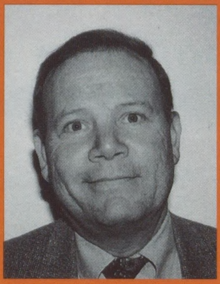

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Thermal Conductivity in Mechanically Fastened Roof Systems

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Styro Systems-Carolinas, Inc., established in 1982, markets Division 7 products and systems (roofing, waterproofing, and insulation). Among those products is the Thermomass System® manufactured by Composite Technologies, Inc., the company which provided the energy analysis used in this article.

As roofing systems evolved during the 20th Century, the need for insulation materials became increasingly important. The oil embargo of the mid-1970s made most people aware that inexpensive oil and gas were things of the past. Consultants, owners and architects began to realize the need for increased R-values in new and retrofitted buildings — something which can create problems with conventional roofing. The further the membrane is distanced from the building by insulation, the more thermal energy the membrane is forced to absorb. Although this thermal swing is more abusive to bituminous membranes, it can also affect polymeric membranes. Exposed black EPDM can reach temperatures as high as 200 degrees F on a 95 degree day. As the membrane's surface temperature increases, performance of the insulation is critical in order to maintain satisfactory interior conditions. Ballast can help temper the heat load, but what about exposed membranes that use mechanically fastened insulation systems through the deck with metallic fasteners? This attachment will not only conduct heat into the building in the summer, but will also conduct heat outward through the assembly during the heating season. This conductivity can greatly reduce the insulation performance. The Energy Policy Act of 1992, signed into law by President Bush, addresses the conductivity of components that bridge the insulation envelope.

Some building components are already being affected by the Energy Policy Act. For example, the new law requires that precast, pre-stressed, and tilt wall concrete panel construction be analyzed by the "isothermal plane" method of calculating heat loss (using ASHRAE Chapter 23 and the series-parallel path analysis).[1] The thermal shorts in these systems must be analyzed to determine how much the metallic connectors and solid zones of concrete reduce the performance of the insulation. In most conventional concrete panel wall systems, the thermal performance is reduced by more than 50 percent by the connectors.

This calculation shows the reduced R-value due to energy loss attributed to conductance. It doesn't predict how much energy is lost (BTUs). However, this can be determined in a life cycle cost analysis by identifying the ΔT (interior and exterior temperatures, etc.). *RSI* published an article in April of 1994 that demonstrates how a metal stud wall with an R-11 batt actually performs to an R-5.5 due to conductivity through the metal studs.[2]

In time, all states and local codes will need to comply with the requirements of the Energy Policy Act. The North Carolina Energy Code requirements, as an example, have changed to reflect this correction factor when dealing with conductance through metal studs (see Figure 1).[3]

Obviously, this phenomenon occurs in roofing systems in which the insulation has been secured with metallic fasteners. In analyzing a roofing system that is mechanically fastened, one can also utilize the same parallel path method of analysis. First, the type of insulation and an accurate R-value must be determined. Make sure a long term stabilized R-value is used instead of a conditioned R-value. Some rigid foams

Figure 1

Wall Sections with Metal Studs Parallel Path Correction Factors *

Size of Members	Gauge of Stud**	Spacing of Framing, in.	Cavity Insulation R-value	Correction Factor	Effective Framing/ Cavity R-value
2x4	18-16	16 o.c.	R-11 R-13 R-15	0.50 0.46 0.43	R-5.5 R-6.0 R-6.4
2x4	18-16	24 o.c.	R-11 R-13 R-15	0.6 0.55 0.52	R-6.6 R-7.2 R-7.8
2x6	18-16	16 o.c.	R-19 R-21	0.37 0.35	R-7.1 R-7.4
2x6	18-16	24 o.c.	R-19 R-21	0.45 0.43	R-8.6 R-9.0
2x8	18-16	16 o.c.	R-25	0.31	R-7.8
2x8	18-16	24 o.c.	R-25	0.38	R-9.6

* This table was developed for C-Channel Metal Studs.
** These factors can be applied to metal studs of this gauge or thinner.

lose up to 36 percent of their published R-value in 180 days. As stated by MRCA/NRCA:

> The current artificial conditioning practices of either 75 degrees F for 180 days (RIC/TIMA 281- 1) or the more recently proposed 140 degrees F for 90 days are useful for determining initial R- values and quality of the materials. However, published data shows that they are not indicative of the (in-service) stabilized R-value needed for design purposes.[4]

If the insulation manufacturer does not show how to calculate an in-service R-value, the designer should refer to the ASHRAE *Fundamentals Handbook* for these R-values.

Once the insulation has been selected, the type of fasteners and the frequency must be determined. There is software available to make the calculations once the data are obtained. Composite Technologies, Inc. software was used for the calculations in this article.[5] In this hypothetical roofing system, a base R-value of 15 is used. There are eight fasteners per 32 square feet (one every 4 square feet) which is a minimal fastening pattern. Assuming a 1/4-inch diameter for the fasteners, a 40,000 square foot roof would have 10,000 fasteners (a total of 490.87 square inches of fastening area).

Currently, mechanically fastened membranes require considerably more fasteners than one per four square feet, so the same system was analyzed with fasteners at the rate of one every two square feet. This represents a fastener area of 981.75 square inches. An analysis of one fastener per square foot was also calculated to represent attached insulation systems using mechanically fastened membranes in high wind zones. These calculations do not consider additional exposed metallic surfaces such as stress plates; however, it should be noted that these exposed surfaces are analogous to the fins of a radiator, increasing the thermal conductivity. The calculations can now be performed (see Figure 2 on page 8).

