MORRISON HERSHFIELD

October 28, 2011

Zoran Prostran
Engineering Technologist, LEED AP
Quad-Lock Building Systems Ltd.
7398 - 132nd St.,
Surrey, BC V3W 4M7

Re: Review of Thermal Properties of Quad-Lock Foam Wall Systems

Dear Mr Prostran:

Morrison Hershfield Ltd (MH) was requested to review the R-value of the QUAD-LOCK foam wall system. We have reviewed the Ecotope Inc report that summarizes a calculation of the R-value of the system using a parallel heat loss calculation. This is in an appropriate calculation method for the QUAD-LOCK foam wall system to determine the R-value of the wall assembly. MH has reviewed the material properties and calculation and we concur with the overall R-value of approximately R-22 for the system as outlined on page 5 of the attached report.

Yours truly,
Morrison Hershfield Limited

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Analysis of Thermal Properties of Building System Ltd.'s QUAD-LOCK® Foam Wall Systems

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Jonathan Heller

and

Bob Davis

23 April 1999

Introduction

Ecotope Inc. has evaluated the thermal performance of the QUAD-LOCK foam wall system. The system's performance is evaluated in a variety of likely above-grade scenarios by using parallel heat loss calculations. Below-grade performance is also evaluated using the finite-difference simulation program, SUNCODE (SERI-RES).

In typical above-grade applications (interior finish of ½" gypsum wallboard, 5/8" T1-11 exterior siding), the nominal 6" QUAD-LOCK wall has a U-value of 0.045 Btu/hr °F ft^2. This value is more than 27% better than a standard 2x6 frame wall with R-19 batt and more than 22% better than a standard 2x6 wall with high-density R-21 batt. The stud cavities of a 2x6 frame wall would have to be insulated with extruded polystyrene (Dow Blueboard or equivalent, at R-5/inch) to match the performance of the QUAD-LOCK system.

Composite wall systems such as QUAD-LOCK offer another energy benefit. When properly installed, the composite wall will provide a tighter infiltration barrier, reducing heating costs and uncomfortable drafts.

The first section below describes the geometry and materials used in the wall system itself. The next section presents the analysis of the steady state heat flow through the panel in above-grade applications. The below-grade analysis is then presented. The final section summarizes the findings.

Description of Wall Systems Analyzed

The QUAD-LOCK wall system uses 12 x 48 inch interlocking panels, 2.25 inches thick, held together with polyethylene ties. The panels are constructed of expanded polystyrene (EPS), molded beads (density of 2.0 lb/ft^3). The space between the panels is then filled with concrete to form a solid wall. The nominal thickness of the concrete can be varied in 2 inch increments from 4 to 10 inches by using different length ties. A detail of the panel is shown in Figure 1 (attached).

QUADLOCK walls are typically finished on the inside surface with 1/2" gypsum wallboard (GWB) glued to the surface of the foam. The outside is typically finished with 5/8" T1-11 (screwed directly to the ties). If a finish is desired which requires mechanical fastening such as lapped wood siding, 1x2 nailers are screwed to the polyethylene ties and the siding then attached to the nailers. This detail creates a ¾" airspace between the nailers and exterior siding.

Above-Grade Wall Performance

The QUAD-LOCK system produces a wall with a very uniform cross section which is relatively easy to analyze using standard ASHRAE parallel heat loss calculations. Since the polyetylene ties are made of a non-thermally conductive material, they have a negligible impact on the thermal performance of the wall.

The 6" and 10" wall systems have slightly different thermal conductivities because of the effect of the additional concrete. The heat loss rate of the 6" QUAD-LOCK wall alone is calculated at 0.0476 Btu/hr °F ft^2. The 10" wall heat loss rate is 0.0469 Btu/hr °F ft^2. The U-values include the effect of a still air film on the inside surface and a 7.5 MPH wind on the outside surface.

The 6 inch and 10 inch were each evaluated with three different wall finish combinations. In all cases, the interior finish is ½" GWB glued to the interior QUAD-LOCK panel. The three exterior finishes were 5/8" T1-11, 1x2 nailers with ½" lapped wood siding, and ½" stucco.

