Evaluating the Future Moisture Performance of the Stucco-Clad Wall Assembly in Selected Canadian Cities

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Abstract. *Due to climate change, it is expected that the amount of precipitation in most parts of Canada will increase in the coming decades. Consequently, the building envelope exposed to such climate could experience a higher moisture load than in the past, which could have a negative impact on its performance in the long run. The stucco-clad wall assembly, which has been widely employed in the construction of low-rise residential buildings throughout Canada may not be adequately designed to be resilient to the future climate. Thus, in the study described in this paper, the future moisture performance of the stucco-clad wall assembly located in two Canadian cities with different levels of moisture load, i.e., Vancouver and Calgary, subjected to projected future climate is investigated. The analysis includes two phases: conducting watertightness for a full-scale stucco wall specimen to determine the relationship between the climate data and the moisture load in the wall assembly and implementing hygrothermal simulations using the relationship obtained from the watertightness test for the performance assessment. Mould growth index at the exterior surface of the oriented strand board of stucco-clad wall assembly for the historical and projected future time periods is compared and discussed.*

Keywords: *Climate Change, Wood Frame Wall Assembly, Moisture Performance, Watertightness Test, Hygrothermal Simulations*

1 Introduction

The continuous rise in global greenhouse gas emissions and the inadequacy of current efforts to limit warming to 1.5°C by 2030 are critical concerns[1,2]. The Representative Concentration Pathway (RCP) predicts different temperature increases between 0.3 and 4.8 degrees Celsius, based on varying greenhouse gas concentration trajectories[1]. Climate change's effects on the global water cycle could lead to escalating temperatures and frequent, more intense extreme sea-level events[3]. Furthermore, the incidence and severity of extreme weather events, such as heatwaves, droughts, and heavy precipitation, are projected to increase[1,4]. These changes could result in increased rainfall and humidity, which could negatively impact the lifespan of building walls[5]. In terms of Canada, the precipitation is projected to increase throughout the 21st century with a more frequent extreme precipitation events[5,6].

The excessive moisture load in wood-frame wall assemblies, resulting from water penetration through imperfect wall cladding, induced by wind-driven rain, can adversely affect the durability of building envelopes in long-term. Given the predicted increase in precipitation across Canada for the future time period [7], it is crucial to consider the potential impact of increased precipitation on wood-frame wall assemblies and take appropriate measures to ensure their continued functionality and durability. Therefore, this study aimed to estimate the moisture performance of stucco-clad wall assemblies, which are commonly used in low-rise residential buildings in Canada. The analysis focused on two Canadian cities and considered both historical and projected future climate conditions to reveal the potential impact of climate change on the moisture performance of the assembly. The estimation involved two steps: (1) quantifying the moisture load using a watertightness test, and (2) evaluating the moisture performance under different time periods through hygrothermal simulations.

2 Methodology

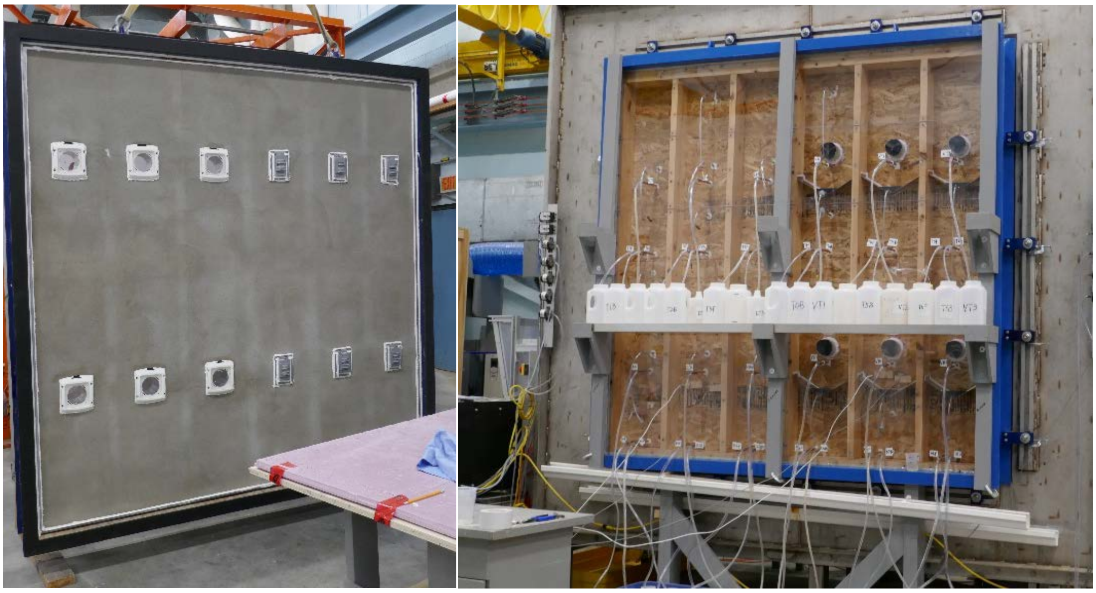
2.1 Climate data

This study employed historical climate data from 1986 to 2016 and projected future climate data from 2034 to 2064 for two Canadian cities: Vancouver, which is relatively wet, and Calgary, which is relatively dry. These climate data were originally generated by the Environment and Climate Change Canada through the use of the regional climate model CanRCM4[8]. The accuracy of the original climate data was then improved by applying bias-correction steps, as performed by Gaur et al [9]. A total of 15 sets of this data were generated to minimize the impact of initial modeling conditions on the results. Three sets of such data were selected for the analysis in this study.

