Technical Report

Development of the CBIS -- Korfil HI-R Block R-value Table

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Introduction

Since the mid-1980's numerous concrete block systems (CBS) approaches have been used to boost the thermal performance of masonry walls -- improving their R-factors -- to meet the needs of architects and builders in providing energy efficient structures for consumers. CBS thermal values have been improved both by adding insulating materials to their cores and through redesigning their webs, but also through adding insulating materials or otherwise changing to concrete aggregates that lower the conductivity of the cross-webs and face-shells of the block. (Howard 1985a) Insulating basement walls in residential buildings and improving the insulating value of commercial building wall "back-up" systems have been major uses for insulating CBS. (Howard, 1993) In many mild climate areas of the US, where development is growing quickly, above grade CBS walls are growing in popularity due to their termite, moisture, and wind resistance when properly erected. Energy code requirements have been strengthened in these same areas to lower air-conditioning demands of new buildings. Hence the better insulating CBS approaches should meet with market acceptance in these areas.

Insulating materials such as expanded mineral materials, plastic pellets, foams, and cellulose have all been tried inside CBS walls at one time or another. The most successful have been the plastic foam inserts, due to their higher R-per-inch performance, and the value of protection they receive from being contained inside the masonry face shells and protected from elevated moisture, UV rays (sunlight), physical damage, and vermin. Of these foam-based systems, the best performing CBS walls result when the insulating materials are integrated across the webs of the block, which themselves are modified to reduce their "thermal bridging" effect. (ORNL 1989) Thermal bridges are pathways of heat flow that are elevated compared to surrounding structural or thermal materials. Thermal bridges have been shown to reduce overall thermal performance and in some cases, lead to moisture problems in complex building assemblies (ibid.).

Once a building is better protected thermally, and constructed using CBS walls, another useful energy advantage can become available called thermal mass. The property of CBS buildings to perform better than their steady-state "R-factors" (a measure of resistance to heat flow across a material) and "U-value" (the thermal transmittance of an assembly of materials; the inverse of the assembly's summed R-factors). Studies on thermal mass (also known as thermal heat capacity) have shown that insulating materials placed inside masonry walls are thermally superior to placing the same amount of insulating materials inside the structural wall (inside insulation position) (Howard 1985a). Building codes and energy standards -- such as the International Model Energy Code (formerly CABO) and ASHRAE Standard's 90.2-1993 and 90.1-1989R -- reflect this fact in their requirements and compliance approaches.

Purpose and Approach

A study by an independent consultant was undertaken to review the thermal performance tables concerning the CBIS Korfil HI-R concrete block system. The results requested in this study were to include:

- data tables for the Korfil HI-R concrete masonry system containing conservative calculated values: at 80, 100, and 120 pounds per cubic foot concrete densities for 8 inch, 10 inch and 12 inch thick concrete masonry units;
- descriptions of methods used to arrive at the results contained in the data tables;
- PC (personal computer) compatible worksheets and printouts of the results, with magnetic copies of the worksheets for use by the client to evaluate various product options; and
- a brief written report including discussion of the process used to create the deliverables.

Methods

Review -- The existing tables of data contained in such publications as Sweets Buyline ® and the Project Focus publications of the Northwest Concrete Masonry Association, as well as in NCMA "TEK" notes on CBS thermal performance (NCMA Manual of Facts on Concrete Masonry) were examined, along with past publications by the consultant on performance of insulated concrete masonry systems containing R-factor information. ASHRAE methods of calculation, and a manual of thermal performance test data for a variety of building systems, were also reviewed.

Test data -- CBIS staff provided test data for the purpose of comparison between the ASHRAE isothermal planes calculation method and what Korfil HI-R walls' R-values would be under full scale built-up conditions. ASHRAE committees on Insulation and Moisture Retarder's (TC-4.4) and Building Thermal Envelopes (TC-4.9) have indicated a preference for test data, and where possible calculations using the isothermal planes methods, or engineering analysis processes that are based on tested results. [Note: author has served as member of these committees for 12 years].

Analysis -- ASHRAE data contained in the Handbook: Fundamentals 1993, Chapter 22 was used as the source of basic physical properties, along with the ASHRAE "isothermal planes" method of calculating the thermal transmittance and hence R-factors of insulating assemblies also described in that chapter. The isothermal planes method results in very conservative calculated assembly R-factors and U-values, according to various ASHRAE studies, compared to measured results especially for more complex assemblies (Van Geem 1985). Further comparisons were made with tested data on various configurations of CBS walls reported in ASHRAE's "Heat Transmission Coefficients" manual (James and Goss 1993)

The isothermal planes method employs the concept that a complex assembly of materials with different conductance values (rates of heat transmission) can not be accurately characterized using the more traditional parallel path methods, commonly employed when framing materials have similar conductance to adjacent insulating materials. The problem is broken down into a network of series and parallel layers, and can be evolved to account for any number of layers, for two conductance values. If the assembly is more complicated -- such as one comprised of multiple parallel paths of dissimilar conductance, with several intervening layers -- a more robust 2- or 3-dimensional heat transfer model would be needed to solve for overall thermal transmittance, or severe errors could result. The HI-R block is not so complicated that a modified isothermal planes method could not be used. However, the isothermal planes method appeared to understate the actual R-factors of the HI-R block in the density range and for the three thickness' studied by between 4% and 34% (see results).

Modifications to ASHRAE isothermal planes method -- only two modifications were required to obtain reasonable results from calculating the HI-R block over a range of concrete densities, at three block thickness'.

Modification 1. The CMU thermal model was broken down into a series of four sectional layers (not including the indoor and outdoor air-films) including a.] outer face shell; b.] web-and-cores; c.] cut-down webs and polystyrene insert; and d.] inner face shell. Each layer was analyzed as a separate network of parallel heat flow paths.

Modification 2. Hot box test data from three accredited laboratory services was reviewed, analyzed and utilized to correct for an observed systematic understatement by the isothermal planes calculations, of the actual assembly thermal transmittance values (and hence R-factor) so that more representative calculated at the three block thickness' could be provided. This modification was done by fitting a curve to test data arrayed as R-factors versus block concrete density, in the range of 80 pcf to 140 pcf concrete's typical of the US concrete masonry industry. Curves tested included, linear, logarithmic and polynomial forms.

Mortar Joints -- Studies of block thermal calculations have indicated that not considering mortar joints can have an effect of permitting overstatement of thermal performance in CBS walls (Van Geem 1985) Analysis of the effect of mortar joints in HI-R walls was conducted, on the basis of physical inspection of a sample block and insulating insert provided to the consultant. This calculation was included since the insulating insert is specifically designed to overlap the mortar joint, to reduce the thermal loss through the wall. Due to the special characteristics of the block design we compared the actual mortar joint surface areas to the overall unit area (as would result in an actual running bond wall when erected) using a physical sample block supplied by the client.

Block Properties -- HI-R block is unlike a standard CBS unit in that it has two rather than three webs. These cross-webs have been designed to accommodate a 2.5 inch (6.35 cm) thick two-piece thermal insulating insert. The face shells are designed to permit overlapping of flanges on the sides of each successive block running in bond, and the bed joints (top and bottom) are also arranged so the insulating insert overlaps into the next successive unit.
The net result is a more complete thermal barrier, and ostensibly reduced air-infiltration across the wall (this was not tested however). Thus, one face shell inner surface of the block directly abuts plastic foam insulation, while the other face shell inner surface faces an air-cavity bounded on the opposite side by the insulating foam.

