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Article

Full-Scale Comparison of Two Envelope Systems for Lightweight Wooden Framing in Cold Climates

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Abstract: Residential homes and apartments' cooling and heating needs account for 63% of total building energy consumption. Improvements in the properties of building envelopes are among the best ways to reduce their energy consumption. The project's general objective was to compare the performance of externally insulated and traditional envelopes of light wooden frame buildings at full scale. Two houses were constructed and equipped with relative humidity sensors and temperature probes to assess the physical properties of the building envelope. The first house was built according to the conventional method (insulation between the studs), and the second house was built according to the method with the insulation outside the wall (also known as the perfect wall). The results showed that external insulation effectively mitigates internal condensation risks by relocating dew points to the exterior surface, thereby enhancing structural durability and thermal stability. Thermographic imaging confirmed reduced thermal bridging and improved thermal performance in the externally insulated walls. Overall, this study supports, with a full-scale experiment, the adoption of external insulation as a viable strategy for enhancing energy efficiency, thermal comfort, and durability in residential buildings.

Keywords: soundproofing; hygrothermal simulation; airtightness; moisture control; Novoclimat program

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1. Introduction

The building sector is one of the three sectors with the highest energy consumption in the world, along with transportation and industry [1]. In 2016, the residential sector accounted for 17% of total secondary energy consumption in Canada. Heating and cooling requirements in residential houses and apartments constitute 63% of the overall energy consumption in these buildings [2]. Improving the energy efficiency of residential buildings directly decreases their heating and cooling demands, consequently lowering their overall energy consumption [3].

Wood is omnipresent in Quebec culture and identity. As a local resource, wood contributes to Quebec's social, economic, and environmental development [4]. Light wood framing constitutes the construction system for most homes in Quebec [5]. The versatility and variety of wood products explain a part of this widespread usage. They allow for complementary arrangements to build effectively [6].

The envelope is the outer layer of the building that separates the living spaces from the external elements. It is an essential component, with its main functions being to ensure the comfort of the occupants who reside within it and to protect the building and occupants from external elements and the harshness of the climate [7]. A well-designed building envelope has the potential to diminish energy consumption [8–10], lower maintenance expenses [11], and decrease greenhouse gas emissions [12–14], while simultaneously enhancing occupant comfort [11,15].

Quebec's government Novoclimat program was established in 1999. It is intended to improve the energy efficiency of new residential buildings and aims to be an influential factor in the residential construction industry, encouraging improvements in construction techniques. The program draws inspiration from similar voluntary programs in the United States and Canada, notably the federal ENERGY STAR® and R-2000 programs for new homes, which evolve in response to technological advancements. The technical requirements of Novoclimat serve as guidelines to be applied during the design and construction of buildings to enable them to achieve the program's objectives. They have been developed to facilitate the design of homes that meet criteria for energy efficiency, comfort, indoor air quality, and durability [16].

One potential solution for improving envelope performance is to use external insulation [3]. First described by Hutcheon [17] and more recently described by Lstiburek [18], this approach, also called the perfect wall, proposes installing the envelope, air control layer, vapor control layer, and thermal control layer on the outside of the light-frame construction, protecting the structural layer, reducing condensation risks and thermal bridging, and improving the performance of the thermal insulation [18].

Several studies have been conducted comparing different versions of an exterior insulated wall. Lstinurek's studies [18,19] suggest that when the thermal control layer is positioned outside the structural layer, it helps prevent the risk of condensation and the expansion of wood studs due to temperature changes in the structural layer. Also, a decrease in moisture buildup and water infiltration was observed. Straube and Smegal [20,21] compared the thermal resistance of various insulation methods used in North America. They noted that the assemblies with thermal insulation on the outside of the cavities performed best by reducing the risk of condensation and thermal bridging. Studies such as those of Craven and Garber-Slaght [22] or Ge et al. [23] corroborated that using external insulation reduced the moisture content.

In 2022, a previous study compared a traditional wall with three different walls insulated externally. The traditional wall had a dew point inside the cavity and the highest humidity within the OSB, leading to potential condensation, especially with interior air exfiltration. The lack of exterior insulation contributed to temperature fluctuations in the OSB, causing higher relative humidity in cold conditions. Using a rigid, airtight panel improved airtightness, while a sealed membrane led to higher air leakage. Externally insulated walls performed worse in sound transmission than walls with cavity insulation. Combining fiberboards and Rockwool boards was necessary to match the acoustic performance of cavity-insulated walls, while extruding polystyrene as the main insulation significantly reduced sound transmission [3].

Although various studies have been conducted on the subject, all have been based on simulations and laboratory tests. The results may differ on a real construction project due to uncontrolled factors such as the influence of residents and meteorological conditions.

The general objective of the project was to compare at full scale the hygrothermal, airtightness, and sound transmission performance of a fully externally insulated assembly with those of traditional assemblies currently built in North America and contrast the results with those obtained in the laboratory study.

2. Materials and Methods

2.1. Characterization of the Assembly

To compare the hygrothermal performance of two light-framed wall construction methods, two identical houses were built in Bécancour, Canada, in 2022. One house followed traditional construction with insulation placed between the studs, while the second had its insulation applied externally. Both houses were equipped with sensors to monitor relative humidity and temperature, facilitating the evaluation of heat and vapor transfer, heat loss, air leakage, and overall airtightness.

This project was conducted in collaboration with the APCHQ (Quebec General Contractors Association), whose technical advisor regularly visited the site to ensure construction consistency. Furthermore, both houses were built by the same general contractor to maintain uniformity in construction practices. Before the installation of the gypsum, airtightness tests were conducted according to the CAN/CGSB 2-149.10-M86 standard [24].

Both buildings share the same square design, measuring 10.11 × 10.11 m. On the ground floor, each house features two north-facing rooms with the main bathroom between them and the living room and kitchen facing south (Figure 1).

