SANTERRA™
STONECRAFT

THERMAL PROPERTIES

HOLLOW STANDARD CONCRETE MASONRY UNITS

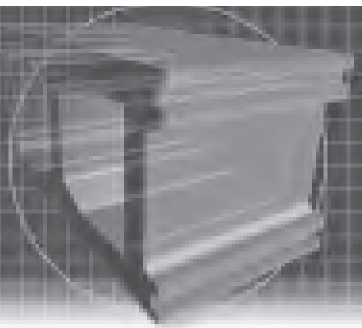
Weight Classification

	Heavy	Medium	Lightweight	Ultra Lightweight
kg. / m^3	2,100	1,975	1,765	1,450
lbs. / ft^3	132	120	110	90
6 inch (140 mm.)				
R-Value	1.95	2.05	2.23	2.45
U-Factor	0.51	0.49	0.45	0.40
8 inch (190 mm.)				
R-Value	2.10	2.21	2.40	2.69
U-Factor	0.48	0.45	0.42	0.37
10 inch (240 mm.)				
R-Value	2.19	2.31	2.50	2.82
U-Factor	0.46	0.43	0.40	0.35
12 inch (290 mm.)				
R-Value	2.26	2.38	2.59	2.93
U-Factor	0.44	0.42	0.39	0.34

The R - and U - Values presented are based upon the ASHRAE Series - Parallel Isothermal Planes method as detailed in the ASHRAE Handbook of Fundamentals.

Physical Block Dimensions were based on product compliance with CSA A165 - 04 and ASTM C 90.

Values as shown are representative of a single unit CMU in respect to a stated weight classification. For values of complete wall tables refer to Thermal Properties & Design Details.



Canadian Concrete Masonry Producers' Association

Thermal Properties & Design Details

Thermal Design

Introduction

Energy conservation addresses the thermal performance of the entire building, not just a component or a system. Every aspect must be taken into account and standards that take this overall "thermal performance" into account are ideal.

Performance standards establish energy budgets and then allow designers, builders and owners to achieve this energy budget in the manner best suited to their requirements.

The sun's energy rays can be used to advantage to reduce energy costs. [Refer to Solar Heat Storage by Professor Tang Lee, page 6-11].
There are both "active" and "passive" solar collectors. "Active" solar collectors collect energy from the sun and then use mechanical equipment such as pumps or fans to distribute that energy. "Passive" collectors simply collect the sun's heat and store it until it is released by radiation or conduction. No materials serve as "passive" collectors better than masonry - Concrete Block.

Wall mass from masonry walls keeps buildings warmer in winter, and cooler in summer because they are passive solar collectors even when not designed as such. Furthermore, because masonry mass can reduce and shift energy flow peaks, the size and capital costs of heating and air conditioning (HVAC) systems may be reduced.

Insulation, is the construction material most widely acknowledged to conserve energy. However, it is important to determine the ideal thickness of insulation to achieve cost efficiency. The law of diminishing returns as applied to insulation thickness should be considered to establish the optimum RSI value.

Insulation affects only the loss or gain of heat through conduction, accounting for about 10 percent of a building's total energy use. Air infiltration through the openings of windows and doors, through cracks and inadequately sealed openings is estimated to account for 25 - 30 percent of the heat loss in buildings.

The total resistance (RSI*) to heat flow through a building section equals the sum of the RSI values of the various components of the building section. These components consist of air films, construction materials and air spaces.

The thermal data supplied in this section will assist in calculating Thermal Resistance for masonry wall construction and is intended as a guide for estimating total thermal resistance where more specific information is not available.

**RSI is the metric abbreviation denoting thermal resistance; the conversion has been based on a factor of .176, applied to the Imperial R Values.*

Points to Consider

- *The function of the building envelope is to separate the interior environment from the exterior environment.*
- *The degree of separation is a design decision which depends on, among other things, an economic trade-off between the present cost of improving the envelope and the future cost of energy for space conditioning.*
- *As the desirable degree of separation is driven upward by higher energy costs, the potential for durability and maintenance problems is increased. This is exacerbated by the present trend toward higher interior humidity levels.*
- *The main envelope-related characteristics of a building which determine its energy consumption are its form, size, the thermal resistance of various elements, airtightness and the window area and orientation.*
- *As thermal resistance is increased, each added unit of resistance reduces heat loss less than the preceding unit so that for each part of the building there is an economic optimum thermal resistance level beyond which further increases do not produce savings commensurate with their cost.*
- *Thermal bridges — conductive materials penetrating a major portion of the thickness of the envelope — not only result in additional energy consumption but also cause internal cold spots, in turn leading to condensation and related deterioration of adjacent material.*
- *Leakage of interior air through the building envelope can result in significant quantities of condensation and is a primary cause of moisture-related building problems. These problems can be avoided by a high degree of airtightness built into the building envelope.*
- *The incorporation of insulation in a building assembly reduces its ability to dry itself should rain penetration or exfiltration/condensation occur. Correct selection of construction type and detailing is therefore important.*
- *Favourable orientation of the building on site.*
- *The geometric shape of the building (ratio of length to width).*
- *The number of stories for a given floor area requirement.*
- *Mass and colour of exterior walls.*
- *Shading or reflections from adjacent structures.*
- *Surrounding topographical features and/or landscape considerations.*
- *Opportunities for natural ventilation wind direction and speed.*
- *Reduced air infiltration and efficiently sized mechanical equipment.*
- *Efficient thermal properties of materials.*

Wall Design

Due to the many design requirements which an exterior wall must satisfy, the initial design considerations can become complex.

Exterior walls must address the following:
- Control rain penetration
- Control admittance of natural light and solar radiation
- Control of heat conductance
- Reduce of Sound Transmission

- Control of air movement and water vapour flow through wall
- Stability against wind pressure and the regulation of differential air pressures
- Protection against fire
- Control movement differential
- Control of vibrations and seismic stress
- Durability combined with low maintenance
- Control outdoor noise
- Economy

In designing a wall to fulfill these requirements it is essential to examine each condition in detail to understand the principles and mechanisms involved.

