BUILDER INSIGHT

BC HOUSING
RESEARCH CENTRE

FACTS AND FIGURES

Construction timeline:
November 2023 – late 2025
Construction budget: $54.9 M
Residential Units: 123
Site Area: 2,968 m², 31,945 ft²
Total Gross Floor Area: 13,039 m², 140,334 ft²
Net Floor Area: 10,446 m², 112,433 ft²
Building Height: 22.64 m, 74.29 ft
Volume of Mass Timber: 1,194.67 m³ of CLT
Annualized Whole Life Carbon Emissions:
7.8 $kgCO_2e/m^2$/year
Total Energy Use Intensity: 49 kWh/ m²/year

PROJECT TEAM

Owner: More Than A Roof Housing Society
Land: Non-Market Housing Development & Operations
Architect: PUBLIC Architecture
General Contractor: Kindred Construction Ltd.
Owners BIM Consultant: Summit BIM
Design BIM Consultant: BIMOne
Construction BIM Consultant: Modelo Tech Studio
Structural Engineering: Wicke Herfst Maver Consulting Inc.
Mechanical and Electrical: Introba
Fire Suppression: Introba
Energy Modeling: Introba
Passive House Consultant: Introba
Embodied Carbon Modeling: Introba
Civil: Core Group Civil Consultants Ltd.
Landscape: Matthew Thomson Design Ltd.
Building Code: GHL Consultants Ltd.
Building Envelope: Morrison Hershfield
Acoustical: BKL Consultants Ltd.
Passive House Certification: Steven Winter Associates, Inc.
Elevator: GUNN Consultants
Project Management: CPA Development
Research Management: Scius Advisory

KEY STAKEHOLDERS

City of Vancouver
BC Housing
City of Vienna
Rüdiger Lainer + Partner

Bulletin No 5 | Vienna House

Testing of Envelope Details

Vienna House is a National Housing Strategy project that demonstrates sustainability and innovation in construction. The project will be Passive House certified. It is the first non-market multi-family housing project in B.C. to use Building Information Management (BIM). BIM was used throughout concept design, project delivery and facility management.

The seven-storey mass timber and lightwood frame hybrid building will provide 123 units ranging from studio to four bedrooms. It is an efficient mid-rise building type, with the potential for it to be recreated in B.C. and across Canada. The project has a counterpart housing project in the City of Vienna, Austria. This provides a unique opportunity to share knowledge and best practices in housing design. It will be subjected to acoustical and vibration testing prior to occupancy and will be monitored for ongoing environmental and structural performance.

Figure 1. Rendering of Vienna House from Stainsbury Ave. (source: PUBLIC Architecture).

This bulletin series describes innovative technologies and processes of the Vienna House project. Find them all in the BC Housing Research Centre Library.

These bulletins discuss the Vienna House project as construction is getting underway. Completion is expected in November 2025.

Introduction

Vienna House has been designed to be a highly energy efficient, resilient building. The project is targeting Passive House certification, which favours an “envelope first approach”, with particular attention paid to insulation and airtightness. The lower the air leakage, the more stable the interior conditions, and the less energy being wasted to maintain it.

Code Requirements

The National Building Code of Canada (NBCC, Part 5, NRC 2020a) and the National Energy Code of Canada for Buildings (NECB, NRC 2020b) define the insulation and airtightness requirements to reduce energy use for heating and cooling. The air barrier system shall incorporate air barrier assemblies that meet the five Performance classes (1-5) for maximum air leakage rates. Rates range from 0.05 $L/(s·m^2)$ to 0.5 $L/(s·m^2)$ (i.e., from 0.18 $m^3/(h·m^2)$ to 1.8 $m^3/(h·m^2)$) measured at a pressure differential of 75 Pa based on the CAN/ULC Standard-S742: Standard for Air Barrier Assemblies – Specification (ULC 2020). The air barrier continuity between opaque assemblies and openings (e.g., windows) must be maintained.

Currently there are no mandatory requirements for whole building airtightness testing within the NECB or the NBCC. Under the BC Energy Step Code (Government of BC 2017), airtightness testing and energy modelling are mandatory to ensure compliance.

