RESEARCH HIGHLIGHT

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PERFORMANCE EVALUATION OF THE ALMON STREET MULTI-UNIT RESIDENTIAL BUILDING

INTRODUCTION

Natural Resources Canada's (NRCan) Commercial Building Incentive Program (CBIP) encourages the design and construction of energy-efficient buildings. It does so by funding a design process that promotes the consideration of all aspects of the design of buildings in one, integrated, process. The primary CBIP objective is to reduce the energy consumption of buildings to a level that is 25 per cent below what the buildings would consume if they had been constructed to the model National Energy Code for Buildings (MNECB). Recently, an apartment building located in Halifax Nova Scotia was designed to meet the CBIP requirements. After the first year of operation, Canada Mortgage and Housing Corporation commissioned a study to evaluate the extent to which the building met the CBIP energy requirements and to characterize the building's water consumption, indoor air quality and ventilation system performance.

Figure 1: The Almon Street Building

BUILDING DESCRIPTION

The building is a fully sprinklered, wood-frame five-storey building with a floor area of 6,604 m^2 (71,060 ft^2) and an underground heated garage with an area of 1,250 m^2 (13,443 ft^2). The building (Figure 1) contains 60 apartments housing a mix of families, singles and elderly persons. The apartments on the 4th floor are two-storey units making up the 4th and 5th floor levels.

The exterior wood-frame walls contain RSI 3.53 fiberglass batt insulation with exterior siding of split face block and vinyl siding. The roof is a vented wood truss attic space insulated with RSI 10.4 mineral wool batt insulation. The building's windows are double pane, sealed units with low E coating and argon gas fill. All of the windows are vinyl, vertical sliders.

The building is heated by a central space heating system comprised of two high-efficiency oil-fired boilers that supply hot water to in-floor radiant heating in the apartments on the first four floors. The floor areas on the 5th level are heated by radiant baseboards. Hydronic fan-coil units are installed to heat the parking garage. The in-suite heating is controlled by thermostats located in each suite. There is no air-conditioning system.

Domestic hot water is supplied by the oil-fired boilers via a heat exchanger and storage water tank. The hot water is delivered to the apartments by a central recirculation system.

Building ventilation is provided by five heat recovery ventilators (HRV) installed on each floor. The HRVs provide outdoor air on a continuous basis to the common corridors and to all the rooms within the individual apartments. The HRVs also exhaust air from the bathrooms in each apartment. The kitchens are provided with independently ducted range hoods. The in-suite clothes dryers are also vented directly outdoors. The airflow capacity of the HRVs is controlled by a fan speed switch located in the HRV closet on each floor.

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The common corridor lighting is provided by compact fluorescent (twin PL-13) wall sconces. LED exit lights are also installed in the corridors. Within the apartments, the kitchens are supplied with twin T-8 tubes with electronic ballasts. The parking garage lighting is supplied by twin T-8 fixtures with electronic ballasts. The overall design lighting density is 7.14 W/m^2 for the entire building. No special energy-efficiency requirements were applied to appliances.

The consumption of oil and water for the building is bulk metered. Each apartment is individually metered for electricity use.

RESEARCH PROGRAM

The research project to assess the performance of the building involved the following tasks

- compilation of annual energy and water consumption information
- modeling of the building energy consumption characteristics—reconciled with actual use
- measurement of the air leakage characteristics
- assessment of the ventilation system's performance
- monitoring of indoor air quality indicators during a one-week period of the heating season

FINDINGS

Energy Performance

The energy modeling indicated that if the building had been constructed to the MNECB, the total energy consumption (electricity and oil) would be 4,378,795 MJ. Therefore, to qualify for the CBIP support, the building was designed to have a total annual energy consumption of 2,844,981 MJ (i.e.; the energy target—which ambitiously exceeded the minimum CBIP requirements by 10 per cent). However, based on the first year's utility invoices, the actual total annual energy consumption was 4,485,806 MJ which exceeded the original design energy target, the minimum CBIP requirement and the MNECB estimate.

