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Canada

Thermal Bridging Modeling with Benchmarking

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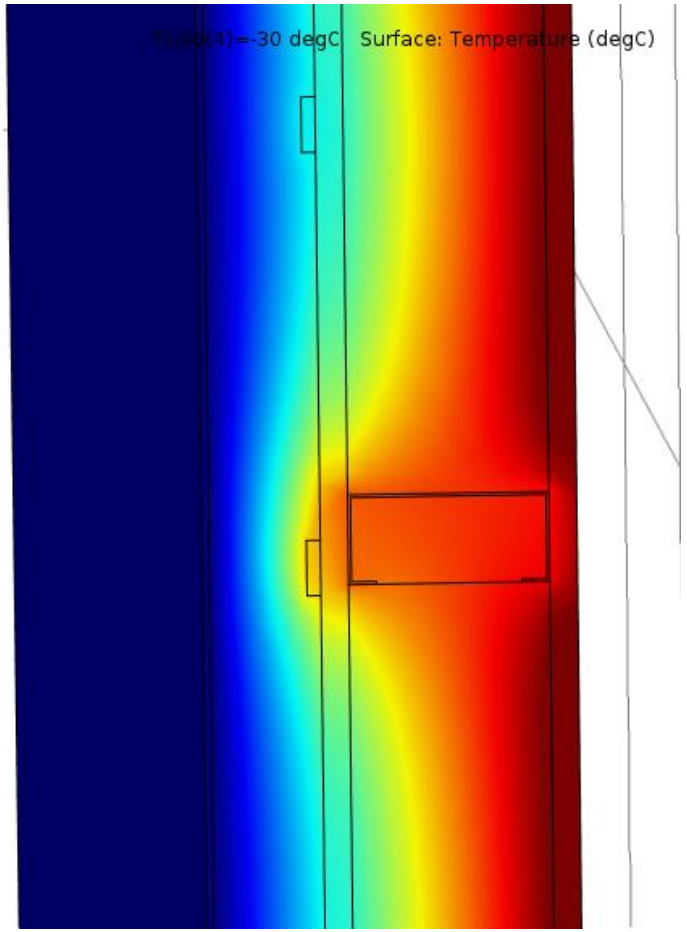
Outline

- Project description
- Wall assemblies
- Experiments
- Numerical simulations
- Results
- Benchmarking
- Conclusion

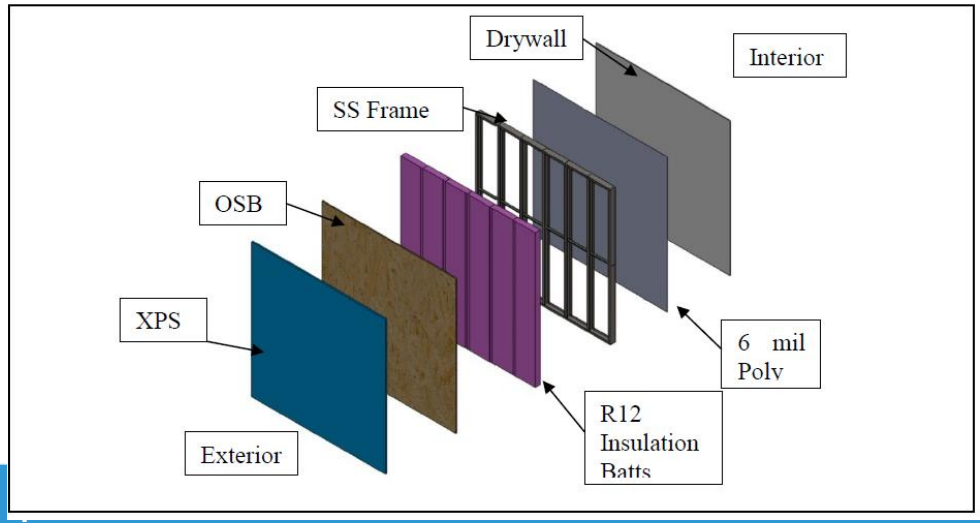
Project Description

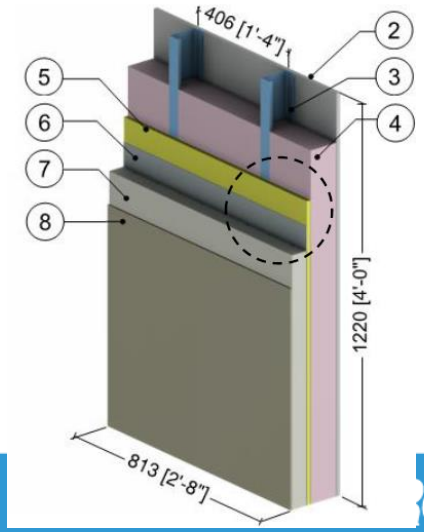
- Pan-Canadian climate plan, which is adopted in 2016, requires Canada to meet its 2030 emissions target
- 17% of Canada's GHG emissions are due to buildings
- Thermal bridging can greatly affect the thermal performance of assemblies specially in high performance buildings
- This project includes guarded hot box testing of seven wall assemblies and COMSOL simulation of 27 wall assemblies in one year
- Numerical results for three WAs are benchmarked against Guarded Hot Box (GHB) test results.



