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An Investigation into the Hygrothermal Performance of a Mineral Wool Based Externally Insulated Enclosure in a Cold Climate

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Abstract

A high RSI enclosure has been developed for use in low energy buildings in cold climates and utilizes high density mineral wool outboard of typical wood frame construction. This study investigated both the in-situ thermal resistance and hygrothermal performance of the proposed enclosure approach. The in-situ data has been used to calibrate 3d thermal models and 1d transient hygrothermal models. The in-situ testing indicated a clear-wall RSI value of 8.96 m^2K/W for the north wall and 10.97 m^2K/W for the south wall, a change of -3.4% and +17.5% from expected nominal. Thermal modelling indicated the metal fasteners reduced the thermal resistance by 7% to 24% depending on the fastener and stud configuration. The calibrated hygrothermal simulations assessed the performance of the proposed enclosure, and a split-insulation variant, in several cold climates. The results indicate acceptable performance in all locations except for the split-insulation case located in an extremely cold climate.

Keywords: Hygrothermal Simulation, In-Situ Testing, Mineral Wool, Exterior Insulation, In-situ RSI, Thermal Resistance

1. Introduction

Buildings account for approximately 14% of Canada's greenhouse gas emissions and the residential sector

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consumes approximately 12% of Canada's energy consumption [1]. Space heating is the largest user of energy in buildings at 63% [1]. Many governing agencies are increasing thermal resistance requirements in building codes to reduce space heating energy consumption. The thermal performance of the enclosure is affected by several factors that include, but are not limited to, thermal bridging, material property changes, airflow, and construction defects. Thermal bridging can have a large impact on thermal resistances and it is recommended that continuous external insulation be installed. However, it is important to understand the effective and in-situ RSI of the wall for both hygrothermal purposes and whole building energy modelling. Increased levels of insulation have a dramatic influence on the energy flow within the envelope and in-turn have an impact on the enclosures ability to manage moisture. This research attempts to determine the hygrothermal suitability in several cold climates and compares effective and in-situ RSI values of a highly-insulated enclosure against the expected nominal RSI.

2. Enclosure testing configuration

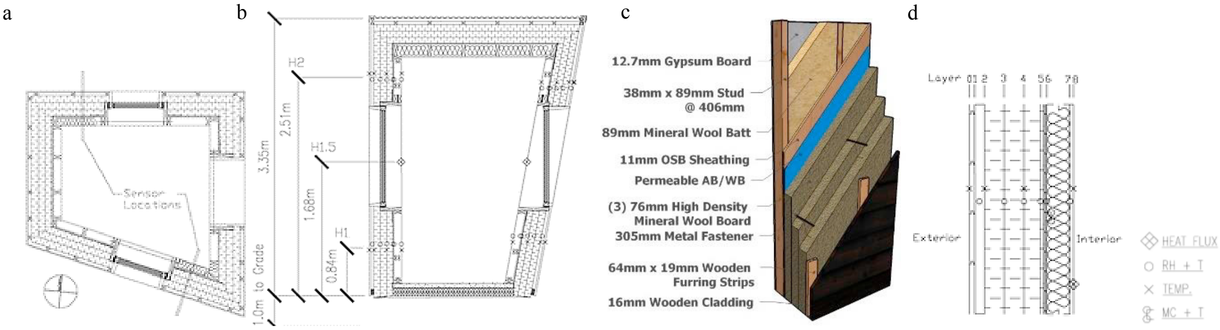

Fig. 1. (a) Test Structure Layout; (b) Test Structure Section; (c) Enclosure Assembly; (d) Envelope Section - Sensor Placement

The enclosure consists of 229mm of high density mineral wool board on the exterior side of a standard wood frame construction (Fig. 1). The mineral wool boards are fastened back to the structure with 305 mm metal screws spaced at 305mm through wooden furring strips. Wooden plank cladding is fastened to the furring strips. A vapour permeable water resistant and air barrier wraps the oriented strand board (OSB) sheathing. Mineral wool batt insulation (89mm) has been placed between the studs.

Table 1. Material properties

Material	Thickness mm	Conductivity W/m·K	Permeance ng / Pa·s·m^2	Specific Heat Capacity J/kg·K	Density kg/m^3
Gypsum	12.7	0.16	2870	870	492-567
Batt Mineral Wool	89	0.036	2160*	850	32
OSB	11	0.012	4 – 306**	1880	650
Sheathing Membrane	0.58	N/A	1659	N/A	N/A
Rigid Mineral Wool	(3x) 76	0.036	2160	850	176

*No data found, value taken from rigid mineral wool ** Permeance changes with relative humidity.
Note: Values are taken from manufacturer data sheets or are commonly used values in WUFI.

A small test structure (2.5m x2.5m x3.6m) was constructed in Toronto, Canada. The enclosure and interior space were instrumented with 61 sensors that included; relative humidity (RH), temperature (T), moisture content (MC) pins, and heat flux sensors. Sensors were installed on both the north and south wall, at several heights, and layered through the enclosure (Fig. 1). The interior climate was set to 21°C and 50% RH and was controlled by a RH/T sensor located in the middle of the structure at a height of 1.63m. Heat and humidity were provided by a small space heater and a small humidifier respectively. An air-conditioning (AC) unit was installed on June 6th to control increased air temperatures during the summer. The AC thermostat was set to 23°C, however temperature fluctuations of ±2°C were common. Interior RH was not controlled during this period and increased to between 50%-96% from June to August. A weather station was installed atop the structure to collect micro-climate data such as, relative humidity and temperature, air pressure, global horizontal radiation, wind speed, wind direction, and normal rain accumulation. Data collection was split into four periods; however, this paper will focus on the winter period (Feb. 12th – Mar. 20th, 2016)