

THERMAL

performance
autoclaved aerated concrete

technical document

Contents

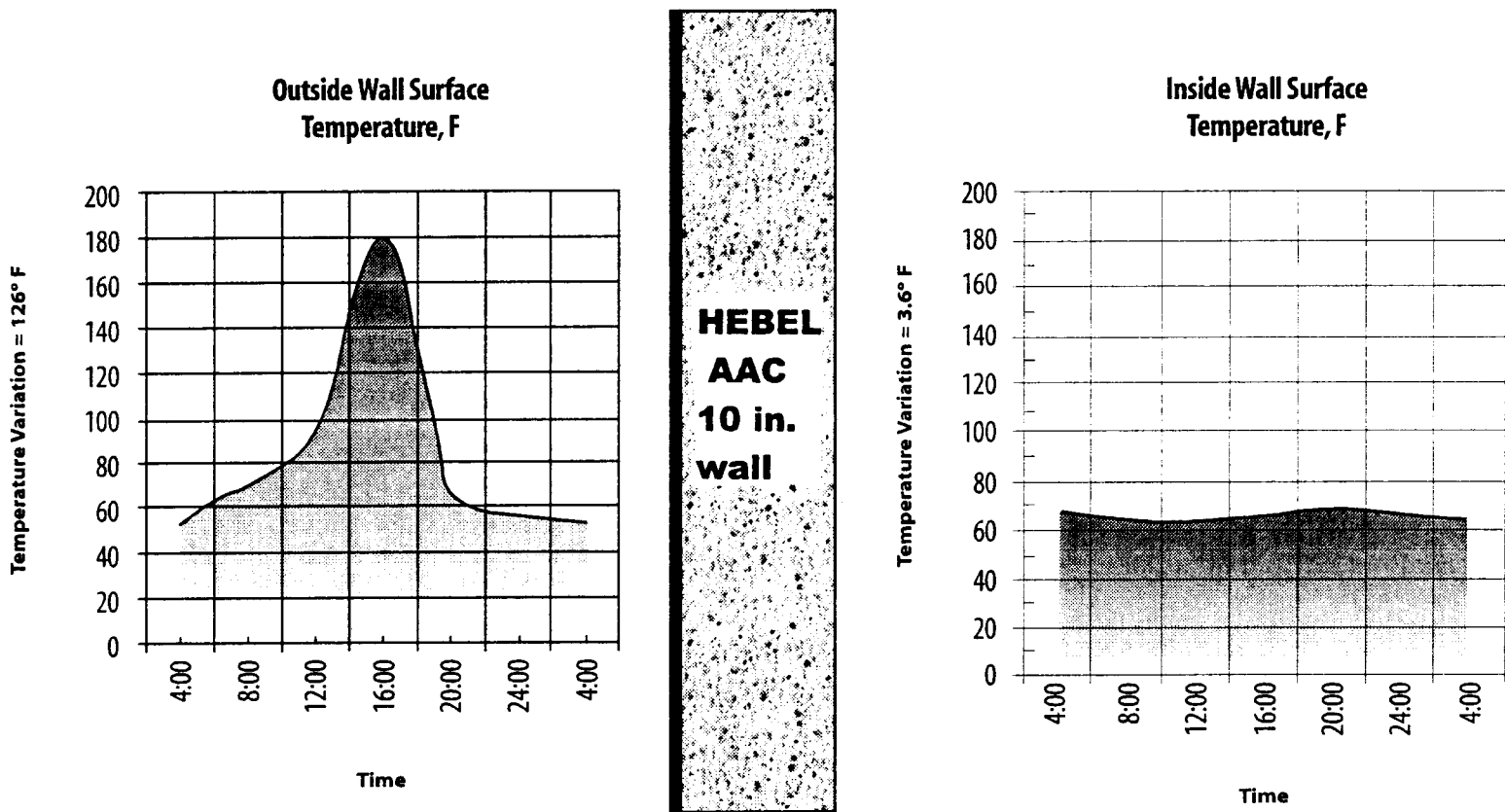
INTRODUCTION TO HEBEL AAC THERMAL PERFORMANCE

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Introduction

Building design and material properties influence thermal performance and energy consumption for residential and commercial buildings. HEBEL AAC wall, floor and roof systems provide an innovative combination of excellent thermal conductivity, thermal mass and low air-infiltration. This practical combination of properties in one system provides an excellent thermal insulation material and permits peak energy usage in the building to be shifted to off-peak hours, thus reducing operation costs for building users and owners, improving comfort of living and reducing the demand on power generation facilities.