Summary of the walls that were tested

ID	ASHRAE ID	Interior Sheathing	Fiberglass Cavity Insulation	Cavity Depth	Steel Stud Thickness	Steel Stud Spacing (o.c.)	Steel Stud Flange	Steel Track Thickness	Steel Track Flange	Exterior Sheathing	Exterior Insulation	Cladding
W1	SS. 19	1/2" (13 mm) gypsum	R-12 (RSI 2.1)	3 5/8" (92 mm)	20 gauge	16" (406 mm)	1 5/8" (41 mm)	1.03 mm	Not stated	5/8" (16 mm) OSB	none	none
W2	SS. 20	1/2" (13 mm) gypsum	R-12 (RSI 2.1)	3 5/8" (92 mm)	20 gauge	16" (406 mm)	1 5/8" (41 mm)	1.03 mm	Not stated	5/8" (16 mm) OSB	1" (25mm) XPS	none
W3	SS. 21	1/2" (13 mm) gypsum	R-12 (RSI 2.1)	3 5/8" (92 mm)	20 gauge	16" (406 mm)	1 5/8" (41 mm)	1.03 mm	Not stated	5/8" (16 mm) OSB	2" (50mm) XPS	none





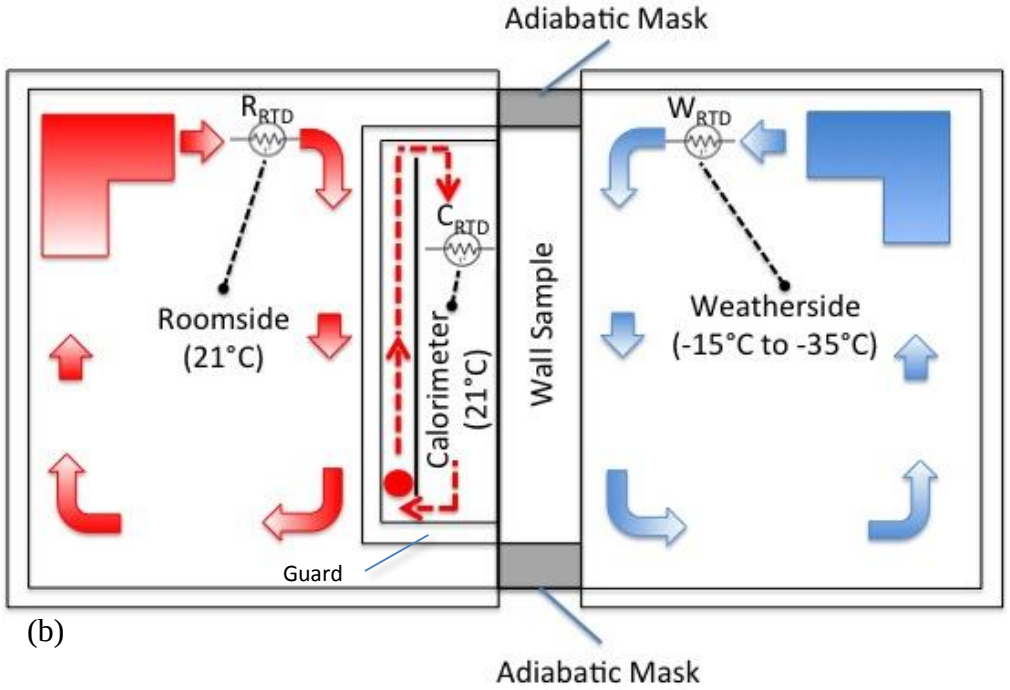
Experiments: Guarded Hot Box (GHB)

$$RSI = \frac{A * \Delta T}{Q}$$

Q = the heat input to the calorimeter (W)

A = the specimen area normal to the direction of heat transfer (m^2)

ΔT = the absolute temperature difference between the interior and exterior air (°K)



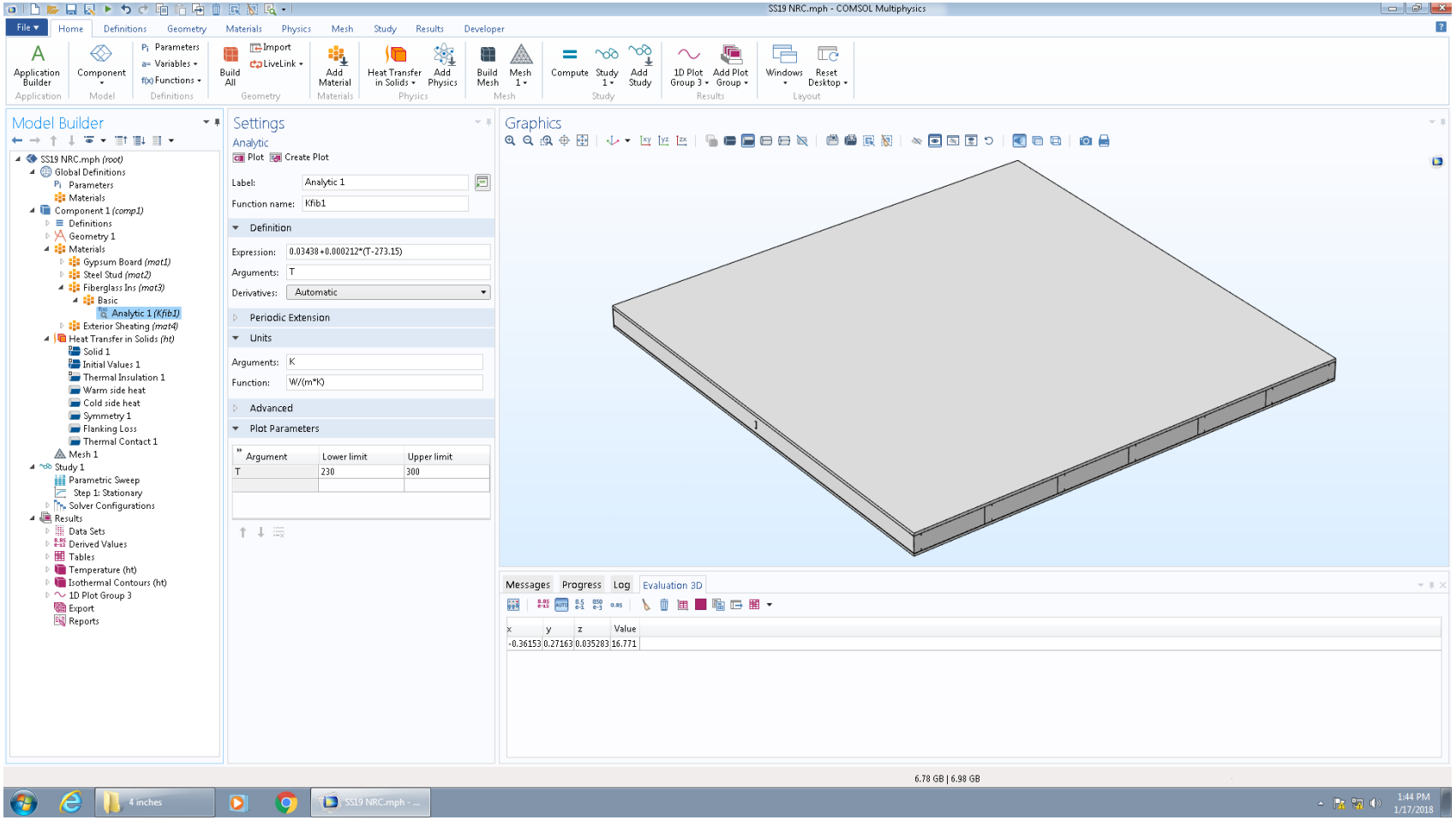
(b)