RAIN-SCREEN WALLS

The open rain-screen wall is essentially two walls: the outer layer or wythe being a vented open rain-screen separated from the inner wall by means of an air space. It is the opinion of some designers that air pressure in the air space can be equal to the pressure on the exterior wall surface. Flashing is located at the base to permit any water that has entered to be redirected to the outside.

Openings such as windows, doors and grills in multi-layer walls must be sealed to the air barrier inner wall with projections or bulkheads connecting with the outer rain screen. The air barrier must prevent major air leakage and resist wind loads on the building.

A rain-screen design approach can result in the following advantages:
- Reduces heating/air conditioning loads by placing the insulation on the cold side of the interior wythe, (inside the cavity), so the building envelope is not directly subject to climactic changes.
- Permits rapid drying of cladding material
- Consider cladding movement and crack control
- Permits better positioning of insulation, minimizing condensation risk within the wall
- Structural elements are maintained at a more uniform temperature, with reduced thermal deformation.

WIND PRESSURE

Wind forces acting on a wall can produce positive and negative pressures. Any opening on the windward side of the wall will cause a considerable pressure drop across the wall surface, thus resulting in a pressure difference that can force or draw a considerable amount of rain water through any small opening. Low wind pressures can move water through extremely small openings; but high wind pressures can force water upwards into confined spaces, bridging joints, and similar barriers. It is impossible to control wind pressure effect on wall surface rain water. The provision of an air space immediately behind the exterior facing, with amply controlled openings to the exterior air, acts as an air pressure equalization chamber to counteract the wind pressure force, and reduce rain penetration. The wall construction on the interior of the air space must be designed to resist the maximum wind pressures possible.

SOLAR AIR TEMPERATURE

The sun's effect on the outer wall surface raises the surface temperature above the outside ambient air temperature. The amount of this solar heating effect depends on:

- Time of day, date and latitude of site
- Wall surface colour
- Direction the wall faces

The effects of solar radiation, combined with outside air temperatures give a calculated outside temperature called the Solar Air Temperature.

Balance of Solar Air Temperature

Flow and temperature variations through a wall in summer can be calculated in the same way as for winter, except the Solar Air Temperature is used instead of the outside ambient air temperature.

The maximum Solar Air Temperature of a dark wall surface facing west is approximately 56°C/100°F higher than the outside ambient air temperatures. A white wall surface is only 28°C/50°F higher.

Expansion and contraction of dark coloured wall elements can be affected by direct solar exposure when facing east, south or west. Ensure that adequate thermal expansion joints are provided in the wall.

INSULATION CONSIDERATIONS

The primary function of thermal insulation in exterior walls is to reduce heat flow and maintain desired inside air temperatures in winter and summer. Interior comfort conditions are predicated on maintaining uniform interior temperatures throughout, with inside wall air temperatures that are no more than 3°C (5°F) lower than room air. If this temperature differential is exceeded, occupants feel chilled and uncomfortable working near exterior walls.

The installed position of insulation in exterior walls is an important consideration. To avoid possible air pockets and spaces between the insulation and the wall, one must ensure that insulation is properly installed. Improper installation will reduce thermal efficiency.

The location of insulation within the wall influences the temperature range each element is subjected to throughout the year.

AIR LEAKAGE AND BARRIERS

A certain amount of air exchange between the indoor and outdoor environments is necessary in order to control indoor air quality. The amount varies from building to building depending on such factors as size, type of occupancy, humidity and pollutants. However, for any given building there is a desirable amount of air exchange, usually accomplished with mechanical ventilation systems.

Air leakage is uncontrolled movement of air through walls - both into a building (infiltration) and out (exfiltration). Pressure differences causing infiltration and exfiltration are produced by wind, chimney effect, and mechanical ventilating systems.

Air leakage occurs as a result of air pressure differences. This wind effect and the difference between inside and outside temperatures can create a chimney effect in high rise buildings. Chimney effects can produce air infiltration at the lower levels and air exfiltration at the upper levels. Continuous air barriers at corners of buildings are essential to resist greatly increased wind pressures. Although the volume of air involved may not be significant in terms of heating and ventilating the building, the amount of moisture carried out by air from inside a humidified building may be large enough to cause trouble.

The air barrier must be designed to withstand the combined forces of wind, chimney effects and mechanical imbalances imposed on the assembly in much the same way a window resists such forces. (Figure 1.0) To accomplish this, a set of building elements (not necessarily composed of the same materials), must be linked continuously within the building envelope. This requirement will prevent the passage of outside air into the building, or inside air out of the building. The air barrier assembly should be designed and considered as a separate and distinct function of any wall or roof assembly. It can be formed from materials used to perform other functions but only if all requirements of both functions are met.

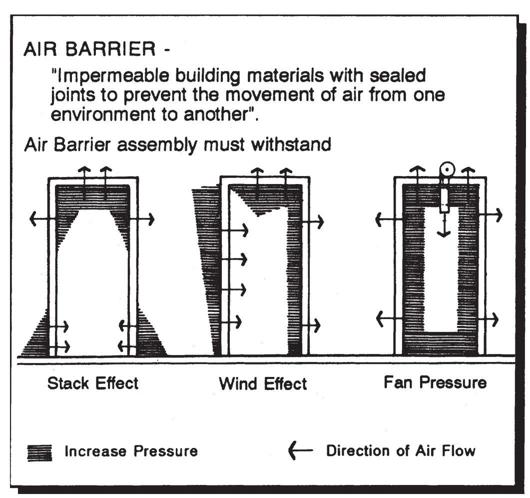


Figure 1.0 Air Barrier Design

Air Barrier Assembly

Based on the best information available, the air barrier assembly should meet the following criteria:

1. It should support and transfer to the structure of the building, any air pressure (e.g. wind loads) acting inwardly or outwardly. The assembly of components should be designed to support this pressure without rupturing, tearing or coming free of its attachment.

