The Thermal Performance of the Durisol Wall Form System.

The standard Durisol Wall System comprises insulated concrete forms that are filled with concrete. This creates a strong, interconnected structural layer of reinforced concrete. Durisol building systems provide many advantages; a highly breathable and moisture regulating wall, a 50-year track record of moisture-, fire- and insect-proof materials, high-recycled content, no off-gassing, etc. Another advantage of Durisol is its thermal performance, which is a result of two properties:

-Lack of thermal bridging; and

-Presence of thermal mass effects

These two characteristics combine to create a wall system with excellent control of heat loss and heat gains.

North American housing has been dominated by wood framed systems since World War 2. As the need to improve thermal performance became more widely recognized, thermal insulation was added to the building enclosure. Codes, standards, and testing procedures were subsequently developed to ensure minimum thermal performance. Thermal performance requirements and testing became biased toward lightweight framed systems, and rational means of assessing alternative systems were not widely adopted because of the limited number of such systems available. The R-value method of assessing thermal performance had value when proposed not because it was absolutely correct, but because it provided a means to compare otherwise similar wood framed wall systems.

This situation is rapidly changing as the building industry seeks new and innovative ways of building, ways that are truly energy and resource efficient, economical and durable. Many different types of building systems are now being used throughout North America, requiring the development of more realistic means of assessing their true thermal performance.

Although the Durisol Wall Form System is not a new system, its thermal performance cannot be fairly assessed by the simple methods of the past. This report will present a more realistic assessment of the thermal performance of the Durisol Wall Form System by accounting for thermal bridging (i.e., 2-D effects) and thermal mass. These benefits will then be discussed in the context of the most modern energy code available, ASHRAE Standard 90.1.

Thermal Bridging and Durisol Insulated Wall Forms

Durisol and framed wall systems are not simple one-dimensional assemblies. Real buildings are three-dimensional, with corners, window openings, etc. However, most wall R-value calculation methods, and almost all marketing brochures, do not factor in the effects of framing at windows, doors, corners, etc. Thus they tend to over-estimate the true thermal performance.

Researchers at Oak Ridge National Labs have conducted detailed analysis of whole houses extensively. The researchers concluded that the true R-value of all framed systems was substantially lower than that commonly quoted. For example, they found that a wall system with 2x6 studs at 24” on center and R19 batts had a true “whole wall” R-value of 13.7. This reduction reflects the fact that stud walls are typically 75% insulated cavity, 21% studs, plates, and sills, and 4% headers. Steel stud walls fared even worse, since the metal is so conductive it easily short-circuits the insulation. A metal stud wall with 3-1/2” deep studs filled with R11 batts was found to have a real R-value of only 7.1.

The construction details that increase heat flow through a framed wall system have little or no influence on the heat flow through the Durisol Insulated Wall Form System. Durisol Wall Forms are designed to ensure that the R-value through the core of the wall is almost the same as that through the web. This not only avoids short-circuiting, it ensures uniform wall temperatures with no cold spots to encourage condensation, create discomfort, or cause dust marking.

Steady-State Thermal Resistance of the Durisol Insulated Wall Forms

Several combinations of insulated Durisol Wall Forms and a standard 2x6 wood framed wall were analyzed using the widely recognized and accepted FRAME two-dimensional steady-state finite volume heat transfer computer program. The standard ASHRAE values for conductivity were used for all materials except Durisol. The Durisol conductivity value was based on test reports from a national laboratory per ASTM standards.

It should be noted that the analyses below are based on “clear wall” samples. As discussed above, corners, partition wall intersections, floor joists, and windows greatly increase the number of thermal bridges in standard 2x6 construction, but not with the Durisol Insulated Wall Form System.

The results of the analysis are presented in tabular format, with the nominal U- (overall transmittance) and overall R-values, followed by the same values through the middle of the core or stud space, and through the web or wall framing. The final column is the total (i.e., actual clear wall) value.