The materials used in the calculations (and their thermal resistivities) are listed below:

Concrete:	0.083 hr · ft^2 · °F/Btu · inch
EPS, 2.0 lb/ft3:	4.20 hr · ft^2 · °F/Btu · inch
Gypsum wall board (1/2"):	0.45 hr · ft^2 · °F/Btu
Lapped wood siding (1/2"):	0.81 hr · ft^2 · °F/Btu
T1-11 siding (5/8"):	0.78 hr · ft^2 · °F/Btu
Stucco (1/2"):	0.24 hr · ft^2 · °F/Btu
Vertical still air (3/4"):	0.94 hr · ft^2 · °F/Btu

Summary of Above-Grade Thermal Performance of QUAD-LOCK and Code Bases

Wall Type	U-Value Btu/hr °F ft^2
Unfinished 6" QUAD-LOCK wall	0.048
6" QUAD-LOCK w/5/8" T1-11	0.045
6" QUAD-LOCK w/1x2 nailers and ½" lapped wood siding	0.043
6" QUAD-LOCK w/ ½" stucco	0.046
Unfinished 10" QUAD-LOCK wall	0.047
10" QUAD-LOCK w/5/8" T1-11	0.044
10" QUAD-LOCK w/1x2 nailers and ½" lapped wood siding	0.043
10" QUAD-LOCK w/1/2" stucco	0.045
Standard R-19 frame wall (2x6 studs 16" o.c., 6" thick FG batt) & T1-11	0.062
Standard R-21 frame wall (2x6 studs 16" o.c., 5.5" thick HD FG batt) & T1-11	0.058
R-19 frame wall w/extruded polystyrene in joist cavities & T1-11	0.045

All cases assume interior finish of ½" GWB

Below-Grade Performance Analysis & Results

The below-grade analysis relies on a multizone thermal simulation program adapted from the SUNCODE building performance program.[1] Heat loss coefficients are calculated using a finite-difference procedure which integrates heat flow into the ground over the heating season. The heat flow is then normalized with heating season degree hours.

Heat flow through the below-grade wall is reported as a U-value (Btu· in/hr ·°F· per ft^2 of wall area), and the heat flow through the basement floor is reported as an F-value (Btu/hr· °F per lineal foot of slab perimeter). Although the wall is the focus of the analysis, both heat loss coefficients are reported to give a full description of heat loss in the basement. Below-grade heat loss rates are most accurately described as a combination of wall and slab edge heat loss rates, since changing the wall construction detail will affect the slab edge heat loss, and changing the slab detail will influence the overall wall U-value. These procedures are explained in detail in an Ecotope report to the Bonneville Power Administration.[2]

In effect, the model examines a pie-slice of a typical basement with an area-to-perimeter ratio of 9 to 1. Three difference basement depths were evaluated: 2, 3.5, and 7 feet below-grade. The wall area includes a mudsill which extends 6" above-grade. Each case was evaluated with two different soil conductivites: 0.5 and 1.0 Btu/lb· °F. The final reported U and F-values include an interpolation to a soil conductivity of 0.75 Btu/lb· °F, customary for regional earth contact heat loss calculations.

The variation in QUAD-LOCK wall concrete thickness has a very small effect on above-grade thermal performance. Therefore, the U-value for the 6" QUAD-LOCK wall is used in all below-grade simulations. The wall is modeled with ½" GWB on the inside surface. The panel is assumed to step on a footing, with the floor slab floating inside of the concrete wall. This effectively gives the floor slab a thermal break at the edge.

The below-grade performance of the 6" QUAD-LOCK wall is considerably better than a standard 8" concrete wall with either R-10 exterior insulation or R-19 interior insulation. (Slab-edge thermal breaks are not required by the code so the values reported below for the comparison walls do not include a thermal break.)

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[1] Larry Palmiter and Terry Wheeling. SUNCODE-PC™. 1985. Ecotope, Inc., Seattle, Washington.

[2] Mike Kennedy. *Super Good Cents Heat Loss Reference*. Earth Contact: Assumptions, Calculations, and Coefficient Tables. 1992. Prepared for Bonneville Power Administration by Ecotope, Inc., Seattle, Washington.

