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RESEARCH IN SUPPORT OF PERFORMANCE-BASED SOLUTIONS IN THE NATIONAL CONSTRUCTION CODES OF CANADA

Denis Bergeron, Architect, MSFPE[1]
National Research Council Canada
Ottawa, Ontario Canada K1A 0R6

ABSTRACT

The National Construction Codes of Canada – the National Building Code, the National Fire Code and the National Plumbing Code – have generally been considered to be essentially prescriptive codes, although they include a certain number of performance solutions, especially in the structural design area.

The Canadian Commission on Building and Fire Codes (CCBFC)[2] and the staff of the Canadian Codes Centre at the National Research Council of Canada (NRC) sought a solution that would make the codes more flexible while avoiding the concerns of those who feared the loss of this "recipe-based" prescriptive approach as well as those who feared that the introduction of performance-based codes would create an "anything goes" atmosphere. The solution that emerged resulted, in September 2005, in the publication by Canada of the world's first objective-based codes. While sharing many characteristics with performance-based codes, objective-based codes have certain key differences.

A major point of departure between countries that have implemented performance-based building regulations and Canada's objective-based codes is how innovative designs are handled. Innovative designs are methods of complying with the regulations that differ from the acceptable solutions. In Canada's objective based codes innovative designs are referred to as "alternative solutions". Generally speaking there are two ways these innovative designs can be assessed for compliance against the regulations:

- in a performance-based regulatory system: assessing against the objectives and performance requirements (first principles approach), or
- in Canada's objective-based codes: comparing against the stated acceptable solutions (benchmark approach).

With the publication of the new codes in 2005 technical code development work has resumed with emphasis placed on identifying opportunities to introduce performance-based solutions hence taking benefit of the clear articulation of objectives, functional

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[1] D. Bergeron is Director, Codes and Evaluation, Institute for Research in Construction, National Research Council of Canada.

[2] The CCBFC is a committee established by the NRC to oversee the development of the National Construction Codes of Canada. It is composed of 40 +/- volunteer members from across Canada and from all segments of the community affected by the Codes – consumer representatives, architects, engineers, building officials, fire officials, plumbing officials, material suppliers, builders, etc. The CCBFC makes all final decisions regarding the contents of the National Construction Codes.

statements and intents provided by the objective-based format of the new codes. This increased interest for performance-based solutions has led to the articulation of research projects aiming at quantifying the level of performance that is embedded in the acceptable solutions of the codes. Research is currently underway at NRC not only in the fire area but also regarding the performance of code complying exterior wall systems against rain penetration. The main research projects currently underway are:

- Fire Performance of Houses: to determine the impact of innovative house construction products and systems on the overall safety of occupants.
- Design Fires: to develop fire characteristics parameters for different occupancies. First research project is for Characterization of real fires in multi-suite dwellings.
- Heat and moisture performance of roof, walls and windows.
- Fire and acoustical performance of building assemblies: walls and floors, fire stops, flanking sound transmission, speech security and speech recognition.

This paper will describe the research currently underway at NRC, other projects under consideration and their potential impact on the inclusion of performance-based solutions in future editions of the codes.

CANADA`S BUILDING REGULATORY FRAMEWORK AND MODEL NATIONAL CONSTRUCTION CODES

The Canadian Commission on Building and Fire Codes (CCBFC) oversees production of the model National Construction Codes of Canada – the National Building Code (NBC), the National Fire Code (NFC) and the National Plumbing Code (NPC), plus other guidance documents.

The provincial and territorial governments have the authority to enact legislation that regulates building design and construction within their jurisdiction. This legislation may include the adoption of the model National Construction Codes of Canada without change or with modifications to suit local needs, and the enactment of other laws and regulations regarding building design and construction, including the requirements for professional involvement.

The National Construction Codes of Canada are published in an objective-based code format for the first time in their 2005 editions. This is the result of ten years of work on an initiative that arose out of the strategic plan adopted by the Canadian Commission on Building and Fire Codes (CCBFC) in 1995[i].

Structure of the 2005 National Construction Codes of Canada

The objective-based code format organizes the 2005 National Construction Codes into three Divisions:

- **Division A**, which defines the scope of the Codes and contains the objectives, functional statements and the conditions necessary to achieve compliance;

- **Division B**, which contains acceptable solutions (formerly referred to as "technical requirements") deemed to satisfy the objectives and functional statements listed in Division A; and
- **Division C**, which contains administrative requirements.

Apart from the inclusion of technical changes resulting from the normal code development process since the last publication of the Codes in 1995, the provisions in Division B are essentially the same as the technical provisions found in the 1995 editions. However, in the 2005 Codes, each provision in Division B is linked to:

- one or more **objectives** (such as safety or health) that individual provisions help to address, and
- one or more **functional statements** (statements on the functions of the building that a particular provision helps to achieve).