2. The materials used as an air barrier should be as "air impermeable" (not necessarily vapour-impermeable) as possible e.g. gypsum board, plywood, concrete, reinforced sheet membrane.

3. It may not be possible to achieve complete air tightness. To avoid a concentration of air leakage, there should be no visible openings, cracks, fissures or holes anywhere on the surface of the air barrier.

4. The air barrier assembly should be rigid so that when subjected to air pressure difference, it can develop a resistance to excessive deflection and span over any openings.

5. The joints between different elements of the air barrier assembly may be flexible. However, they should meet criteria 1, 2 and 3 outlined above.

6. It should perform for the expected life of the building: alternatively provision made to maintenance or replacement.

VAPOUR DIFFUSION AND VAPOUR RETARDERS

Vapour diffusion is a result of vapour pressure difference which causes water vapour molecules to migrate through most materials. The amount of water vapour entering the wall will depend upon the permeance of the wall assembly and the pressure difference between the inside and outside air.

ASHRAE Fundamentals, provides complete data and methods of calculating vapour flow, including examples of walls with interior and exterior insulation.

The function of a vapour retarder is to reduce the diffusion of water vapour. Diffusion is a process by which water molecules permeate through building materials.
In Ontario this is generally from the inside of the building to the outside. Speciality constructions and seasonal climate variations may reverse this direction of flow.
All building materials offer some resistance to water-vapour diffusion; some materials offer more resistance than others.

The most common available vapour retarders include:

- Polyethylene or vinyl films
- Asphalt coated felts and papers
- Metal foils, copper or aluminium
- Foil/kraft laminates
- Paints and coatings

Important considerations when selecting a vapour retarder in addition to vapour permeability include: tensile strength, tear resistance, pliability under freeze-thaw or wetting and drying conditions.

RELATIVE HUMIDITY AND CONDENSATION CONTROL

The amount of water vapour that air can hold increases with the temperature of the air. Relative humidity is the percentage of water vapour in the air compared to the maximum amount that the air can hold at a given temperature.

The presence of a vapour retarder will not prevent condensation of water on the outside of the retarder as condensation on the surface is controlled by insulation thickness. The thickness should be selected to raise the surface temperature above the dew point.

Since the ability of air to hold water vapour decreases as temperature decreases, a point can be reached where the temperature is cool enough for the water vapour to condense into moisture. This temperature is known as the Dew Point.

DEW POINT

The actual dew point location within exterior wall construction is important. Should the freezing plane be located within the wall elements, serious damage can result from ice lensing expansion and produce wall deterioration and failure.

Thermal Bridges

Thermal bridges are components with relatively low thermal resistance which "bridge" through the insulation layer of the building envelope. The unavoidable small thermal bridges (ties, hangers, shelf angles, insulation fasteners) do not contribute significantly to overall heat losses or gains. They should be placed or detailed to avoid lowering temperatures at the interior surface of other places where condensation and related corrosion or other degradation may occur.

Problems may arise with large thermal bridges such as structural floor, cross wall and partition penetrations through the insulation plane. A serious thermal bridge infraction occurs when the design has the floor slab extending beyond the exterior wall to form the balcony slab (figure 2.0). Actual wintertime temperature measurements on large thermal bridges, such as concrete slabs and cross-walls bridging the interior side insulation, show that interior surface temperatures at these points are as much as 21°C/70°F below the average temperature of surrounding surfaces.

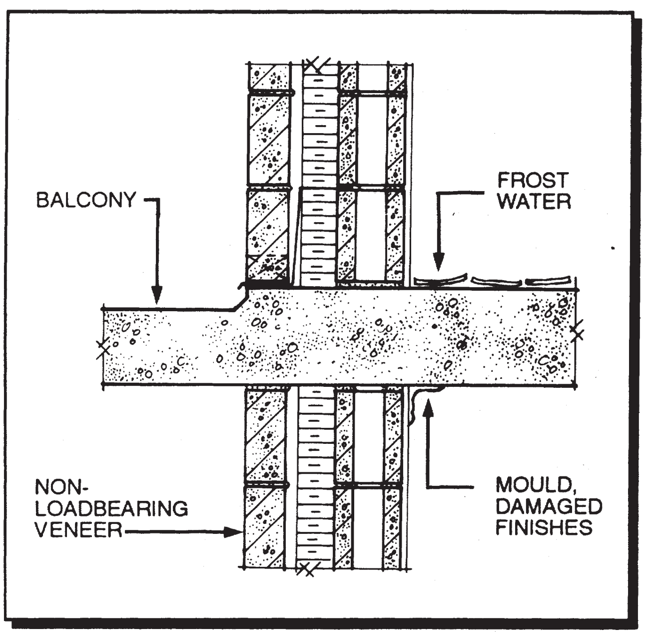


Figure 2.0
Effect of thermal bridge when indoor relative humidity is appreciable (above 20% RH in mid-winter)