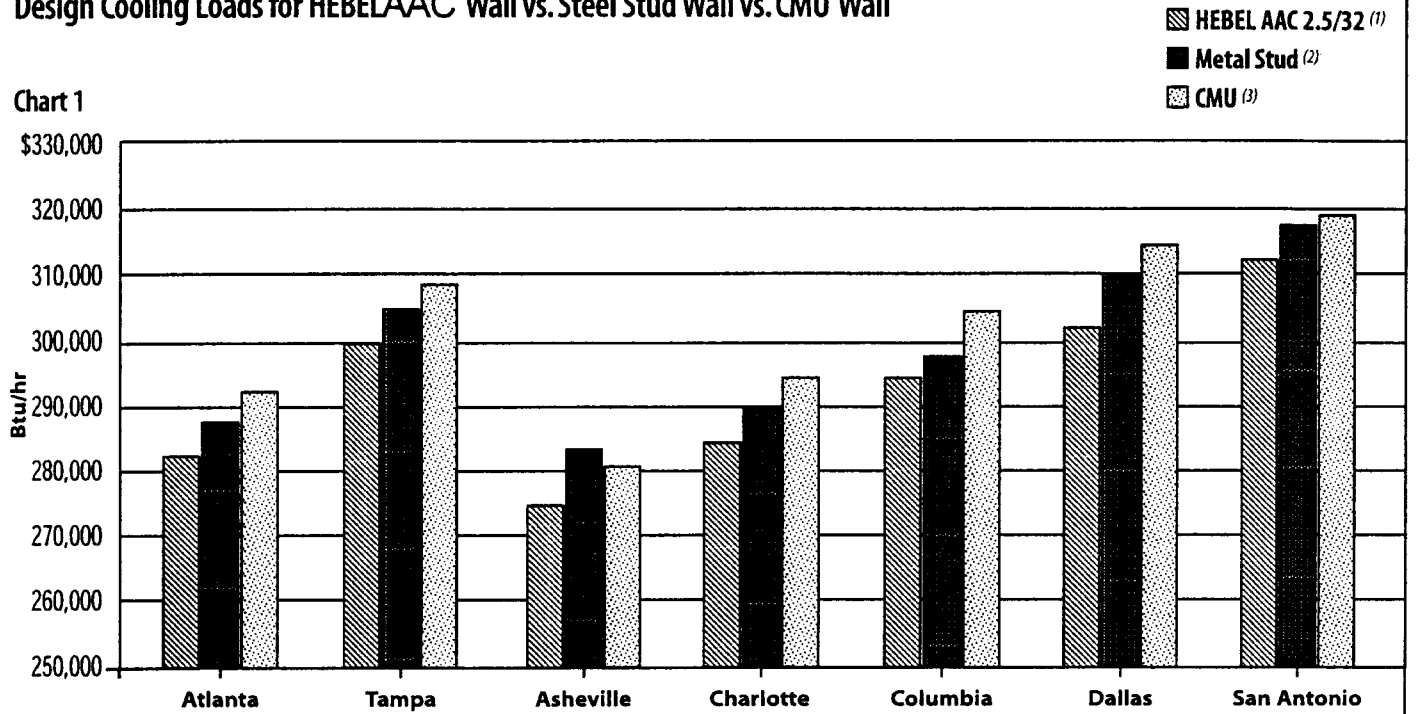
The effectiveness of HEBEL AAC material in providing and controlling interior climatic conditions was illustrated by testing a HEBEL AAC wall in conditions that simulate actual climatic conditions. In this test, HEBEL AAC wall surface temperatures were measured over a 24 hour period on a west wall, which was painted black to increase surface temperature.



The outside wall temperature fluctuated by as much as 126 °F. The inside temperature remained at a pleasant 68 °F with a mere 3.6 °F variation. Additionally, the peak temperature was shifted to a later time of the day when energy is no longer required to mechanically adjust the indoor temperature. This "time lag" combined with the heat capacity of HEBEL AAC results in substantial reduction of peak energy consumption. This reduction is larger in residential buildings than commercial buildings due to smaller internal heat loads (fewer lights, office equipment, etc.). The result of this thermal performance is a financial saving for the owner and greater comfort for the occupants.