Of the face shell area, only 14% to 16% is attached to the cross-webs which has an effect upon overall heat transfer compared to typical block which may have 30% to 35% of the face shell area

attached to conductive cross webs. The webs are also reduced in height to accommodate the insulating insert, which placed on end looks like the letter "E" and is shouldered to fit snugly into the cut-down portions of the cross webs.

Results

HI-R block R-factors and U-values were calculated using the methods described in this report, and reasonable yet conservative thermal performance factors are provided. HI-R block (described in the previous section) provides good thermal performance compared to uninsulated typical CMU's now on the market. Table 1 provides a summary of the results of this study for three block thickness', at three representative densities. Additional data comparing expected HI-R block performance with block density is provided in Appendix A.

Table 1.

CBIS/Korfil HI-R Block			*Standard Insert (R 4.35/inch)*	
Summary -- Modified "Isothermal Planes" Calculated Thermal Values				
Concrete Density		**Thickness of Concrete Block (inches)**		
(Lb. / Cu. Ft)		**8**	**10**	**12**
80	**R-factor**	**12.21**	**13.92**	**14.56**
	U-value	0.082	0.072	0.069
100	**R-factor**	**10.27**	**11.87**	**12.48**
	U-value	0.097	0.084	0.080
120	**R-factor**	**8.50**	**9.95**	**10.50**
	U-value	0.118	0.100	0.095
Oct. 25, 1996		R-factors include inside and outdoor air-films		
Note: Corrected using hot-box test data ~ 10in CMU; R-11.18 overall @ 107 pcf (std. inserts)				

A separate worksheet was developed for each block thickness; 8 inch, 10 inch, and 12 inch, so that calculations could be performed using the exact block dimensions provided by the manufacturer of the CMU molding boxes, which are provided to block plants for the manufacture of concrete masonry units.

An example of this worksheet is shown in Figure 1 including all relevant information on the block dimensions, insulating insert, and the layers of the assembly which are used to calculate the R-factor and U-value in each case.

In addition, the worksheets each provide a dynamic graph of R-factor versus block density in pounds per square foot, for quickly checking the values.

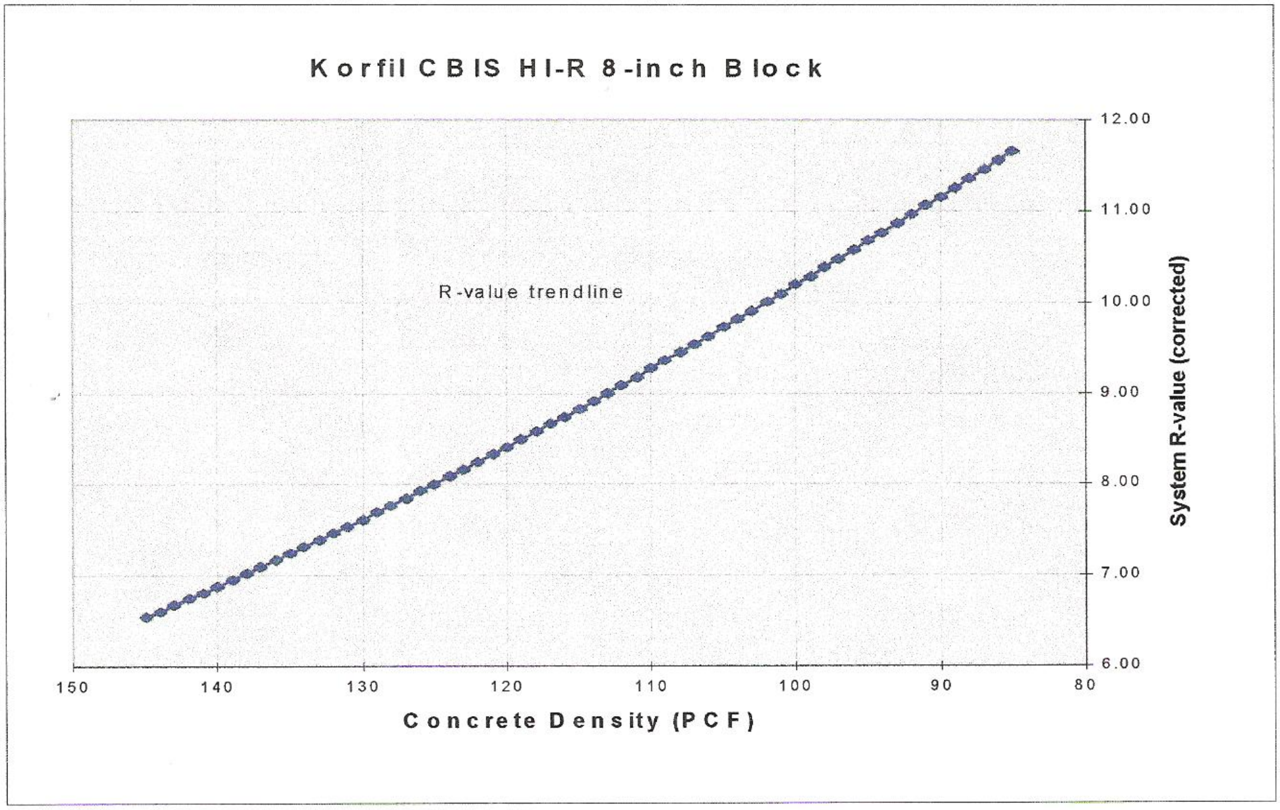
Figure 1. -- Example Worksheet Table

Korfil Insulated Block -- 8 inch thickness							
Properties Data Base		(dimensions in inches unless otherwise noted)					
Concrete Density:	85.000	**Input #/CF**		**Air-films**	R-value		
Calculated K-value	2.737			Outside	0.17	Winter	
Enter "hard" K-value	*	< enter " * " to calc. with value superseding)		Indoors	0.68		
				Total (R)	0.85	"raf"	
Face Shell thickness	1.401	"fs_thick"		Still air	0.97	"rair"	
Width (avg)	15.875	"fs_w"		R+ to cores	0.00	"xr_cor"	
Height (avg)	7.688	"fs_ht"		**Ins added(")**	0.00	"xr_thk"	
Area (avg)	122.039	"a_fs"		R-core (eff)	0.97	"rc_eff"	
Block Webs:	**Section 1 (cores)**		**Section 2 (inserts)**				
Height	6.975		5.128				
Thickness	1.281		1.281				
Length	2.250	"lw1"	2.625	"lw2"			
Web-area (sq. in.)	17.873	"aw_1"	13.141	"aw_2"			
fractional area (W)	0.146		0.108				
Non-web area (sq. in.)	104.166	"ac_1"	108.899	"ac_2"			
fractional area (nW)	0.854		0.892				
Polystyrene Insert Properties							
Gross Area (squ.-in.)	125.015	"ins_area"					
Insert Thickness	2.500	"tins"					
R-value / inch	4.350	**Input R / in**					
K =	0.230	"kins"					
R-value Calculations (isothermal planes method, ASHRAE HOF 1993; Ch. 22.5)							
General Equation:	Rt = Ri + Rf + (1 / (Aw / Rw + Ac / Rc)) + Ro						
where:	Rt: overall thermal resistance (R) based on "isothermal planes"						
	Ri: R value inside surface air-film						
	Rf: Sum of R-values for the block face shells						
	Rw: R-value of the webs between face shells						
	Rc: R-value of the cores between face shells						
Section 1 (cores & webs)			**Section 2 (insulating insert sec.)**				
Rs1 =	1.76	**Block (only)**	Rs2 =	6.97			
	R-Total =	11.66			**R-total =**	11.716	
	U-Value =	0.086			Includes mortar joint		

The worksheet shows the block internal and exterior dimensions, the insert properties and the other input data along with a general form of the isothermal planes equation used to calculate the baseline R-factors and U-values.