Figure 2 shows the "Reference" MNECB, "Design" Target and "Actual" annual energy consumption for each energy source and in total. The actual electricity consumption was 22.3 per cent below the MNECB ("Reference") and is 16.7 per cent higher than the design target ("Design"). The actual oil consumption was 15.0 per cent higher than the reference MNECB building and 78.8 per cent higher than the design target. Subsequent analysis of the energy loads and the building itself indicate that the discrepancy between the targets and actual performance may have been due to higher-than-anticipated electricity plug loads, high domestic hot water consumption and boiler/space heating system controls.

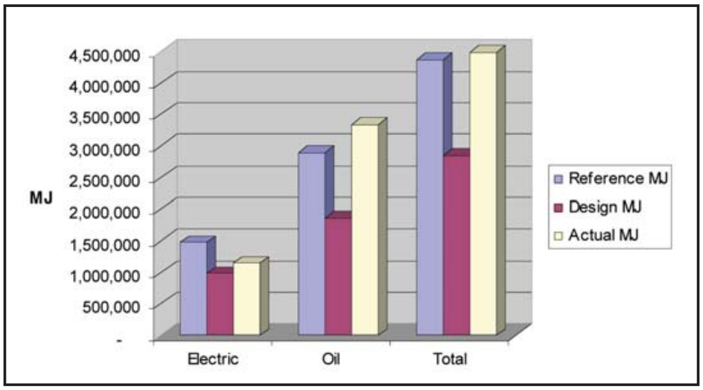

Figure 2: Annual Energy Consumption – Actual vs. Targets

It is of interest to note that while the building failed to meet CBIP and MNECB targets, the total normalized annual energy consumption was only 158 ekWh/m^2. This compares well with the average annual consumption—278 ekWh/m^2—of other multi-unit residential buildings contained in the CMHC HiSTAR database.

Water Consumption

The metered annual building water consumption in 2003 was 10,227 cubic metres (m^3) or 170.5 m^3/suite. The per suite water consumption compares favourably to the average annual water consumption of the buildings contained in the CMHC HiSTAR database of 216 m^3/suite.

The domestic hot water usage was estimated to be 6,213 m^3/year or 17,022 litres per day (17.022 m^3). This estimate was based on the summer monthly oil consumption.

Air Leakage Characteristics

The air leakage test results for the entire building and one apartment are shown in Table 1. The tests were conducted with the building's ventilation systems "on" and the boiler venting system unobstructed representing a "worst case" scenario. All the interior apartment doors were open and all the windows were closed so the test would measure the leakage area of the entire building exterior envelope. The air leakage test was conducted using conventional residential blower door equipment. For the single apartment test, the results reflect the air leakage characteristics of both the interior and exterior partitions.

	Normalized Leakage Rate (L/s/m^2 @ 75 Pa)
Apartment no. 417	2.48
Total Building	2.68
Other MURBs	0.83 - 10 (ave 2.73)
Governor's Road CBIP Building	1.18

Table 1: Air Leakage Test Results

The air leakage tests indicate that the building is more airtight than most multi-unit residential buildings on record but not as tight as the CBIP Governor's Road building (the Governor's Road building was designed, constructed and supervised to be very airtight). Considering that no extraordinary measures were taken to ensure the continuity of the air barrier system, the Almon Street building achieved a modest degree of airtightness. The air leakage test of the individual apartment revealed that significant leakage existed between apartments. Test results for other recently constructed apartments indicate that NLR's as low as 0.38 L/s/m^2 @75 Pa are possible when measures are taken to reduce leakage in interior and exterior partitions.

Heat Recovery Ventilation System Performance

The ventilation system for the building was designed to meet ASHRAE Standard 62-2001 "Ventilation for Acceptable Indoor Air Quality." The combined design ventilation rate specified for the five HRVs was 1,416 L/s which provided 0.35 air changes per hour in the building. For the bathrooms, which are continuously exhausted by the central HRV systems, ASHRAE Standard 62-2001 required 10 L/s continuous. As there are 105 bathrooms served by the HRVs, the combined design capacity of the HRVs (1,416 L/s) was more than enough to meet this requirement. The ASHRAE Standard also required 50 L/s per kitchen if intermittent exhaust was installed. However, the apartments were equipped with independently ducted range hoods with a design capacity of 27 L/s which fails to meet the ASHRAE requirement.

