - protect users from injury due to structural failure
    - protect users from injury due to fire
        - ...due to combustion of fabrics
            - ... due to **deterioration** of flame retardants

Functional Requirement

- **2.3.2.2.(1)** Flame retardant treatment shall be renewed to ensure **on-going performance**.

Quantitative performance criteria

- per NFPA 701

Acceptable solution

- **2.3.2.2.(1)** Testing in accordance with NFPA 701.

5 Presentation of information in an objective-based code

Organizing objective-based code material to reflect its logical structure is relatively simple in electronic form but extremely cumbersome in hardcopy. Consequently, the codes will be organized with respect to the subjects addressed, similar to the existing documents.

The following provides one possible presentation of an excerpt from the objective-based NBCC. This excerpt provides information related to controlling heat loss, including potential consequences for deterioration. Information is provided on the application of the provisions, the objectives and the functional requirements. QPC and accepted solutions are not included in this excerpt. Accepted solutions would include sources of climate data, accepted calculation procedures, prescriptive installation provisions, and referenced material and installation standards.

5.1. Heat transfer control

5.1.1. Exposure to intended temperature differential

<u>Application</u>

This Subsection applies to building components or assemblies that will be subjected to an intended temperature differential, except where it can be shown that the effects of the temperature differential will not adversely affect achieving the Objectives of this Subsection.

<u>Objectives</u>

The Objectives of this Subsection are

1) Health
   a) To reduce the likelihood of unacceptable interior air or surface temperature fluctuations due to inadequate control of heat transfer through *environmental separators*
   b) To reduce the likelihood of harmful indoor air pollution from biological growth or from materials becoming unstable due to wetting from condensation of moisture from interior spaces
   c) To reduce the likelihood of premature failure of environmental separators caused by deterioration due condensation of moisture from interior spaces.
   d) To reduce the likelihood that the means of heat transfer control presents a health hazard
2) Safety
   a) To reduce the likelihood of injury from the loss of integrity of building components due to deterioration caused by condensation of moisture from interior spaces
   b) To reduce the likelihood that the means of heat transfer control presents a safety hazard

<u>Requirements</u>

A.5.1.1-R-1

Building components or assemblies identified in Application shall be designed and built to provide sufficient resistance to heat transfer,

a) in conjunction with systems installed for space conditioning, to meet the interior design thermal conditions for the intended occupancy (Objective 1a)

c) to reduce the likelihood of surface condensation on the warm side of the component or assembly to a degree that will not initiate deterioration, (Objectives 1b, 2a)

b) in conjunction with other materials or components in the assembly, to reduce the likelihood of condensation within the component or assembly to a degree that will not initiate deterioration, (Objectives 1b, 2a)

A.5.2.1-R-2

Building materials, components, assemblies or systems installed to control air transfer shall be (Objectives 1a, 1b, 1c, 1d, 2a, 2b)

a) compatible with adjoining materials,

b) resistant to any mechanisms of deterioration which would be reasonably expected given the nature, function and exposure of the building element.

A.5.2.1-R-3

Building materials, components, assemblies or systems installed to control air transfer shall not substantially contribute to the pollution of indoor air (Objective 1d)

A.5.2.1-R-4

Building materials, components, assemblies or systems installed to control air transfer shall not create a safety hazard (Objective 2b)

6 Opportunities and challenges

Because an objective-based code permits a large number of acceptable solutions to meet its objectives, there are numerous means of providing for durability and on-going performance that are not currently specified in the NBCC or NFCC. Furthermore, as noted above, there are instances where the current documents do not provide any QPC or acceptable solutions for some functional requirements. The development of the objective-based codes opens the doors to the development of these criteria and alternative solutions.

Where prescriptive acceptable solutions are included in the current codes, the degrees of durability and on-going performance provided by these provisions are largely unknown. The first challenge in these instances is to determine what are the currently acceptable levels of durability and on-going performance; that is, what are the QPC. Once these are defined, there is a basis for determining whether proposed acceptable solutions will fulfill the functional requirements and the related objective(s). Whether acceptable solutions are incorporated directly into the codes or are included by reference, it is vital that they address all the necessary requirements and objectives.

The transition to objective-based codes is providing an opportunity to review all of the current code provisions and to identify areas where rationalization and further information are needed to assist in their on-going development.

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