Output from the worksheet was plotted to aid in analysis and quality assurance that the results reflected the corrections to the test data, according to the modifications to the method described previously. Figure 2 -- on the next page -- illustrates such a plot for an 8 inch HI-R unit, and is replicated for 10 inch and 12 inch block thickness' in the PC worksheet.

Figure 2.
Example Plot of Corrected System R-values for HI-R Block



Discussion

Correcting for tested results -- The HI-R block was examined for physical properties, and then the ASHRAE isothermal planes equation was expanded to account for the additional layer comprised of two materials of dissimilar conductance. This equation took the form:

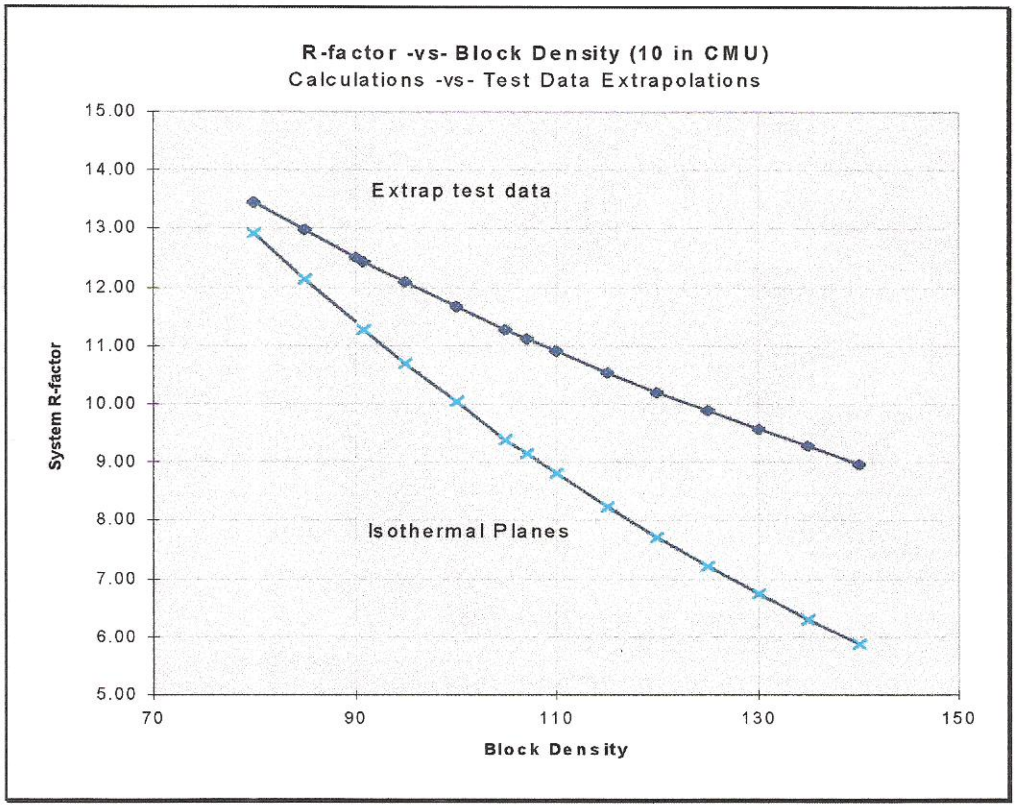
System Equation derived for bi-sectional article with two dissimilar conductance values:		
R-system-total=	(((lw1 / kc) * (lw1 / (1 / rc_eff))) / (((aw_1 / a_fs) * (lw1 / (1 / rc_eff))) + ((ac_1 / a_fs) * (lw1 / kc)))+ ((lw2 / kc) * (lw2 / (1 / (tins / kins))) / (((aw_2 / a_fs) * (lw2 / (1 / (tins / kins))))+ ((ac_2 / a_fs) * (lw2 / kc)))) + (2.0 * fs_thick * (1 / kc)) + raf)	
Where:	kc	concrete density in block
	lw1	web length through cores section
	lw2	web length through insert section
	rc_eff	effective R-factor of cores including still-air and any insulating materials
	aw_1	area of webs in cores section
	aw_2	area of webs in the insert section
	tins	thickness of the insert materials
	kins	conductance value of the insert materials
	a_fs	area of face shell(s) of block
	fs_thick	face shell thickness
	ac_1	non-web area in cores section
	ac_2	non-web area in insert section
	raf	thermal resistance; sum of indoor and outdoor air-films

Using this form of the equation permitted the two distinctly different sections of the block -- the section with the webs and cores (air-space) and the section containing cut-down webs and the 2.5

inch thick insulating insert -- to be calculated separately then added in parallel with the face shells and air films, both of which are homogeneous sections.

The results from the initial calculations were very conservative, as had been pointed out in the ASHRAE Handbook: Fundamentals Chapter 22. The "raw" calculated R-factors fell between 4% to 34% below tested values, provided by three accredited laboratories. Also, the comparison of calculated R-factors with the tested data appeared to indicate the value (ability to reduce the thermal transmittance of the CMU walls) of the insulating inserts increases as a function of concrete density. This observation is intuitive since the inserts should reduce the heat flows of the whole system proportionally more, when the structural components (the webs) are more conductive -- there is greater relative heat transfer to reduce. Figure 3 illustrates these findings, when we compared the calculated R-factors for 10 inch block, with a curve fitted to the available test data for similar HI-R block.