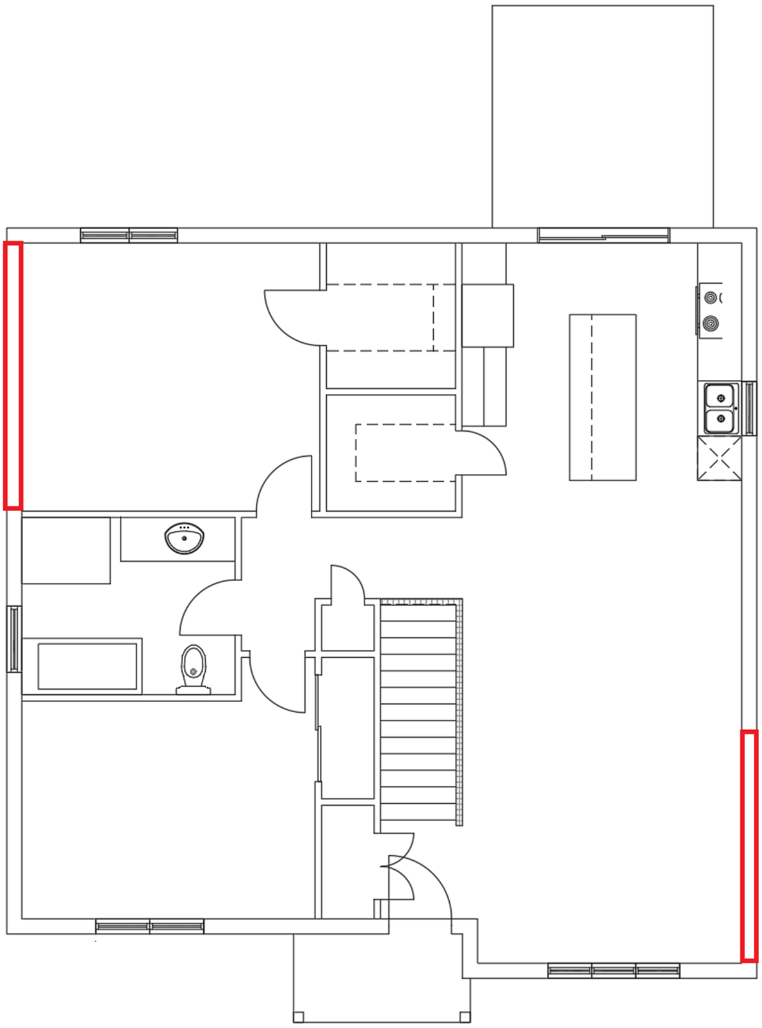


Figure 1. Ground floor plan with the studied walls highlighted in red.

(a) Traditional wall

A classic wall meeting Novoclimat 2.0 requirements was constructed. The composition of the envelope, from external to internal, was a 12.7 mm CanExel^{TM} type exterior siding (Maibec, QC, Canada), an external rain and air control Tyvek membrane, an 11 mm wide OSB, external insulation of 38 mm wide extruded polystyrene (XPS) (λ: 0.029 W/mK; vapor permeance: 52 ng/Pa·s·m^2), internal insulation of 140 mm wide glass wool (λ: 0.040 W/mK) inserted into the 2 × 6 (38 × 140 mm) studs, a polyethylene film vapor barrier (vapor permeance: 3.4 ng/Pa·s·m^2), and a standard 12.7 mm gypsum inner. The total thickness of the wall is 242.2 mm (Figure 2), and it has a total thermal resistance of 4.78 m^{2}K/W.

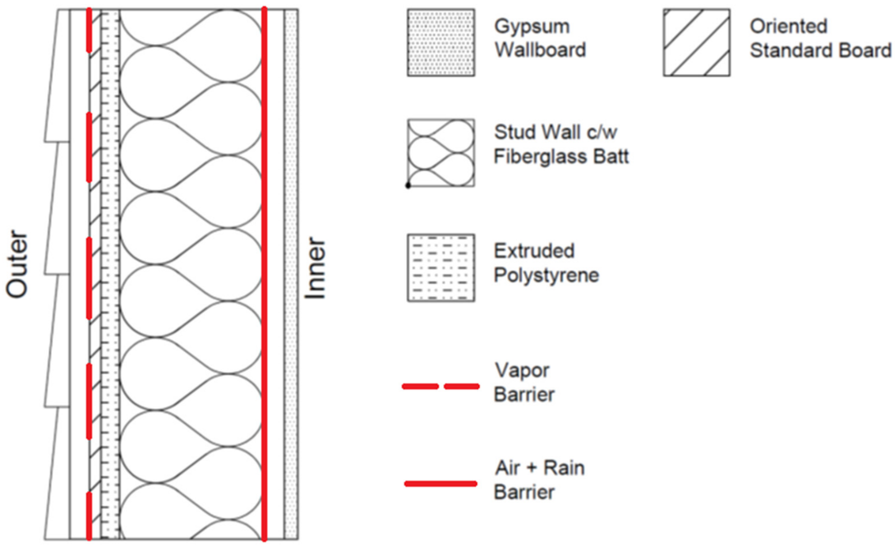


Figure 2. Design of the Standard Wall.

(b) Exterior insulation concept

A wall insulated on the outside was designed with a 12.7 mm CanExel^{TM} exterior siding and a 12.7 mm gypsum inner. Two distinct insulation elements were implemented: a 51 mm rock wool board, selected for its thermal and acoustic insulation attributes (λ: 0.035 W/mK; Noise Reduction Rating: 1.00), and a 51 mm ZipSystem^{TM} panel (Huber Engineered Woods, Charlotte, NC, USA). The latter serves multifaceted roles, functioning as thermal insulation, a weather barrier, a structural support element, and an effective air sealing component. The ZipSystem panel is a laminated panel composed of 12 mm of Advantech type II OSB from Huber with 39 mm of polyisocyanurate (Figure 3a). The wood frame is empty, creating an 88.9 mm air layer (Figure 3b). To mitigate the outward diffusion of vapor, a vapor-retardant paint with a vapor permeance ranging between 30 and 45 ng/Pa·s·m^2 and a water repellency index of 0.58 perm according to ASTM D1653 standard [25] was employed. The total thickness of the wall is 233.5 mm (Figure 4), and it has a total thermal resistance of 3.83 m^{2}K/W.

(**a**) (**b**)

Figure 3. (**a**) Composition of the ZipSystem panel; (**b**) Model of the "perfect wall".

