Research Summary
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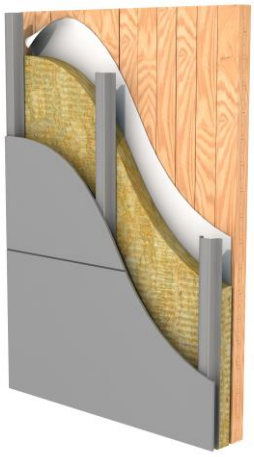
Energy and Hygrothermal Analysis of Cross Laminated Timber (CLT) Enclosures

Comparing assemblies using stone wool and rigid foam exterior continuous insulation



Project Overview

Mass timber construction has recently seen worldwide interest and increased use due to its multiple benefits such as structural robustness and high level of pre-fabrication. While much of the CLT studies in North America focus on structural and fire performance, both critical for overall building resiliency, combined energy and hygrothermal performance of CLT buildings has not been investigated or demonstrated systematically.

This study, conducted by the Colorado School of Mines in Golden, CO, analyzes the energy and hygrothermal performance benefits from CLT for a typical mid-rise multi-unit residential building. The simulations were conducted for two locations representative of both a cooling and heating dominated climate conditions: Austin, TX (climate zone 2A) and Boston, MA (climate zone 5A). Energy simulations include building enclosure considerations along with other energy efficiency parameters such as natural ventilation, increased airtightness and appropriate temperature setpoints. Hygrothermal modelling includes enclosure solutions using either ROCKWOOL stone wool or extruded polystyrene (XPS) insulation types in CLT and non-CLT assemblies for comparison.

Simulation Methodology

The energy simulations were conducted using OpenStudio software. A mid-rise multi-unit residential building prototype developed by the Department of Energy (DOE) that meets the International Energy Conservation Code (IECC) 2015 code was used as the baseline model. The building enclosure was then modified to a CLT[1] assembly, and then optimized by incorporating additional energy efficiency measures such as natural ventilation, exterior shading and thermostat schedules.

The hygrothermal analysis was conducted using WUFIv6.2 following industry standard guidelines[2]. Generic materials were selected from the software database except for the stone wool insulation material files that are specific to ROCKWOOL COMFORTBATT® and ROCKWOOL COMFORTBOARD™ 110, as tested by Fraunhofer Institute for Building Physics (IBP)[3]. The simulations were run for a 3-year analysis using ASHRAE Year 2 climate data[4] and includes 1% rain water penetration behind the cladding and 0.01% penetrating into the CLT simulating a leak.

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[1] Modifications were made following guidelines provided in the CLT handbook for North America.
[2] ASHRAE Standard 160-2016, Criteria for Moisture-Control Design Analysis in Buildings was used as a reference for the modelling setup and analysis criteria.
[3] ROCKWOOL product specific material files are included in WUFI material database and available for download.
[4] Climate file selected form software data with data derived from ASHRAE 1325-RP.

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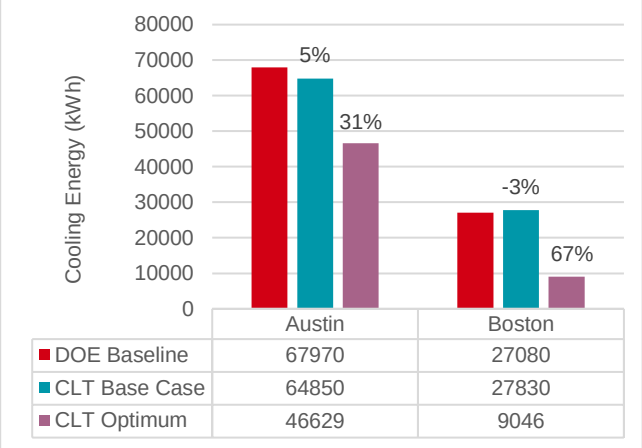
Table 1: Wall assemblies' description and nominal insulation R-values for both Austin, TX (climate zone 2A) and Boston, MA (climate zone 5A) analysis.

Non-CLT	CLT	
Wall 1 R-19.8 (Rsi 3.49) U-0.051 (Usi- 0.29)	Wall 2 **R-19.7 (Rsi 3.47)** **U-0.051 (Usi- 0.29)**	Wall 3 **R-18.9 (Rsi 3.32)** **U-0.053 (Usi- 0.30)**
Ventilated exterior siding	Ventilated exterior siding	
1" (25mm) Air space	1" (25mm) Air space	
1" (25mm) R-4 (RSI 0.70) ROCKWOOL COMFORTBOARD™ 110	3" (76mm) R-12 (RSI 2.11) ROCKWOOL COMFORTBOARD™ 110	2.5" (64mm) R-12.5 (RSI 2.20) XPS
SBPO sheet	SBPO sheet	
1/2" (13mm) plywood	~4" (~102mm) 3-ply CLT	
3.5" (89mm) R-15 (RSI 2.64) ROCKWOOL COMFORTBATT® (B/W steel stud framing)		
1/2" (13mm) interior gypsum board		

Energy Analysis Results

In comparison to the DOE Baseline model, the CLT Base Case demonstrates energy savings, especially in heating energy with over 40% savings in both climates. This reduction is mostly driven by the increased thermal performance and CLT air tightness. The CLT Optimum case which includes additional efficiency measures demonstrated deeper savings, mainly in cooling energy by 31% in Austin and 67% in Boston. From an energy cost[5], the CLT Optimum case provides the highest savings up to 25% Austin and 50% in Boston.