Temperature dependent conductivity

- The temperature dependent conductivity of the materials used in the wall assemblies tested in the GHB.

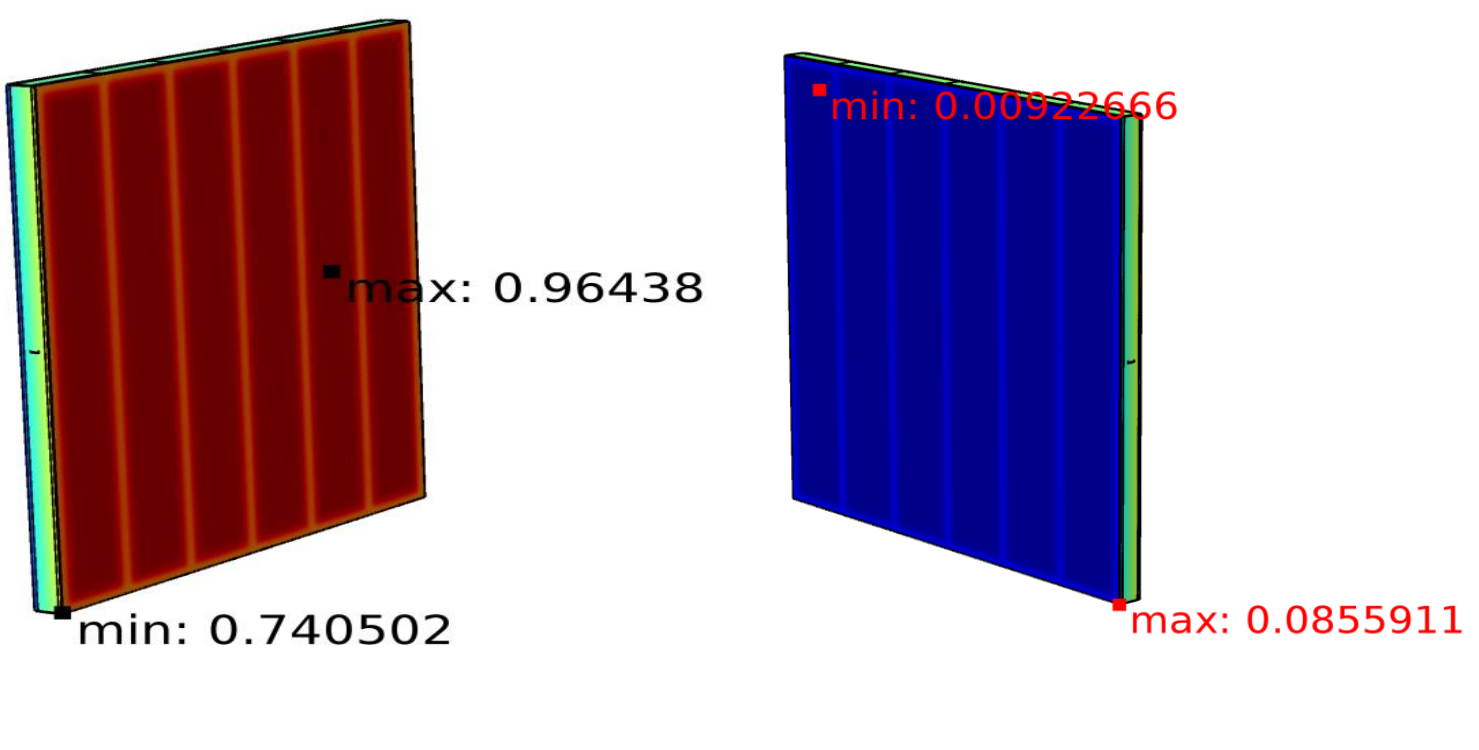
Material	Thickness (mm)	T_{mean}	RSI (m^2K/W)	Fitted Equation for R	K (W/(m.K))	Fitted Equation for K
OSB	6	24.68	0.123	$0.13(1-0.0019T_{mean})$	0.0487	$K=0.0464+0.00009T_{mean}$
		12.95	0.126		0.047	
		0.58	0.129		0.0465	
Glass-fiber	89	24.08	2.248	$2.603(1-0.0057T_{mean})$	0.0395	$K=0.0342+0.0002T_{mean}$
		11.99	2.421		0.0367	
		-0.6	2.606		0.034	
XPS	25	23.95	0.88	$0.97(1-0.0042T_{mean})$	0.0284	$K=0.0255+0.0001T_{mean}$
		11.93	0.928		0.0269	
		0	0.978		0.0255	
XPS	50	24.02	1.73	$1.939(1-0.0045T_{mean})$	0.0289	$K=0.0258+0.0001T_{mean}$
		12.04	1.832		0.0272	
		0.02	1.939		0.0257	