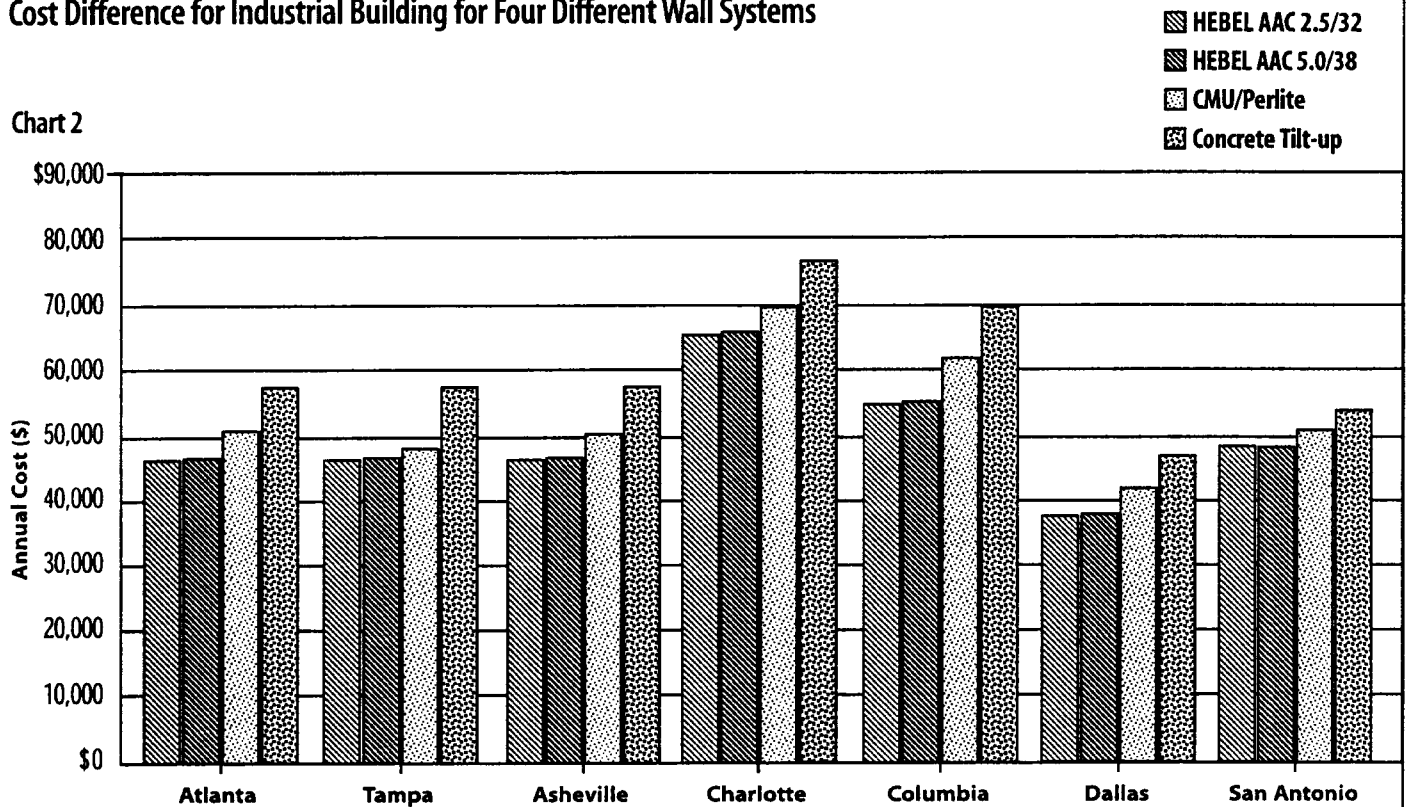
The difference in the energy consumption is demonstrated in Chart 1 for 12,000 ft² office building, while the cost difference and savings for a 35,000 ft² industrial building are shown in Charts 2,3 & 4 when HEBEL AAC 3.5/32 pcf and AAC 5.0/38 pcf are used.

Design Cooling Loads for HEBEL AAC Wall vs. Steel Stud Wall vs. CMU Wall



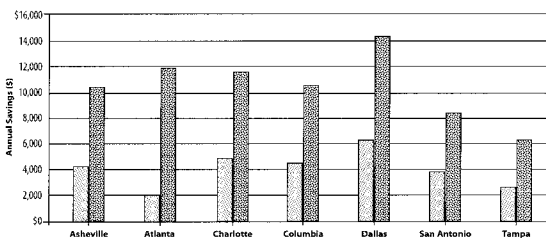
(1) HEBEL AAC 2.5/32
 (2) Steel Stud with R-13 Batt insulation
 (3) CMU filled with Perlite R-4.5

Cost Difference for Industrial Building for Four Different Wall Systems



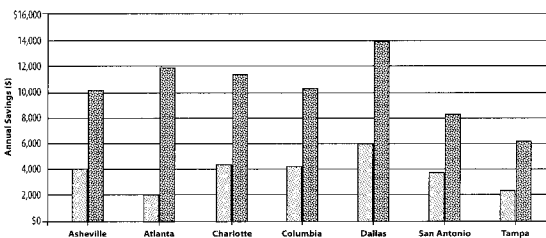
Annual Savings Using HEBEL AAC 3.5/32 pcf vs. CMU & Tilt-up

Chart 3



Annual Savings Using HEBEL AAC 5.0/38 pcf vs. CMU & Tilt-up

Chart 4



The examples cited make the point that HEBEL AAC products can offer the client and the designer several important benefits if the material's thermal properties are used appropriately. To aid in that, this chapter of the Technical Manual provides the information needed by the design professional to understand and utilize the properties and design values that will result in the utmost thermal efficiency when HEBEL AAC is used.

For the mechanical engineer, included are simple design tools, tips and general directions to assist in design of residential and commercial projects. All tables and design aids were developed by a mechanical engineering consulting firm and are based on current energy codes such as ASHRAE, Model Energy Code and State mandated codes such as the Florida Energy Code. Step by step procedures are included for energy code compliance, load calculation and equipment sizing using ASHRAE manual calculation methods and commercially available software. For a copy of this information, please contact Customer Service at the MATRIX office in Atlanta.

Definitions

It is important to remember that thermal performance of any building material is the result of several factors and may not be assumed either effective or ineffective on the basis of any one factor. In this section, there are definitions and examples of the various thermal properties that are used to determine the overall thermal efficiency of any building material. It will be shown how these thermal properties generally influence the design of the building envelope and specifically how the HEBEL AAC thermal properties result in outstanding performance and energy savings. The values for the various HEBEL AAC thermal properties are included in a later section of this chapter.