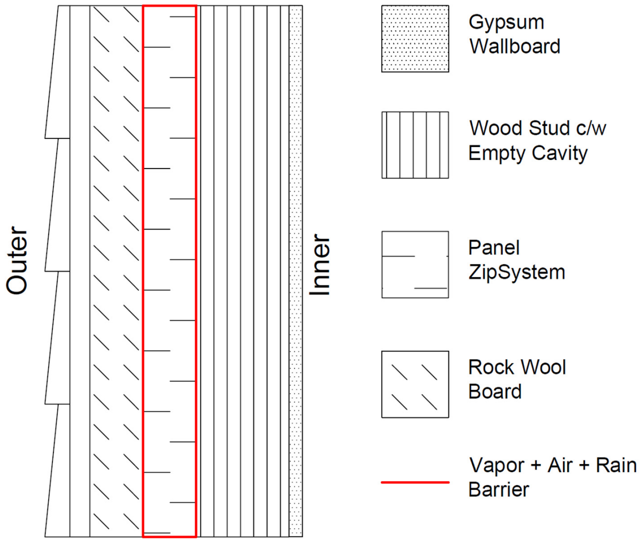
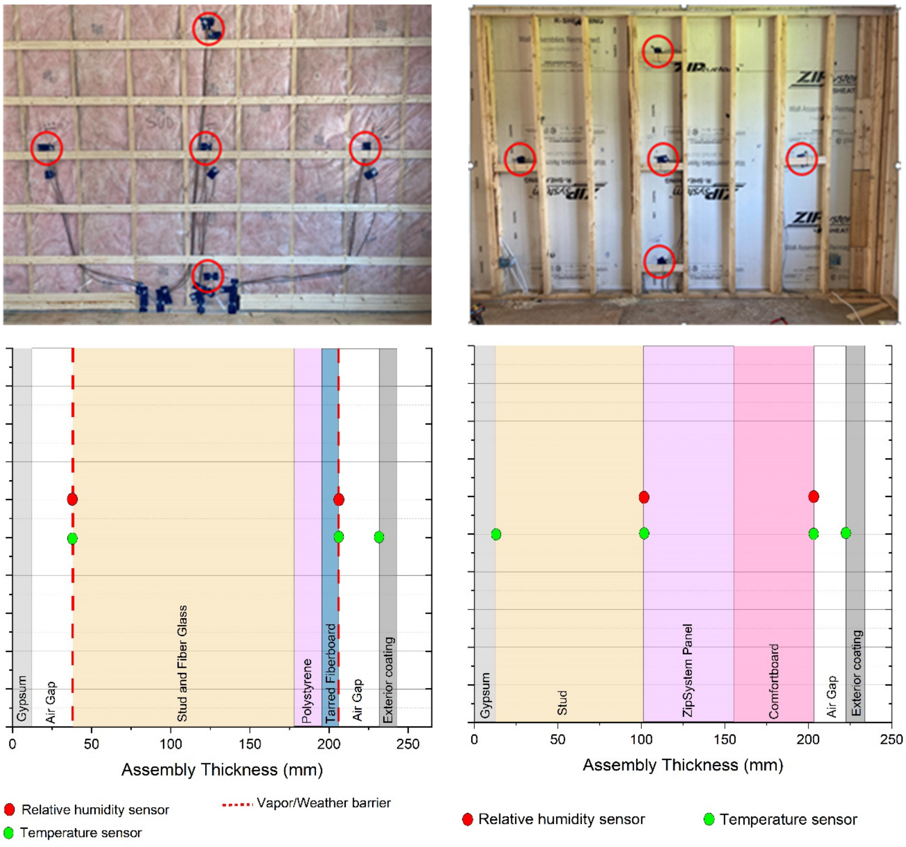


Figure 4. Design of the wall with external insulation, also called the perfect wall.

2.2. Hydrothermal Measurements

To assess the efficacy of these envelopes, temperature and relative humidity sensors were installed on two exterior walls of each residence. Specifically, the selected walls comprised the bedroom (north-facing) and the living room (south-facing). These sensors were strategically positioned at varying elevations and within different layers of the walls' structure (Figure 5). Additionally, sensors were deployed to ascertain the rooms' indoor relative humidity and temperature.



(**a**) (**b**)

Figure 5. Location of the probes in the traditional wall (**a**) and the externally insulated wall (**b**).

The data acquisition system utilized in this study is the MAQ20-COM2, manufactured by DATAFORTH (Tucson, AZ, USA).

The HIH-4000 sensor (Quebec City, QC, Canada) connected to the MAQ20-VSN module was employed to measure humidity. This sensor boasts an accuracy of ±3.5% within a 0–100% range. Prior to data collection, meticulous calibration procedures were conducted to ensure the accuracy of the humidity sensors. Calibration was performed against reference values of 30%, 50%, and 80% relative humidity (RH) to achieve a deviation of less than 2% from the reference values. The reference instrument used for calibration was the VAISALA HMI41 (Vantaa, Finland), with precision of ±2% within the range of 10% to 90% RH.

A MAQ20-TTC module paired with GG-T-24-SLE thermocouple type T sensors (St-Eustache, QC, Canada) (Figure 6) was utilized to capture temperature data. With a repeatability of ±0.1 °C and a wide operating range spanning from −200 to 200 °C, this combination ensured reliable temperature measurements throughout our investigation. Similarly, stringent verification measures were implemented to validate the accuracy of the temperature sensors. The verification involved comparing with temperature values taken with a reference sensor and ensuring that the maximum deviation was less than 1 °C. The reference instrument employed for this purpose was the FLUKE 1524 (Everett, WA, USA) with a precision of ±0.011 °C.

Figure 6. HIH-4000 humidity sensor and GG-T-24-SLE thermocouple type T sensors.

A computer interface is linked to the sensors in each dwelling (Figure 7), systematically gathering data at ten-minute intervals. These computer systems are network-connected, facilitating remote access to the collected datasets and enabling comprehensive analysis and monitoring.