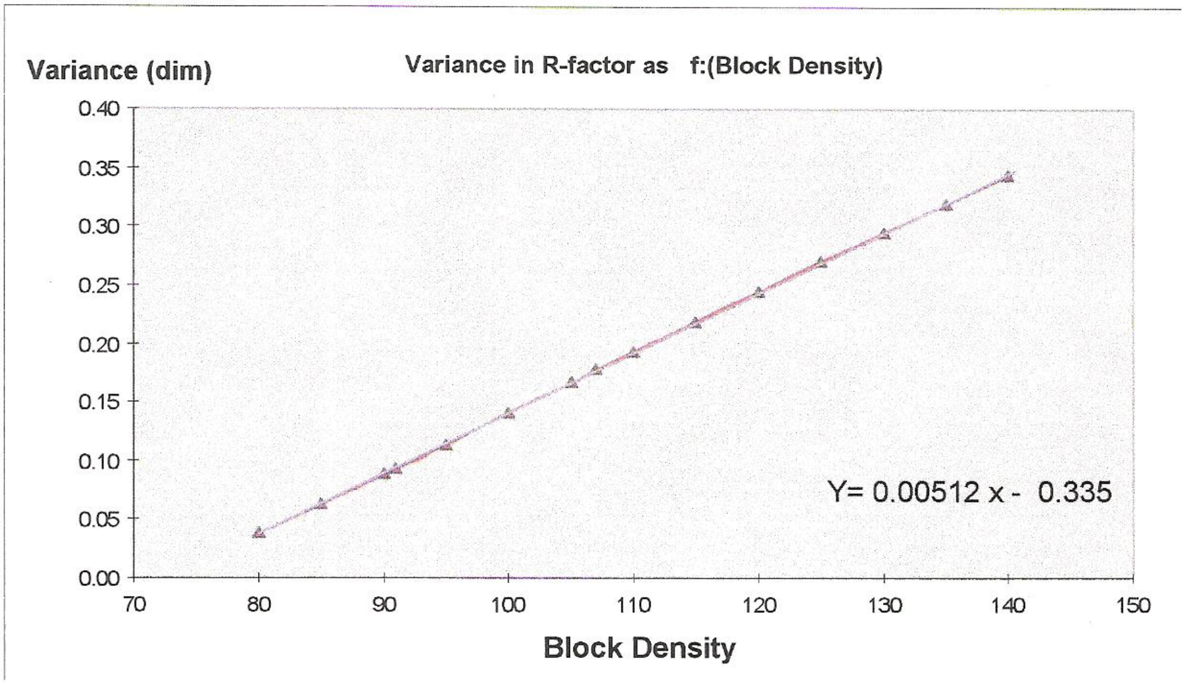
Figure 3.
Calculated isothermal planes R-factors versus Test data (extrapolated)



The calculated R-factors and the extrapolated test data have curves with similar logarithmic form, and when the difference in R-factor between the two curves was analyzed, it was found to be linear in the range of 80 to 145 pounds per cubic foot concrete density typical of CMU's that are produced in the US.

The differences across this range were calculated at five-pound per cubic foot intervals, and an equation fitted to the results. This fit had an R^2 of 0.99, for a nearly perfect correlation. This equation was then applied to the raw isothermal planes results to "calibrate" the R-factors to the test data; with the key point being the 10 inch thick CMU test result (system R-11.18). The graphic in Figure 4 illustrates the fit along the difference results comparing the calculated R-factors with the test results.

Figure 4.
Correction for the Isothermal Planes Calculated R-factors



Once the correction equation was produced, recalculating the R-factors and U-values for the HI-R walls so the results would agree more closely with the tested values was accomplished arithmetically using the PC worksheet.

Each R-factor calculation was also corrected for the influence of the mortar joint, which is insulated in the case of the HI-R block design. Since the plastic expanded foam insulation insert protrudes from one block course to the next, and at each head joint slightly protrudes with an interlocking arrangement with the adjacent unit, this area is well insulated. The mortar joints in HI-R block provide a net beneficial effect upon the overall system R-factor of between 0.1 % to 1.3 %. This is also reflected in the tested system R-factors which exceed the raw calculated values at every concrete density and every block thickness. A portion of this performance increase may be due to the insulation inserts overlapping the mortar joint section in the HI-R block, reducing thermal losses that in ordinary block are often responsible for considerable increases in heat flow (Van Geem 1985).

In summary, the final calculation results for HI-R block include:

- the raw ASHRAE isothermal planes calculated R-factor;
- a correction for the difference between tested and calculated values across an 80- to 145-pound concrete density range; and
- the compensation for the mortar joint on an area weighted basis;

to provide the results contained in the summary table, and data tables in Appendix A.

Observations

1. Test data indicates HI-R block performs generally better than predicted by ASHRAE isothermal planes R-factor calculations across a range of block densities; by a factor of 4% to 34% dependent upon block density. At higher densities, the ASHRAE method appeared to grossly under-predict the actual R-factor of the HI-R block system.

2. The insulating inserts were observed to augment the thermal performance of heavy weight block proportionally more than for lightweight block. This was very likely due to the higher conductance of the block webs at the higher block densities.

3. Additional full wall thermal testing in the higher block density ranges -- such as 120 to 130 pcf -- could confirm the observation made in item two, above, and give added validity to correction curves permitting calibration of conservative ASHRAE calculation procedures for the HI-R block's special shape and thermal characteristics.

Conclusions

CBIS/Korfil HI-R block performs significantly better than conventional uninsulated masonry, and other insulating masonry systems familiar to the consultant. An 8 inch HI-R block made with 100 pcf lightweight aggregate should produce a sound R-10 performance capable of meeting new more rigorous energy standards, both for foundation walls and above grade uses.

When these levels of steady-state thermal performance are combined with the now-permitted thermal mass corrections in the energy codes and standards -- including the Model Energy Code and ASHRAE 90.1 and 90.2 -- such a wall will perform as well or better than a 2x4 fibrous insulated wood frame wall, and up to 40% better than a 2x4 fibrous insulated steel framed wall (according to correction factors now in the standards) in most temperate areas of the US (with below 5000 heating degree days).

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Appendix A.

HI-R Thermal Performance Data Detail

Table of R-values by density (1# steps)

8 inch Block

K-conc	R-value	Density	Corr-Rv	U-value (Rc)	R-block w/ Mortar Joint	U-value w/ Mortar Jt	Effect of Mortar Joint
2.48	**11.32**	**80**	**12.16**	**0.082**	**12.213**	**0.082**	**-0.004**
2.53	11.17	81	12.06	0.083	12.113	0.083	-0.004
2.58	11.03	82	11.96	0.084	12.014	0.083	-0.004
2.63	10.88	83	11.86	0.084	11.914	0.084	-0.004
2.68	10.74	84	11.76	0.085	11.815	0.085	-0.005
2.74	10.60	85	11.66	0.086	11.716	0.085	-0.005
2.79	10.46	86	11.56	0.087	11.617	0.086	-0.005
2.85	10.32	87	11.46	0.087	11.519	0.087	-0.005
2.91	10.18	88	11.36	0.088	11.421	0.088	-0.005
2.96	10.05	89	11.26	0.089	11.323	0.088	-0.005
3.02	9.92	90	11.16	0.090	11.225	0.089	-0.006
3.09	9.78	91	11.06	0.090	11.128	0.090	-0.006
3.15	9.65	92	10.97	0.091	11.031	0.091	-0.006
3.21	9.52	93	10.87	0.092	10.934	0.091	-0.006
3.28	9.40	94	10.77	0.093	10.838	0.092	-0.006
3.34	9.27	95	10.67	0.094	10.742	0.093	-0.006
3.41	9.15	96	10.58	0.095	10.646	0.094	-0.007
3.48	9.02	97	10.48	0.095	10.551	0.095	-0.007
3.55	8.90	98	10.39	0.096	10.457	0.096	-0.007
3.62	8.78	99	10.29	0.097	10.362	0.097	-0.007
3.69	**8.66**	**100**	**10.20**	**0.098**	**10.269**	**0.097**	**-0.007**
3.77	8.55	101	10.10	0.099	10.175	0.098	-0.007
3.85	8.43	102	10.01	0.100	10.082	0.099	-0.007
3.92	8.31	103	9.91	0.101	9.990	0.100	-0.008
4.00	8.20	104	9.82	0.102	9.898	0.101	-0.008
4.08	8.09	105	9.73	0.103	9.807	0.102	-0.008
4.17	7.98	106	9.64	0.104	9.716	0.103	-0.008
4.25	7.87	107	9.55	0.105	9.625	0.104	-0.008
4.34	7.76	108	9.46	0.106	9.535	0.105	-0.008
4.42	7.66	109	9.37	0.107	9.446	0.106	-0.009
4.51	7.55	110	9.28	0.108	9.357	0.107	-0.009
4.60	7.45	111	9.19	0.109	9.269	0.108	-0.009
4.70	7.35	112	9.10	0.110	9.181	0.109	-0.009
4.79	7.25	113	9.01	0.111	9.094	0.110	-0.009
4.89	7.15	114	8.93	0.112	9.008	0.111	-0.009
4.99	7.05	115	8.84	0.113	8.922	0.112	-0.009
5.09	6.95	116	8.75	0.114	8.836	0.113	-0.009
5.19	6.86	117	8.67	0.115	8.751	0.114	-0.010
5.30	6.76	118	8.58	0.117	8.667	0.115	-0.010
5.40	6.67	119	8.50	0.118	8.583	0.117	-0.010
5.51	**6.58**	**120**	**8.42**	**0.119**	**8.500**	**0.118**	**-0.010**
5.62	6.49	121	8.33	0.120	8.418	0.119	-0.010
5.74	6.40	122	8.25	0.121	8.336	0.120	-0.010
5.85	6.31	123	8.17	0.122	8.255	0.121	-0.010
5.97	6.22	124	8.09	0.124	8.175	0.122	-0.011
6.09	6.14	125	8.01	0.125	8.095	0.124	-0.011