Durisol WF30 Wall Form with 3.5” insert, plastered inside and out

Data File Name: WF30-89A.F40 (CSA) (WALL JUNCTION)
Title.........: WF30 W/3.5 INSULATION
RUN Status....: Standard (Completed)

	Nominal	**Middle**	**Web**	**Total**	**Units**
U-Value	0.0441	0.0486	0.0471	0.0484	BTU/hr•ft^2•^{o}F
R-Value	22.67	20.58	21.23	20.66	hr•ft^2•^{o}F/BTU

Durisol WF30 Wall Form with 3" insert, plastered inside and out

Data File Name: WF30-76A.F40 (CSA)   (WALL JUNCTION)

Title.........: WF30 W/3.0 INSULATION

RUN Status....: Standard   (Completed)

	Nominal	**Middle**	**Web**	**Total**	**Units**
U-Value	0.0485	0.0529	0.0512	0.0526	BTU/hr•ft^2•^{o}F
R-Value	20.61	18.90	19.53	19.01	hr•ft^2•^{o}F/BTU

Comments: There is almost no difference in R-value between the web and the center of the unit in these highly insulated Wall Forms.   As a result, the temperature across the inside face does not vary by more than 0.2 degree Fahrenheit under design conditions.

Standard 2x6 (D.Fir-L) wood framing at 16" o.c. with 1/2" OSB, stucco outside and drywall on the inside

Data File Name: 2X6-STUC.F40 (CSA) (WALL JUNCTION)

Title.........: 2X6 W/WAFERBOARD AND STUCCO

RUN Status....: Standard   (Completed)

	Nominal	**Middle**	**2x6**	**Total**	**Units**
U-Value	0.0476	0.0520	0.0918	0.0558	BTU/hr•ft^2•^{o}F
R-Value	21.00	19.23	10.89	17.92	hr•ft^2•^{o}F/BTU

Comments: There is a large difference between the R-value through the framing and the middle of the batt. This causes a relatively large temperature difference of 2.5 degrees F across the interior face. The coldest temperature is 64.8 degrees Fahrenheit, 2.3 degrees colder than the coldest spot on the WF30 Wall Form with a 3" insert.

Durisol WF25 Wall Form with 2" insert, plastered inside and out

Data File Name: WF25-50A.F40 (CSA)   (WALL JUNCTION)

Title.........: WF25 W/2" INSULATION

RUN Status....: Standard   (Completed)

	Nominal	**Middle**	**Web**	**Total**	**Units**
U-Value	0.0612	0.0651	0.0627	0.0648	BTU/hr•ft^2•^{o}F
R-Value	16.33	15.36	15.95	15.43	hr•ft^2•^{o}F/BTU

Durisol WF25 Wall Form with 1.5" insert, plastered inside and out

Data File Name: WF25-38A.F40 (CSA) (WALL JUNCTION)

Title.........: WF25 W/1.5" INSERT

RUN Status....: Standard (Completed)

	Nominal	**Middle**	**Web**	**Total**	**Units**
U-Value	0.0696	0.0728	0.0701	0.0724	BTU/hr•ft^2•^{o}F
R-Value	14.37	13.74	14.27	13.81	hr•ft^2•^{o}F/BTU

Comments: The performance of the WF25 Wall Form is similar to the WF30 in terms of uniform surface temperature, amount of thermal mass, etc., but the total heat flow is higher because less supplemental insulation is provided. The coldest surface temperature for the WF25-5 insulated form is 66.5 degrees Fahrenheit, considerably higher than the 2x6 wall system.

Durisol WF30 Wall Form with no additional insulation, plastered inside and out

Data File Name: WF30-0A.F40 (CSA) (WALL JUNCTION)

Title.........: WF30 BLOCK NO INSERTS

RUN Status....: Standard (Completed)

	Nominal	**Middle**	**Web**	**Total**	**Units**
U-Value	0.1124	0.1101	0.1062	0.1095	BTU/hr•ft^2•^{o}F
R-Value	8.90	9.08	9.42	9.13	hr•ft^2•^{o}F/BTU

Comments: Even with no additional insulation, the Durisol Wall Form provides uniform interior wall temperatures. The 8" concrete core provides a significant amount of thermal storage mass, and the capacity to resist very high structural loads.

Durisol Wall Forms and Mass Effect

Materials like concrete, brick, and Durisol have a high heat capacity, that is, they can store a significant amount of heat or "cool". This material characteristic has long been known and was taken advantage of by ancient builders of adobe walls, sod roofs, and brick buildings. After many years of neglect, the benefits of thermal mass, as the ability to store heat is called, are being rediscovered by mainstream builders and accepted by building codes, spurred on by studies of passive solar heating, passive cooling, and low-energy houses. The improved thermal performance provided by thermal mass is called the mass effect.