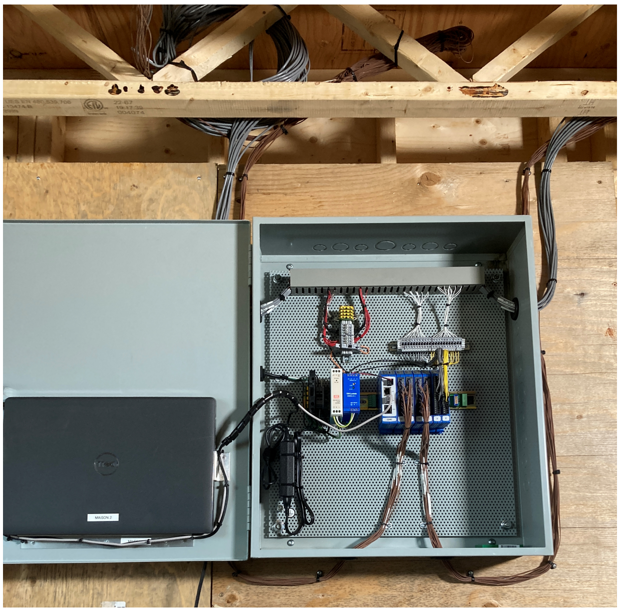


Figure 7. Computer interface with DATAFORTH MAQ20-COM2 data acquisition system installed in the basement of each dwelling.

2.3. Thermography

A thermographic study was conducted to identify structural thermal bridges and discern differences between the two methods.

(a) Equipment

A Fluke TiX500 (Everett, WA, USA) thermal camera was utilized, featuring a temperature range from −20 °C to +650 °C (−4 °F to −1202 °F). Equipped with a built-in laser distance meter capable of calculating distances up to 30 m (100 feet) to designated targets, this device boasts laser autofocus technology and is compatible with wide-angle, 2× telephoto, and 4× telephoto lenses, all of which were used in this study.

To validate the accuracy of the data obtained via the camera, the temperature of key points was measured using a Wintact WT320 model infrared thermometer (Shenzhen, China), followed by a comparative analysis.

(b) Climatic conditions

Photographs were captured on March 16th between 9:00 AM and 10:00 AM. The weather conditions prevailing at the time featured overcast skies with light northerly and northwesterly winds. The external temperature stood at 0.3 °C, accompanied by a relative humidity of 78%.

Across both settings, identical conditions were maintained within the interiors of the dwellings. The primary bedroom, situated along the northern wall, was heated to a set temperature of 18.5 °C, while the living room, positioned along the southern wall, was maintained at 21 °C.

(c) Data collection and analysis

For all images, the camera's emissivity was set to 0.9, a representative value for common opaque building materials, and an automatic scale designated by the camera was established based on the detected temperatures. All images were captured in IS2 format, a thermal image data format created by Fluke thermal imaging devices. This format contains image data, including raw and calibrated temperatures, an RGB image, and metadata recorded by the device, enabling their modification and analysis.

Two types of photographs were taken for each wall: one at the corner and another at the center of the wall. This approach allowed for the observation of the thermal conditions of the wooden frames within the wall, as well as the roof-wall junction and wall-wall junction, which are among the most significant structural thermal bridges in buildings [25].

The images underwent post-processing using the software Fluke Connect v1.1.550.0, developed by Fluke, where new scales were created to facilitate comparison between photos of the same elements.

2.4. Hygrothermal Simulations

WUFI 2D was used to perform one-dimensional hygrothermal transfer simulations. The version used was the 4.5 developed by the Department of Hygrothermics at Fraunhofer IBP (Stuttgart, Germany).

Both walls were designed within the software, leveraging its material database to attribute specific properties to each constituent layer. The CanExel™ exterior siding, while absent from the library, was integrated by incorporating thermal properties sourced directly from manufacturer specifications. Adhering to the software's prescribed methodology, the ZipSystem panel was represented by two distinct layers, capturing its dual functionality in providing rain control and thermal insulation.

For the simulation phase, initial conditions of 20 °C and 50% relative humidity were imposed on the walls. Specific interior and exterior climatic conditions corresponding to selected dates were incorporated. Subsequently, a week-long simulation was conducted under these constant conditions to analyze the hygrothermal performance within the walls. The data generated by the simulation was compared against the real-time measurements obtained from the probes installed within the walls.

2.5. Airtightness Testing

The airtightness of the buildings was measured according to the standard CAN/CGSB-149.10-M86 [26]. This test was conducted using a fan, which creates negative pressure in the building, making it possible to measure air leaks and establish a leak rate, which is expressed in air change per hour at 50 Pascals (ACH50).

2.6. Measurement of the Airborne Sound Transmission Loss

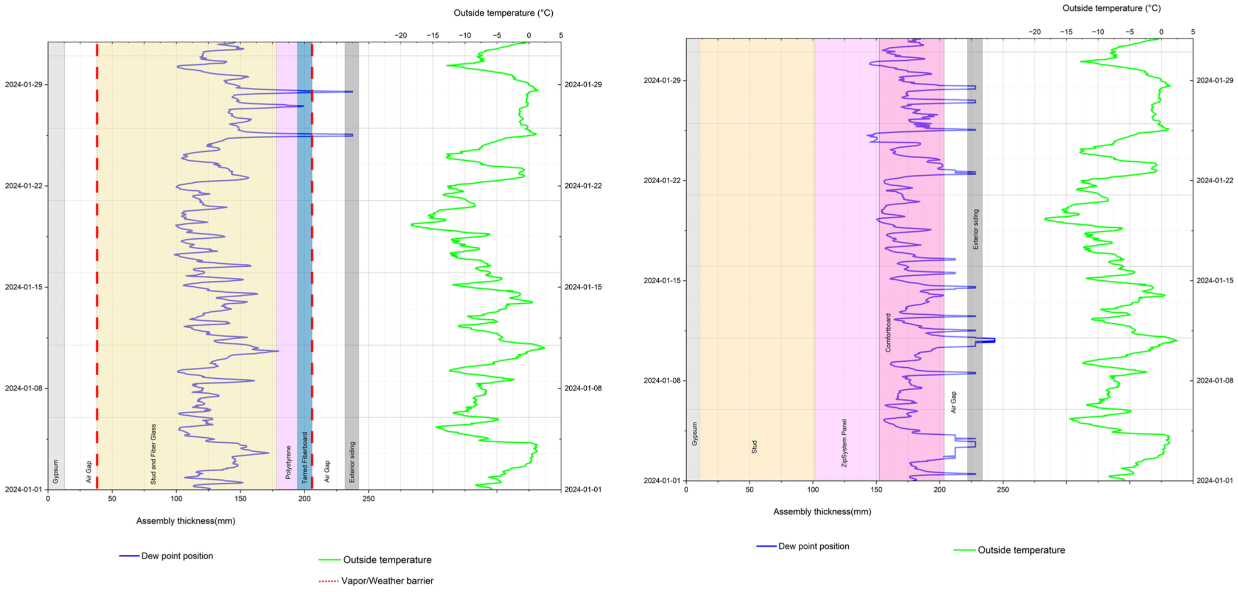
The indices of airborne noise insulation were measured according to the ASTM E336-19A [27]. The test involves a source and a receiver separated by the building element under test. A standardized sound source (a loudspeaker), placed at the exterior, emits a steady and uniform noise signal across a range of frequencies. Sound level meters or microphones are placed on both sides of the wall. These instruments measure the sound pressure levels (SPL) in decibels (dB) at various frequencies.