2.2 Test specimen and watertightness tests

The tested stucco-clad wall assembly has a dimension of 2.44m by 2.44m (8-ft by 8-ft), as shown in Figure 1(a) and is composed of several layers. The wall specimen for the test was constructed as a stucco-clad wall with a 25mm furring depth, measuring 2.44m by 2.44m (8-ft by 8-ft). Its components include a stucco cladding layer applied directly to a 30-minute, asphalt-impregnated paper-based membrane layer. With a 25mm furring depth, an 11mm (3/8”) thick Oriented Strand Board (OSB), 51 mm x 152 mm (2” by 6”) wood stud frames, and a 10-mm (3/8”) transparent polycarbonate sheathing serving as the gypsum board and air barrier.

The configuration and construction of the test specimen complied with the minimum requirement of the National Building Code of Canada (Provide reference). In order to increase the water penetration data samples, the wall was divided into 12 equal sections, each containing ventilation ducts and electronic outlets. Water collection troughs were installed under these appliances to collect any water that reached the water resistive barrier at these locations. The collected water was then guided into reservoirs for weighing (Figure 1(b)).



(a) (b)

Figure 1. (a) Stucco wall specimen (front); (b) stucco wall specimen (back) mounted on the DWTF.

The watertightness test was conducted using the Dynamic Wind and Wall Testing Facility (DWTF) at the National Research Council Canada (NRC). This testing facility has the capability to apply simulated WDR and dynamic wind pressures to a test specimen measuring up to 2.44m by 2.44m. The testing protocol was developed by considering the projected future WDR extremities. Thus, the specimen can be exposed to all possible WDR and driving rain wind pressure (DRWP) conditions during the test, throughout its lifetime. Each experimental condition was repeated three times and the average values of results were used for subsequent analysis. Results obtained from the watertightness tests were used to establish a relationship between the water entry rate and the applied WDR and DRWP conditions using equation (1) and equation (2). The adjustment coefficients α and β in equation (1) were derived by correlating the water entry results with the Wind-Driven Rain Pressure Index (WDRPI). Once the maximum correlation coefficient (R^2) was achieved, values of α and β were determined. A similar method was also applied to equation (2) to determine values of adjustment coefficients a and b. With these adjustment coefficients, the hourly WDR and hourly DRWP from the climate data can be used in equation (1) and equation (2) to compute the moisture load for the tested specimen [10].

$$WDRPI = WDR\alpha \times DRWP\beta. \ (1)$$

$$Water\ Entry\ Rate = a \times WDRPIb. \ (2)$$

2.3 Hygrothermal simulations and performance indicator

The hygrothermal simulation in this study was conducted using the simulation program – DELPHIN. A one-dimensional numerical model of the assembly was established, which had the same configuration as the tested specimen. Basic properties of materials used in the simulations are shown in Table 1 [11]. Considering the interior surface of the stucco cladding is not uniform, a 1-mm air space was added between the stucco and the 30-minute water resistive barrier in the simulation, and the air change rate (ACH) at this space was assumed to be 2. The 31-year hourly climate data for different time period were used as the climate input for the simulation. Once the simulation was completed, the relative humidity and the temperature at the exterior surface of the OSB were extracted from the output files to calculate the mould growth index (Cite ASHRASE standard 160 here) at this location for moisture performance assessment. The mould growth index has a range of 0 to 6. A higher value of the mould growth index indicates more severe mould growth and worse moisture performance.

Table 1 Basic Properties of Materials

	Density	Porosity	Vper	Vperm	A	CE	λ
	kg/m^3	m^3/m^3	s	ng/m^2sPa	$kg/m^2s^{0.5}$	J/kg K	W/mK
Stucco	1960	0.235	2.70E-13	14.1	0.0123	840	0.407
Air space	1.2	0.99	1.97E-10	7880	-	1214	0.15
Water Resistive Barrier	909	0.97	9.80E-14	404.2	0.00093	1256	0.159
OSB	600	0.96	2.50E-13	22.6	0.0022	1880	0.094
Mineral fibre	37	0.66	1.30E-10	928.6	-	670	0.032
Polyethylene	1256	0.25	1.00E-16	0.7	-	840	0.16
Gypsum board	700	0.4	5.80E-11	4430	0.001	870	0.15

Vper: vapour permeability; Vperm: Vapour permeance; A: water absorption coefficient; CE: specific heat capacity; λ: heat conductivity

3 Results and Discussion

Results of the watertightness tests for the stucco-clad wall assembly are shown in Figure 2. At the majority of water collection troughs (24 in total), a significant quantity of water was collected. Thus, the average water entry rates from all locations were used to derive the subsequent water entry equations. The resulting coefficients for the WDRPI were determined to be a = 0.742 and b = 1.23, while the exponential function's adjustment coefficients, α and β, were calculated to be 0.00000741 and 0.858, respectively. Hourly WDR load and hourly DRWP in the climate data were thereafter used to calculate the moisture load for the hygrothermal simulations using these equations.