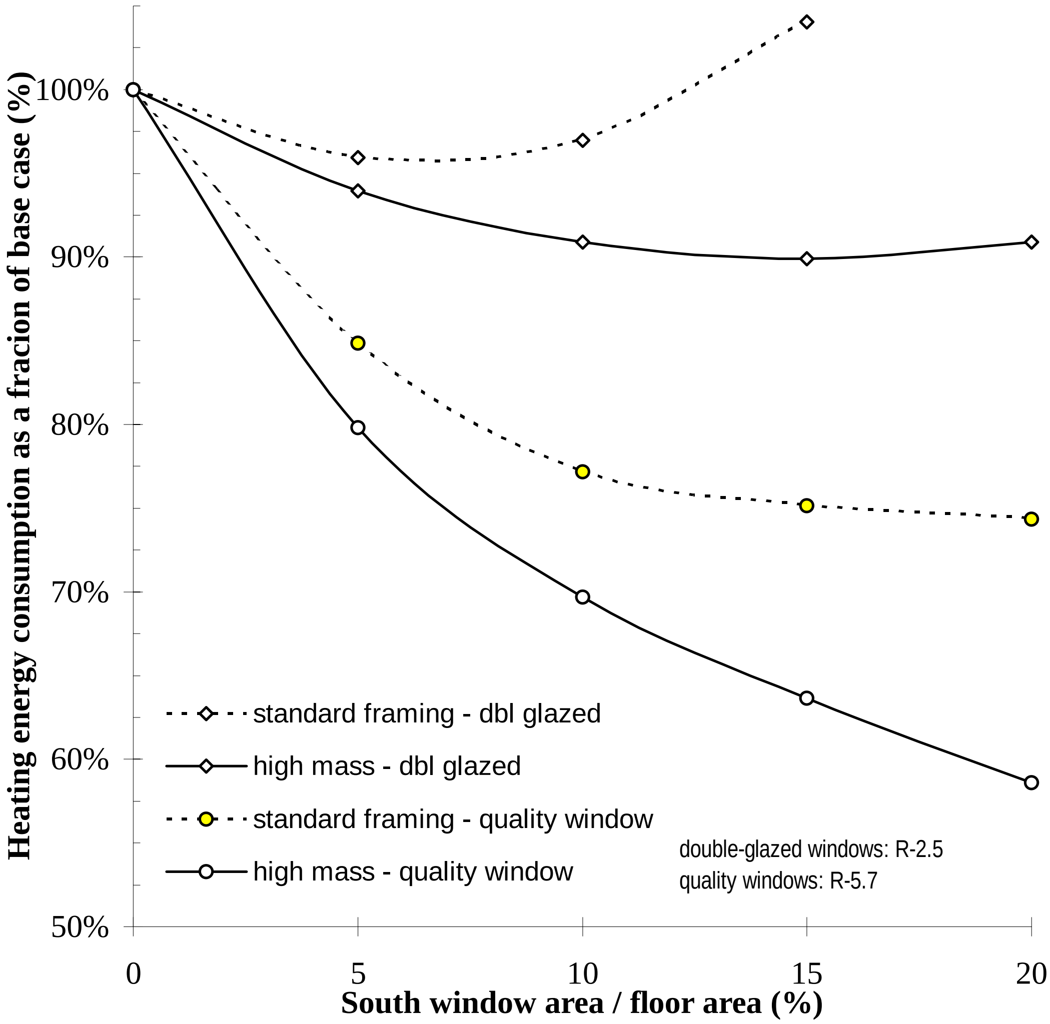
Constructing walls, floors and fireplaces of high heat capacity materials results in a building with an abundance of thermal mass. The thermal mass absorbs and stores heat when the indoor air is higher and releases heat when the indoor air is cooler. This temperature moderating effect improves comfort, and can also greatly reduce space conditioning energy consumption.

In the winter all modern buildings with double-glazed south-facing windows collect more solar energy when the sun is shining than they lose through the windows at other times. The more insulating the window (e.g., low-E and argon filled, triple-glazed), the more "free" energy is collected. However, if the energy that is collected during sunny hours cannot be stored for use during nights and overcast days, it is often lost to overheating of the house and ventilation. Thermal mass allows the free solar energy to be used by providing the energy storage required to level the peaks (sunny days) and valleys (cold nights).