3. Results

3.1. Hydrothermal Measurements

(a) North wall

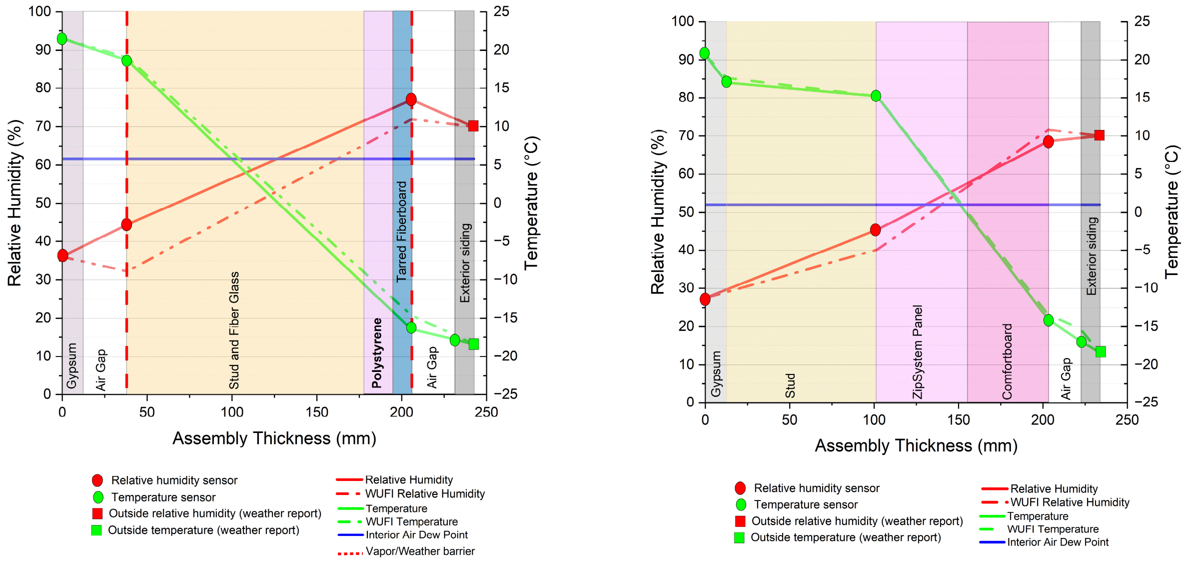
As expected and consistent with the laboratory tests of Caron-Rousseau et al. [3] and the work of Craven and Garber-Slaght [22], placing insulation on the exterior of the sheathing helps to shift the potential for condensation, related to the dew point, to the exterior of the wall (Figure 8). In the analysis conducted during January 2024, the coldest month of the year, the dew point location in the standard wall, with insulation inside the structural cavity, was inside the cavity 99% of the time. In contrast, condensation never occurred inside the cavity in the wall with exterior insulation. The dew point was found on the ZipSystem panel (the innermost of the two external insulation layers) only 16% of the time. These results are also consistent with other studies on the effects of external insulation on the relative humidity of internal sheathing in cold climates [21,28,29].



(**a**) (**b**)

Figure 8. Position of the Dew Point and Outside Temperature during January 2024 for the north traditional wall (**a**) and external insulated wall (**b**).

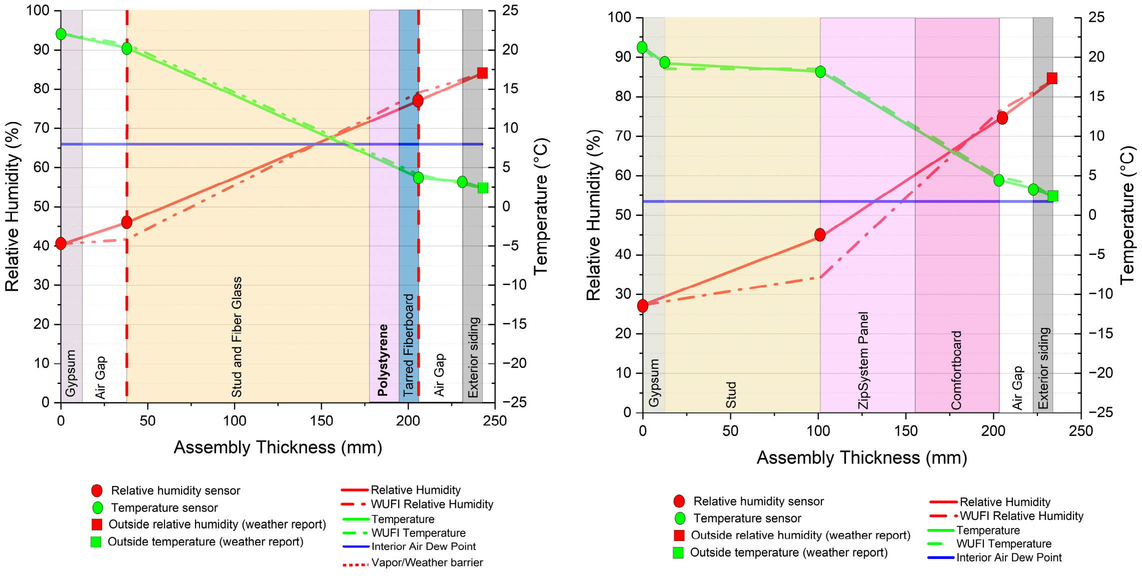
The temperature and relative humidity profiles on 19 January 2024 (Figure 9), which reached the lowest temperatures of the year (−18.4 °C), show how the position of the dew point causes higher humidity inside the cavity. It can also be observed that placing the insulation on the exterior provides a higher temperature for most of the wall. It was 66% of the wall with exterior insulation above 0 °C, compared to 46% for a traditional wall. This prevents the structural elements from suffering negative effects such as movement, stress, and fatigue caused by sudden temperature changes or exposure to extreme conditions, which affect the durability of the materials [30].



