Study of potential nonconformities of a new recreation center building’s envelope

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Abstract. This article presents a building envelope’s analysis in order to verify the compliance with mandatory provisions of the Model National Energy Code for Buildings in Canada (MNECB 1997). Because some of the requirements are «not met», investigations were carried out to provide justifications in order to prove that the building can be considered as an exception to the mandatory provisions of MNECB. Therefore, we evaluate the impact of three (3) potential nonconformities of the building’s walls on the building energy performance. In regards to article 3.1.1.1.4 of MNECB, there is an exception if it can be proved that permanent process (like heat recovery of refrigeration compressors) can produce at all times enough heat that no other heating source is required. First of all, by using simulation, we were able to indicate that almost all building’s heating will be provided by energy recovery from ice rinks refrigeration systems (99.2%). Secondly, by using an energy analysis carried out with HEAT2 software, we can show that the increase of heating energy demand caused by the 3 studied walls is very low. This represents an increase of the heating energy demand of only 0.2%, and this, regardless of the heat recovery process. Because the nonconforming wall sections are small (0.97% of the envelope area), this mainly explains the minor impact in terms of building performance. In conclusion, according to the results obtained, we were able to recommend the building for consideration as an exception to the mandatory provisions of MNECB.

1. Introduction

The project of the new recreation center includes the construction of a building of 6 611 m² located in Montréal, Canada. This building includes two skating rinks, locker rooms, offices, staff and first-aid rooms, meeting rooms, an outdoor pool and various other facilities. The aim of this article is to analyse some components of the building’s envelope not meeting the mandatory provisions of MNECB 1997 [1]. Secondly, we evaluate the impact of the building’s envelope components on building energy performance to see if the building may be exempt from some or all of the MNECB mandatory provisions.

2. Methodology

To carry out the analysis, the three following steps are required: (i) provide a summary of the MNECB content and structure to place the analysis in context; (ii) present the three problematic components of the building envelope; (iii) finally, discuss the relevant sections of the MNECB against these walls sections and analyse their conformity.

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2.1. MNECB structure
The MNECB is prepared by the Canadian Commission on Building and Fire Codes (CCBFC). It is essentially a code of minimum regulations for energy efficiency in buildings, which takes into consideration climate, fuel types and costs, and construction costs. The buildings parameters covered by the MNECB must comply with the basic mandatory provisions (building envelope, heating, ventilation or air-conditioning, service water heating, lighting, electrical power), and cannot be bypassed.

Beyond basic mandatory provisions that cannot be bypassed, the MNECB features three alternate routes for compliance, as:

- The prescriptive requirements (i.e. envelope, lighting, HVAC and service water) which generally dictates minimum thermal characteristics for envelope elements and energy conservation measures that can be stated as specific instructions;
- Trade-offs, that allows the user to reduce thermal resistance in one portion of the envelope, provided that the thermal resistance in other areas is increased so that the energy demand of the building is not increased;
- The performance path: the building energy performance calculated on the actual design should be less than that of a similar building designed in strict conformity with the prescriptive requirements.

Our study focuses on the first part, i.e. the analysis of mandatory provisions for the building’s envelope.

2.2. Problem definition
A thermal bridge is an area of a building which has a significantly higher heat transfer than the surrounding materials resulting in an overall reduction in thermal insulation of the building. Thermal bridges occur in three ways, through: materials with higher thermal conductivity than the surrounding materials, penetrations of the thermal envelope, and discontinuities or gaps in the insulation material.

The MNECB indicates that there must be continuity of insulation. However that is not always physically possible or it often implies a very high investment cost. Some buildings components in the current project are considered to break the continuity of the insulation. To identify the degree of non-compliance, we analyse the relevant articles of the MNECB and study each potential nonconforming element with the mandatory provisions of the code.
2.3. Presentation of potential nonconforming elements

The potentially non-compliant walls are presented in this section. The figure 2 is used only to show the location of three potentially nonconforming walls (W₁, W₂ and W₃). Figure 3 shows the details and some dimensions of sections W₁, W₂ and W₃. Lengths (L) of sections W₁, W₂ and W₃ are 3.1 m, 8.8 m and 7.0 m as presented in table 1. In the case of the studied building, the potentially nonconforming wall sections are very small (6.51 m² compared to 671 m² exterior wall gross area for the entire building) and represents approximately 1% of the envelope area.

2.4. Analysis of the appropriate aspects of the MNECB 1997

Some articles of MNECB 1997 were extracted and presented in the following sections as they provide important elements to our analysis.