In addition, each Code provision is linked to two new types of explanatory material:

- **intent statements** (detailed statements of the specific intent of the provision), and
- **application statements** (detailed statements of what the provision applies to).

Compliance with the 2005 National Construction Codes of Canada

Sentence 1.2.1.1.(1) of Division A is a very important new Sentence: it is a precise statement of the relationship between Divisions A and B and is central to the concept of objective-based codes:

1.2.1.1. Compliance with this Code

1) Compliance with this Code shall be achieved by

a) complying with the applicable acceptable solutions in Division B, or

b) using alternative solutions that will achieve at least the minimum level of performance required by Division B in the areas defined by the objectives and functional statements attributed to the applicable acceptable solutions.

Clause (a) makes it clear that the acceptable solutions in Division B are automatically deemed to satisfy the objectives and functional statements of Division A.

Clause (b) introduces the new term "alternative solutions." This Clause makes it clear that alternative solutions can be used in lieu of compliance with the acceptable solutions. However, to do something different from the acceptable solutions described in Division B, a builder, designer or building owner must show that their proposed alternative solution will perform at least as well as the acceptable solution(s) it is replacing. The objectives and functional statements attributed to the acceptable solution(s) identify the areas of performance where this equivalency must be demonstrated. Assessing compliance cannot be based on the objectives and functional statements alone.

- Areas of performance. Objectives and functional statements provide qualitative performance criteria only: they determine what areas of performance of a proposed alternative solution must be evaluated.
- Level of Performance. It is the acceptable solutions in Division B that provide the benchmark for quantitative performance against which to compare a proposed

alternative solution. Many acceptable solutions in Division B are not framed in precise measurable terms, with specific methods for evaluating building performance. Proponents will nevertheless be required to prove that their alternative solution will perform at least as well as the applicable acceptable solution(s) it is replacing: not "well enough" but "as well as."

PERFORMANCE OF CODE COMPLIANT BUILDING SOLUTIONS: INITIATIVES UNDERWAY AT NATIONAL RESEARCH COUNCIL CANADA

Some stakeholders may perceive objective-based codes as a transitional approach towards the introduction of fully performance-based building regulations. This is not necessarily the case since some parts of the codes might logically be left in prescriptive format and some parts of the code-using community might prefer it that way. Nevertheless, there is a general trend towards performance-based building solutions and objective-based codes can help guide the way along that path.

The implicit level of performance embedded in the acceptable solutions can be viewed as representing society's expectations of building performance. Converting this implicit level of performance into quantitative terms is a critical first step in the development of measurable and verifiable performance criteria that closely reflect society's expectations – the performance criteria that are essential to true performance-based codes. This is an area where research is needed to develop tools and methods that allow the quantification of the implicit level of performance of acceptable solutions. As more knowledge becomes available, more areas of the codes may be developed into a performance path with quantitative, measurable and verifiable performance criteria, including their verification methods.

A fully articulated performance path would facilitate the development and evaluation of innovative building products, materials and systems. The NRC Institute for Research in Construction (NRC-IRC) supports innovation in construction not only through research but also through the product evaluation service it provides through its Canadian Construction Materials Centre (CCMC). The following describes some of the initiatives and activities underway at NRC-IRC that provide immediate support to innovation and performance solutions and/or develop the knowledge that will contribute to the development of a performance path in the National Construction Codes of Canada.

Evaluation of Innovative Building Solutions

The Canadian Construction Materials Centre (CCMC), a part of the National Research Council's Institute for Research in Construction, offers the construction industry a national evaluation service for new and innovative building materials, products, systems and services. One of the primary objectives of CCMC is to help the construction industry meet the challenge of competition in the marketplace at home and abroad by evaluating construction products with respect to their conformance to applicable codes and standards. Its focus is on providing information that supports innovation in the built

environment. Manufacturers, specifiers, and regulators all benefit from the service, which is supported by all provincial and territorial building regulatory bodies.

The CCMC evaluation of products or systems is an impartial third party technical opinion on the compliance of a product or system to the NBC 2005 (or provincial code). Innovative products are evaluated as an alternative to code-identified solution(s) in NBC Division B. As part of the evaluation process, a technical guide, which is prepared for an innovative product for which no standard exists, conveys CCMC's criteria and requirements to facilitate the assessment. In order to develop these criteria and requirements CCMC's evaluation process includes a detailed code analysis that will identify:

- all applicable acceptable solutions in Division B of the NBC – this will help determine the level of performance expected by the code, and
- the objectives and functional statements attributed to these acceptable solutions – this will help determine the areas of performance to be evaluated.