To achieve Passive House performance, the building must achieve a maximum of 0.6 air changes per hour (ACH) at a pressure difference of 50 Pa, as verified with an onsite pressure test in both pressurized and depressurized states. This is the most stringent airtightness requirement among energy-related codes and programs. Maintaining the air barrier throughout the entire project is critical to achieving this performance.

Air Barrier Design

For wood-frame buildings, there are a range of air barrier approaches that can be used to achieve airtight building envelopes. These include sealed interior polyethylene, airtight drywall, sealed interior or exterior sheathing, sealed water-resistive membrane, and airtight insulation (e.g., rigid foam, spray foam).

The air barrier system of the Vienna House building relies on taped oriented strand board (OSB) sheathing, located between an exterior structural wall frame and an interior service wall as an interior air barrier (Figure 2). The thickness of the OSB, the sealing methods for the sheathing joints and the location, number and type of penetrations may affect the airtightness. For the installed performance of the air barrier, other factors were also considered such as the quality of the materials, the workmanship, and whether there are accidental penetrations in the air barrier system.

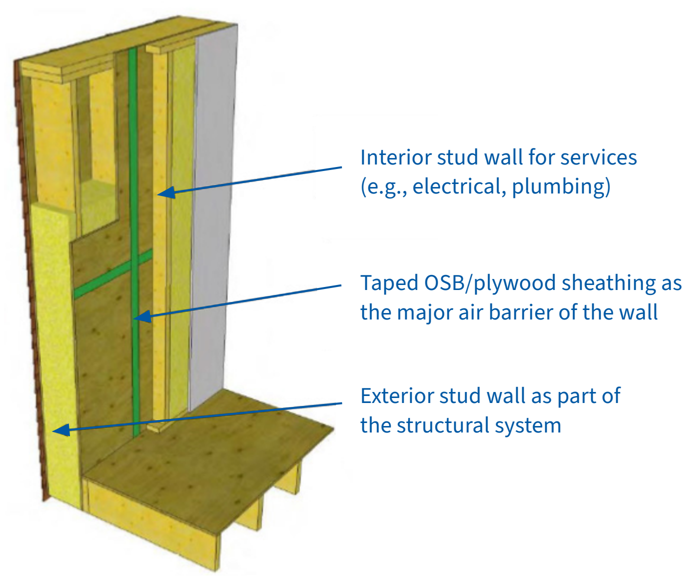

Figure 2. An illustration of using taped interior OSB/plywood sheathing as the major air barrier of an exterior double-stud wall assembly (source: FPInnovations).

Studies and Tests

To ensure the proposed design meets the target performance, a series of studies were conducted by FPInnovations to address specific concerns from the designers. However, the studies' findings are applicable to other energy efficient building projects. The tests focused on airtightness and water tightness of the envelope, generally, and looked specifically at the balcony details.

Note that these studies were conducted prior to construction commencing on site. Further testing will be conducted on the project, including the installation of sensors to monitor moisture content, relative humidity, temperature, CO_2, vibration, and long-term shortening (including creep).

Rain and Air Infiltration (RAIN) Chamber

FPInnovations used the Rain and Air INfiltration (RAIN) Chamber located in the rear yard of their Vancouver laboratory (Figure 3).

The RAIN Chamber has highly airtight construction with a 2.5 m x 2.5 m opening in its front wall for placing a test wall panel and has an internal volume of 12.9 m^3. It is equipped with an air pressure system, i.e., a blower to provide a controlled positive or negative pressure difference between the inside and outside of the chamber (Figure 5). Figure 4 provides a schematic diagram showing each element of the RAIN Chamber.

Both the pressure difference and the air flow rate are monitored during testing using an accurate pressure gauge and logged into a computer for calculations. A water-spray system can be placed on the exterior of the chamber to simulate wind-driven rain. This delivers a controlled spray of water on the surface of the rest specimen while the chamber is depressurized to assess potential water penetration. Efforts were made during both the construction of the chamber and the testing to follow the ASTM standards for laboratory airtightness testing and watertightness testing.