Temperature dependent conductivity

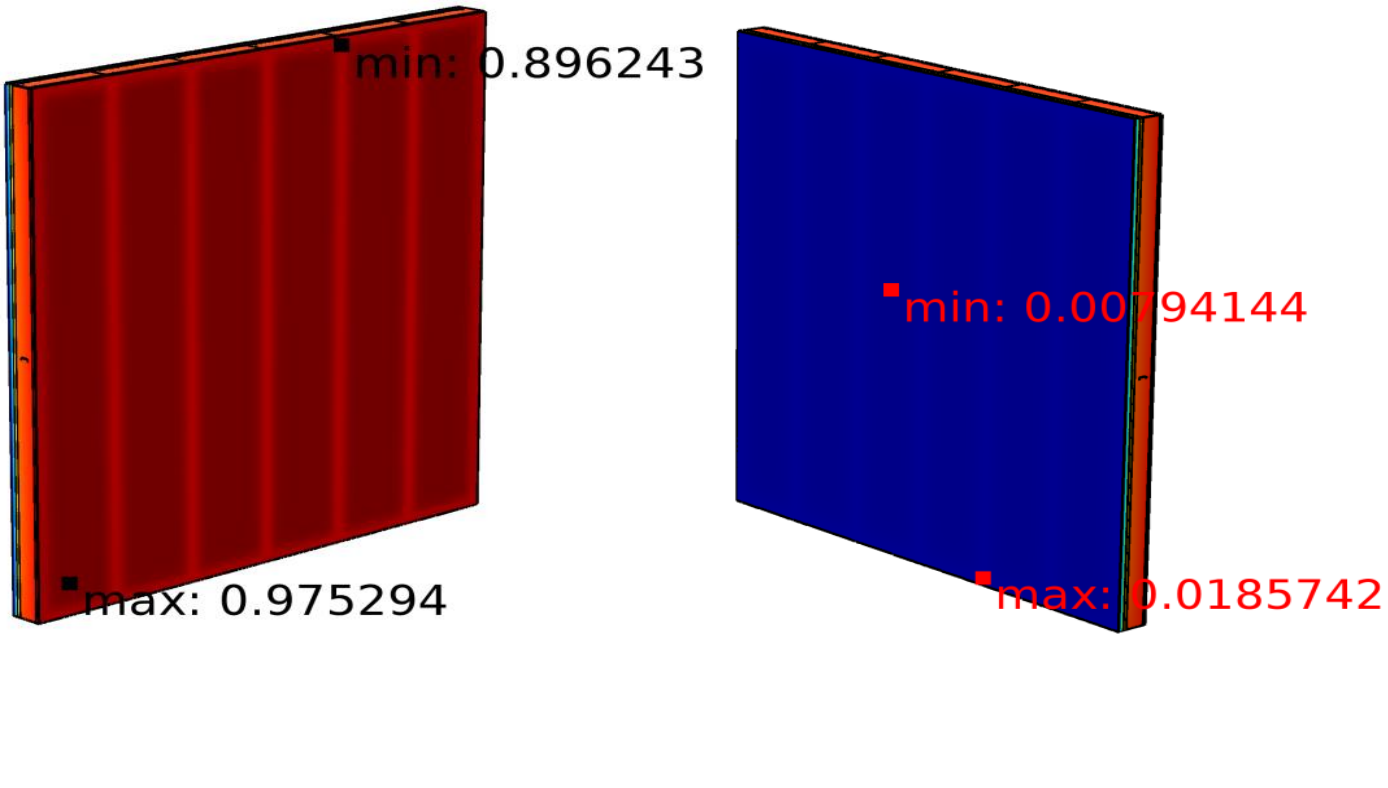


W1 Surface Temperature Index

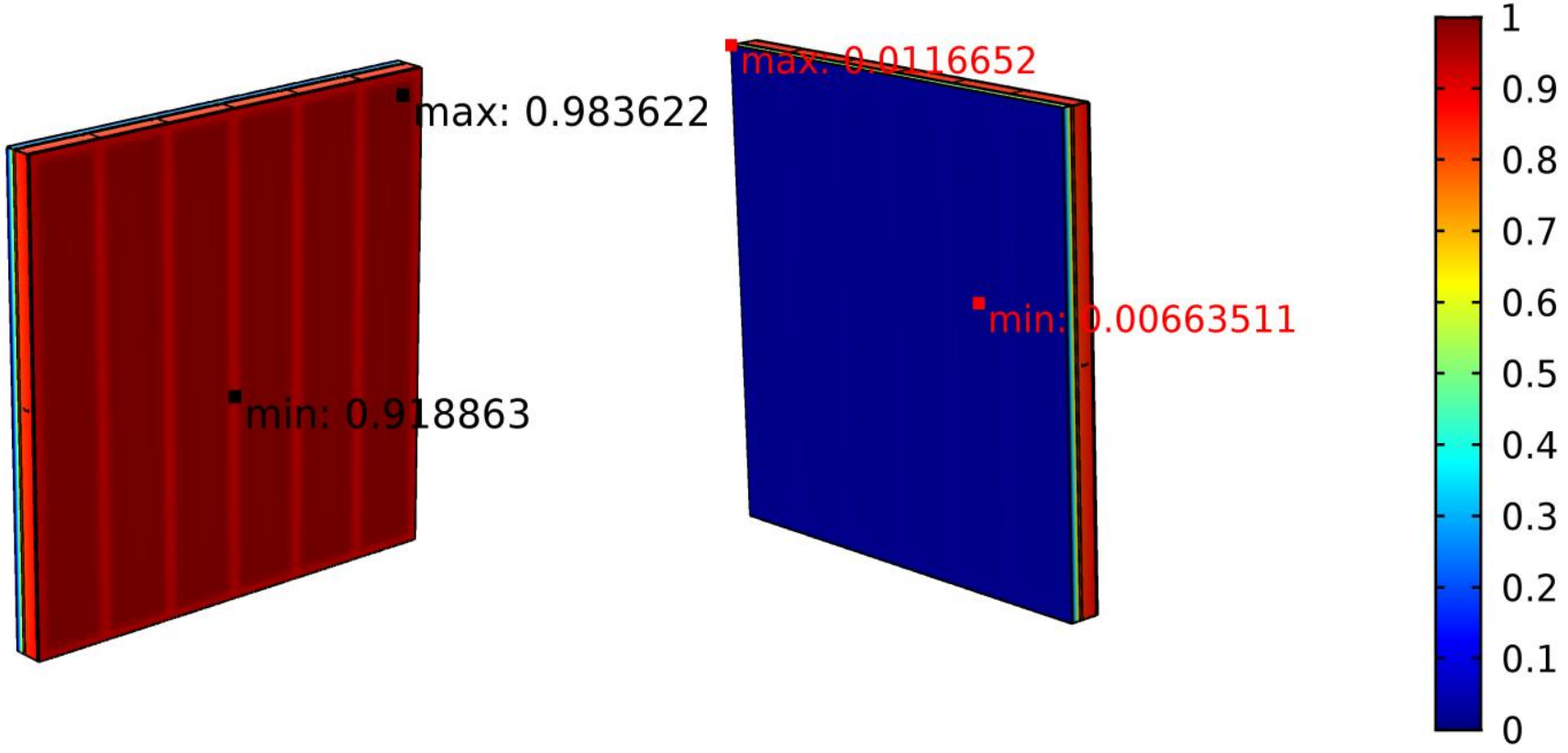
$$T_i = \frac{T_{surface} - T_{outdoor}}{T_{indoor} - T_{outdoor}}$$