A successful evaluation results in a report that states CCMC's opinion with regard to the product's/system's performance and its compliance with the minimum acceptable solution stated in the NBC. This opinion is based on the test evidence submitted in accordance with these requirements. Limitations are set based on the scope of the evaluation, the code and the evidence submitted. The issuance of a CCMC report and evaluation number does not constitute an approval or a certification of the product or system. Regulators, specifications writers, builders or general users can use the information to determine approval or acceptability.

As building construction becomes more complex and sophisticated CCMC frequently needs to conduct extensive study and research in order to properly determine the performance expectation of the codes and evaluate that of innovative solutions. Following are a two examples of this work.

Performance of Air Barrier Systems[ii] [iii]

The air barrier system is an essential element in the performance of building envelopes. It plays an important role in the control of air, heat and moisture movement across the building envelope. Many performance and deterioration problems of building envelopes can be attributed to inadequate or failed air barrier systems. Although the importance of the air barrier system has been known for decades, the characteristics that it must have to perform adequately have not been clear. Recent research has allowed for the development of a test method that enables its performance to be evaluated.

While the National Building Code (NBC) stipulates performance requirements for the air barrier system, there has been no standard procedure to assess whether an assembly of materials meets the NBC requirements. This meant that when a non-standard approach to air leakage was proposed, there was no way to evaluate it. At the request of industry, the Canadian Construction Materials Centre (CCMC) initiated a program to gain a better understanding of the fundamental performance requirements of an air barrier system and

develop a method for evaluating the effectiveness and durability of such systems. As part of this process, CCMC determined acceptance criteria and identified test procedures to establish whether a proprietary system meets the intent of the code. The work resulted in a technical guide.

The technical guide provides requirements, methods and criteria for evaluating the performance of proprietary air barrier systems for walls of low-rise buildings (up to three storeys high). Its technical criteria address the air barrier system's air leakage test characteristics (in the form of a test protocol for verifying compliance to the air leakage rate requirement stipulated in the NBC), its structural capacity, continuity, durability and buildability.

Rain Penetration and Moisture Management of Claddings[iv]

Exterior claddings are required to have a rain penetration control strategy. Strategies that have been incorporated in the NBC 2005 as elements of acceptable solutions are: a clear 10 mm air space; the insertion of drainage material behind the cladding; or the use of loosely-fastened cladding components whose configuration incorporates a series of drained and vented spaces. Recently proposed alternative solutions have include new cavity devices and innovative claddings, or systems using reduced air space behind the cladding. CCMC and the Building Envelope and Structures Research Program of NRC-IRC initiated a consortium project to develop a controlled repeatable laboratory method to evaluate the water penetration and moisture management of these innovative products and systems.

Steps of the project include the following:

- construct new facilities to accommodate large-scale test walls,
- develop a protocol to assess cladding products in the laboratory under controlled and repeatable conditions,
- analyze the NBC 2005 requirements that apply to cladding and supporting wall assemblies,
- develop specifications for a benchmark system based on acceptable solutions in the NBC,
- categorize claddings based on the method of attachment, the drainage medium, and the configuration and complexity of the cladding system,
- determine pass/fail criteria for proposed alternative solutions from the moisture management performance of benchmark systems,
- development of a method to evaluate water and moisture management capabilities for each category of cladding system,
- verify and utilize hygrothermal modeling for cladding systems.

Expected outcomes include:

- controlled and repeatable method to evaluate water penetration and moisture management of cladding systems,
- quantifiable performance level for acceptable solutions in the NBC (benchmark).

The objective of the project is to develop the experimental and analytical assessment procedures as well as the pass/fail criteria needed to assess the capability of a cladding system to manage rainwater entry in relation to minimum requirements of the NBC. The project outcome is to facilitate CCMC is evaluating the moisture management aspects of cladding systems. The results of the research study may be made available for use by codes upon completion.

Fire Performance of Houses[v] [vi]

The risk of fire is always present in buildings, including low-rise housing. With the introduction of technological changes and innovations to building materials, design and construction practices, the challenge is to determine the impacts of such changes on the fire safety of occupants in low-rise housing. The Canadian Commission on Building and Fire Codes (CCBFC) and the Canadian Commission on Construction Materials Evaluation (CCCME)[3] have requested information regarding the potential effect of such changes on the fire safety of occupants in low-rise housing.

In response to this request, the National Research Council of Canada, through the Fire Research Program of NRC-IRC, has initiated a project to research fires in single-family dwellings and the factors affecting fire safety of occupants. The primary objective of this basic research is to develop methodologies to determine the impact of innovative residential construction products and systems on fire safety of occupants.

The fire history of modern Canadian houses is very good; so good, in fact, that the National Building Code has not had to include fire performance criteria for traditional wood and concrete structural components used in detached houses. However, the introduction or proposed introduction of innovative structural products for house construction, some of which are quite radical, is necessitating this examination of just what are the minimum acceptable levels of structural fire performance in houses. Quantifying the actual fire performance of normal minimum code-complying construction is a key step in this evaluation.