(**a**) (**b**)

Figure 9. Temperature and Relative Humidity profiles on 19 January 2024, North (**a**) traditional wall (**b**) external insulated wall.

The same profiles for 10 January 2024 (Figure 10), when the highest temperatures of the month were reached (2.4 °C), show that in the wall insulated on the outside, the dew point is never reached and there is no condensation inside the wall. However, despite shifting about 63.3 mm outward in the standard wall, the dew point is still within the insulation cavity.



(**a**) (**b**)

Figure 10. Temperature and Relative Humidity profiles on 10 January 2024, North (**a**) traditional wall (**b**) external insulated wall.

(b) South Wall

In the south wall of the houses, due to its location in the house, the traditional south wall showed a 3% increase in temperature and a 4% decrease in humidity compared to the north wall. Higher temperatures with lower relative humidity caused the dew point to shift outward by an average of 11.4 mm throughout the month of January (Figure 11).

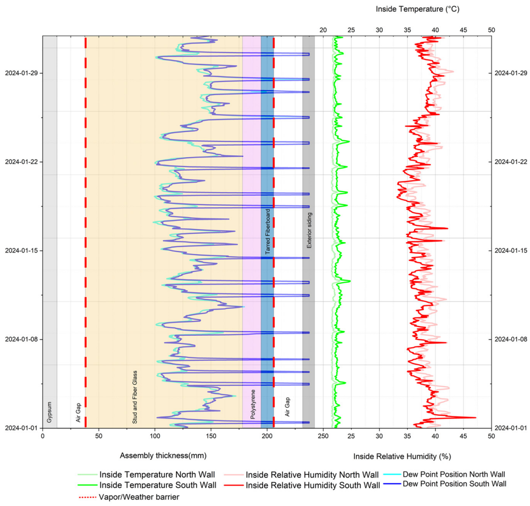


Figure 11. Position of the Dew Point, Inside Temperature, and Inside Relative Humidity during January 2024 for the south traditional wall.

Contrary to what was observed with the traditional insulation, in the external insulated wall, higher internal temperature and relative humidity values were observed compared to the north wall. On average, for January 2024, the internal temperature of the south wall was 1.3 °C higher and the relative humidity was 4% greater, showing changes of 6% and 13%, respectively. These changes in internal conditions caused the dew point to move to an average of 9.6 mm into the wall. Even under these conditions, the dew point was never found inside the cavity and was located outside the external insulation 10% of the time (Figure 12).

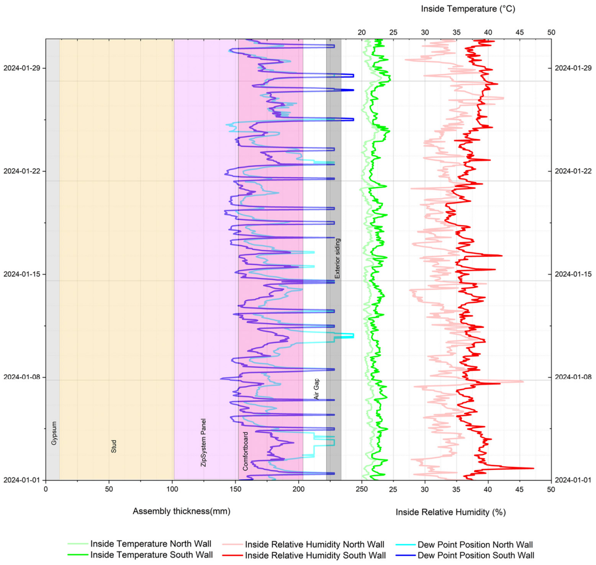
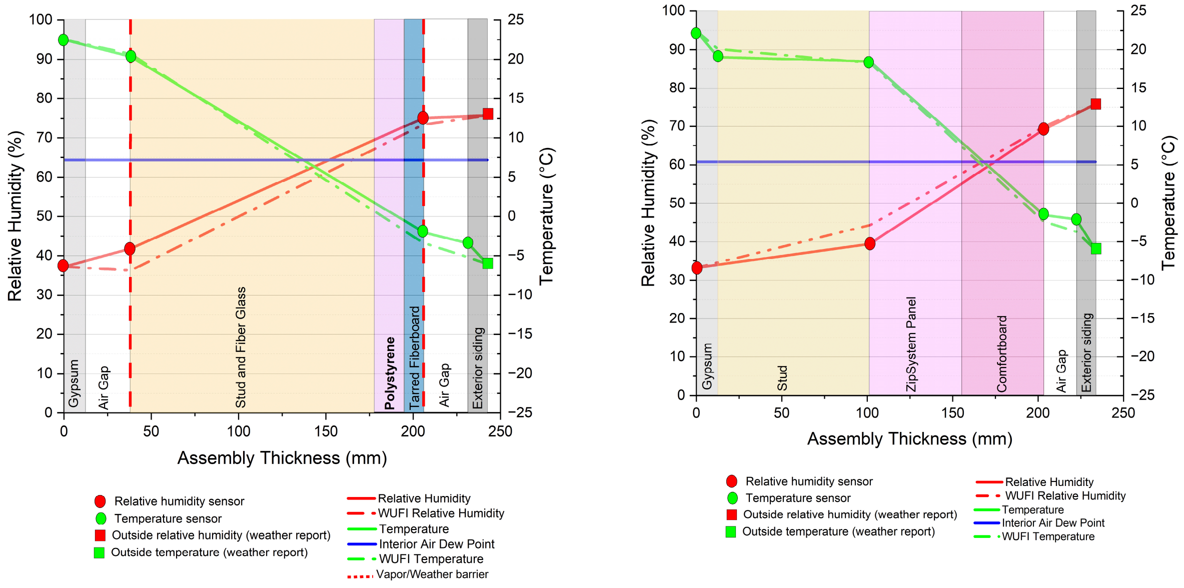


Figure 12. Position of the Dew Point, Inside Temperature, and Inside Relative Humidity during January 2024 for the south external insulated wall.