Summary of Below-Grade Performance of Basement Walls

Wall Type	Depth of Basement (ft.)	U-Value (Btu/hr °F ft^2)	F-Value (Btu/hr °F ft)	Heat Loss Rate per ft. (Btu/hr °F)
6" QUAD-LOCK	2	0.038	0.582	0.677
	3.5	0.036	0.550	0.694
	7	0.032	0.502	0.742
8" concrete w/R-10 exterior insulation	2	0.089	0.562	0.785
	3.5	0.075	0.525	0.825
	7	0.058	0.474	0.909
8" concrete w/R-19*	2	0.042	0.678	0.783
	3.5	0.041	0.625	0.789
	7	0.036	0.554	0.824

*Furred with 2x4s and finished with ½" GWB

The final column, titled *Heat Loss Rate per ft.*, calculates the overall heat loss rate of the below-grade basement wall and floor per foot of basement perimeter. This is the most accurate way to compare basement insulation details, since wall heat loss rate influences heat loss through the slab edge (and vice versa). The heat loss rate per foot of basement perimeter assumes an overall wall height of the listed basement depth plus a 6-inch mudsill extending above-grade. Note the U-values and F-values improve with depth (because of the buffering effect of the ground) but the heat loss rate per foot increase because the area of wall considered increases with depth.

As an example, the heat loss rate per foot of a 3.5 ft basement would include the 3.5 feet of below-grade wall, the 0.5 foot mudsill, and the slab perimeter, and would be calculated to have a heat loss rate of:

4 ft^2 x (basement wall U-value (from table) + 1 ft x (listed slab F-value from table)

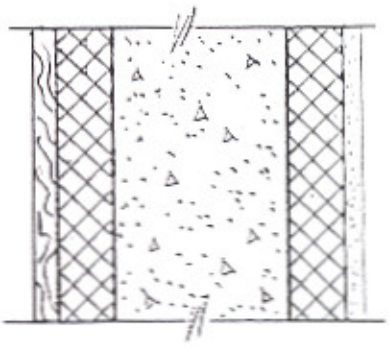
Conclusions and Summary

Ecotope's analysis shows that in typical construction, QUAD-LOCK above-grade walls perform much better than typical R-19 and R-21 frame walls; the QUAD-LOCK performance is equivalent to a 2x6 frame wall insulated with 5 ½" of Dow Blueboard (R-5 per inch). In below-grade applications, QUAD-LOCK significantly outperforms standard construction (8" concrete wall with R-10 exterior rigid insulation).

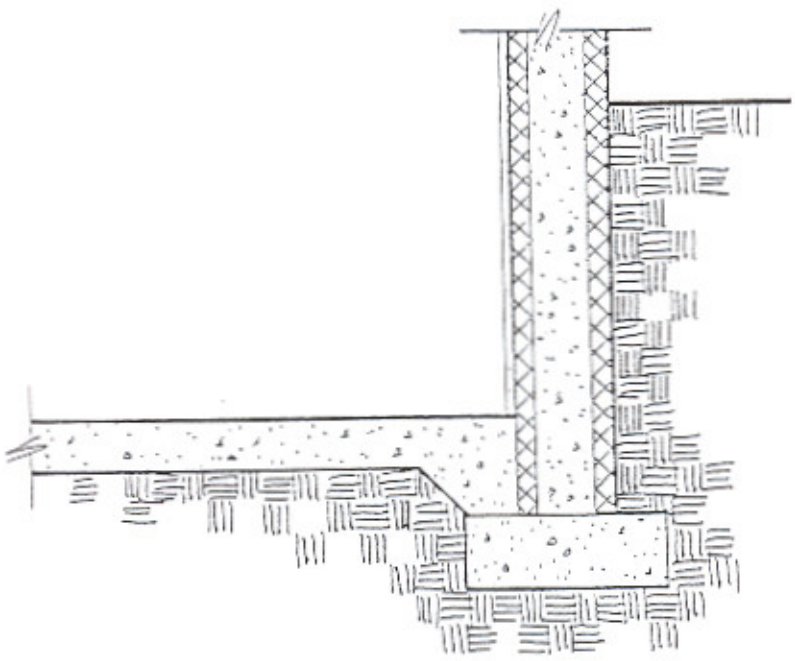
The QUAD-LOCK wall system should out-perform frame walls in ways that cannot be quantified by a steady-state heat loss analysis. Standard parallel heat flow calculations assume that the fiberglass insulation is uniformly installed with no voids or compressed batts. This is not what is usually found in the field. If installed correctly, concrete walls will not settle, bend, sag, and crack, as framed walls will do with time. The QUAD-LOCK system should also create a wall which is significantly more airtight than a standard framed wall.