Calibrations

Prior to this study, the blower and the pressure/flow rate measurement devices were sent to and calibrated by the manufacturer to minimize potential errors associated with the equipment. The chamber was calibrated both before and after the airtightness testing in this study.

Airtightness Test

For testing airtightness of the mock-up wall, pressure differences of 40 Pa, 50 Pa, 75 Pa, 100 Pa, 150 Pa, and 200 Pa, were sequentially applied to the specimen installed on the RAIN Chamber. An average was taken of the results every second for three minutes during stable air flow at each selected pressure difference to determine the experimental air flow rate. Temperature and relative humidity were also measured at two locations both inside and outside the chamber for applying the correction factors described in ASTM E283.

Figure 3. RAIN chamber with the mock-up wall installed *(source: FPInnovations).*

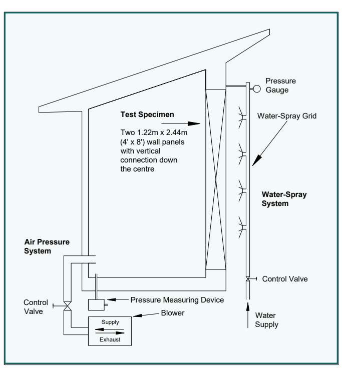

Figure 4. Schematic of the RAIN chamber *(source: FPInnovations).*

Figure 5. The blower used for creating a pressure difference between the inside and outside of the RAIN chamber *(source: FPInnovations).*

Pressure differences of 50 Pa or 75 Pa are typically used for whole building airtightness measusrements and were obvious selections for testing. The other values were selected to provide a range to assess measurements conformed to known models to check the validity of results. This range of pressure differences roughly corresponds to between four and eight on the Beaufort Wind Force Scale, with 50 Pa being a fresh breeze, 75 Pa being a strong breeze and 200 Pa, a gale.

Watertightness Test

Watertightness testing, which was not a priority of this study, was conducted to assess potential penetration under strong wind-driven rain conditions. The mock-up wall was covered with an exterior water-resistive barrier membrane, with the joints between the two membrane sheets (with an overlap of about three inches) sealed with tape. With water being uniformly sprayed onto the surface of the test wall, the pressure difference between the interior and the exterior of the chamber (depressurization) was increased in steps from 75 Pa, 150 Pa, 300 Pa, 500 Pa, 750 Pa, to 1000 Pa. The pressure at each step lasted for 10 mins, plus an initial 10 mins of wetting with no pressure applied. Directly after the test was completed, the interior OSB sheathing was removed to examine if any water had penetrated the wall assembly.

Test Wall Assemblies

The Vienna House building is designed to have a double-stud exterior wall, consisting of an exterior structural wall frame and an interior service wall frame. A taped OSB sheathing located between the two wall frames is specified to be the major air barrier. A mock-up wall, in a size of 4 ft X 8 ft (1.22m X 2.44m), was built with nominal 2 in. X 10 in. dimension lumber, together with nailing commonly used for wood framing. The mock-up wall was used to assess the effect of changes in the OSB sheathing (e.g., thickness), taping at the sheathing joints, and sealing at various penetrations on the airtightness of the exterior wall. On its exterior side, the frame was covered with two sheets (each in a standard size of 4 ft x 8 ft) of plywood sheathing, in a thickness of ½ in. (12.7 mm), fastened with wood screws. On its interior side, it was sheathed with two sheets of OSB, each in a standard size of 4 ft x 8 ft and thickness of 7/8 in. (22 mm).

A gap, approximately 2 mm, was created between the plywood/OSB sheets to simulate the joints between sheathing panels in construction. The middle vertical joint between the two OSB sheets, as one of the focus areas of testing, was not sealed in the base wall in the initial airtightness testing. A series of changes, for example, taping at the middle vertical joint and creation of other penetrations/joints (e.g., connection, hatch), as other focused areas of the study, were made in the mock-up wall prior to each step of airtightness testing. The interior service wall frame designed as part of the exterior wall of the building was not included in the mock-up wall specimen since it was not part of the specified air barrier system and was not expected to affect the test results. Other fastening through the sheathing panels and the membrane, and the insulation inside the wall cavities were not taken into consideration.