W2 Surface Temperature Index

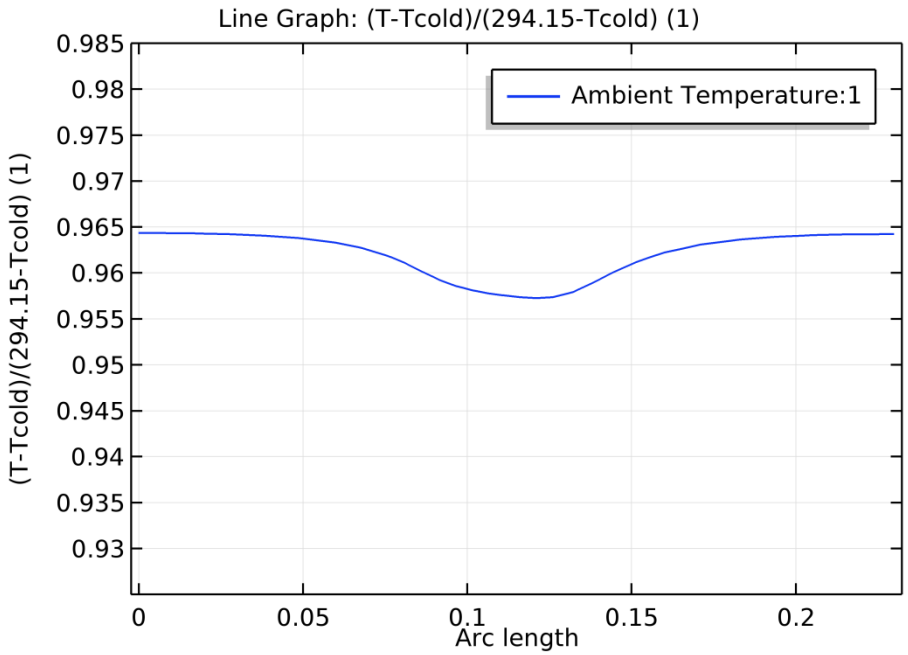


W3 Surface Temperature Index

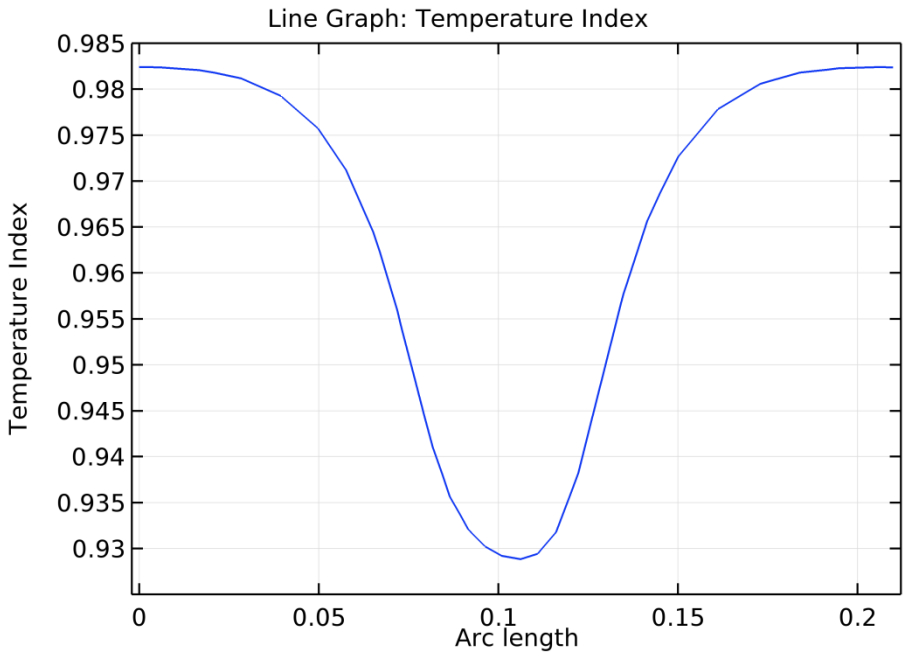


Temperature on the warm surface

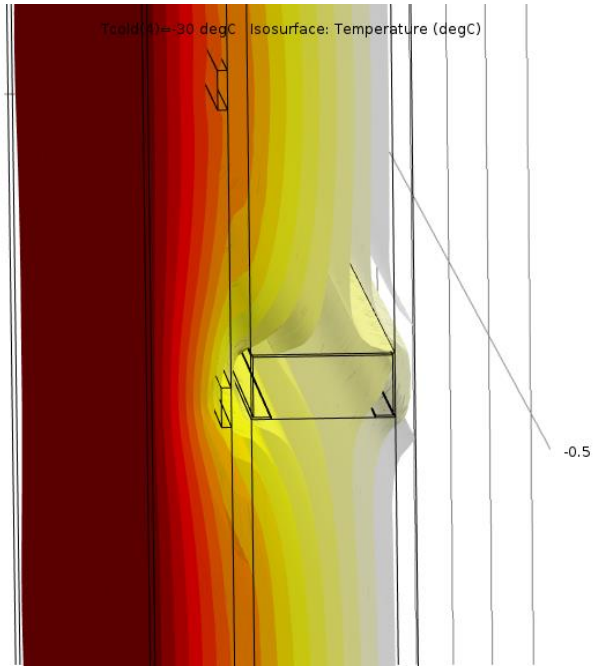
With exterior insulation

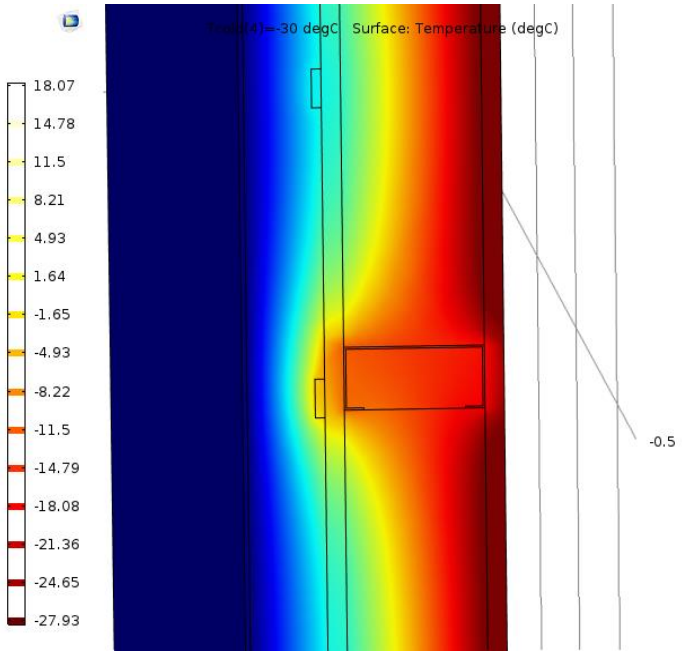


Without exterior insulation



W3. Temperature/isothermal surfaces along a stud





Benchmarking with the new GHB results

Benchmarking results for W1

	COMSOL results		GHB Results			No Thermal Bridging		
T_o (°C)	RSI StS	R StS	RSI StS	R StS	Difference	RSI StS	R StS	Increase
-5	1.36	7.77	1.43	8.17	**5.13%**	2.82	16.02	**106%**
-20	1.37	7.73	1.42	8.30	**3.55%**	3.03	17.20	**122%**
-35	1.45	8.14				3.14	17.82	**119%**

Benchmarking results for W2

	COMSOL results		GHB Results			No Thermal Bridging		
T_o (°C)	RSI StS	R StS	RSI StS	R StS	Difference	RSI StS	R StS	Increase
-5	2.26	12.86	2.35	13.34	**3.66%**	3.59	20.40	**59%**
-20	2.39	13.60	2.40	13.63	**0.21%**	3.87	21.96	**61%**
-35	2.46	13.97	2.45	13.91	**0.39%**	3.98	22.59	**62%**