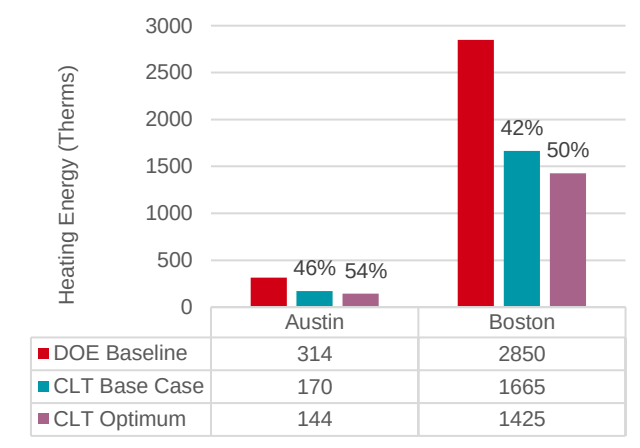


Figure 1: Energy use comparison, cooling (left) and heating (right), for Austin and Boston.

[5] Energy cost calculated from state averages obtained from the BEopt interface program for EnergyPlus based on geographical location.

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Hygrothermal Analysis Results

When comparing the stone wool CLT assembly (Wall 2) and XPS CLT assembly (Wall 3), the option with stone wool insulation demonstrates lower overall relative humidity levels - as low as 45%. In comparison, the XPS assembly has a lower drying rate and higher overall humidity levels - with lower levels around the 75% range. This is especially noted in the Boston cases where the colder climate has a greater effect.

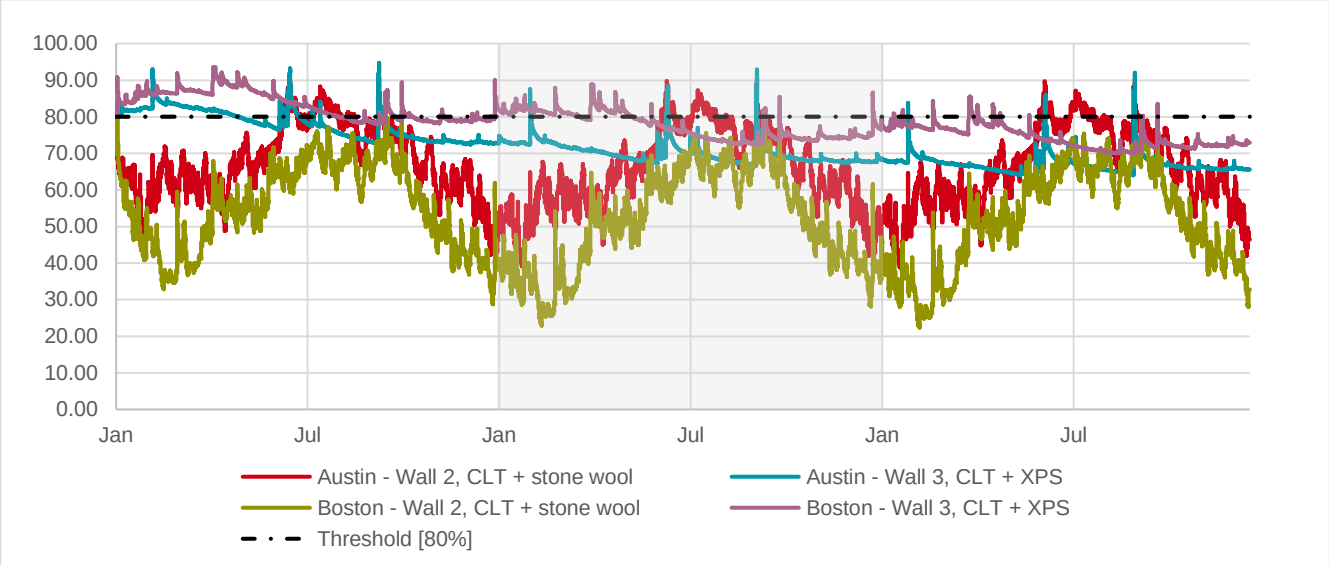

Figure 2: Relative humidity [%] at CLT (3mm from exterior), cases with 1% water penetration behind the cladding and 0.01% penetrating into the CLT.

Conclusions

Overall, this study demonstrated that using a CLT enclosure for mid-frame buildings reduced energy consumption and provided energy cost savings of up to 50%. Importantly, the energy simulations indicated that whole building efficiency measures are critical to asses full building performance and their combined benefits. This would include conducting hygrothermal analysis for insulation selection and risk assessment. Based on the selected cases, the use of either stone wool or XPS exterior continuous insulation changes the performance of a CLT exterior wall assembly. The stone wool assembly (Wall 2) demonstrated higher drying potential in comparison to the XPS assembly (Wall 3) in both climate zones. However, further research for different construction sets and climate zones is necessary to expand knowledge and identify further conclusions.

Full conference paper from 2019 Buildings XIV International Conference can be downloaded here:
Wijesuriya, S. Nieto, A. and Tabares-Velasco, P.C. " Energy and Hygrothermal Analysis of Cross Laminated Timber (CLT) and Wood Framed Mid-rise Commercial Buildings," 2019 Buildings XIV International Conference, Clearwater Beach, FL.

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