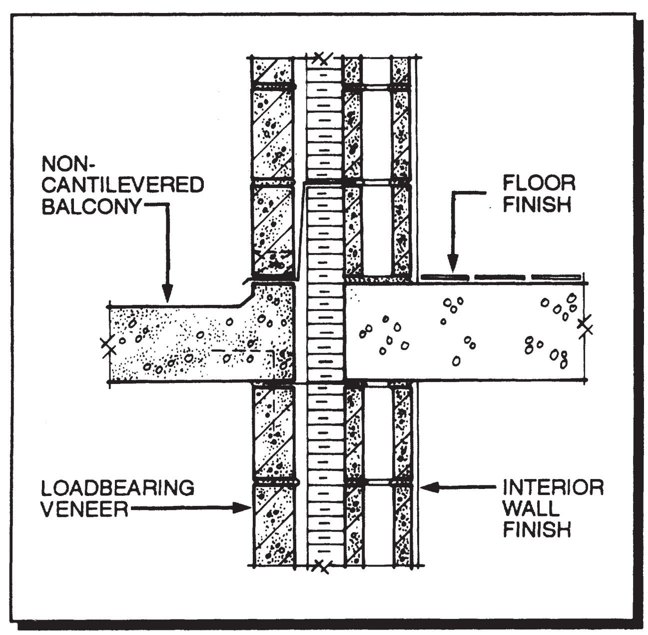


Figure 3.0
Balconies supported from ground

Masonry Walls

DESCRIPTION

Concrete block walls are designed to:

- Resist Rain Penetration
- Control Heat Flow
- Resist Wind Pressure
- Resist Fire
- Control Water Vapour and Air Flow
- Control Noise
- Carry Compressive Loads
- Accommodate Building Movements
- Be Aesthetically Pleasing

In the case of masonry cavity wall construction the wall consists of inner and outer wythes, separated by an air space.

The inner wall (wythe) may be loadbearing, supporting the floors and roof, or may simply be an infill wall. It is tightly sealed to prevent movement of air and water vapour, and is provided with a vapour retarder to prevent water vapour diffusion. The inner wythe is insulated to prevent heat loss in winter and heat gain in summer.

The outer wall (wythe) assists the inner wythe in resisting lateral loads such as wind pressure and protects the inner wythe from the elements.

Good detailing and execution of vents and weepholes prevent moisture from penetrating the inner wall assembly.

All windows, doors, or other openings are tightly sealed to the inner wythe to complete the air barrier. The bottom of the cavity and above all window and door openings are flashed and weep holes are installed to drain any water which may have penetrated to the airspace.

WALL ELEMENTS

Outer Wythe - Concrete Block

Insulation - Select thickness to achieve desired overall thermal resistance. Insulation should be placed in the wall cavity along with an air space. It should be carried over the face of columns and beams to avoid thermal bridges and to protect the structure from temperature differences which would cause the various materials to expand and contract at different rates.

Where additional thermal resistance is desired, insulation may be added to the interior surface of the inner wythe or placed in the unit cores.

Vapour Retarder - If additional insulation is used on the interior of the inner wythe, a vapour retarder should be placed on the warm side of the insulation.

Air Barrier - Is continuous throughout the assembly by caulking and sealing the interior gypsum board assembly, including all penetrations. Alternatively, cement parging can be utilized on the inner wythe of the cavity, taking care to seal all gaps in the wythe. Sheet membranes may also be employed.

Inner Wythe - The use of concrete block, either loadbearing or non-loadbearing when structural rigidityis required for the framing members.

TABLE 6.A
THERMAL RESISTANCE VALUES (R VALUES) FOR VARIOUS CONSTRUCTION MATERIALS

Except where noted, the following values are taken from the model National Energy Code, Table C-2, Thermal Properties for Building Materials.

All values are given in m²•°C/W

DESCRIPTION	THERMAL RESISTANCE PER mm	THERMAL RESISTANCE FOR THICKNESS LISTED
Air Surface Films		
Still Air: Interior Surface		0.120
Moving Air: (6.7 m/s) Exterior 24Km/h		0.030
Air Spaces: -Faced with Non-reflective Materials- 12 mm Minimum Dimension		
Vertical Space: Heat Flow Horizontal		0.171
Air Spaces Less than 12 mm in Minimum Dimension		0
Air Spaces: -Faced with Reflective Materials*- 12 mm Minimum Dimension		
Vertical Space: Faced 1 Side - Heat Flow Horizontal		0.465
Vertical Space: Faced 2 Sides - Heat Flow Horizontal		0.480
Air Spaces Less than 12 mm in Minimum Dimension		0
Insulation		
Mineral Fibre (range 0.024-0.028)	0.026	
Cellulose Fibre	0.0253	
Vermiculite	0.015	
Expanded Polystyrene		
- TYPE 1	0.026	
- TYPE 2	0.028	
- TYPE 3	0.030	
- Extended Polystyrene	0.035	
Rigid Glass Fibre Roof Insulation	0.0277	
Natural Cork	0.0257	
Rigid Urethane or Isocyanurate Board	0.0420	
Mineral Aggregate Board	0.0182	
Fibreboard	0.0194	
Phenolic Thermal Insulation	0.0304	

NOTE: * These values may not be used in calculations for areas where the mean annual total degree days exceed 4400 Celsius degree days.

TABLE 6.A CONTINUED DESCRIPTION	THERMAL RESISTANCE PER mm	 FOR THICKNESS LISTED
Concrete Block: Rectangular Core, O.C.B.A. Metric Sizes		
Normal Density (2100 kg/m3)		
No Insulation in Cores		
- 90 mm		0.17
- 140 mm		0.19
- 190 mm		0.21
- 240 mm		0.24
- 290 mm		0.26
Cores Filled with Vermiculite		
- 90 mm		---
- 140 mm		0.40
- 190 mm		0.51
- 240 mm		0.61
- 290 mm		0.69
Low Density (1700 kg/m3		
No Insulation in Cores		
- 90 mm		0.24
- 140 mm		0.30
- 190 mm		0.32
- 240 mm		0.33
- 290 mm		0.41
Cores filled with Vermiculite		
- 90 mm		---
- 140 mm		0.58
- 190 mm		0.81
- 240 mm		0.98
- 290 mm		1.06
Sheathing Materials		
Softwood Plywood	0.0087	
Particle Board	0.0087	
Insulating Fibreboard Sheathing	0.016	
Gypsum Sheathing	0.0061	
Sheathing Paper		0.011
Asphalt Coated Kraft Paper Vapour Barrier		Negligible
Polyethylene Vapour Barrier		Negligible
Interior Finish Materials		
Gypsum Board, Gypsum Lath	0.0062	
Gypsum Plaster, Sand Aggregate	0.0014	
Gypsum Plaster, Lightweight Aggregate	0.0044	
Plywood	0.0087	
Hard-Pressed Fibreboard	0.0050	
Insulating Fibreboard	0.0165	
Mat-Formed Particleboard	0.0087	