Table of R-values by density (1# steps) (Continued)

8 inch Block

K-conc	**R-value**	**Density**	**Corr-Rv**	**U-value (Rc)**	**R-block w/ Mortar Joint**	**U-value w/ Mortar Jt**	**Effect of Mortar Joint**
6.21	6.05	126	7.93	0.126	8.015	0.125	-0.011
6.34	5.97	127	7.85	0.127	7.937	0.126	-0.011
6.47	5.89	128	7.77	0.129	7.859	0.127	-0.011
6.60	5.81	129	7.69	0.130	7.781	0.129	-0.011
6.73	5.73	130	7.62	0.131	7.705	0.130	-0.011
6.87	5.65	131	7.54	0.133	7.628	0.131	-0.011
7.01	5.57	132	7.47	0.134	7.553	0.132	-0.012
7.15	5.49	133	7.39	0.135	7.478	0.134	-0.012
7.29	5.42	134	7.32	0.137	7.404	0.135	-0.012
7.44	5.34	135	7.24	0.138	7.331	0.136	-0.012
7.59	5.27	136	7.17	0.139	7.258	0.138	-0.012
7.74	5.20	137	7.10	0.141	7.186	0.139	-0.012
7.90	5.12	138	7.03	0.142	7.114	0.141	-0.012
8.06	5.05	139	6.96	0.144	7.043	0.142	-0.012
8.22	4.98	140	6.89	0.145	6.973	0.143	-0.013
8.39	4.92	141	6.82	0.147	6.904	0.145	-0.013
8.56	4.85	142	6.75	0.148	6.835	0.146	-0.013
8.73	4.78	143	6.68	0.150	6.766	0.148	-0.013
8.91	4.72	144	6.61	0.151	6.699	0.149	-0.013
9.09	4.65	145	6.55	0.153	6.632	0.151	-0.013

Table of R-values by density (1# steps)

10 inch block

K-conc	R-value	Density	Rcorr	U- Corr	R-block w/ Mortar Joint	U-value w/ Mortar Jt	Effect of Mortar Joint
2.48	**12.94**	**80**	**13.91**	**0.072**	**13.924**	**0.072**	**-0.001**
2.53	12.78	81	13.80	0.072	13.820	0.072	-0.001
2.58	12.62	82	13.69	0.073	13.716	0.073	-0.002
2.63	12.47	83	13.59	0.074	13.612	0.073	-0.002
2.68	12.31	84	13.48	0.074	13.509	0.074	-0.002
2.74	12.16	85	13.38	0.075	13.405	0.075	-0.002
2.79	12.01	86	13.27	0.075	13.301	0.075	-0.002
2.85	11.86	87	13.17	0.076	13.198	0.076	-0.002
2.91	11.71	88	13.06	0.077	13.095	0.076	-0.003
2.96	11.56	89	12.96	0.077	12.992	0.077	-0.003
3.02	11.42	90	12.85	0.078	12.889	0.078	-0.003
3.09	11.27	91	12.75	0.078	12.786	0.078	-0.003
3.15	11.13	92	12.64	0.079	12.684	0.079	-0.003
3.21	10.99	93	12.54	0.080	12.582	0.079	-0.003
3.28	10.85	94	12.44	0.080	12.480	0.080	-0.004
3.34	10.71	95	12.33	0.081	12.378	0.081	-0.004
3.41	10.57	96	12.23	0.082	12.276	0.081	-0.004
3.48	10.44	97	12.13	0.082	12.175	0.082	-0.004
3.55	10.31	98	12.02	0.083	12.074	0.083	-0.004
3.62	10.17	99	11.92	0.084	11.974	0.084	-0.004
3.69	**10.04**	**100**	**11.82**	**0.085**	**11.874**	**0.084**	**-0.005**
3.77	9.91	101	11.72	0.085	11.774	0.085	-0.005
3.85	9.79	102	11.62	0.086	11.674	0.086	-0.005
3.92	9.66	103	11.52	0.087	11.575	0.086	-0.005
4.00	9.53	104	11.42	0.088	11.476	0.087	-0.005
4.08	9.41	105	11.32	0.088	11.378	0.088	-0.005
4.17	9.29	106	11.22	0.089	11.280	0.089	-0.006
4.25	9.17	107	11.12	0.090	11.182	0.089	-0.006
4.34	9.05	108	11.02	0.091	11.085	0.090	-0.006
4.42	8.93	109	10.92	0.092	10.988	0.091	-0.006
4.51	8.81	110	10.83	0.092	10.892	0.092	-0.006
4.60	8.70	111	10.73	0.093	10.796	0.093	-0.006
4.70	8.58	112	10.63	0.094	10.700	0.093	-0.006
4.79	8.47	113	10.54	0.095	10.605	0.094	-0.007
4.89	8.36	114	10.44	0.096	10.511	0.095	-0.007
4.99	8.25	115	10.34	0.097	10.417	0.096	-0.007
5.09	8.14	116	10.25	0.098	10.323	0.097	-0.007
5.19	8.03	117	10.16	0.098	10.230	0.098	-0.007
5.30	7.93	118	10.06	0.099	10.137	0.099	-0.007
5.40	7.82	119	9.97	0.100	10.045	0.100	-0.008
5.51	**7.72**	**120**	**9.88**	**0.101**	**9.953**	**0.100**	**-0.008**
5.62	7.62	121	9.79	0.102	9.862	0.101	-0.008
5.74	7.52	122	9.69	0.103	9.772	0.102	-0.008
5.85	7.42	123	9.60	0.104	9.682	0.103	-0.008
5.97	7.32	124	9.51	0.105	9.592	0.104	-0.008
6.09	7.22	125	9.42	0.106	9.503	0.105	-0.008
6.21	7.13	126	9.33	0.107	9.415	0.106	-0.009
6.34	7.03	127	9.25	0.108	9.327	0.107	-0.009
6.47	6.94	128	9.16	0.109	9.239	0.108	-0.009
6.60	6.84	129	9.07	0.110	9.153	0.109	-0.009
6.73	6.75	130	8.98	0.111	9.066	0.110	-0.009