The figure below demonstrates the results of a Canadian study of mass effect for a wide range of locations[†] . Although some locations were colder than others, all were predominately heating climates. The basic house (with a heat load of 100%) was a well-insulated 2200 square foot home.

The plot compares the total wintertime heating consumption of a house (vertical axis) to the amount of south-facing window area (the horizontal axis), and the amount of mass and type of windows (the four sets of curves).

[†] *Passive Solar House Designs for Canada*. Report to Canada Mortgage and Housing Corp., by Allen Associates and Marbek Resource Consultants, Ottawa, 1989.



Heating Energy Savings Due to Mass Effect

Clearly, thermal mass plays as much of a role as the use of quality windows in reducing heating energy consumption, yet it often costs less to provide this mass. Other benefits of thermal mass include the increased ability to survive heating system failures without discomfort or damage, and the ability to use smaller heating systems.

The benefits of thermal mass are even more important in cooling climates and in heating climates during the summer. In most locations, the night-time air temperature is considerably lower than the day-time air temperature. This difference in air temperature can be taken advantage of by encouraging ventilating during the night, thereby cooling the thermal mass. As the temperature rises during the following day, the interior will remain cool. Although this use of thermal mass was widely employed thousands of years ago by, for example, the Anasazi Indians of Arizona, thermal mass is still a relevant and highly successful means of providing a comfortable interior environment with no supplemental air conditioning.

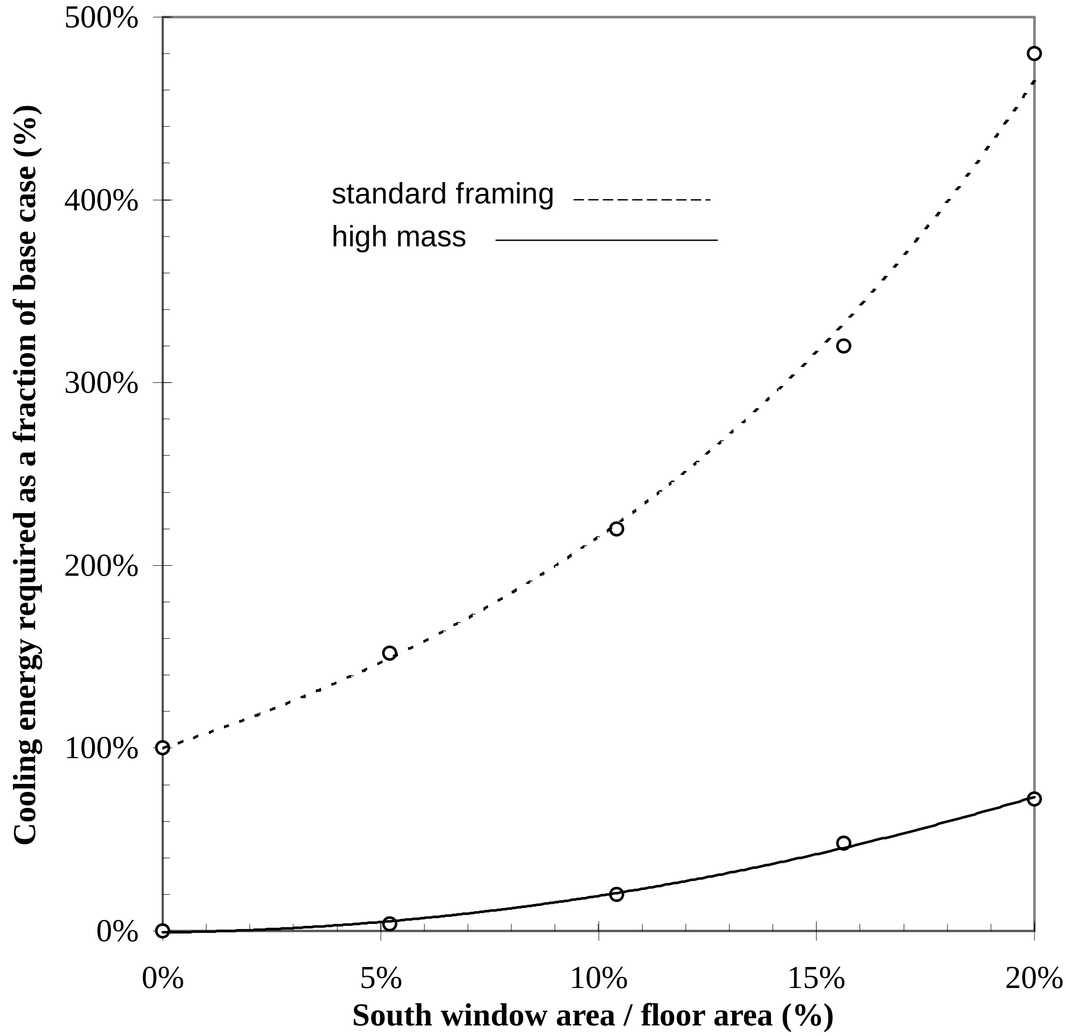
Even in hot climates with warm evenings, major benefits can be had from a substantial downsizing in equipment and the shift of maximum cooling to the evening hours, when air conditioning equipment is more efficient and power can be less expensive.