TABLE 6.B
VAPOUR RESISTANCE VALUES OF VARIOUS MATERIALS

MATERIAL	THICKNESS (mm)	VAPOUR RESISTANCE (Pa•m2•s/ng	VAPOUR RESISTANCE PER mm
Plastic and Metal Foils and Films			
Aluminum Foil	0.025		
Aluminum Foil	0.009	0.35	
Polyethylene	0.05	0.11	21 114.
Polyethylene	0.10	0.22	21 114.
Polyethylene	0.15	0.30	21 114.
Polyethylene	0.20	0.44	21 114.
Polyethylene	0.25	0.58	21 114.
Polyvinylchloride, unplasticized	0.05	0.026	
Polyvinylchloride, plasticized	0.10	0.013-0.023	
Polyester	0.025	0.025	
Polyester	0.008	0.075	
Polyester	0.02	0.22	
Cellulose acetate	0.25	0.0035	
Cellulose acetate	3.18	0.054	
Construction Materials			**(x 10^{-4})**
Concrete (1:2:4 mix)			2.11
Brick Masonry	102.0	0.023	
Concrete Block (cored, limestone aggregate)	203.0	0.007	
Tile Masonry, glazed	102.0	0.145	
Asbestos Cement Board	3.05	0.0018-0.0036	
With Oil Finishes		0.035-0.07	
Plaster on metal lath	19.0	0.0012	
Plaster on wood lath		0.0016	
Plaster on plain gypsum lath (with studs)		0.0009	
Gypsum wall board (plain)	9.5	0.00035	
Gypsum Sheathing (asphalt impreg.)	12.7		0.341
Structural insulating board (sheathing qual.)			0.136-0.341
Structural insulating board (interior, uncoated)	12.7	0.00019-0.00035	
Hardboard (standard)	3.18	0.0016	
Hardboard (tempered)	3.18	0.0035	
Wood, sugar pine			1.29-17.03
Plywood (douglas fir, exterior glue)	6.35	0.025	
Plywood (douglas fir, interior glue)	6.35	0.009	
Acrylic, glass fibre reinforced sheet	1.42	0.145	
Polyester, glass fibre reinforced sheet	1.22	0.035	
Thermal Insulations			
Air (still)			0.057
Cellular glass			∞
Corkboard			2.59-3.27
Mineral wool (unprotected)			0.059
Expanded polyurethane ((r-11 brown) board stock			4.22-17.03
Expanded Polystyrene - extruded			5.65
Expanded Polystyrene – bead			1.16-3.4
Phenolic foam (covering removed)			0.259
Unicellular synthetic flexible rubber foam			45.6-340.6

Tang G. Lee, MRAIC

Introduction

Solar space heating in Canada is not widespread due to its high capital cost.The intermittent and diffuse nature of solar radiation requires large apertures to collect solar heat, and large storage mass for heat storage. One of the most important challenges of the solar heating industry is to reduce the base component cost for solar heating systems.

This article describes an innovative approach to heat storage using concrete block walls. Significant cost savings are realized when the block wall also serves as a necessary fire separation or a structural element in a building. The concept is referred to as a "building integrated" solar heating system, rather than the traditionally and more costly "component based" system.

Tang G. Lee *is a professor in the Faculty of Environmental Design at The University of Calgary. He maintains a small architectural practice specializing in energy conserving designs and solar heating. He is frequently called upon to testify as an expert witness in civil and criminal courts on matters pertaining building sciences and other construction matters.*

Solar Heat Storage

Trombe Walls Are Ineffective In Cold Climates

Traditional use of masonry walls for solar heat storage is primarily based on the "Trombé" wall concept that was developed in Europe. A massive wall is positioned behind a south facing window where it intercepts heat from the sun. At night the warmed wall radiates heat into the building to counteract heat loss. In cold climates however, more heat is radiated back out the window because the window surface temperature is colder than the interior room temperature. To be effective the window must be better insulated than double glazing. Insulated shutters between the masonry wall and window will reduce the radiant heat loss back out through the window, but current technology is expensive and prone to failure.

The Trombe wall therefore is not suitable for cold climates (Lawand, 1978).

Solar Heat Storage In Concrete Block Walls

Walls used for heat storage must be positioned away from the thermally weak windows to reduce radiant heat loss to the outside. In a remote location, the block wall is able to effectively radiate heat into the building rather than to the exterior.

Calgary Chinese Alliance Church

In 1981, the first Canadian application of a building integrated solar heating system for heat storage was in the Calgary Chinese Alliance Church (Figure 1.0). Solar heat is stored in concrete block walls positioned on the inside of north walls (Lee, 1983b).

The 3000m2 building is constructed as a rain screen masonry wall assembly. The following materials were used:

- 200mm concrete block (interior)
- air barrier
- 100mm rigid insulation
- 50mm air gap
- 100mm face brick (exterior)

Natural gas consumption for the church is 2/3 less per year than churches of similar size and function. With these savings the solar system has paid for itself in a period of 4 1/2 years.

Figure 1.0 Calgary Chinese Alliance Church

The interior concrete block walls are used as a finishing material, structural wall and for storing solar heat. The interior concrete blocks used were the readily available vertically scored pattern to simulate 100mm x 100mm wall tiles (Figure 2.0). The blocks were stack-bonded to ensure the cores would line up vertically. Blocks with fully grouted cores and bond beams occur only where structural needs deemed it necessary. As such the design and construction of the block wall is no different than that currently in practise.