Thermal Conductivity "K" (Btu.in/h.Ft².F)

Thermal Conductivity "K" (Btu.in/h.Ft².F) is a measure of material conductivity as tested in a laboratory procedure that measures the heat flow through building material under steady and constant climatic conditions. It is important to remember that these laboratory conditions do not reflect the normal climatic cycles. This issue will be discussed in further detail in the thermal mass section. Based on the above definition, it is obvious that the lower the K value, the higher the insulating value. The following table gives the "K" value for different materials;

Designation	Thermal Conductivity, K (Btu.in/h.Ft ² .F)
HEBEL AAC 32 pcf	0.96 ⁽¹⁾
Concrete (Density 150 pcf)	9.98 ⁽²⁾
Insulation Board (Polystyrene)	0.2 ⁽³⁾
Steel	329
Water	4.15

(1) Based on ASTM C518

(2) ASHRAE

(3) ASHRAE

Thermal Resistance "R" (h.Ft².F/BTU)

Thermal Resistance "R" (h.Ft².F/Btu) is the opposite of the thermal conductivity and is the resistance of material to conduct or allow heat flow.

R = (1 / K) x Wall Thickness (in.)	
Designation	Thermal Resistance, "R" (h.Ft ² .F/Btu)
8" HEBEL AAC 32 pcf Wall System	10.0
8" Concrete 150 pcf Wall System	1.0
3 1/2" Batt Insulation	13
1" Steel Plate	0.003

Note: HEBEL AAC System and Concrete Wall System assumed to have plaster on both sides of the wall

T H E R M A L P E R F O R M A N C E

Heat Transmission Coefficient, U-Value (Btu/h.Ft².°F)

Heat Transmission Coefficient, U-value (Btu/h.Ft².°F) is defined as the amount of heat, expressed in BTU's, transmitted in one hour through one square foot of a building envelope in 1 °F temperature difference.

U = 1 / R	
Designation	U-Value (Btu/h.Ft².F)
8" HEBEL AAC 32 pcf Wall System	0.10
8" Concrete 150 pcf Wall System	1.0
3 1/2" Batt Insulation	0.077
1" Steel Plate	329

Note: HEBEL AAC Wall System and Concrete Wall System assumed to have plaster on both sides of the wall

In addition to the above basic material thermal properties, other thermal properties such as specific heat and heat capacity effect the performance of building envelope.

Specific Heat, s (Btu/lb.°F)

Specific heat, s (Btu/lb.°F) is the amount of heat required to raise one pound of material one degree °F.

Designation	Specific Heat, s (Btu/lb.°F)
HEBEL AAC	0.25
Concrete (Density 150 pcf)	0.21
Insulation Board (Polystyrene)	0.085
Steel	0.125

Heat Capacity, HC (Btu/Ft².°F)

Heat capacity, HC (Btu/Ft².°F) or sometimes is referred to as "thermal mass", is a measure of how much heat a building component can store or hold per unit of mass.

Designation	Heat Capacity, HC (Btu/F².°F)
HEBEL AAC	6.07 ⁽¹⁾
Concrete (Density 150 pcf)	25.0 ⁽²⁾
Insulation Board (Polystyrene)	0.007 ⁽³⁾
Steel	5.10 ⁽⁴⁾

(1) HC for HEBEL 8 in. = Ext. plaster (0.48) + HEBEL AAC (5.33) + Int. plaster (0.26)