Balconies

The balconies for Vienna House (Figure 6) will be prefabricated from aluminum and bolted to the structure (see Prefabrication Insight for further information), penetrating the OSB air barrier. To mitigate the effects of this disruption to the air barrier, this study was conducted prior to construction to evaluate the options to optimize airtightness and watertightness against simulated wind-driven rain. The data assisted in optimizing the design for durability and energy performance. Testing was conducted for three thicknesses of OSB and a range of sealing options for the joints between the sheathing panels, detailing the penetrations from connectors on the airtightness of the OSB sheathing.

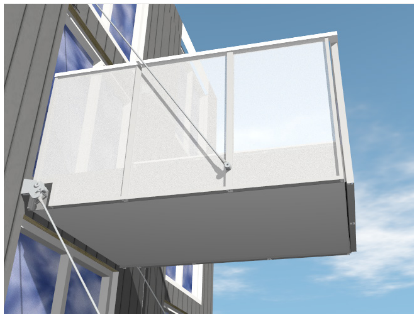

Figure 6. Design of aluminum balconies on south-facing wall of Vienna House

(source: Sapphire Balconies Ltd.).

Findings

Effect of Installing Bolts for Attaching Balconies

Holes will need to be drilled through the interior OSB sheathing to install bolts to attach balconies on the building and will very likely affect the airtightness of the envelope. For the mock-up study, one hole with a bolt, together with its regular metal washer and nut installed was found to increase air flow by 20% at 50 Pa (0.200 ±0.007 $m^3/h{\cdot}m^2$) and 18% at 75 Pa (0.289 ±0.012 $m^3/h{\cdot}m^2$).

Two measures were tested to reduce air flow through the bolt penetration: adding a foam rubber gasket between the washer and OSB, which was fitted around the bolt; and applying silicone sealant between the washer and OSB. These measures were found to be similarly effective, decreasing air flow by around 9% at 50 Pa compared to the bolt without any sealing (Figure 7). Air flow with the foam rubber gasket measured as 0.181 ±0.005 $m^3/h{\cdot}m^2$ at 50 Pa and 0.255 ±0.008 $m^3/h{\cdot}m^2$ at 75 Pa. This is compared to the silicone sealant measured as 0.183 ±0.006 $m^3/h{\cdot}m^2$ at 50 Pa and 0.263 ±0.007 $m^3/h{\cdot}m^2$ at 75 Pa for the silicone sealant. Therefore, although the gasket gave a slightly lower air flow, the measurements were within experimental error of each other. The gasket may have the advantage that it is easier to install, given availability of products; and to disassemble as needed.

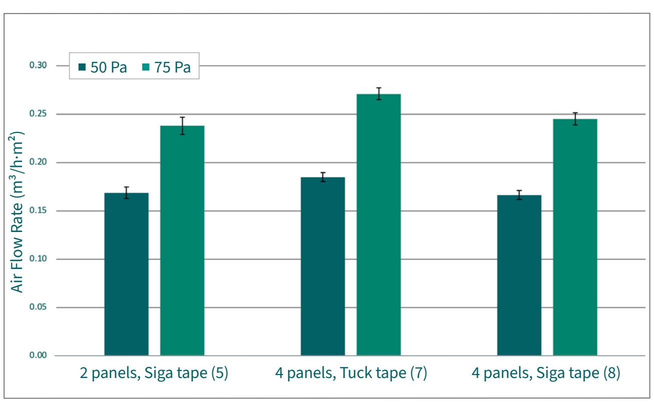

Figure 7. Effect of installing a bolt through OSB and different sealing methods around the bolt on air flow (source: FPInnovations).

Effect of OSB Sheathing Joint Tape

Applying adhesive tape along the joint between the interior OSB sheathing sheets decreased air flow through the wall assembly to a fraction of a percent of the air flow without the tape. Air flow without the tape was around 30 $m^3/h{\cdot}m^2$ at 50 Pa and after taping it was around 0.1 to 0.2 $m^3/h{\cdot}m2$ at 50 Pa.