Air which had been heated by the solar collectors is ducted to the block wall. Lintel block (200mm x 200mm) positioned on its edge, were used at top and bottom of the wall. This technique allowed the solar heated air to enter the wall (Figure 3.0) by means of a `C' shaped heater air duct (Figure 4.0). Depending on the time of year, the forced air travels down and out through the bottom.

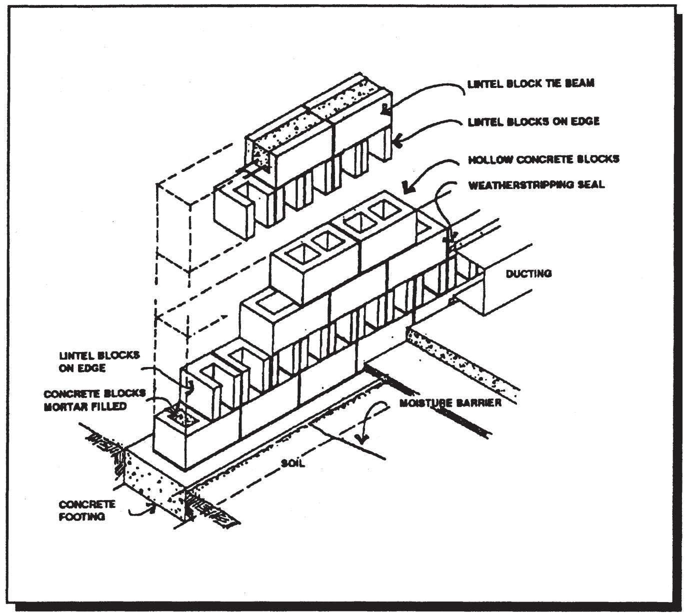


Figure 2.0 Interior Concrete Block Wall (Lee Residence)

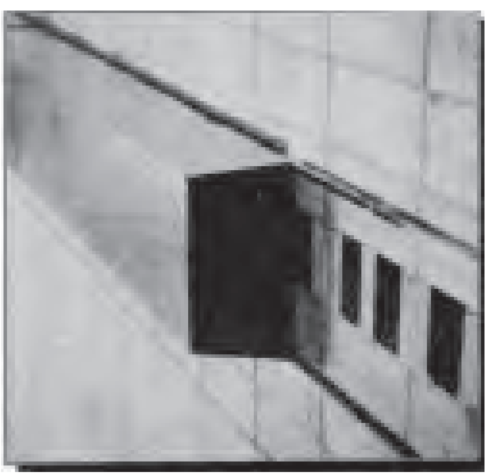


Figure 4.0 `C' Shaped Heater Duct

Figure 3.0 Solar Heat Air Duct (Alliance Church)

Solar Heat Storage

As the hot air migrates through the hollow cores, heat is transferred to the blocks. Exhausted air is at room temperature, indicating that the heat was successfully extracted and stored in the block wall (Figure 5.0). Thermographic scans of the block wall show progressive transfer of heat in the block walls (Lee, 1984).

In the Chinese Alliance Church, there was the opportunity to experiment with filling the cores of the concrete blocks to increase thermal storage and extend lag time between thermally charging the wall and heating the building.

In one of the experimental wall panels, high water ratio concrete filled every other hollow core. In another wall section, the alternate cores were filled with sand. Tests indicate there is very little difference in storage capacity and thermal lag time between the two walls (Lee, 1984). The additional thermal mass took longer before it started to radiate heat into the building, thus more suitable for this type of application and building occupancy.

A computer simulation (Byrne, and Lee, 1986) of the masonry heat storing walls suggests a minimum ratio of 2:1 for wall surface area (for alternate filled cores) to solar collector area or, window area. With cores not filled the ratio should be 4:1 for a concrete block wall to a solar collector or sunspace area.

If the ratio of 5:1 wall area to solar collector is exceeded, the rate of radiant heat loss from the block wall will be compromised.

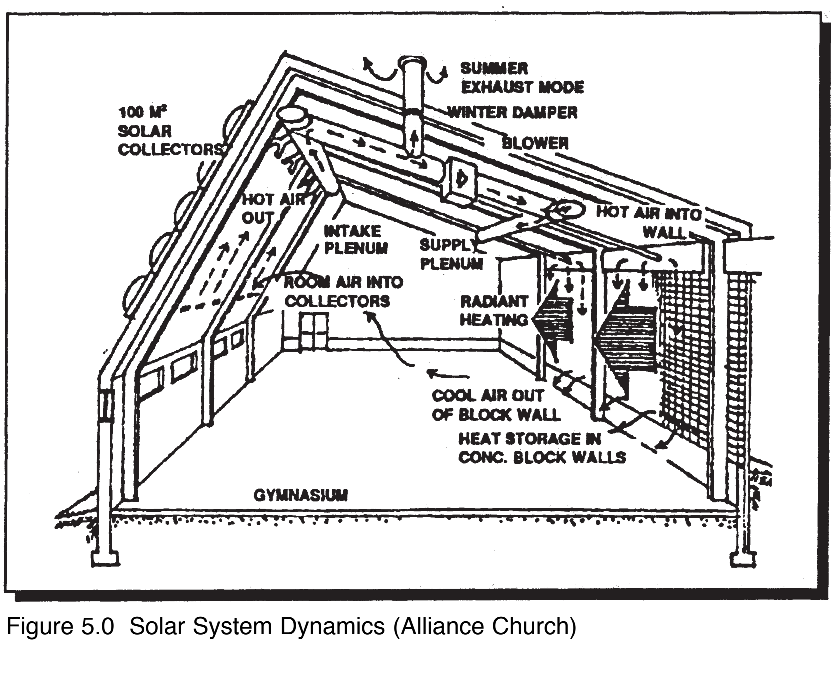


Figure 5.0 Solar System Dynamics (Alliance Church)