(2) For 8 in. wall

(3) For Batt insulation

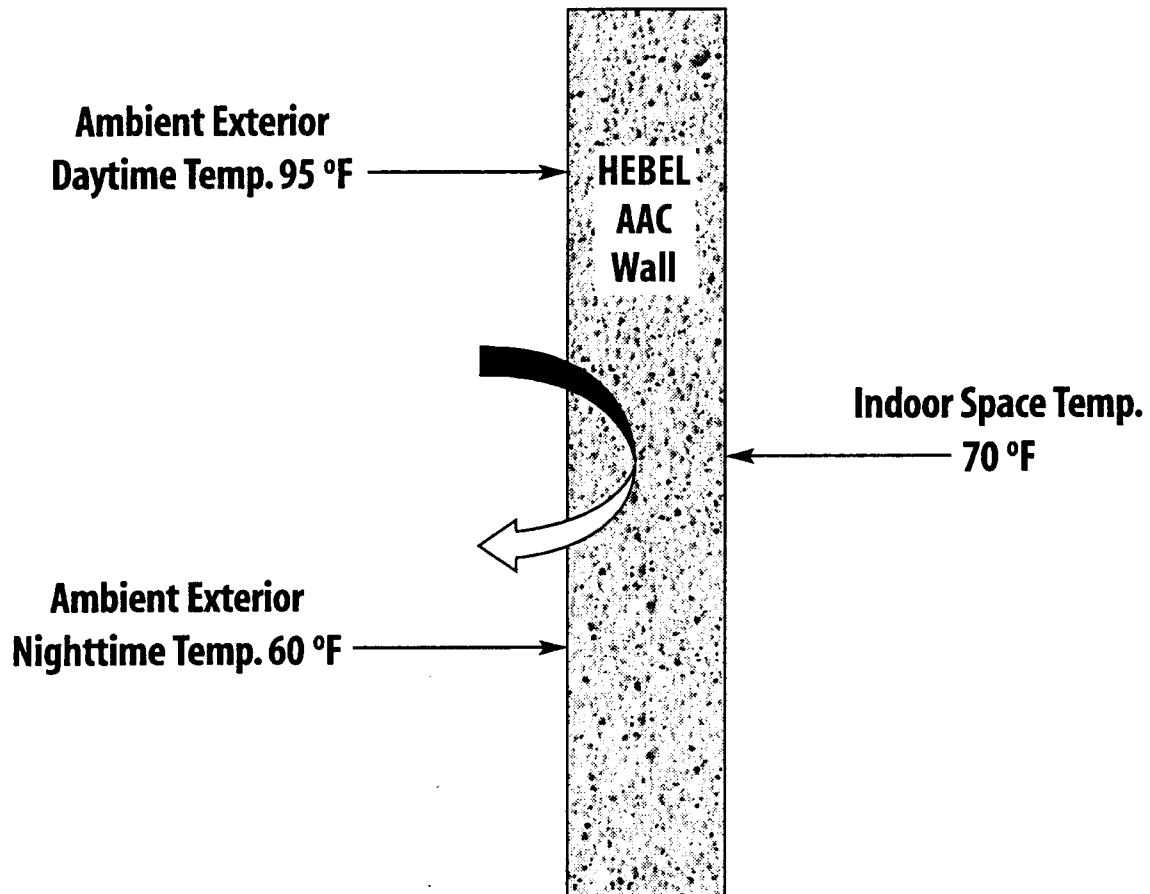
(4) For 1 in. plate

Understanding the Thermal Mass Benefit Concept

In the "steady state" thermal values obtained from laboratory testing, it is assumed that temperatures at both sides of a wall are constant and remain constant for a period of time, unlike what actually occurs in normal conditions. In actual conditions, the temperature levels on both sides of walls may change during a 24-hour period. In many cases, the exterior temperature may experience large temperature swings. These changes may cause a reversal in direction of the heat flow or at the least, "delay" the heat flow to the point where it substantially reduces the heat transfer to the inside the building envelope. The following diagrams illustrate each of these conditions.

Reversed Heat Flow Example

Amarillo, TX

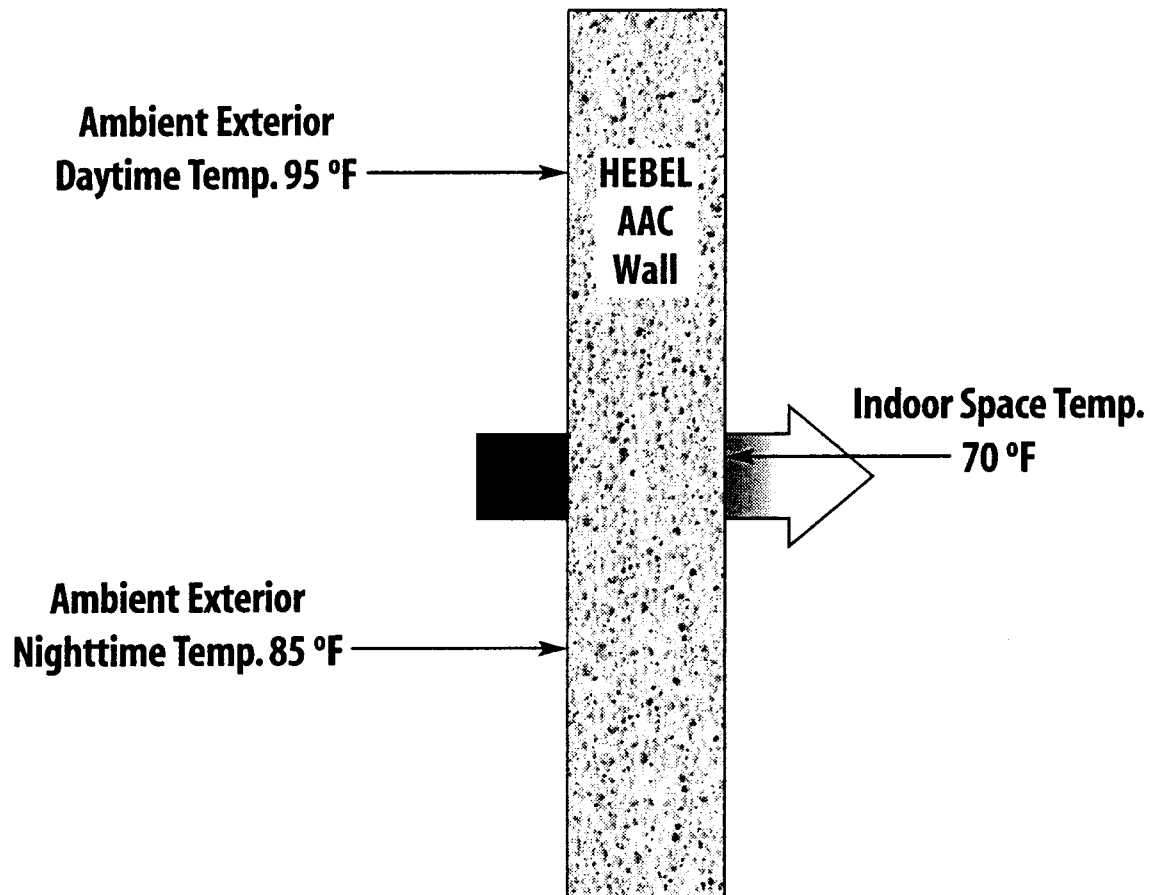


In Amarillo, Texas, it is not unusual that the outside day temperature may fluctuate from 95 °F down to 60 °F in the same 24 hour period while the indoor temperature is 70 °F. This drop in temperature and the excellent heat capacity of HEBEL AAC materials cause a reversal in the direction of heat transfer back to the outside within the 24 hours. Subsequently, the total heat gain through the HEBEL AAC wall system is significantly less than low thermal mass wall system such as framed wall. In this case, the combination of the heat capacity and the excellent thermal resistance exceeds the performance of a high "steady state" R-value. This dynamic process is known as the "thermal mass benefit" or "mass-enhanced" R-value.