Thermal mass also acts to reduce the need for cooling by absorbing and storing solar energy that falls on walls. The thermal lag of a Durisol wall is at least 8 hours, meaning that the maximum temperature on the inside occurs 8 hours after the maximum on the outside.

As an example of the potential for reducing cooling energy consumption, consider the plot on the following page. Sophisticated computer modeling of a wide variety of low-energy homes was conducted for the California Energy Commission by researchers from the California Polytechnic State University[‡] . The plot shown is for a cold climate with warm summers at a latitude of 42 degrees, and about 5000 heating degree days. This is a climate similar to South-western Ontario.

It can be seen from the plot that thermal mass can have a major influence on the cooling energy consumption of a building -- an even greater effect than that on the heating energy consumption. For normal window areas (10 to 15%), the cooling energy consumption of a building with thermal mass is five to ten times less than that of a typical lightweight framed building! In practice, air conditioning equipment can be eliminated in moderate summer climates, providing a major up-front cost savings. Proper sizing of the window overhangs and west-facing window area will also help control summertime solar gains and reduce the need for cooling even further.

[‡] *Passive Solar Handbook*. California Energy Commission, Sacramento, California, 1980.



Cooling Energy Savings Due to Mass Effect

Durisol and Energy Codes - ASHRAE 90.1

The BSR/ASHRAE/IESNA Standard 90.1, is widely used by individual states to govern the insulation levels of buildings other than single family dwellings. The latest version of this standard provides large benefits for buildings with thermally massive walls and systems with little thermal bridging. The size of these benefits was based on the results of thousands of detailed energy simulations for many locations and wall assemblies throughout North America.

A thermally massive wall with a much lower steady-state R-value (the value normally quoted) is considered the equivalent of a lightweight framed wall by ASHRAE. Conversely, using a Durisol Wall Form with the same or slightly less than the R-value typically quoted for a framed wall will result in significant space heating energy savings and improved comfort.

The tables below provides some summary examples of the standard's requirements for residential buildings (whose requirements are more stringent than commercial buildings). The R-values are overall minimum R-values including the surface films for Durisol, and the minimum installed R-value for framed systems. The climate regions are defined by the number of heating degree days (HDD65) and cooling degree days (CDD50). The data for some representative cities are shown below.

City	Heating Degree Days	Cooling Degree Days	Heat/Mix/Cool
Anchorage, AK	10570	688	H
Atlanta, GA	2991	5038	M
Charlotte, NC	3341	4704	M
Lexington, KY	4783	3754	M
Miami, FL	200	9474	C
Ottawa, ON	8571	2045	H
Phoenix, AZ	1350	8425	C
Pittsburgh, PA	5968	2836	H
Sioux City, IA	6893	3149	H
Toronto, ON	7306	2370	H

Representative Cities and Their Climate Data

From the tables below it can be seen that for a cold heating climate (i.e., 7201-9000 HDD), and a cool summer (CDD <1800), a Durisol Wall Form with an R-value of 11.1 is considered the equivalent of a wood framed wall with R13 batt insulation and insulating sheathing with a R-value of 3.8 (e.g., 1" of polystyrene). The thermal bridging caused by steel framing requires even more insulating sheathing (about 2” of EPS).