2.4.1. Application (article 3.1.1.1.4)

« The authority having jurisdiction may exempt a building or part of a building from some or all of the requirements of this Part where it can be shown that the nature and duration of the occupancy makes it impractical to apply these requirements. »

One of the possible exceptions of the article 3.1.1.1.4 relates that « buildings in which permanent processes produce at all times enough heat that no other heating source is required; they may have their insulation requirements reduced to the extent that the processes can still provide all of the required heating ». This exception is relevant in the case of the current building because heat recovery processes produce enough heat to meet envelope heating needs. Our statement is based on the building energy simulation realised with the EE4 and GENIE EE software. In the simulation model, the heating system is simulated as an electrical system. The simulation results show that the building heating energy demand non-covered by recovery is only 1 435 kWh/year. This represents 0.8% of the building’s heating energy demand (184 796 kWh) and 0.05% of the total building energy consumption (2 651 237 kWh). Therefore, according to the presented results, it can be considered that the building has permanent processes (heat recovery of refrigeration compressors) which produce at all times enough heat that no other heating source is required. As the heating requirements of the building are covered at 99.2%, this seems to meet the intent of the architect.
Moreover, in this article, the MNECB gives way to other exceptions saying that «any list of exceptions would necessarily be incomplete». Our interpretation is that this partial exception list can be complemented with other exceptions that should be documented.

2.4.2. Equivalence demonstrated by past performance, test or evaluation (article 2.5.1.3.1)
«Materials, appliances, systems, equipment, methods of design, methods of calculation and construction procedures nor specifically described herein, or that vary from the specific requirements...»
in this Code, may be used if it can be shown that these alternatives are suitable on the basis of past performance, tests or evaluations."

The exception of section 2.5.1.3.1 is entitled «Equivalence demonstrated by computer analysis» and said: «Thermal characteristics of building assemblies may be determined by two and three-dimensional finite element and finite difference models. « Vision », « Frame », « KOBRU », « TRISCO », « ISO2 », « HEAT2 » and « HEATING7 » are such programs, which may also be used to determine equivalency of other computer simulation programs used to perform these calculations. In making such simulations, can must be taken to use the data prescribes in Appendix of this code. »

According to our interpretation, this article and its exception does not provide elements that can help us directly because in fact, we cannot demonstrate the equivalence.

However, we are looking to use one of numerical computing software presented above (HEAT 02.09) to evaluate the additional heat lost calculated for the current building versus that of a reference building designed in strict conformity with the prescriptive requirements for the building envelope. The purpose of this analysis is to demonstrate that the difference in energy consumption between a building complying with the MNECB requirements and the actual building is negligible and that the additional energy costs are also negligible compared to the costs required to improve the walls design conforming to MNECB. We then, consider this approach as a complement to the list of exceptions mentioned in section 3.1.1.1.4 of MNECB.

2.5. Methodology for the thermal analysis of potential nonconforming elements
The following methodology was used to assess the impact of the potential nonconforming envelope elements on the building energy demand.

- For each potentially nonconforming wall, the parameters and the sections to be analysed are identified;
- The elements of the thermal envelope, the thermal resistances and the boundary conditions are identified;
- Using the software HEAT 2 (based on the finite-difference method), the heat losses through the analyzed building’s envelope sections are calculated;
- The additional energy demand induced by these nonconformities is evaluated to demonstrate that their impact in the case of the actual building is not significant.

The models were established according to the architectural plans and by using the information provided by designers. The developed models are approximate representations of the concept that allow reasonable accuracy depending on the objectives identified above. Also, some assumptions were required to complete the analysis and will be presented later.

3. Calculation of the additional heat loss

3.1. Brief description of the method
Normally, the thermal bridges calculation requires the use of digital resolution methods such as finite-element or finite-difference methods.

To use the finite-difference method a mesh is required. This represents a set of isolated points (called nodes) that covers the object under study by also including nodes located on the boundary of the domain in order to impose the boundary conditions with sufficient accuracy.

While there are many programs using this method to "solve" problems in various areas, it is important that the user selects the mesh density, the boundary conditions and the various envelope components specific to his problem in order to find the approximate solution.

3.2. Application of the method
In our study, the HEAT 2.0 software was used to obtain the solution. A 1000 mesh nodes design was created. The imposed stopping criterion is a difference of 0.001% of the net heat flow at the boundaries.
The imposed boundary conditions presented in the figure 5 can be resumed as follows:
- BC1: for the upper and lower bounds, the heat exchange was considered adiabatic (q=0);
- BC2: an ambient temperature of 21°C and a convection heat resistance was considered for the interior vertical wall’s surface (T_{int}=21°C; R_{th}_{int_v}=0.12 m^2·C/W) [3];
- BC3: an ambient temperature of 21°C and a convection heat resistance was considered for the interior horizontal wall’s surface (T_{int}=21°C; R_{th}_{int_h}=0.11 m^2·C/W);
- BC4: an outside air temperature of -1.04°C and a convection heat resistance was considered for the outside wall’s surface (T_{ext}=-1.04°C; R_{th}_{ext}=0.03 m^2·C/W);

The average outside air temperature $T_{ext} = -1.04°C$ was calculated using monthly average weather data for Montréal / Pierre Elliott Trudeau from October to April (months with heating demand).