Table of R-values by density (1# steps) **(continued)**

10 inch block

K-conc	R-value	Density	Rcorr	U- Corr	R-block w/ Mortar Joint	U-value w/ Mortar Jt	Effect of Mortar Joint
6.87	6.66	131	8.90	0.112	8.981	0.111	-0.009
7.01	6.57	132	8.81	0.113	8.896	0.112	-0.009
7.15	6.48	133	8.73	0.115	8.811	0.113	-0.010
7.29	6.40	134	8.64	0.116	8.727	0.115	-0.010
7.44	6.31	135	8.56	0.117	8.644	0.116	-0.010
7.59	6.23	136	8.48	0.118	8.561	0.117	-0.010
7.74	6.14	137	8.39	0.119	8.479	0.118	-0.010
7.90	6.06	138	8.31	0.120	8.398	0.119	-0.010
8.06	5.98	139	8.23	0.121	8.317	0.120	-0.010
8.22	5.90	140	8.15	0.123	8.236	0.121	-0.010
8.39	5.82	141	8.07	0.124	8.157	0.123	-0.011
8.56	5.74	142	7.99	0.125	8.078	0.124	-0.011
8.73	5.66	143	7.91	0.126	7.999	0.125	-0.011
8.91	5.59	144	7.84	0.128	7.921	0.126	-0.011
9.09	5.51	145	7.76	0.129	7.844	0.127	-0.011

Table of R-values by density (1# steps)

12 Inch Block

K-conc	R-value	Density	R-corr	U-corr	R-block w/ Mortar Joint	U-value w/ Mortar Jt	Effect of Mortar Joint
2.48	**13.55**	**80**	**14.56**	**0.069**	**14.563**	**0.069**	**0.000**
2.53	13.39	81	14.45	0.069	14.457	0.069	0.000
2.58	13.22	82	14.34	0.070	14.352	0.070	-0.001
2.63	13.06	83	14.24	0.070	14.247	0.070	-0.001
2.68	12.90	84	14.13	0.071	14.141	0.071	-0.001
2.74	12.74	85	14.02	0.071	14.036	0.071	-0.001
2.79	12.59	86	13.91	0.072	13.931	0.072	-0.001
2.85	12.43	87	13.81	0.072	13.826	0.072	-0.001
2.91	12.28	88	13.70	0.073	13.721	0.073	-0.002
2.96	12.13	89	13.59	0.074	13.617	0.073	-0.002
3.02	11.98	90	13.49	0.074	13.512	0.074	-0.002
3.09	11.83	91	13.38	0.075	13.408	0.075	-0.002
3.15	11.68	92	13.27	0.075	13.303	0.075	-0.002
3.21	11.54	93	13.17	0.076	13.199	0.076	-0.002
3.28	11.39	94	13.06	0.077	13.095	0.076	-0.003
3.34	11.25	95	12.96	0.077	12.992	0.077	-0.003
3.41	11.11	96	12.85	0.078	12.888	0.078	-0.003
3.48	10.97	97	12.75	0.078	12.785	0.078	-0.003
3.55	10.83	98	12.64	0.079	12.682	0.079	-0.003
3.62	10.70	99	12.54	0.080	12.579	0.079	-0.003
3.69	**10.56**	**100**	**12.43**	**0.080**	**12.477**	**0.080**	**-0.004**
3.77	10.43	101	12.33	0.081	12.375	0.081	-0.004
3.85	10.30	102	12.23	0.082	12.273	0.081	-0.004
3.92	10.17	103	12.12	0.082	12.172	0.082	-0.004
4.00	10.04	104	12.02	0.083	12.070	0.083	-0.004
4.08	9.91	105	11.92	0.084	11.969	0.084	-0.004
4.17	9.78	106	11.81	0.085	11.869	0.084	-0.005
4.25	9.66	107	11.71	0.085	11.769	0.085	-0.005
4.34	9.53	108	11.61	0.086	11.669	0.086	-0.005
4.42	9.41	109	11.51	0.087	11.569	0.086	-0.005
4.51	9.29	110	11.41	0.088	11.470	0.087	-0.005
4.60	9.17	111	11.31	0.088	11.371	0.088	-0.005
4.70	9.05	112	11.21	0.089	11.273	0.089	-0.006
4.79	8.94	113	11.11	0.090	11.175	0.089	-0.006
4.89	8.82	114	11.01	0.091	11.077	0.090	-0.006
4.99	8.71	115	10.91	0.092	10.980	0.091	-0.006
5.09	8.59	116	10.82	0.092	10.883	0.092	-0.006
5.19	8.48	117	10.72	0.093	10.787	0.093	-0.006
5.30	8.37	118	10.62	0.094	10.691	0.094	-0.006
5.40	8.26	119	10.53	0.095	10.596	0.094	-0.007
5.51	**8.15**	**120**	**10.43**	**0.096**	**10.501**	**0.095**	**-0.007**
5.62	8.05	121	10.33	0.097	10.407	0.096	-0.007
5.74	7.94	122	10.24	0.098	10.312	0.097	-0.007
5.85	7.84	123	10.15	0.099	10.219	0.098	-0.007
5.97	7.73	124	10.05	0.099	10.126	0.099	-0.007
6.09	7.63	125	9.96	0.100	10.033	0.100	-0.008
6.21	7.53	126	9.87	0.101	9.941	0.101	-0.008
6.34	7.43	127	9.77	0.102	9.850	0.102	-0.008
6.47	7.33	128	9.68	0.103	9.759	0.102	-0.008
6.60	7.24	129	9.59	0.104	9.668	0.103	-0.008
6.73	7.14	130	9.50	0.105	9.578	0.104	-0.008

Table of R-values by density (1# steps) (continued)

12 Inch Block

K-conc	R-value	Density	R-corr	U-corr	R-block w/ Mortar Joint	U-value w/ Mortar Jt	Effect of Mortar Joint
6.87	7.04	131	9.41	0.106	9.489	0.105	-0.008
7.01	6.95	132	9.32	0.107	9.400	0.106	-0.009
7.15	6.86	133	9.23	0.108	9.311	0.107	-0.009
7.29	6.77	134	9.14	0.109	9.224	0.108	-0.009
7.44	6.68	135	9.05	0.110	9.136	0.109	-0.009
7.59	6.59	136	8.97	0.112	9.050	0.111	-0.009
7.74	6.50	137	8.88	0.113	8.963	0.112	-0.009
7.90	6.41	138	8.79	0.114	8.878	0.113	-0.009
8.06	6.33	139	8.71	0.115	8.793	0.114	-0.010
8.22	6.24	140	8.62	0.116	8.709	0.115	-0.010
8.39	6.16	141	8.54	0.117	8.625	0.116	-0.010
8.56	6.08	142	8.46	0.118	8.541	0.117	-0.010
8.73	5.99	143	8.37	0.119	8.459	0.118	-0.010
8.91	5.91	144	8.29	0.121	8.377	0.119	-0.010
9.09	5.83	145	8.21	0.122	8.295	0.121	-0.010

ADDENDUM - 1 NOVEMBER 2002

By D.L. Nickerson, P.E.

The original design of the Hi-R Masonry Wall System did not consider the use of a reflective foil material placed on the surface of the Hi-R insert facing the inside cavity of the Hi-R block.