The testing of the HRV airflows found that the design airflow rates were not achieved in practice. Table 2 contains the measurements of the supply and exhaust airflow at the HRV units.

For the building, the measured outdoor airflow rate is 73 per cent of the design supply airflow rate and the measured exhaust flow rate is 66 per cent of the design exhaust airflow rate. It was suspected the discrepancy between the design flow rates and those actually achieved in practice was due to duct installation problems that constricted airflow and resulted in leakage.

HRV		Supply Air (L/s)	Exhaust Air (L/s)
First Floor Unit	Measured	103	116
	Design	283	283
Second Floor Unit	Measured	297	330
	Design	283	283
Third Floor Unit	Measured	231	297
	Design	283	283
Fourth Floor Unit	Measured	190	116
	Design	283	283
Fifth Floor Unit	Measured	215	69
	Design	283	283
Total Building Capacity	Measured	1,036	928
	Design	1,416	1,416

Table 2: Airflow Measurements for Individual Floor Heat Recovery Ventilators

IAQ Monitoring and Survey Occupants:

Indoor Air Quality measurements and occupant surveys were conducted in three apartments. Temperature, Relative Humidity, CO$_2$ and TVOCs were measured over a five-day period during the late space heating season. The occupants were surveyed to ascertain opinions relating to indoor environment (air quality, temperature, humidity), and comfort. The results of the air quality monitoring are shown in Table 3. The measurements were taken in the living room of each apartment.

		Apartment 112	Apartment 306	Apartment 417
Temperature (^{0}C)	Max	27.7	28.9	24.4
	Min	26.1	20.6	17.8
	Ave	26.9	25.8	23.7
Relative Humidity (%)	Max	57	49	37
	Min	26	19	20
	Ave	31	24	23
CO$_2$ (PPM)	Max	1,257	1,382	1,202
	Min	442	697	252
	Ave	717	862	524
TVOC (mg/m^3)	Week ave	0.35	0.21	0.20

Table 3: Indoor Air Quality Measurements for Individual Apartments

The recommended range for relative humidity by ASHRAE is 20-40 per cent in winter, thus the measured RH levels were within an acceptable range though excursions above recommended limits were noted. All of the apartments were warmer than is recommended by ASHRAE. This represents a comfort concern as well as an energy-efficiency opportunity for the building management by improving in-suite and boiler temperature controls. All of the apartments had average CO_2 levels higher than 700 ppm except for apartment 417. There were times when CO_2 exceeded the 1,000 PPM threshold that represents one indicator of acceptable indoor air quality. TVOC measurements were well below the "good practice" guidelines of 5 mg/m^3.

A survey was done of the occupants in three apartments to informally assess their perceptions of comfort and indoor air quality. In general, the occupants of the suites found the air quality to be "average"—neither notably bad nor exceedingly good. Comments were made by the occupants in each apartment regarding the apartments being stuffy and humid—observations that were reflected in the temperature and CO_2 monitoring results.

IMPLICATIONS FOR THE HOUSING INDUSTRY

While the performance of the building failed to meet design expectations, the energy-efficiency measures and innovative ventilation strategy implemented in the building represent significant improvements over conventional buildings. The failure of the building to fully meet its challenging performance targets reflects the need for the development and use of quality assurance processes that can ensure that what is designed and specified on paper is actually achieved in practice. This would include *continuous design review* to modify and optimize design details as construction proceeds; *diligent construction supervision* and *ongoing testing* of materials and systems as they are installed, as well as *system commissioning*. Nevertheless, the good performance of the building (and its potential to fully realize its original design objectives) reflects the success of building programs such as CBIP in moving the construction industry towards higher performing buildings.

A full report on this project is available from the Canadian Housing Information Centre

CMHC Project Manager: Duncan Hill, Senior Researcher
Policy and Research Division
Consultant: David Stewart, P. Eng;
David C. Stewart & Associates Inc.

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or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1 800 668-2642
Fax: 1 800 245-9274

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