Delayed Heat Flow Example

Orlando, FL

In Orlando, it is not unusual that when the outside day temperature is 95 °F, the outside night temperature will only drop down to 85 °F. During the same time frame, the inside temperature could be at 70 °F. In this case, the drop in the outside temperature may not be enough to cause a reversal in the direction of heat transfer. However due to the HEBEL AAC wall thickness, its thermal conductivity (pg. 4) and its heat capacity (pg. 5), a time delay or "time lag" results and shifts the peak temperature load to between 7 to 9 hours later.



Since HVAC systems are required to be designed for peak loads, this shift in timing of the peak load can result in a significant reduction in the size of mechanical equipment with a subsequent reduction in energy consumption and cost. The following table shows "time lag" values for different building materials.

Material	Time Lag, hr
HEBEL AAC	8
CMU	6 ⁽¹⁾
Frame Wall	2 ⁽¹⁾

(1) NCMA Tek 6-3: Shifting Peak Energy Loads with Concrete Masonry Construction (1991)

The above example serves to point out the value of considering all the thermal properties of any given material in order to determine its true value in actual conditions as opposed to reliance on a single laboratory determined value.

Thermal Properties of Different Material

The following table illustrates how the thermal properties for different building assemblies vary and when they need to be considered in total.

Material	Density (pcf)	Thickness (in.)	K-value (Btu/h.Ft2.F)	R-Value (h.Ft2.F/Btu)	Specific heat (Btu/lb. °F)	Heat Capacity (Btu/F.ft2)	System Rating
HEBEL AAC	32	8	0.96	10	0.25	6.07	★★★★
			★	★	★	★	
Concrete	150	8	9.98	0.80	0.21	25.0	★★
CMU (^a 110 pcf) w/o insulation	110	8		2.0	0.21	7.5	★★
					★	★	
2 x 4 Stud Wall with insulation	1.0	1	0.24	4.20	0.085	0.007	★★
			★	★			
Water	64	1	4.15	0.24	1.0	5.34	
Mild Steel	490	1	329	0.003	0.125	5.10	

By using this type of comparison it can be shown that an assembly having a combination of low thermal conductivity plus good heat capacity or "thermal mass" will produce excellent thermal performance compared to an assembly with high "steady state" R-value and low heat capacity. To express this difference, engineers use the expression "mass-enhanced" R-value or "effective" R-value. This means a low heat capacity wall assembly would have to have a higher R-value to perform as well as an assembly with a high R-value and a high heat capacity.

Beyond the thermal properties already discussed and included in this chapter thus far, test of actual buildings have shown the air infiltration of a HEBEL AAC wall to be 63% less than a wood stud framed structure and 48% less than an uninsulated 8" CMU wall. The impact of this on thermal performance will be discussed in later section of this chapter.

"Mass-enhanced" or "effective"

"Mass-enhanced" or "effective" R-value can be calculated by computing the overall thermal performance of a building. The following chart was developed by using HEBEL AAC thermal properties and air infiltration values to determine annual cooling load in different cities using an 8" thick HEBEL AAC wall of 32 pcf density. Then, it was determined what the R-value would have to be for a wood stud framed wall with insulation to result in the same annual cooling load. Thus, the "effective" R-value.