Comparing the two types of tapes used in this study, using the Siga tape along the joint was found to considerably improve the airtightness of the assembly compared to the Blue Tuck tape (Figure 8). Air flow with the Tuck tape along both the vertical and horizontal joints was measured as 0.185 ±0.005 $m^3/h{\cdot}m^2$ at 50 Pa, whereas with the Siga tape the result was 0.166 ±0.005 $m^3/h{\cdot}m^2$ at 50 Pa. A similar effect was measured at 75 Pa with air flow rates of 0.271 ±0.006 $m^3/h{\cdot}m2$ and 0.245 ±0.006 $m^3/h{\cdot}m^2$ for the Tuck and Siga tapes, respectively. Measurements on the two 4 ft x 8 ft panels and four 4 ft x 4 ft panels when using the Siga tape for both were within experimental error of each other. The test results do not consider any long-term deterioration of the bonding between the tape and the OSB.

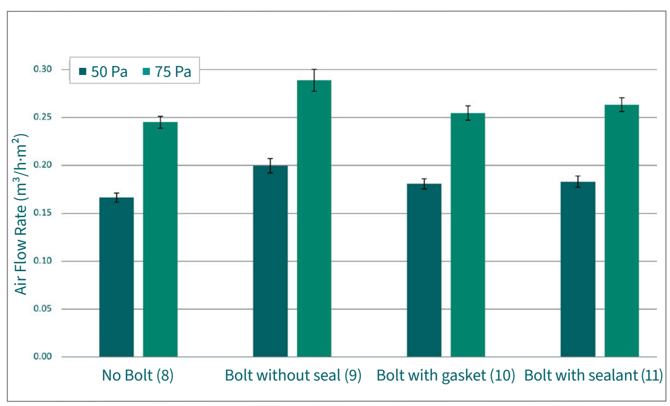

Figure 8. Comparison of 15 mm OSB with different joints and joint tapes (source: FPInnovations).

Effect of Installing a Hatch to Access Wall Cavity

To simulate the effect of installing a hatch in the OSB sheathing, an opening measuring 150 mm by 300 mm was cut around the hole where the bolt was installed for ease of installation. The bolt was removed, and the hole filled with silicone sealant, allowed to dry, and taped over the back. The section of OSB was then fixed back into the opening by screwing it into the stud with two screws.

Installing this hatch resulted in around a 10-fold increase in air flow through the wall assembly, measured at 1.78 ±0.05 $m^3/h{\cdot}m^2$ at 50 Pa and 2.31 ±0.10 $m^3/h{\cdot}m^2$ at 75 Pa (Figure 9). However, it was found that this loss in airtightness could be almost completely mitigated by taping over the hatch. Both the Tuck tape and Siga tape were tested and found to give similar results. Air flow with the Tuck tape measured as 0.161 ±0.006 $m^3/h{\cdot}m^2$ at 50 Pa and 0.240 ±0.007 $m^3/h{\cdot}m^2$ at 75 Pa, compared to 0.172 ±0.006 $m^3/h{\cdot}m^2$ at 50 Pa and 0.256 ±0.006 $m^3/h{\cdot}m^2$ at 75 Pa for the Siga tape. Therefore, although the Tuck tape gave a slightly lower air flow, the measurements were within experimental error of each other.

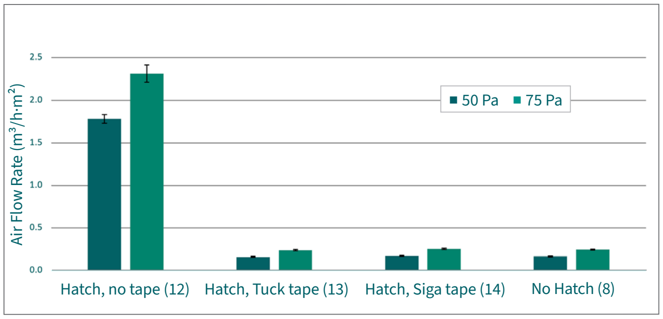

Figure 9. Effect of installing a hatch in the OSB and sealing with different tapes on air flow (source: FPInnovations).