As seen in Figure 2, the loss of R-value can be significant. Systems that use one fastener per square foot will lose over 30 percent of the R-value due to thermal conductivity; systems using one fastener per two square feet will lose 22 percent; and systems using one fastener per four square feet will lose 13 percent. Mechanically fastened membranes are usually installed over insulation that has already been fastened using the required pattern. Installing the membrane will obviously add additional fasteners. Fastener size can vary, so a 1/4-inch diameter fasten-

Figure 2

Roof Connection Comparisons: Fully Adhered Membrane vs. Mechanically Fastened Membrane

Thermal Conduction Based on "Isothermal Planes" (Series-Parallel Path) Analysis, ASHRAE 1985 Fundamentals Handbook, Chapter 23

SYSTEM DESIGN	FASTENERS @ 1 PER 4 SQ. FT.	FASTENERS @ 1 PER 2 SQ. FT.	FASTENERS @ 1 PER 1 SQ. FT.
Insulation Type	Extruded	Extruded	Extruded
Fastener Type	Deck Screw @ 1/4" dia.	Deck Screw @ 1/4" dia.	Deck Screw @ 1/4" dia.
Fastener Conductivity	365	365	365
Fastener Area	490.87 sq. in.	981.75 sq. in.	1,963.50 sq. in.
Roof Area	5,760,000 sq. in.	5,760,000 sq. in.	5,760,000 sq. in.
Insulation Conductivity	0.2	0.2	0.26
Deck Conductivity	365	365	365
Open Deck Area	0.00 sq. in.	0.00 sq. in.	0.00 sq. in.
Surface Resistance	0.85	0.85	0.85
Deck Thickness	0.14 in.	0.14 in.	0.14 in.

COMPARISON RESULTS: ASSUMED SYSTEM RESISTANCE & U-VALUE VS. ACTUAL SYSTEM RESISTANCE & U-VALUE

INSULATION THICKNESS	R-VALUE		LOSS	R-VALUE		LOSS	R-VALUE		LOSS
	Assumed	Calculated	%	Assumed	Calculated	%	Assumed	Calculated	%
1.0 in.	5.85	5.18	11.5	5.85	4.66	20.27	4.7	3.45	26.49
1.5 in.	8.35	7.34	12.08	8.35	6.57	21.3	6.62	4.75	28.19
2.0 in.	10.85	9.51	12.4	10.85	8.48	21.86	8.54	6.05	29.13
3.0 in.	15.85	13.83	12.73	15.85	12.29	22.44	12.39	8.66	30.13
4.0 in.	20.85	18.16	12.9	20.85	16.11	22.75	16.24	11.26	30.66
5.0 in.	25.85	22.49	13.01	25.85	19.92	22.94	20.08	13.86	30.98
6.0 in.	30.85	26.81	13.08	30.85	23.74	23.06	23.93	16.46	31.2
7.0 in.	35.85	31.14	13.13	35.85	27.55	23.15	27.77	19.06	31.36
8.0 in.	40.85	35.47	13.17	40.85	31.36	23.22	31.62	21.67	31.48

Assumptions: Roof connection information based on typical manufacturer specifications with assumed 1/4" deck screw size. Fastener requirements for membrane attachments dictated by wind uplift requirements.

The new National Energy Standard ASHRAE/ISE 90.1 is being implemented by the Department of Energy throughout the U.S.A. To be in compliance with this standard, all wall assemblies must be calculated as provided for in the ASHRAE 1985 Fundamentals Handbook, Chapter 23. This states, generally, if the construction contains any layer in which lateral conduction is significantly higher than the transmittance through the wall, "a value closer to the combined series-parallel calculation should be used." For insulated concrete walls, the large difference between the conductivity of the concrete wythes and the insulation board warrants the use of the isothermal planes method. The lateral conductance through the concrete is high compared to the transmittance through the wall.

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er fastened at one per two square feet would affect the insulation performance the same as 1/2-inch diameter fasteners at one per four square feet because the area of conductance is the same in both.

Thermal conductivity should always be considered when designing systems requiring mechanically fastened insulation and membranes. Increasing the thickness of the insulation to compensate for thermal loss should become a design consideration. Mechanical systems (HVAC) are sized based on the R-value of the entire envelope. If this is understated, increased heating and cooling costs can be expected.

Conclusion

The foregoing illustrates the influence of conventional fasteners on the thermal efficiency of various roof assemblies. The efficiency of the thermal medium diminishes in direct proportion to the fastening rate.

Individuals involved in the design of controlled environments should recognize this phenomenon. Failing to develop the anticipated efficiency may promote condensation on fastening devices, underperforming mechanical systems, and unexplained moisture gain within components. Selecting the best insulation is important, but it is also important to understand how thermal bridging can greatly reduce the overall R-value of the roofing system.

Further information can be obtained by calling the author at (704) 552-0829, fax (704) 824- 5054.

References

1. ASHRAE, 1985 *Fundamentals Handbook*.

2. Kwart, Michael, "The Thermal Gap Caused by Metal Studs", *RSI*, April, 1994, pg. 8.

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