Benchmarking results for W3

	COMSOL results		GHB Results			No Thermal Bridging		
T_o (°C)	RSI StS	R StS	RSI StS	R StS	Difference	RSI StS	R StS	Increase
-5	3.27	18.57	3.15	17.89	**3.84%**	4.62	26.22	**41%**
-20	3.37	19.14	3.23	18.34	**4.37%**	4.89	27.77	**45%**
-35	3.43	19.48	3.23	18.34	**6.21%**	5.02	28.51	**46%**

The importance of temperature dependent K

Benchmarking results for W1

	Experimental results [5]		MH Simulations [2]			COMSOL results		
T_o (°C)	RSI S-t-S	R S-t-S	RSI S-t-S	R S-t-S	Difference	RSI S-t-S	R S-t-S	Difference
-5	1.35	7.67	1.39	7.90	**2.96%**	1.33	7.56	**1.33%**
-35	1.42	8.07	1.39	7.90	**2.11%**	1.44	8.17	**1.37%**

Benchmarking results for W2

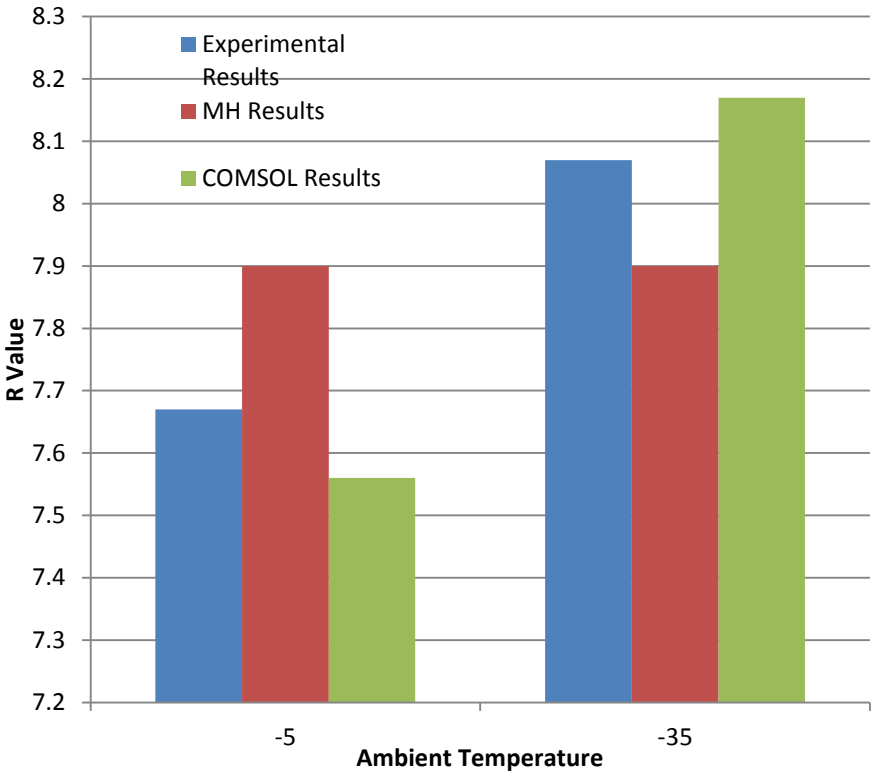
	Experimental results [5]		MH Simulations [2]			COMSOL results		
T_o (°C)	RSI S-t-S	R S-t-S	RSI S-t-S	R S-t-S	Difference	RSI S-t-S	R S-t-S	Difference
-5	2.29	13.00	2.38	13.51	**3.93%**	2.31	13.10	**0.71%**
-35	2.41	13.68	2.38	13.51	**1.24%**	2.44	13.86	**1.29%**

Benchmarking results for W3

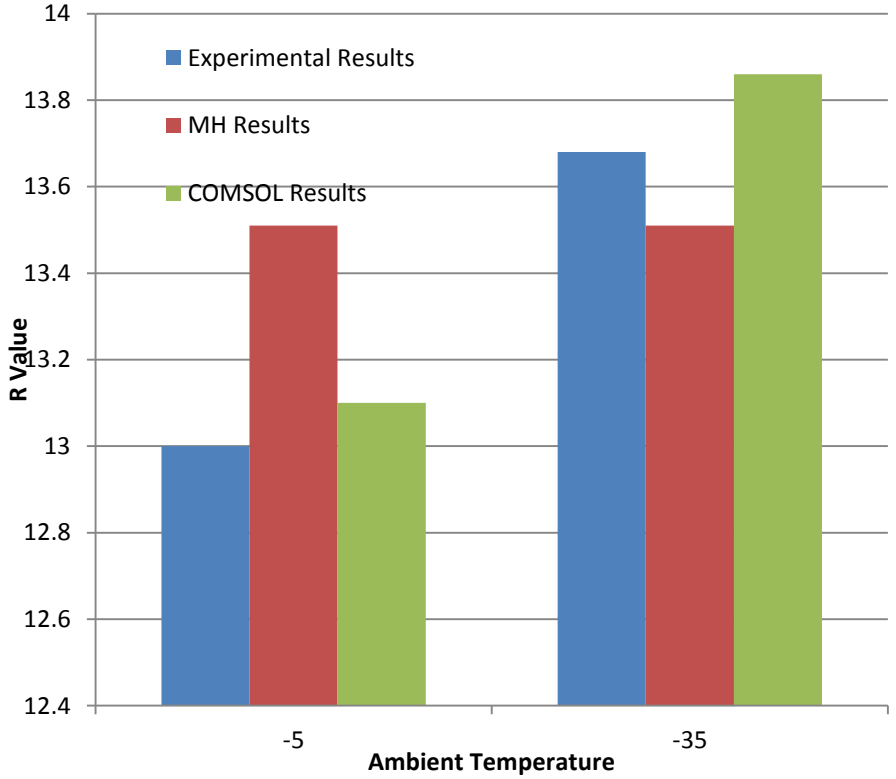
	Experimental results [5]		MH Simulations [2]			COMSOL results		
T_o (°C)	RSI S-t-S	R S-t-S	RSI S-t-S	R S-t-S	Difference	RSI S-t-S	R S-t-S	Difference
-5	3.09	17.55	3.30	18.74	**6.80%**	3.20	18.18	**3.56%**
-35	3.29	18.68	3.30	18.74	**0.30%**	3.42	19.45	**3.95%**