Effect of Installing an Exterior Membrane

The water-resistive airtight membrane, i.e., the commonly called water-resistive barrier (WRB), was installed on the outside of the plywood exterior sheathing in two loose sheets with a 3-inch overlap taped along the joint. No fasteners were used, and the perimeter was taped to the chamber.

Installing the exterior air barrier resulted in around a 10% decrease in air flow through the wall assembly at 50 Pa, measured as 0.150 ±0.006 $m^3/h{\cdot}m^2$ at 50 Pa and a 30% decrease in air flow at 75 Pa, measured as 0.172 ±0.003 $m^3/h{\cdot}m^2$ at 75 Pa (Figure 10).

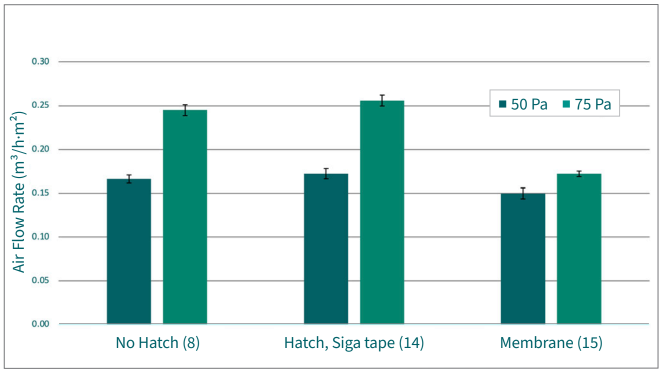

Figure 10. Effect of installing tapes at joints alone and a combination of an airtight and water-resistive membrane to the exterior of the plywood exterior sheathing (source: FPInnovations).

Effect of OSB Thickness

OSB sheathing panels in three thicknesses were assessed in this study. The panels were taped along the centre joint and around the perimeter with Siga Rissan tape. Note there was significant uncertainty in the measurement of the 11 mm thick OSB as testing was conducted following the water penetration test, which appeared to have affected the airtightness of the chamber. The result shown in Figure 11 is much lower than would be expected for this material, so caution is needed to understand its real performance.

Testing under consistent conditions prior to the water penetration test, using the 22 mm thick OSB internal sheathing demonstrated a much lower air flow rate compared to the 15 mm OSB (Figure 11). Air flow was 44% lower at 50 Pa pressure difference than the assembly using the 15 mm thick OSB sheathing, and 50% lower at 75 Pa pressure difference. The taped 22 mm OSB alone, or the taped 15 mm OSB together with the exterior WRB membrane, showed an air flow below 0.18 $m^3/h{\cdot}m^2$ measured at 75 Pa, meeting the NBCC requirement for Class 1 Air Barrier Assembly (NRC 2020a).

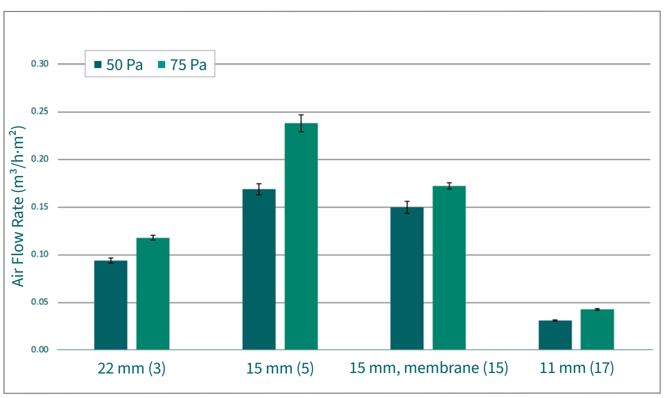

Figure 11. Effect of thickness of OSB sheathing and a combination of exterior water-resistive barrier, on air flow with taped joints (source: FPInnovations).

Watertightness

The mock-up wall was exposed to simulated wind-driven rain under pressures of up to 1000 Pa to assess the potential for water penetration. The pressure was increased in steps from 75 Pa, 150 Pa, 300 Pa, 500 Pa, 750 Pa, to 1000 Pa with each step lasting for 10 mins. Visual inspection of the water leakage, however, was not conducted until completion of the test. It was found that some water penetrated around the perimeter of the test wall through the CLT wall (i.e., gaps between boards etc.) of the chamber. No water penetrated through the WRB membrane with taping at the middle vertical joint between the two sheets installed outside the plywood sheathing.