### 3.3. Results of the studied wall sections

Simulation results are presented in figure 6, and a summary is presented in table 1:

- In column $q'_{PB}$ (for the proposed building), the values of the linear heat transfer rate that crosses the existing envelope for sections W1, W2 and W3 are presented.
- In column $q'_{MNECB}$, the values of the linear heat transfer rate through the envelope in strict conformity with the prescriptive requirements of MNECB are presented.
- Three next columns presents: (i) the difference ($\Delta q'$) between the linear heat transfer rate values $q'_{PB}$ and $q'_{MNECB}$, (ii) the lengths (L) of each studied section and (iii) the heat loss (q) resulting from the potential nonconformities.

- Finally, in the last column the additional energy demand, associated with potential nonconformities is presented. It is calculated with the average outside air temperature ($T_{ext} = -1.04°C$) as mentioned before. This corresponds to 5088 hours annually.

#### Table 1. Summary of the additional energy demand for the proposed envelope compared to an envelope conform to the MNECB

| Case studied | $q'_{PB}$ [W/m] | $q'_{MNECB}$ [W/m] | $\Delta q'$ [W/m] | L [m] | q [W] | Energy demand [kWh] |
|--------------|----------------|-------------------|----------------|------|------|-------------------|
| Section W₁   | 16.93          | 5.45              | 11.48          | 3.1  | 35.58| 181.03            |
| Section W₂   | 8.56           | 6.75              | 1.81           | 8.8  | 15.92| 81.00             |
| Section W₃   | 14.19          | 9.52              | 4.67           | 7.0  | 32.69| 166.32            |
| Total (sections W₁, W₂, W₃) |                 |                   |                |      |      | 428.35 kWh        |
| Scale | Section W_1 | Section W_2 | Section W_3 |
|-------|-------------|-------------|-------------|
| Heat transfer array (proposed building) | | | |
| **T[^0C]** Isotherms (proposed building) | | | |
| Improvement of the envelope (conform MNECB) | Add of 4 inch extruded polystyrene on the outside | Addition of the insulation in the middle (extends over 540 mm) | With continuous insulation of 90 mm thickness on the outside |
| Heat transfer array (MNECB sections) | | | |
| **T[^0C]** Isotherms (MNECB sections) | | | |

Legend of materials:
- Polystyrene extruded
- Concrete
- Polyurethane foam
- Concrete cellular
- Air
- Gypsum Board
- Brick

*Figure 6.* Simulation results for the 3 nonconforming walls
This additional energy demand of 428 kWh represents only 0.2% of the annual building heating energy demand. Also, this heating energy can be covered by heating energy recovery process. Since the annual building energy consumption is 2 651 237 kWh ($342 735), this additional energy is only 0.01% ($13).

4. Conclusions and recommendations

The objective of this study was to evaluate three (3) potential nonconformities of the building’s walls in regards to the basic mandatory provisions of the building envelope. The impact of these walls on the building energy performance was used in this evaluation. The wall’s sections (W1, W2 and W3) do not respect the MNECB mandatory provisions. The simulation results of proposed building indicates that almost all building heating will be provided by energy recovery from ice rinks refrigeration systems (99.2 %).

Since the exception of article 3.1.1.1.4 allows other documented exceptions, it was demonstrated that the effects related to the heat loss of nonconforming walls are negligible compared to the building overall performance. Therefore, we recommend using this approach if the exception in section 3.1.1.1.4 in regards to the heat recovery process is not respected.

Using an energy analysis carried out with HEAT 2 software, we showed that the impact on the increase in annual heating energy demand is only 428.35 kWh, distributed as: 181.03 kWh for section W1, 81 kWh for section W2 and 166.32 kWh for section W3. This additional energy demand represents only 0.2% of the annual building heating energy demand. Since the annual building energy consumption is 2 651 237 kWh ($342 735), this additional energy is only 0.01% ($13). This additional energy cost generated by the potential nonconforming wall sections (13 $/year) can be considered negligible in the context of additional construction costs that would be required to make these walls sections compliant.

In conclusion, according to the results obtained, this case study should be admissible to the list of additional exceptions to the article 3.1.1.1.4 and considered as an exception to the mandatory provisions of MNECB.

5. References

[1] MNECB: 1997 Model National Energy Code of Canada for Buildings, National Research Council, Natural Resources Canada NRC-CNRC, ISBN 0-660-16897-9, 1997.
[2] Gorse C A and Johnston D. 'Oxford Dictionary of Construction, Surveying, and Civil Engineering. 3rd ed. Oxford: Oxford UP, 2012, pp 440-441 ("thermal bridge" definition).
[3] 2009 ASHRAE Handbook Fundamentals, SI edition, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329.