A 2x6 wood framed wall with a drywall interior finish and stucco exterior finish was shown earlier to have a calculated “clear wall” R-value of 17.9, but when the extra thermal bridging inherent in framing around doors and windows is accounted for, ASHRAE considers such a wall to have an R-value of 14.3. This value is still higher than that calculated by the Oak Ridge researchers. Such a 2x6 wall system does not meet the requirements of the ASHRAE standard for residential buildings (U<0.067, R>14.9) in colder regions (7201-9000 HDD). The Durisol WF25 with 1.5” of insulation (R13.8) easily complies for even colder regions (9001-10800 HDD) because of the substantial thermal mass benefits. Even the steady-state, no mass effect R-value of the same WF25 form with 2” of insulation (R15.4) exceeds the requirements for these regions.

Climate (HDD65/CDD50)	**Durisol Wall** (Overall R-value)	**Wood Framing** (min. installed)	**Steel Framing** (min. installed)
3601-5400 / < 1800	R8.1	R13	R13+3.8*is*
5401-7200 / < 1800	R11.1	R13	R13+R7.5*is*
5401-7200 / 1801-3600	R11.1	R13+R3.8*is*	R13+R7.5*is*
7201-9000 / < 1800	R11.1	R13+R3.8*is*	R13+R7.5*is*
7201-9000 / 1801-3600	R11.1	R13+R7.5*is*	R13+R7.5*is*
9001-10800 / < 1800	R12.5	R13+R7.5*is*	R13+R7.5*is*

Note: “*is”* denotes that the R-value must be provided by a continuous blanket of insulating sheathing.

Typical Heating Climate Minimum R-value Requirements of Proposed ASHRAE 90.1 for Residential Buildings

For warmer climates, i.e., those with mostly cooling requirements, similar benefits accrue. All of the Durisol Wall Forms easily provide sufficient insulation in these locations, even in locations with more than 12000 CDD.

Climate (HDD65/CDD50)	Durisol Wall (Overall R-value)	Wood Framing (min. installed)	Steel Framing (min. installed)
< 1800 / < 5400	R6.6	R13	R13
< 1800 / < 9000	R6.6	R13	R13+3.8*is*
< 900 / >9000	R6.6	R13	R13+3.8*is*

Note: "*is*" denotes that the R-value must be provided by a continuous blanket of insulating sheathing.

Typical Cooling Climate Minimum R-value Requirements of Proposed ASHRAE 90.1 for Residential Buildings

In mixed climates (i.e., those that require some cooling and some heating), Durisol wall systems can provide sufficient insulation, whereas all steel framing systems require some exterior insulating sheathing to meet the requirements of ASHRAE 90-R1.

Climate (HDD65/CDD50)	Durisol Wall (Overall R-value)	Wood Framing (min. installed)	Steel Framing (min. installed)
1801-2700 / 3601-5400	R6.6	R13	R0+R7.5*is*
2701-3600 / 3601-7200	R8.1	R13	R13+3.8*is*
3601-5400 / 3601-5400	R9.6	R13	R13+7.5*is*
5401-7200 / 1801-5400	R11.1	R13+3.8*is*	R13+7.5*is*

Note: "*is*" denotes that the R-value must be provided by a continuous blanket of insulating sheathing.

Typical Mixed Climate Minimum R-value Requirements of Proposed ASHRAE 90.1 for Residential Buildings

While this assessment of ASHRAE 90.1 is only cursory and the standard has not yet received final approval, it should be clear that codes and standards are beginning to recognize the substantial benefits provided by the thermal mass and continuous insulation of Durisol Wall Systems.

The ASHRAE standard also provides for the option of elevated levels of insulation for increased energy savings: these more demanding performance targets are termed the Tier II requirements. Tier II levels may be prescribed as minimum values for some energy-saving incentive programs by utilities and government programs. The Durisol WF25 with 2" of insulation can meet Tier II requirements for all building types in climates with HDD < 12600 and any value of CDD.

Durisol Building Systems will assist designers, builders, owners, and code officials in calculating the actual required R-value for any performance target, whether ASHRAE 90.1, or other codes. Whole building analysis can be conducted for larger projects to assess the impact of orientation, window type, size, and distribution, internal heat generation, etc.