Mr. Bion Howard of Howard Associates/Building Environmental Science and Technology, has performed an analysis using a reflective foil surface of the insert facing outward to the cores and Pages 2 through 5 of this Addendum detail the thermal advantages attained with the foil addition.

HI-R Block: Summary of R-factor and U-values

CBIS/Korfil HI-R Block		**HI-R Insert (R 4.35/inch) with reflective liner**		
Summary -- Modified "Isothermal Planes" Calculated Thermal Values				
Concrete Density		**Thickness of Concrete Block (inches)**		
(Lb. / Cu. Ft)		**8**	**10**	**12**
80	**R-factor**	**13.31**	**16.54**	**17.99**
	U-value	0.075	0.060	0.056
100	**R-factor**	**11.56**	**14.40**	**15.59**
	U-value	0.086	0.069	0.064
120	**R-factor**	**9.08**	**11.30**	**12.16**
	U-value	0.110	0.088	0.082
Aug. 2002 (update)		R-factors include inside and outdoor air-films		
Note: NCMA K-values, using hot-box test data for 10in CMU; R-11.2 overall @107 pcf (std. inserts)				

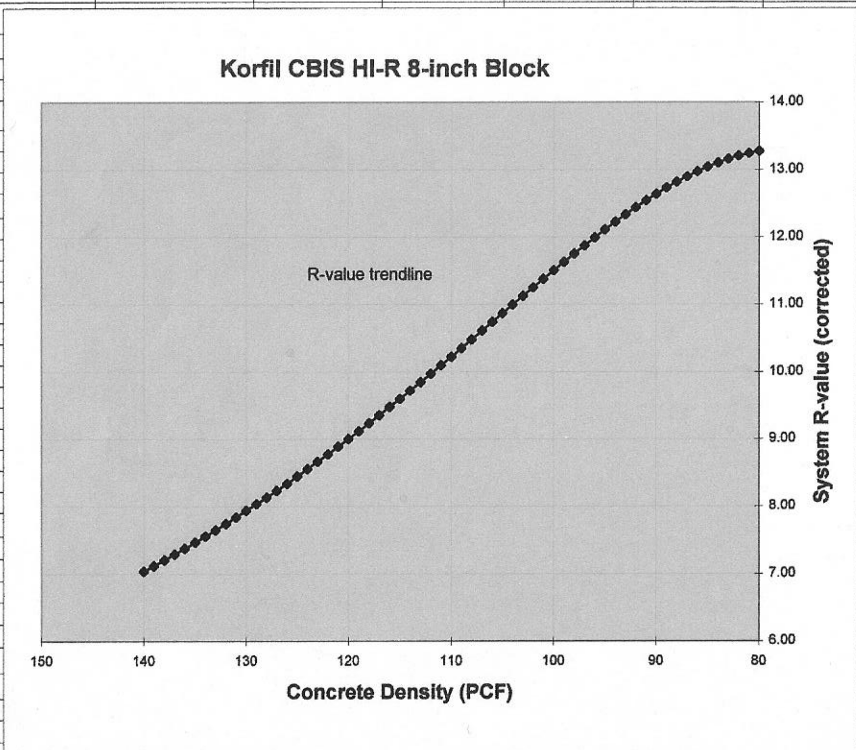
Assumptions / changes

* **Apply Low-emittance/high reflectance foil to surface of insert facing outward to cores**
* **using NCMA K-values in the high resistivty end of range (low moisture content concrete)**

CBIS R-value Worksheet Series:

This sheet = 8 inch block; Sheet 3 = 10 inch block; Sheet 4 + 12 inch block

((0.0013*D^2) - (0.181*D) + 8.9566)



Korfil Insulated Block -- 8 inch thickness

Properties Data Base		(dimensions in inches unless otherwise noted)					
Concrete Density:		120.000	**Input #/CF**		**Air-films**	R-value	
Calculated K-value		5.957			Outside	0.17	Winter
Enter "hard" K-value		*	< enter " * " to calc. with value superseding)		Indoors	0.68	
					Total (R)	0.85	"raf"
Face Shell	thickness	1.401	"fs_thick"		Still air	0.97	"rair"
	Width (avg)	15.875	"fs_w"		R+ to cores	3.18	"xr_cor"
	Height (avg)	7.688	"fs_ht"		**Ins added(")**	0.73	"xr_thk"
	Area (avg)	122.039	"a_fs"		R-core (eff)	4.1455	"rc_eff"
Block Webs:		**Section 1 (cores)**		**Section 2 (inserts)**			
Height		6.975	6.975	5.128	5.128		
Thickness		1.281		1.281			
Length		2.250	"lw1"	2.625	"lw2"		
Web-area (sq. in.)		17.873	"aw_1"	13.141	"aw_2"		
fractional area (W)		0.146		0.108			
Non-web area (sq. in.)		104.166	"ac_1"	108.899	"ac_2"		
fractional area (nW)		0.854		0.892			
Polystyrene Insert Properties							
Gross Area (squ.-in.)		125.015	"ins_area"				
Insert Thickness		2.500	"tins"				
R-value / inch		4.350	**Input R / in**				
K =		0.230	"kins"				

R-value Calculations (isothermal planes method, ASHRAE HOF 1993; Ch. 22.5)

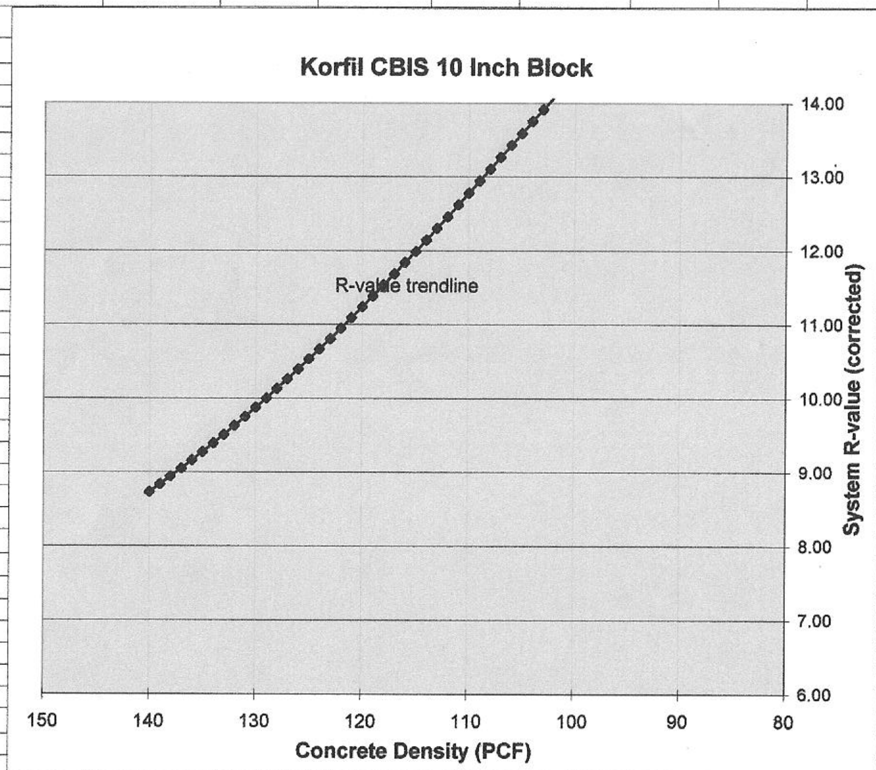
General Equation: Rt = Ri + Rf + (1 / (Aw / Rw + Ac / Rc)) + Ro

where:

- Rt: overall thermal resistance (R) based on "isothermal planes"
- Ri: R value inside surface air-film
- Rf: Sum of R-values for the block face shells
- Rw: R-value of the webs between face shells
- Rc: R-value of the cores between face shells

Section 1 (cores & webs)			**Section 2 (insulating insert sec.)**		
Rs1 =	2.09	**Block (only)**	Rs2 =	3.63	
	R-Total =	9.00		R-total =	9.083
	U-Value =	0.111		Includes mortar joint	

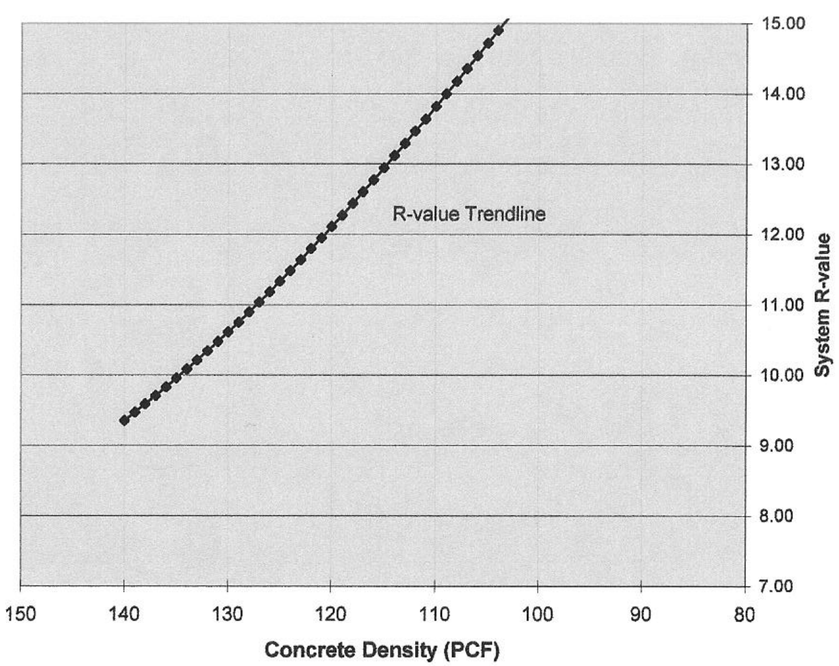
Note: cell in pink denotes where data may be entered



Korfil Insulated Block -- 10 inch thickness

Properties Data Base			(dimensions in inches unless otherwise noted)				
Concrete Density:		120.000	**Input #/CF**		**Air-films**	R-value	
Calculated K-value		5.957			Outside	0.17	(Winter)
Enter "hard" K-value		*	< enter " * " to calc. with		Indoors	0.68	
			value superseding)		Total (R)	0.85	"raf3"
Face Shell	thickness	1.656	"fs_thick3"		Still air	0.97	"rair3"
	Width (avg)	15.875	"fs_w3"		R+ to cores	3.18	"xr_cor3"
	Height (avg)	7.688	"fs_ht3"		**Ins added(*)**	0.73	"xr_thk3"
	Area (avg)	122.039	"a_fs3"		R-core (eff)	4.1455	"rc_eff3"
Block Webs:		**Section 1 (cores)**		**Section 2 (inserts)**			
Height		6.880	*6.88*	5.128	*5.128*		
Thickness		1.281		1.281			
Length		4.000	"lw3"	2.625	"lw4"		
Web-area (sq. in.)		17.630	"aw_3"	13.141	"aw_4"		
fractional area (W)		0.144		0.108			
Non-web area (sq. in.)		104.409	"ac_3"	108.899	"ac_4"		
fractional area (nW)		0.856		0.892			
Polystyrene Insert Properties							
Gross Area (squ.-in.)		125.015	"ins_area3"				
Insert Thickness		2.500	"tins3"	*was 2.5"*			
R-value / inch		4.350	**Input R / in**				
K =		0.230	"kins3"				
R-value Calculations (isothermal planes method, ASHRAE HOF 1993; Ch. 22.5)							
General Equation:		Rt = Ri + Rf + (1 / (Aw / Rw + Ac / Rc)) + Ro					
	where:	Rt: overall thermal resistance (R) based on "isothermal planes"					
		Ri: R value inside surface air-film					
		Rf: Sum of R-values for the block face shells					
		Rw: R-value of the webs between face shells					
		Rc: R-value of the cores between face shells					
Section 1 (cores & webs)				**Section 2 (insulating insert sec.)**			
Rs3 =	3.75		**Block (only)**	Rs4 =	3.63		
		R-Total =	11.24			**R-total =**	**11.300**
		U-Value =	0.089			Includes mortar joint	
	Note: cell in	**pink**	**denotes where data may be entered**				

Korfil CBIS HI-R 12 Inch Block



Korfil Insulated Block -- 12 inch thickness

Properties Data Base			(dimensions in inches unless otherwise noted)				
Concrete Density:		120.000	**Input #/CF**		**Air-films**	R-value	
Calculated K-value		5.957			Outside	0.17	(Winter)
Enter "hard" K-value		*	< enter " * " to calc. with		Indoors	0.68	
			value superseding)		Total (R)	0.85	"raf4"
Face Shell	thickness	1.781	"fs_thick4"		Still air	0.97	"rair4"
	Width (avg)	15.875	"fs_w4"		R+ to cores	3.18	"xr_cor4"
	Height (avg)	7.688	"fs_ht4"		**Ins added(")**	0.73	"xr_thk4"
	Area (avg)	122.039	"a_fs4"		R-core (eff)	4.1455	"rc_eff4"
Block Webs:		**Section 1 (cores)**		**Section 2 (inserts)**			
Height		6.825	6.825	5.128	5.128		
Thickness		1.438		1.438			
Length		5.500	"lw5"	2.625	"lw6"		
Web-area (sq. in.)		19.622	"aw_5"	14.743	"aw_6"		
fractional area (W)		0.161		0.121			
Non-web area (sq. in.)		102.417	"ac_5"	107.296	"ac_6"		
fractional area (nW)		0.839		0.879			
Polystyrene Insert Properties							
Gross Area (squ.-in.)		125.015	"ins_area4"				
Insert Thickness		2.500	"tins4"				
R-value/inch		4.350	**Input R / in**				
K =		0.230	"kins4"				
R-value Calculations (isothermal planes method, ASHRAE HOF 1993; Ch. 22.5)							
General Equation:		Rt = Ri + Rf + (1 / (Aw / Rw + Ac / Rc)) + Ro					
	where:	Rt: overall thermal resistance (R) based on "isothermal planes"					
		Ri: R value inside surface air-film					
		Rf: Sum of R-values for the block face shells					
		Rw: R-value of the webs between face shells					
		Rc: R-value of the cores between face shells					
Section 1 (cores & webs)				**Section 2 (insulating insert sec.)**			
Rs5 =	4.74		**Block (only)**	Rs6 =	3.28		
		R-Block=	12.11			**R-total =**	12.163
		U-Value =	0.083			Includes mortar joint	
	Note:cell in	pink	**denotes where data may be entered**				