Table A
RULES of THUMB for STORAGE GEOMETRY

DESIGN CRITERIA	CONSTRUCTION TECHNIQUES
Thickness	100mm to 200mm thick walls; down to 50mm acceptable with large surface wall area
Surface Area	4 times the aperture when cores not filled or 2 times the aperture for alternate core filled wall
Air Distribution	as evenly distributed as possible
Orientation	vertical walls preferred; horizontal position required more mass on top
Location	interior of building away from windows; lower level preferred
Air Flow	11 e/s per m^2 of aperture (collector)

Table B
SIZING RULES for SOLAR COLLECTOR

ITEM	RULE
Aperture	$1m^2$ per 800 - 1200 kJ(^{0}C.day) of load
Storage	800 - 1200 kJ/^{0}C per m^2 of glazing

Sandstone Valley Ecumenical Centre

Figure 6.0 Sandstone Valley Ecumenical Centre

Other buildings have been designed by the author which incorporate the concrete block walls as an architectural element and to store solar heat. A recent example is the 3 200m^2 Sandstone Valley Ecumenical Centre. This is a Catholic and Lutheran church built in 1988. In this building, the solar heated air is generated by vertical south facing solar collectors which appear to be windows (Figure 6.0). The solar collectors use curtain wall technology which was site installed at the time of construction (Lee, 1987).

Solar heated air is ducted to the northern section of the church where it is stored in a large concrete block wall. This wall is strategically located to provide the necessary fire separation between the gymnasium and the nursery (Figure 7.0). In addition to serving as a solar heat storage and fire separation, this block wall also has a structural responsibility which is to support two floors and the roof. Lintel blocks laid on edge were used again to provide entry to the hollow cores of the block wall. In addition to space heating, the solar system is used to preheat water.

Summer Cooling

During the summer, the concrete blocks can be used to cool the building. Using the same components for solar heating, cool night air is ducted through the block walls. The blocks are thus cooled throughout the night. The cooled block walls provide a large thermal mass to keep the building cool throughout the hot summer day. A simple timer turns on the fan at night and off at sunrise. The amount of electricity consumed by the fan is considerably less than what is consumed by an air conditioner. In addition, the fan uses electricity during off-peak hours, i.e. Midnight to 6:00AM.

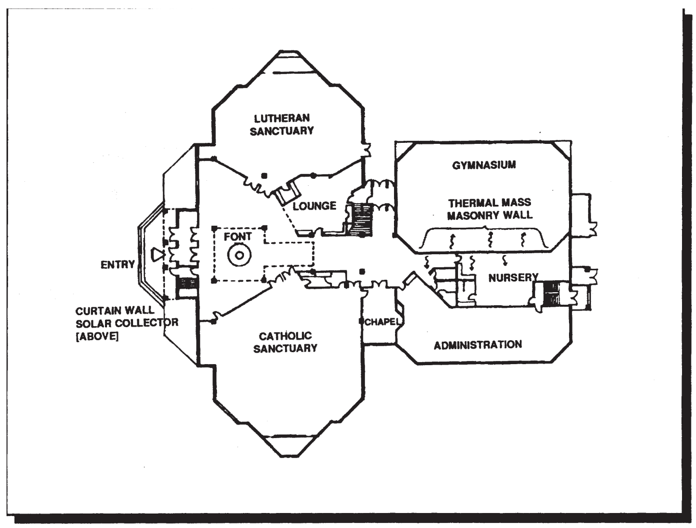


Figure 7.0 Ground Floor Plan (Ecumenical Centre)

Conclusion

Concrete blocks with hollow cores can be used as an air plenum. When air travels through the blocks, heat can be transferred to the blocks or extracted for cooling purposes. The advantages of using the concrete block wall as thermal storage is that it is essentially achieved at no additional cost to the building owner. This assumes the architect strategically positions the block wall to also serve as a structural component, for fire separation or for sound separation purposes.

Whereas traditional solar heat storage dedicates material strictly for heat storage and it occupies valuable interior space, the block walls described here do not require such additional space. The buildings featured here demonstrates the effective use of concrete blocks for solar heat storage.

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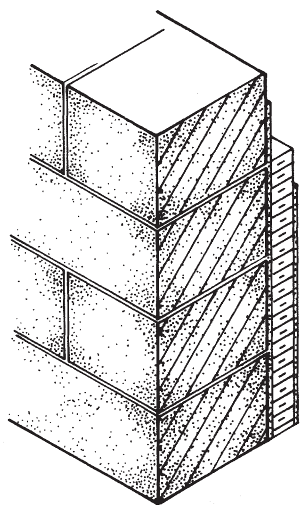
Wall Components



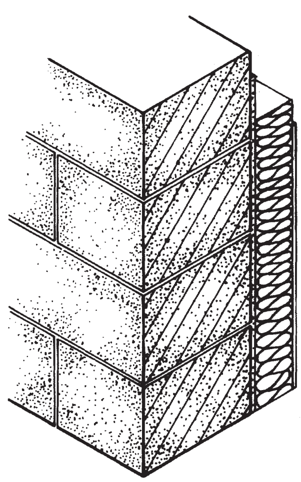
WALL COMPONENTS	RSI VALUE	R VALUE
OUTSIDE AIR FILM	0.03	0.17
25cm ARCHITECTURAL BLOCK C/W INSULATION IN CORES	0.61	3.47
AIR BARRIER-PARGING	0.17	0.97
51mm POLYURETHANE INSULATION	2.20	12.5
13mm GYPSUM WALL BOARD	0.08	0.45
INSIDE AIR FILM	0.12	0.68
TOTAL	3.21	18.24