Even with the changes in conditions, the average temperature and relative humidity profiles (Figure 13) of the south walls show similar behavior to that observed in the north walls. There is generally lower relative humidity and temperature inside the cavity, and the dew point is located 29.5 mm further outward in the wall with external insulation.



(**a**) (**b**)

Figure 13. Temperature and Relative Humidity profiles in January 2024 for the South (**a**) traditional wall and (**b**) external insulated wall.

3.2. Thermography

To the best of our knowledge, this is the first study on externally insulated walls in which thermographic studies are conducted. The analysis of the thermal images (Figures 14 and 15) showed that externally insulated walls reduce thermal bridges associated with structural elements such as wall-to-ceiling and wall-to-wall junctions and eliminate and counteract the effect of studs. It was also observed that the externally insulated walls exhibited a temperature similar to or even higher than that of traditional walls.

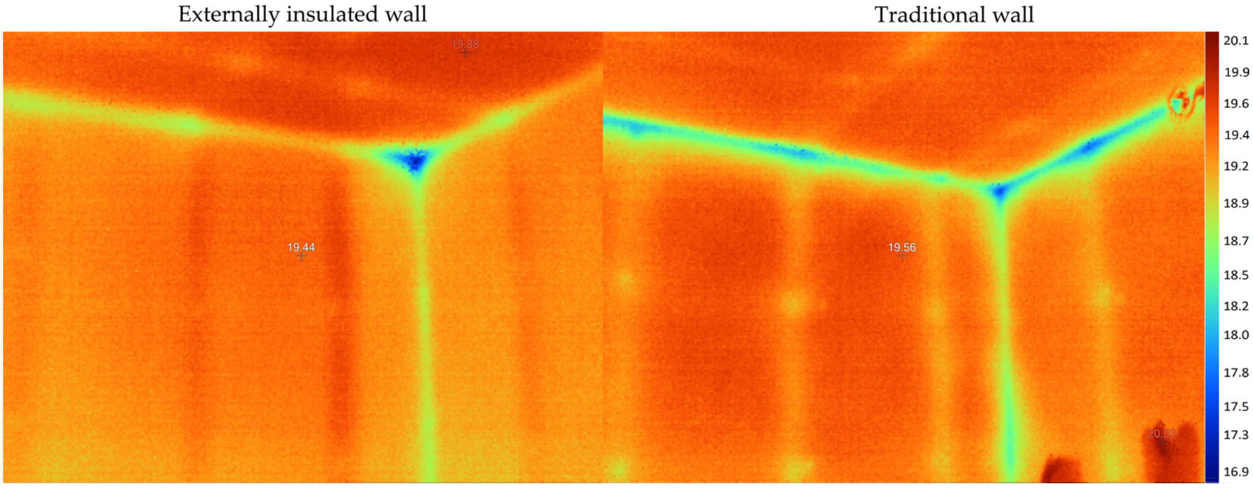


Figure 14. Images of the interior south wall taken by a thermal camera on 16 March 2023.

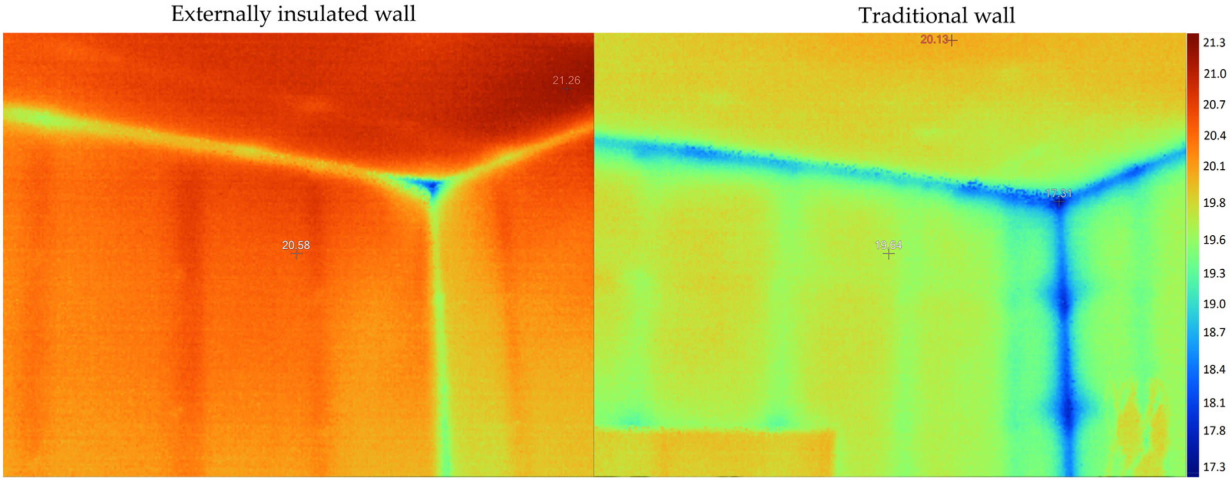


Figure 15. Images of the interior north wall taken by a thermal camera on 16 March 2023.

3.3. Measurement of Airtightness of the Buildings

Table 1 shows the air infiltration test results conducted on 15 December 2022 using the fan depressurization method during the commissioning at the building. It shows that both methods have similar performance, meet the Novoclimat 2.0 requirements, and are below 1.5 ACH50.

Table 1. Results of the airtightness by the fan depressurization method test.