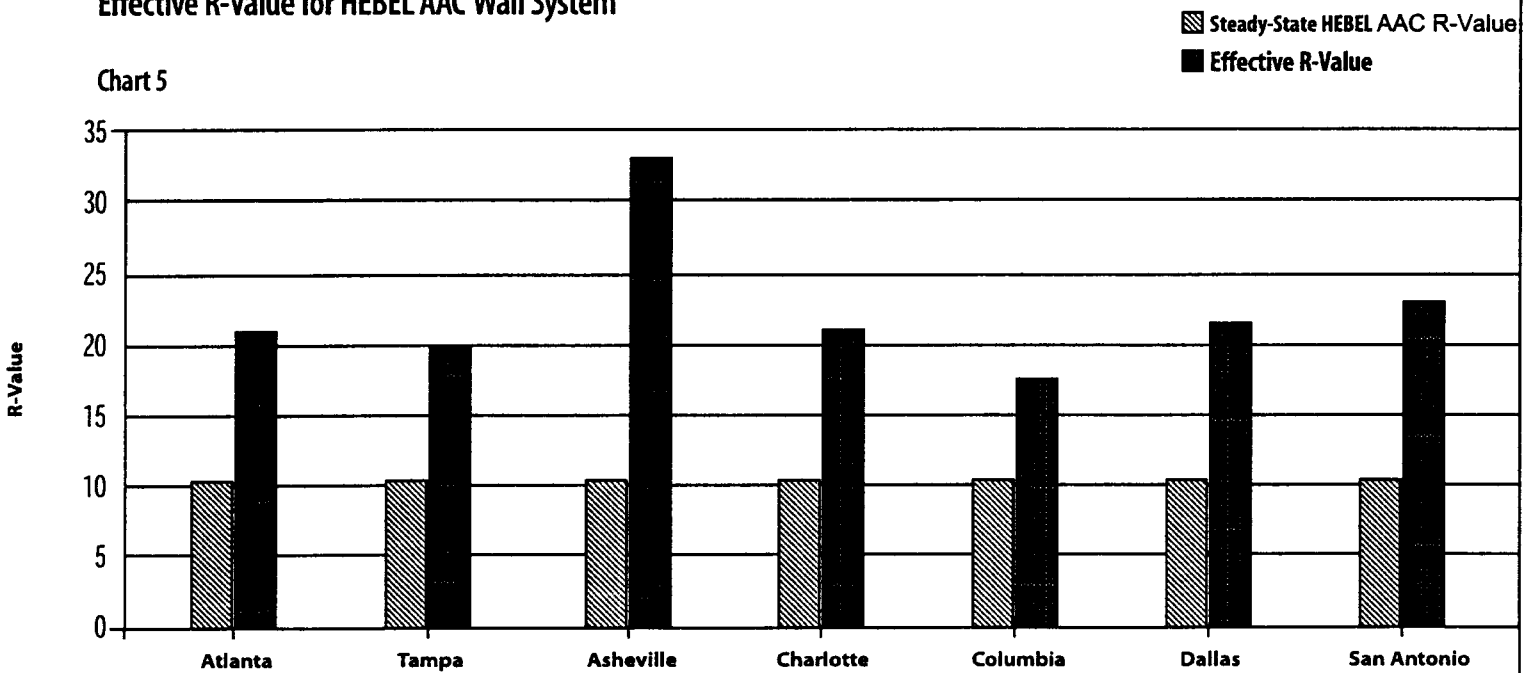
R-Value of HEBEL AAC Wall System for 12,000 sf one-story Office Building

City	Design Cooling Load 9Btu/h ⁽¹⁾		HEBEL AAC Wall R-Value ⁽²⁾	Effective R-Value
	Design Temp	HEBEL AAC Wall		
Atlanta	92	281,708	10.0	R-23.9
Tampa	91	298,268	10.0	R-21.6
Asheville	87	275,038	10.0	R-37.4
Charlotte	93	283,232	10.0	R-23.2
Colombia	95	292,255	10.0	R-20.2
Dallas	100	301,145	10.0	R-25.6
San Antonio	97	310,137	10.0	R-25.5

(1) Calculated by the Trane Trace Load Design 600 computer program

(2) HEBEL AAC 2.5/32 Wall System R-Value; Total R-Value = Outside air film (0.17) + Exterior Plaster (0.36) + HEBEL 8" (8.33) + Interior Plaster (0.11) + Inside Air Film (0.68)

Effective R-Value for HEBEL AAC Wall System



Thermal Properties for Different HEBEL AAC Material

Thermal Conductivity (K-value), R-value and U-value for HEBEL AAC Only

Table 1

HEBEL AAC Type	Density pcf	Thermal Conductivity	R-Value				U-Value			
			Thickness, in.				Thickness, in.			
			6	8	10	12	6	8	10	12
AAC 2.5	26	0.79	7.59	10.13	12.66	15.19	0.13	0.10	0.08	0.07
AAC 2.5	32	0.96	6.25	8.33	10.42	12.50	0.16	0.12	0.10	0.08
AAC 5.0	38	1.15	5.22	6.96	8.70	10.43	0.19	0.14	0.12	0.10
AAC 7.5	44	1.15	5.22	6.96	8.70	10.43	0.19	0.14	0.12	0.10

Thermal Conductivity (K-Value), R-Value and U-Value for HEBEL AAC, Exterior and Interior Plaster

Table 2

HEBEL AAC Type	Density pcf	Thermal Conductivity	R-Value				U-Value			
			Thickness, in.				Thickness, in.			
			6	8	10	12	6	8	10	12
AAC 2.5	26	0.79	8.91	11.45	13.98	16.51	0.11	0.09	0.07	0.06
AAC 2.5	32	0.96	7.57	9.65	11.74	13.82	0.13	0.10	0.09	0.07
AAC 5.0	38	1.15	6.54	8.28	10.02	11.75	0.15	0.12	0.10	0.09
AAC 7.5	44	1.15	6.54	8.28	10.02	11.75	0.15	0.12	0.10	0.09

$\cdot R\text{-value} = R_{\text{outside air}}(0.17) + R_{\text{ext plaster}}(0.36) + R_{\text{HEBEL AAC}} + R_{\text{int plaster}}(0.11) + R_{\text{inside air}}(0.68)$

Thermal Conductivity (K-Value), R-Value and U-Value for HEBEL AAC, Brick Veneer and Interior Plaster