The importance of temperature dependent K

Wall 1 comparison



Wall 1 comparison

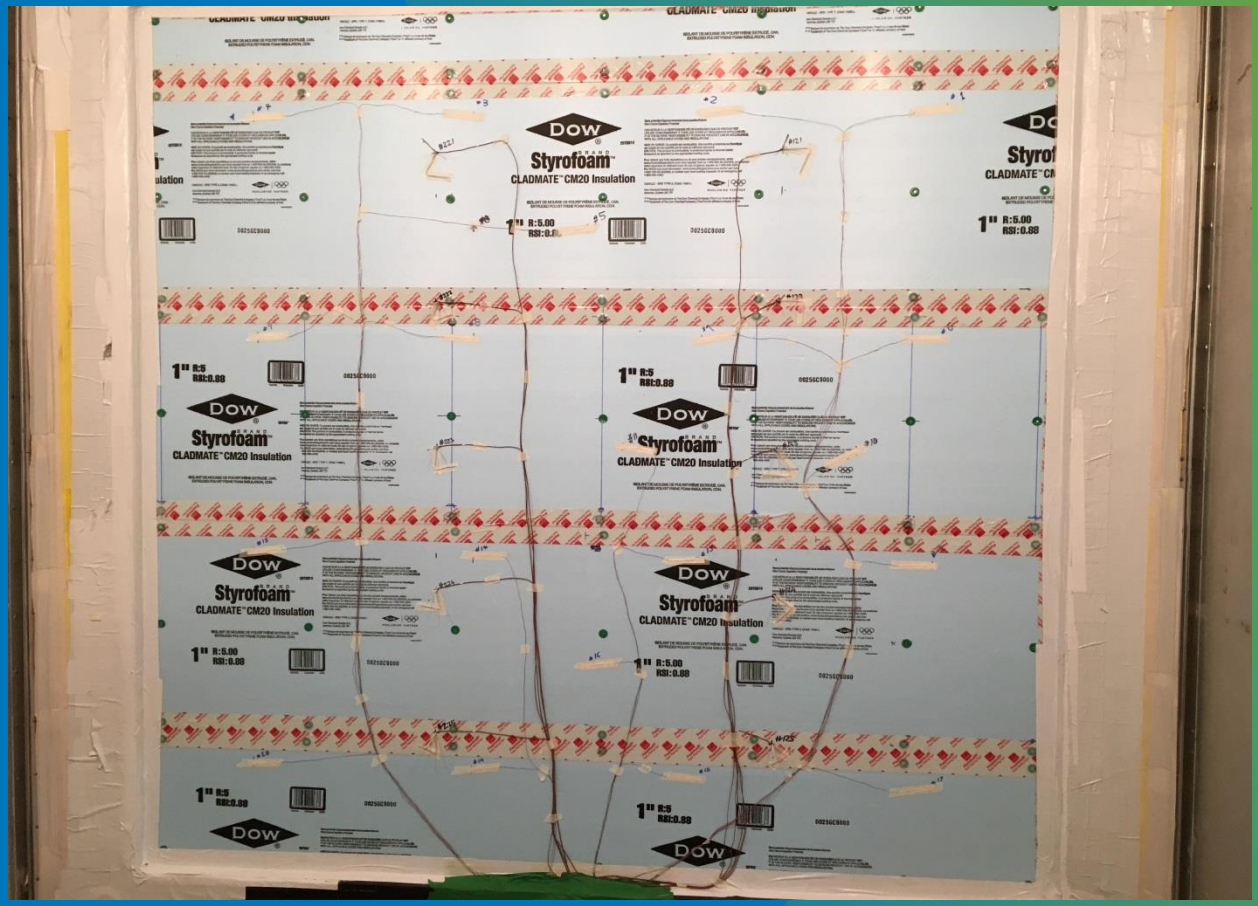


Summary

- Three wall assemblies from previous experimental studies were simulated in COMSOL and average differences of 1.35%, 1.00% and 3.75% were observed between our numerical results and the reported GHB results. All the values are within $\pm 8\%$ which is the uncertainty of GHB tests.
- The wall assemblies were tested again in the NRC GHB facilities and another series of simulations were conducted and benchmarked against the results. Average differences of 4.34%, 1.42% and 4.80% were observed between our numerical results and the GHB results.
- We also conducted another series of simulations replacing the thermal bridging material (steel) with the embedded insulation (glass-fiber) and calculated the R value increase. Average R value increases of 115%, 61% and 41% for the wall assemblies were found. It has been shown that the effect of thermal bridging can become less important by adding exterior insulation.
- It has been shown that using high conductive materials within insulation materials can decrease the thermal performance of the wall more significantly.
- Using the temperature dependent properties can highly affect the end results when the thermal properties of the used materials change with temperature.

Thank you for your attention.

Questions?



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