PROJECT

THERMAL RESISTANCE-SINGLE WYTHE WALL

BLOCK TYPE

25cm ARCHITECTURAL



WALL COMPONENTS	RSI VALUE	R VALUE
OUTSIDE AIR FILM	0.03	0.17
25cm ARCHITECTURAL BLOCK C/W INSULATION IN CORES	0.61	3.47
AIR BARRIER-PARGING	0.17	0.97
75mm RIGID FIBROUS GLASS INSULATION C/W VAPOUR BARRIER	2.20	12.5
13mm GYPSUM WALL BOARD	0.08	0.45
INSIDE AIR FILM	0.12	0.68
TOTAL	3.21	18.24

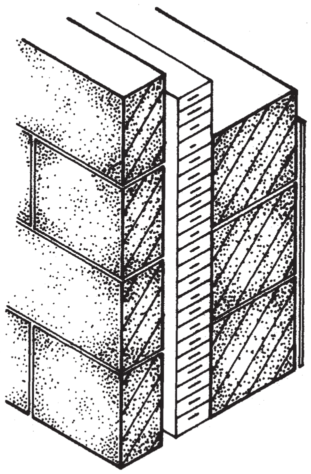
PROJECT

THERMAL RESISTANCE-SINGLE WYTHE WALL

BLOCK TYPE

25cm ARCHITECTURAL

Wall Components



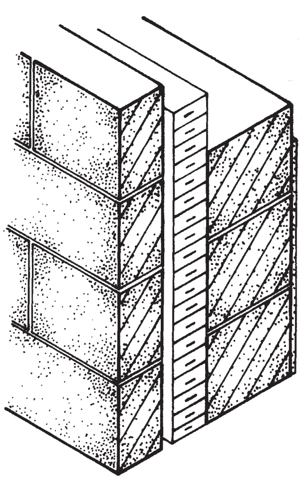
WALL COMPONENTS	RSI VALUE	R VALUE
OUTSIDE AIR FILM	0.03	0.17
10cm ARCHITECTURAL BLOCK	0.17	0.97
25mm AIR SPACE	0.17	0.97
75mm EXPANDED POLYSTYRENE	2.10	11.93
AIR BARRIER	—	—
20cm CONCRETE BLOCK	0.21	1.19
13mm AIR SPACE	0.17	0.97
13mm GYPSUM BOARD	0.08	0.45
INSIDE AIR FILM	0.12	0.68
TOTAL	3.05	17.33

PROJECT

THERMAL RESISTANCE-RAINSCREEN WALL

BLOCK TYPE

10cm ARCHITECTURAL 20cm NW HOLLOW



WALL COMPONENTS	RSI VALUE	R VALUE
OUTSIDE AIR FILM	0.03	0.17
10cm ARCHITECTURAL BLOCK	0.17	0.97
25mm AIR SPACE	0.17	0.97
75mm RIGID FIBROUS GLASS INSULATION	2.20	12.5
AIR BARRIER	—	—
20cm LW CONCRETE BLOCK	0.30	1.70
13mm GYPSUM BOARD	0.08	0.45
INSIDE AIR FILM	0.12	0.68
TOTAL	3.07	17.44

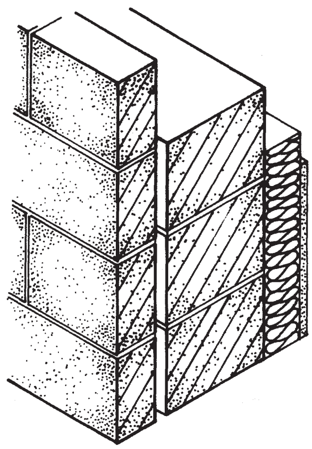
PROJECT

THERMAL RESISTANCE-RAINSCREEN WALL

BLOCK TYPE

10cm ARCHITECTURAL 20cm LW HOLLOW

Wall Components



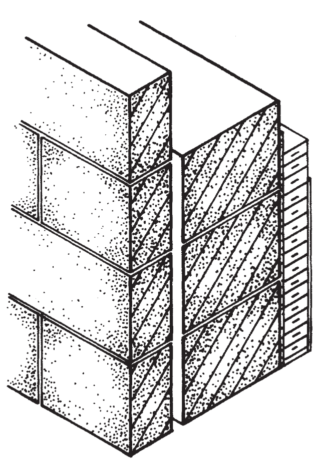
WALL COMPONENTS	RSI VALUE	R VALUE
OUTSIDE AIR FILM	0.03	0.17
10cm ARCHITECTURAL BLOCK	0.17	0.97
25mm AIR SPACE	0.17	0.97
20cm NW CONCRETE BLOCK C/W INSULATION IN CORES	0.51	0.51
AIR BARRIER	—	—
75mm RIGID FIBROUS GLASS INSULATION C/W VAPOUR BARRIER	2.20	1.70
16mm GYPSUM BOARD	0.10	0.45
INSIDE AIR FILM	0.12	0.68
TOTAL	3.30	18.75

PROJECT

THERMAL RESISTANCE-COMPOSITE WALL

BLOCK TYPE

10cm ARCHITECTURAL 20cm NW HOLLOW



WALL COMPONENTS	RSI VALUE	R VALUE
OUTSIDE AIR FILM	0.03	0.17
10cm ARCHITECTURAL BLOCK	0.17	0.97
25mm AIR SPACE	0.17	0.97
20cm NW HOLLOW C/W INSULATION IN CORES	0.51	2.90
13mm PARGING -AIR BARRIER-	0.17	0.97
51mm POLYURETHANE	2.20	12.5
13mm GYPSUM BOARD	0.08	0.45
INSIDE AIR FILM	0.12	0.68
TOTAL	3.45	19.61

PROJECT

THERMAL RESISTANCE-COMPOSITE WALL

BLOCK TYPE

10cm ARCHITECTURAL 20cm NW HOLLOW