SUMMARY SHEET

QUADLOCK Foam and Concrete Wall System (Typical Installations)

ABOVE GRADE	MATERIAL	R-VALUE
	1. Inside Air	0.68
	2. 0.5" G.W.B.	0.45
	3. 2.25" 2PCF EPS	9.79
	4. 6" Concrete	0.50
	5. 2.25" 2PCF EPS	9.79
	6. 5/8" T1-11 Finish	0.78
	7. Outside Air	0.25
	Overall R-Value	22.24

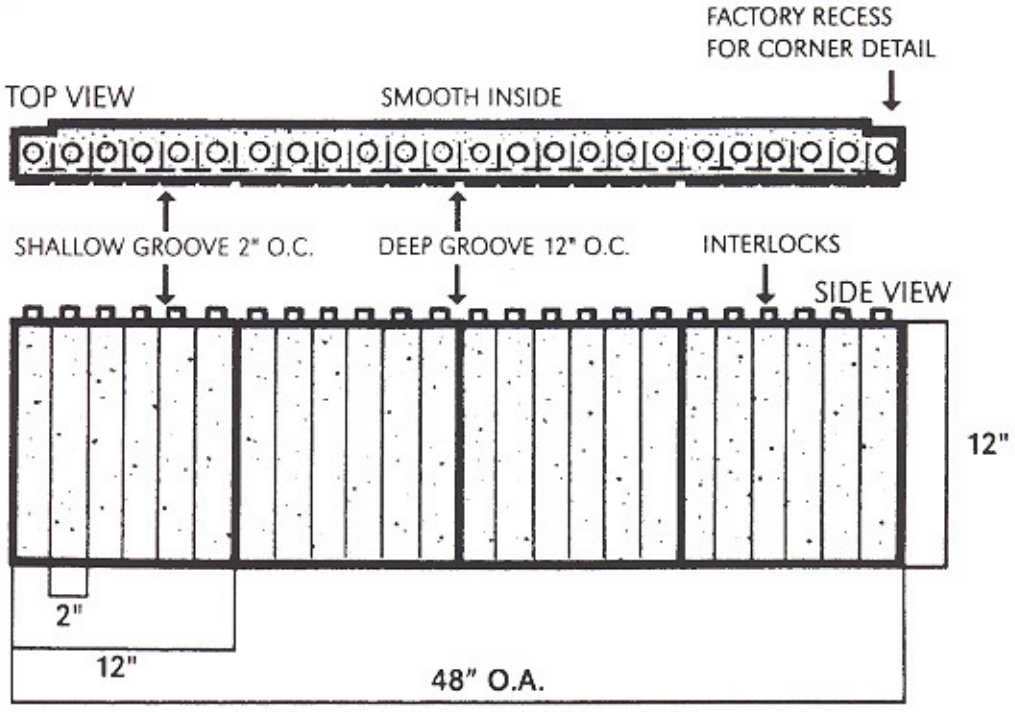
OVERALL U-VALUE OF ABOVE GRADE WALL SECTION: **0.045 Btu/Hr °F ft²**



BELOW GRADE WALL SECTION WITH INTERIOR SHEETROCK

Heat Loss Coefficients	Depth Below Grade (Feet)		
	2	3.5	7
U-VALUE (Btu/Hr °F ft²)	**0.038**	**0.036**	**0.032**
F-VALUE (Btu/Hr °F ft)	**0.582**	**0.550**	**0.502**

Figure 1


FACTORY RECESS
FOR CORNER DETAIL
TOP VIEW
SMOOTH INSIDE
SHALLOW GROOVE 2" O.C.
DEEP GROOVE 12" O.C.
INTERLOCKS
SIDE VIEW
12"
2"
12"
48" O.A.