To support this research effort, NRC-IRC has invested in a new three-level experimental facility, representing the typical basement, first and second storey of a single house. This facility enables NRC-IRC to build typical house sections and apply the appropriate loading in order to study structural fire performance as well as smoke movement and tenability under conditions typical of fires likely to occur in different areas within a house.

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[3] The CCCME is a committee established by the NRC to provide general policies for and technical advice to the Canadian Construction Materials Centre (CCMC). Members are selected from a mix of backgrounds to ensure that the CCCME can address both policy and technical issues in a manner representative of the different regions of Canada, sectors of the construction industry, and users of CCMC evaluation, technical information and listing services.

The results of this research will help inform the decisions of the CCCME, which guides the work of CCMC, and the CCBFC, which is responsible for the content of the National Building Code of Canada (NBC).

The Characterization of Fires in Low Rise Multi-Suite Dwellings[vii] [viii]

Fires in residential buildings result in substantial property losses and are often fatal. Canadian fire statistics for the period 1986 to 2000 show that the fires in residential buildings accounted for approximately 42% of the total number of fires and 80% of the total number of fire fatalities. The monetary losses associated with residential fires are also of significant importance as they represent 43% of the total losses in structural fires. Designing buildings so as to minimize the occurrence of fires and their impact requires the use of computational tools that rely on suitable quantitative characteristics of fires, or design fires, which must be realistic to produce credible results[ix].

To better understand these fires, the Fire Research Program of NRC-IRC has initiated a project to:

- Quantify and characterize the combustibles present;
- Characterize fires in residential buildings in terms of their temporal sequence and quantities such as heat release rate, temperature and combustion products, and;
- Develop and validate rational tools for evaluating fire safety

This project studies the characteristics of fires in living rooms, bedrooms and kitchens in low-rise multi-suite residential dwellings of light-frame construction by using computer simulations and full-scale fire experiments in realistically furnished rooms. The experiments will be instrumented to measure the heat release rate, products of combustion such as smoke, soot and gas species, and other parameters. Computer modelling of various fire scenarios will be used to assist in designing experiments, as well as to allow extrapolation from the experimental data.

This project will provide a comprehensive analysis of fire characteristics in various areas within multi-suite residential dwellings and a greater understanding of the main features of these fires. The design fires and calculation methods that will be developed may be used in the development of design guides, codes and standards by industry, regulatory authorities, and other agencies. A database of experimental results will also be made available.

Decision-Making and Fire Risk Assessment Tools

FiRECAM™ [x] and FIERAsystem[xi] are computer-based fire risk assessment tools that can be used to evaluate fire protection options and costs for office, apartment and light-industrial buildings. FiRECAM and FIERAsystem are developed by the Fire Risk Management group at the Institute for Research in Construction (IRC) of National Research Council Canada. These tools do not establish the level of performance in absolute terms but allow the benchmarking of current codes and can be used to determine

if different fire protection options would have an impact (reduction or increase) - and the relative importance of such impact – on the overall level of fire safety performance of a building. These are decision-making tools that can be used to compare the impact of such features as sprinkler systems or smoke detectors on life safety and property preservation. FiRECAM™ and FIERAsystem are examples of the research that NRC-IRC is conducting to support Canada's move from a prescriptive to an objective-based system of construction codes.

Other Research Projects

Supporting innovation and competitiveness of the construction industry and developing performance-based solutions and decision-making tools are very important goals of NRC-IRC`s strategic plan. Many research projects are directly or indirectly related to these goals and include:

- Performance Guidelines for Basement Envelope Systems and Materials
- Consortium for Moisture Management for Exterior Wall Systems
- Evaluation of Photoluminescent Way-Guidance Installations for Evacuation of Office Buildings
- Special Interest Group - Suitable Acoustic and Firestop Technologies

A complete list of research projects can be found on NRC-IRC website at http://irc.nrc-cnrc.gc.ca

CONCLUSIONS

A fundamental difference between the objective-based concept of the 2005 National Construction Codes of Canada and the performance or function-based approaches adopted in other countries is the reliance in the Canadian codes on the acceptable solutions – essentially prescriptive - to determine the minimum level of performance against which proposed alternative solutions shall be evaluated to determine if they provide equivalent performance. This “benchmarking” approach needs to be supported by sufficient knowledge to determine in measurable terms the level of performance expected from code-compliant building solutions. This knowledge may not be readily available in many areas covered by the National Construction Codes of Canada and research is undertaken at NRC-IRC to better understand the performance expectations of the codes and develop performance-based decision-making tools and methodologies to help evaluate alternative and innovative solutions for equivalency to the codes.

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