Table 3

HEBEL AAC Type	Density pcf	Thermal Conductivity	R-Value				U-Value			
			Thickness, in.				Thickness, in.			
			6	8	10	12	6	8	10	12
AAC 2.5	26	0.79	10.00	12.54	15.07	17.60	0.10	0.08	0.07	0.06
AAC 2.5	32	0.96	8.66	10.74	12.83	14.91	0.12	0.09	0.08	0.07
AAC 5.0	38	1.15	7.63	9.37	11.11	12.84	0.13	0.11	0.09	0.08
AAC 7.5	44	1.15	7.63	9.37	11.11	12.84	0.13	0.11	0.09	0.08

$\cdot R\text{-value} = R_{\text{outside air}}(0.17) + R_{4''\text{ brick}}(0.44) + R_{\text{Air space } 1''}(1.0) + R_{\text{HEBEL AAC}} + R_{\text{int plaster}}(0.11) + R_{\text{inside air}}(0.68)$

T H E R M A L P E R F O R M A N C E

Thermal Conductivity (K-Value), R-Value and U-Value for HEBEL AAC, Exterior Plaster and Glued 1/2" Gypsum Board

Table 4

HEBEL AAC Type	Density pcf	Thermal Conductivity	R-Value				U-Value			
			Thickness, in.				Thickness, in.			
			6	8	10	12	6	8	10	12
AAC 2.5	26	0.79	9.25	11.79	14.32	16.85	0.11	0.08	0.07	0.06
AAC 2.5	32	0.96	7.91	9.99	12.08	14.16	0.13	0.10	0.08	0.07
AAC 5.0	38	1.15	6.88	8.62	10.36	12.09	0.15	0.12	0.10	0.08
AAC 7.5	44	1.15	6.88	8.62	10.36	12.09	0.15	0.12	0.10	0.08

$R\text{-value} = R_{\text{outside air}} (0.17) + R_{\text{ext plaster}} (0.36) + R_{\text{HEBEL AAC}} + R_{\text{drywall}} (0.45) + R_{\text{inside air}} (0.68)$

Thermal Conductivity (K-Value), R-Value and U-Value for HEBEL AAC, Exterior Plaster, Furring and 1/2" Gypsum Board

Table 5

HEBEL AAC Type	Density pcf	Thermal Conductivity	R-Value				U-Value			
			Thickness, in.				Thickness, in.			
			6	8	10	12	6	8	10	12
AAC 2.5	26	0.79	10.25	12.74	15.27	17.80	0.10	0.08	0.07	0.06
AAC 2.5	32	0.96	8.86	10.94	13.03	15.11	0.11	0.09	0.08	0.07
AAC 5.0	38	1.15	7.83	9.57	11.31	13.04	0.13	0.10	0.09	0.08
AAC 7.5	44	1.15	7.83	9.57	11.31	13.04	0.13	0.10	0.09	0.08

$R\text{-value} = R_{\text{outside air}} (0.17) + R_{\text{ext plaster}} (0.36) + R_{\text{HEBEL AAC}} + R_{\text{drywall + furring}} (1.4) + R_{\text{inside air}} (0.68)$

Specific Heat (s) and Heat Capacity (HC) for HEBEL AAC, Exterior and Interior Plaster

Table 6

HEBEL AAC Type	Density pcf	Specific Heat	Heat Capacity			
			Thickness, in.			
			6	8	10	12
AAC 2.5	26	0.25	4.00	5.08	6.17	7.25
AAC 2.5	32	0.25	4.75	6.08	7.42	8.75
AAC 5.0	38	0.25	5.50	7.08	8.67	10.25
AAC 7.5	44	0.25	6.25	8.07	9.92	11.75

Specific Heat (s) and Heat Capacity (HC) for HEBEL AAC, Exterior Plaster and 1/2" Drywall

Table 7

HEBEL AAC Type	Density pcf	Specific Heat	Heat Capacity			
			Thickness, in.			
			6	8	10	12
AAC 2.5	26	0.25	4.28	5.36	6.45	7.53
AAC 2.5	32	0.25	5.03	6.36	7.70	9.03
AAC 5.0	38	0.25	5.78	7.36	8.95	10.53
AAC 7.5	44	0.25	6.53	8.36	10.20	12.03

Specific Heat (s) and Heat Capacity (HC) for HEBEL AAC, Brick Veneer and Interior Plaster

Table 8

HEBEL AAC Type	Density pcf	Specific Heat	Heat Capacity			
			Thickness, in.			
			6	8	10	12
AAC 2.5	26	0.25	12.51	13.59	14.68	15.76
AAC 2.5	32	0.25	13.26	14.59	15.93	17.26
AAC 5.0	38	0.25	14.01	15.59	17.18	18.76
AAC 7.5	44	0.25	14.76	16.59	18.43	20.26

Specific Heat (s) and Heat Capacity (HC) for HEBEL AAC, Brick Veneer and 1/2" Glued Drywall

Table 9

HEBEL AAC Type	Density pcf	Specific Heat	Heat Capacity			
			Thickness, in.			
			6	8	10	12
AAC 2.5	26	0.25	12.79	13.88	14.96	16.04
AAC 2.5	32	0.25	13.54	14.88	16.21	17.54
AAC 5.0	38	0.25	14.29	15.88	17.46	19.04
AAC 7.5	44	0.25	15.04	16.88	18.71	20.54

Brick 4"
 Density = 135 pcf,
 Specific heat = 0.20 Btu/lb. °F