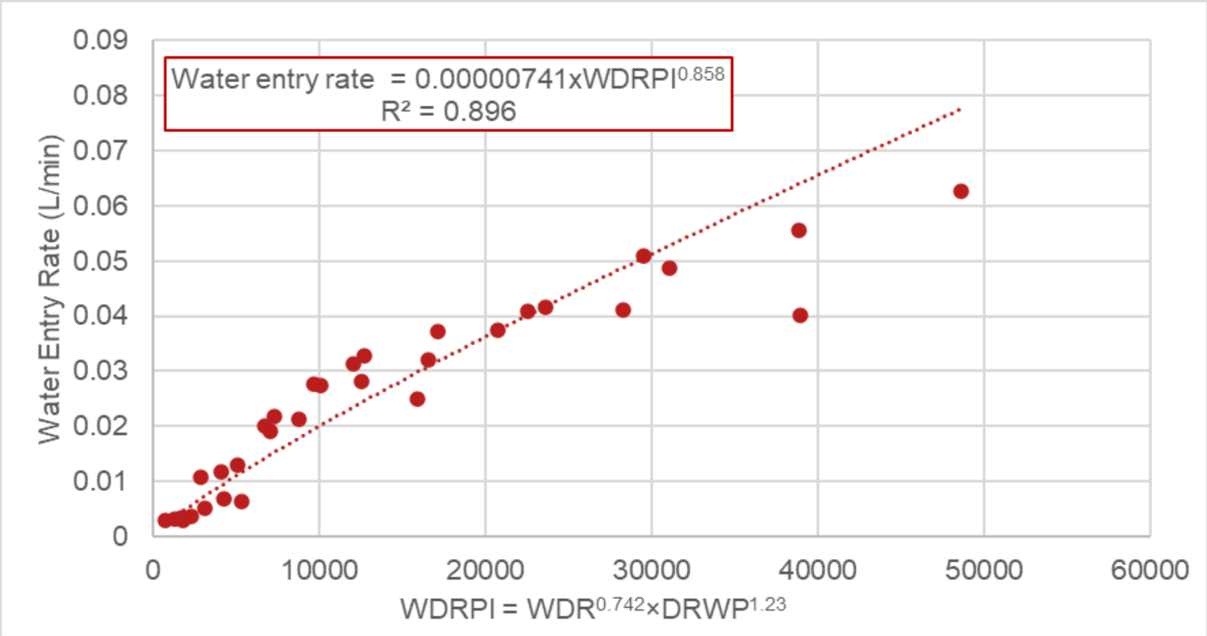


Figure 2 Water entry results and the water entry equation for the stucco-clad wall assembly

The mould growth index for the OSB of the stucco-clad wall assembly situated in the two cities for the historical and future time periods are shown in Table 2. The three sets of selected 31-year climate data were represented by R1, R2, and R3, respectively. It is evident that for R2, the moisture performance of the stucco-clad wall assembly in Calgary worsened considerably, while for R1 and R3, it deteriorated slightly. According to the analysis of the climate data, it was projected that the average WDR load in Calgary would decrease by approximately 2%, and the durations of WDR events would increase by 30% for the future time period. The changes in the moisture performance of the stucco wall in this city complied with the changes in the climatic conditions. Meanwhile, the WDR load in Vancouver was projected to increase by 5%, and the durations of WDR events were expected to increase by 6%. However, the moisture performance of the assembly located in Vancouver during the historical and future time periods was nearly identical. This is because the level of the mold growth index was already considerably severe during the historical time period. Therefore, an increase in the WDR load from the atmosphere would not further deteriorate the moisture performance.

Table 2 Mould growth index at the OSB of the stucco-clad wall assembly located in selected cities exposed to climate for different time periods

Cities	Time period	R1	R2	R3
Calgary	1986-2016	3.81	3.25	3.39
	2034-2064	3.88	4.44	3.46
Vancouver	1986-2016	5.02	5.02	4.99
	2034-2064	5.05	5.01	4.95

4 Conclusions

The objective of this research was to estimate the moisture load in a commonly used stucco-clad wood frame wall assembly for low-rise residential buildings in Canada and evaluate its moisture performance under future projected climate conditions in two Canadian cities. The study's findings emphasized the importance of considering climate change's impact on building performance and durability, especially in the face of increased precipitation. The results indicated that water penetration through imperfect wall cladding caused by WDR could adversely affect the moisture load in wood-frame wall assemblies, potentially reducing their lifespan. This situation could be exacerbated by the effects of climate change. Therefore, it is crucial to take appropriate measures to improve the durability and functionality of building envelopes under future climate conditions.

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