It should be noted that the watertightness test was conducted to simulate severe wind-driven rain events. The pressure difference of 1000 Pa used for the test would be equivalent to a scale of hurricane using the Beaufort scale. The ASTM 331 standard for laboratory water penetration test suggests using a steady pressure difference of 137 Pa for 15 mins of water spray. Moreover, the mock-up wall did not have cladding installed for the test. In a real building, the cladding would serve as the first plane of protection against wind-driven rain. Wind-driven rain penetration of the first plane, caused by a defect in construction, would mostly be intercepted by the rainscreen wall. Capillary break, drainage, and other dissipation means are provided by the drained and vented/ventilated space of the rainscreen wall required for a building in Vancouver's climate.

Conclusions

The following conclusions can be made based on the test results:

- All joints between the interior OSB sheathing panels shall be sealed. Comparing the two types of tapes used in this study, using the Siga tape along the joint of OSB sheathing would improve the airtightness of the assembly compared to the Blue Tuck tape, without assessing long-term effect,
- For all holes made through the OSB sheathing to install bolts (and other fasteners), measures can be taken to reduce air flow. It was found from this study that adding a foam rubber gasket between the washer and OSB, which fitted around the bolt, and applying silicone sealant between the washer and OSB had similar effect,
- Installing a hatch in the OSB sheathing for accessing the wall cavity would greatly increase the air flow, without sealing at the joints. The loss in airtightness can be almost completely mitigated by taping over the joints,
- Installing the specified exterior water-resistive and airtight membrane resulted in around a 10% decrease in air flow through the wall assembly at 50 Pa and a 30% decrease in air flow at 75 Pa,
- The taped 22 mm thick OSB sheathing was found to provide a much lower air flow, compared to the taped 15 mm OSB. The taped 22 mm OSB alone, or the taped 15 mm OSB together with the exterior WRB membrane showed an air flow below 0.18 $m^3/h \cdot m^2$ measured at 75 Pa, meeting the NBCC requirement for Class 1 Air Barrier Assembly,
- The water spray test, with the pressure elevated to 1000 Pa to simulate severe wind-driven rain conditions, did not cause water penetration through the WRB membrane with taping at the vertical joint between the two sheets installed outside the plywood sheathing.

This material was extracted from a technical report “Airtightness testing of envelope details for the Vienna House building”, submitted by Neal Holcroft and Jieying Wang of FPInnovations to BC Housing in 2023 and condensed for industry readers. The testing was completed by a technical team from FPInnovations.

NATIONAL HOUSING STRATEGY

The Vienna House Multi-Unit Affordable Housing Demonstrations Initiative received funding from Canada Mortgage and Housing Corporation (CMHC) under the National Housing Strategy Demonstrations Initiative. The views expressed are the personal views of the author and CMHC accepts no responsibility for them.

Acknowledgement

BC Housing gratefully acknowledges funding support from Canada Mortgage and Housing Corporation (CMHC) for this bulletin series. Our sincere appreciation to More Than a Roof Housing Society and the entire project team for their cooperation.

About BC Housing Research Centre

BC Housing’s Research Centre works in collaboration with housing sector partners to foster excellence in residential construction and find innovative solutions for affordable housing in British Columbia. Sharing leading-edge research, advances in building science, and new technologies encourages best practice. The Research Centre identifies and bridges research gaps to address homelessness, housing affordability, social housing challenges and the needs of distinct populations. Mobilizing knowledge and research expertise helps improve the quality of housing and leads to innovation and adoption of new construction techniques, Building Code changes, and enhanced education and training programs. Sign up to receive the latest news and updates from BC Housing’s Research Centre at www.bchousing.org/subscribe.

BC HOUSING RESEARCH CENTRE

1701-4555 Kingsway, Burnaby, BC V5H 4V8

Phone: 778-452-6454
Toll-free: 1-866-465-6873

Email: research@bchousing.org
www.bchousing.org