Building	Traditional Wall	Externally Insulated
Air changes per hour at 50 Pa (ACH50)	0.96	0.94
Equivalent leakage area (po^2)	23.46 ± 4.57%	24.36 ± 3.99%
Normalized leakage area (po^2/100 pi^2)	0.53	0.55

3.4. Measurement of the Airborne Sound Transmission Loss

Table 2 shows the ratings of Apparent Sound Transmission Class (ASTC), Normalized Noise Isolation Class (NNIC), and Noise Isolation Class (NIC). Similar results were observed, slightly better in the wall with the insulation between the studs.

Table 2. The ASTC, NNIC, and NIC ratings of the tested buildings.

Building	Traditional Wall	Externally Insulated
ASTC (dB)	42	40
NNIC (dB)	43	41
NIC (dB)	44	41

4. Discussion

The findings from this study provide compelling evidence of the advantages of external insulation in enhancing the performance of building envelopes in cold climates.

The results of this study align with findings from previous research on the benefits of external insulation. For instance, Lstiburek's studies [18,19] have shown that placing the thermal control layer outside the structural layer helps prevent the risk of condensation and reduces thermal bridging. Straube and Smegal [20,21] also observed that assemblies with external insulation perform better in reducing condensation risks and thermal bridging. Caron-Rousseau et al. [3] study corroborated these findings in a climatic unit, demonstrating that external insulation shifts the dew point outside the cavity, reducing internal moisture content and potential condensation risks [3].

One of the most significant findings of this study is the shift of the dew point to the exterior of the wall in externally insulated assemblies. The dew point is the temperature at which air becomes saturated with moisture and condensation begins to form. In traditional wall assemblies, the insulation is placed within the structural cavity, causing the dew point to occur within the wall, leading to moisture accumulation and potential damage to structural elements.

The insulation layer is placed outside the structural cavity in externally insulated walls. This configuration alters the thermal gradient across the wall assembly. Providing a continuous thermal barrier on the exterior maintains the temperature within the structural cavity above the dew point, thereby preventing internal condensation. The external insulation acts as a shield, keeping the inner layers warmer and more stable in temperature. As a result, the dew point shifts outward, often occurring at the interface between the external insulation and the exterior environment, where it poses no risk to the structural integrity of the building.

This study's results further confirm these observations by showing that in the coldest month, the traditional wall with insulation between the studs was at risk of internal condensation 99% of the time, whereas the externally insulated wall did not. Additionally, the thermographic analysis indicated that external insulation effectively reduces thermal bridges.

The fundamental reason why external insulation outperforms traditional methods lies in its ability to create a more stable internal environment. Enhanced durability is achieved by preventing internal condensation, reducing the risk of moisture-related damage such as mold growth, wood rot, and corrosion of metal components, thereby enhancing the longevity and durability of the building structure [30–32]. Additionally, external insulation helps mitigate issues related to the movement caused by swelling and shrinking of the light-frame structure, which can lead to a loss of quality in the building envelope. Such movement can disrupt seals, create gaps, and result in thermal bridging, further compromising the envelope's performance. Improved thermal performance is another benefit of continuous external insulation, as it minimizes thermal bridging and internal relative humidity, thereby maintaining the material's low thermal conductivity. In contrast, traditional building envelopes experience increased humidity, which can lead to higher thermal conductivity. Moisture absorbed by insulation materials replaces the air within their pores, and water conducts heat more efficiently than air. This degradation of the material's insulating properties results in greater heat transfer through the building envelope, reducing energy efficiency and potentially leading to higher heating and cooling costs [8,10]. Additionally, external insulation enhances occupant comfort by stabilizing internal temperatures and reducing temperature fluctuations, which improves thermal comfort [11,15]. Externally insulated walls also offer better protection against extreme weather conditions, further boosting comfort levels. Moreover, the reduced heat loss and improved thermal performance of externally insulated walls contribute to lower energy consumption for heating and cooling, supporting broader energy efficiency and sustainability goals in the residential sector.

Both wall types met Novoclimat 2.0 requirements for airtightness, with minimal differences observed in air leakage rates. This consistency suggests that external insulation does not compromise the overall airtightness of the building envelope when adequately implemented.

The sound transmission analysis revealed that the traditional wall assembly performed slightly better. While the differences were not substantial, they suggest that cavity insulation may offer marginally better acoustic performance compared to external insulation. However, the use of materials such as fiberboards and Rockwool boards in the externally insulated assembly can mitigate this gap by acting as absorbent panels, achieving comparable acoustic performance.

5. Conclusions

This study compared a traditional light-framed wall construction with an externally insulated assembly. The comprehensive evaluation of hygrothermal, airtightness, and sound transmission performances, along with the comparison with the results of previous laboratory tests, underscores several key conclusions:

- Despite the inevitable variations in materials, positioning, and climatic conditions across buildings, this study's results strongly support the benefits of external insulation over traditional wall assemblies in reducing the risk of internal condensation and moisture accumulation. This improvement enhances building durability and thermal performance while reducing maintenance costs associated with moisture-related damage.
- External insulation improves thermal stability within the building envelope, minimizing temperature fluctuations and enhancing occupant comfort. The insulation's external placement mitigates thermal bridging, contributing to overall energy efficiency.
- Both wall configurations demonstrated satisfactory airtightness levels, meeting stringent industry standards. When installed correctly, external insulation does not compromise the building envelope's ability to maintain airtight integrity.
- While external insulation provides adequate thermal benefits in all the walls analyzed, the analysis of this study results confirms the laboratory findings that the use of fiberboards or Rockwool boards is necessary to optimize the acoustic performance of the structures and achieve a performance similar to that of traditional walls with fiberglass between the studs.

Overall, this study supports the notion that externally insulated wall assemblies offer a robust solution for enhancing residential buildings' energy efficiency, durability, and comfort. As the construction industry continues to evolve towards more sustainable practices, the insights gained from this research can inform best practices and guidelines for building envelope design and construction for light frame systems.

Future research should focus on long-term monitoring of externally insulated buildings in diverse climatic conditions to validate these findings and explore the performance of various insulating materials. Additionally, investigating the cost-benefit analysis of external insulation compared to traditional methods would provide a comprehensive understanding of its economic viability for widespread adoption. Such analysis should include the energy consumption cost and the duration of the life service.

In conclusion, the full-scale study underscores the potential of external insulation as a viable strategy for improving building performance in cold climates, aligning with broader goals of sustainability and energy efficiency in the residential sector.

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