Insulating Masonry Walls

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ABSTRACT

The wide variety of wall constructions that incorporate masonry provides many options for insulating masonry walls. These insulation strategies include interior furring with insulation, insulated cavities, insulation inserts, foamed-in-place insulation, granular fills, and exterior insulation and finish systems. The relative performance of these systems, including energy efficiency, fire resistance, sound transmission, and water penetration, is discussed.

INTRODUCTION

Although walls are primarily designed to provide structural performance, other performance requirements such as fire resistance, sound penetration resistance, durability, weather resistance, and energy efficiency must also be fulfilled. Masonry walls are capable of satisfying these many design requirements economically and effectively through the wide variety of masonry systems and insulation strategies available. Each wall design has different advantages and limitations with regard to each of these design requirements.

The thermal performance of masonry walls depends on the R-value of the wall as well as the thermal mass characteristics of the wall. Thermal mass describes the ability of certain materials to store heat. Masonry, because of its relatively high density and specific heat, provides effective thermal mass in buildings. Thermal mass allows masonry walls to remain warm or cool long after the heat or air conditioning has shut off. Thermal mass has been effectively used to reduce heating and cooling loads, to moderate indoor temperature swings, and to shift heating and cooling loads to off-peak hours (Burch et al. 1984; NBS 1981; Wessling 1974).

The effectiveness of thermal mass varies with factors such as climate, building design and insulation position. Thermal mass is most effective when insulation is placed on the exterior of the masonry (BOCA 1990). This insulation strategy keeps the masonry directly in contact with the interior conditioned air.

Integral insulation refers to insulation placed between, or integral with, masonry, such as an insulated cavity in a cavity wall or a concrete masonry wall with the cores of the masonry filled with insulation.

Interior insulation, such as furring and insulation on the interior side of the masonry, results in the least effective utilization of thermal mass, since the mass is isolated from the conditioned space and is primarily responding to the exterior temperature swings.

SINGLE-WYTHE MASONRY

Single-wythe masonry refers to a wall that is one masonry unit thick. Single-wythe masonry may be constructed with interior, integral, or exterior insulation. Interior insulation strategies typically consist of interior furring with insulation between the furring. In single-wythe construction, integral insulation is placed in the cores of the masonry units. Integral insulation strategies for single-wythe walls include foamed-in-place insulation, granular loose fill insulation, or rigid insulation inserts. Exterior insulation is typically either rigid board insulation, protected by stucco, or an exterior insulation and finish system (EIFS).

Interior Insulation

Masonry walls with interior insulation can be either structural masonry furred out on the interior or a nonstructural masonry veneer over a structural stud wall (such as a brick veneer over a wood-frame residential wall). Furring and insulation are usually finished with gypsum wallboard. The insulation may be fibrous batt, rigid board (polystyrene or polyisocyanurate) as illustrated in Figure 1, or fibrous blown-in insulation. If the wall will be exposed to severe moisture conditions, the furring strips are held away from the face of the masonry with spacers or horizontal furring strips. The space created by the furring strips is a convenient and economical location for wiring, pipes, and outlets.
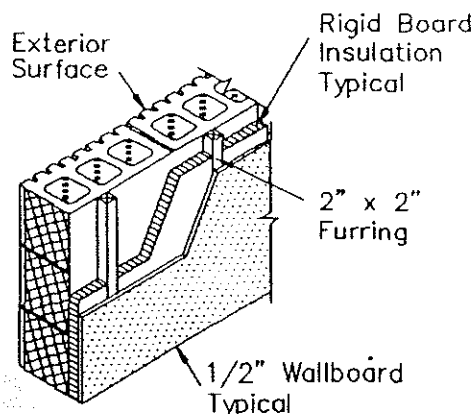

Figure 1   Interior insulation.

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TABLE 1
Single-Wythe Walls
Interior and Exterior Insulation Strategies

Insulation Type	3.5" Fiberglass Batt	1.5" Rigid Polystyrene
R-Value of Insulation[a]	11 (1.94)	8.1 (1.43)
R Value of Wall[b]:		
8" CMU	11.2 (1.97)	10.3 (1.81)
12" CMU	11.4 (2.01)	10.5 (1.85)
Heat Capacity[c]:		
8" CMU	8.5 (174)	8.5 (174)
8" CMU, reinforced[d]	10.5 (215)	10.5 (215)
12" CMU	11.8 (241)	11.8 (241)
12" CMU, reinforced[d]	15.2 (311)	15.2 (311)
STC[e]:		
8" CMU	48	48
8" CMU, reinforced[d]	50	50
12" CMU	51	51
12" CMU, reinforced[d]	53	53
Fire Rating (hours):		
8" CMU	1.5 - 2.75	1.5 - 2.75
12" CMU	2.75 - 4	2.75 - 4
Installed cost of insulation (Means 1991): dollars/ft^2	$0.43	$1.11
Insulation installed per day, ft^2 (m^2) (Means 1991):	1350 (125)	730 (68)
Other considerations:	• Convenient if furing is required for all wall finish. • Can be used for retrofit. • Reduces interior floor area. • Maximized thermal mass benefits when placed on exterior. • Requires protection. • Relatively expensive. • Can be used for retrofit.	

[a]Units are hr·ft^2·°F/Btu (m^2·K/W).
[b]Wall R-values were calculated using the isothermal planes calculation method, assuming a concrete density of 125 pcf (2002 kg/m^3) and wood furring for batt insulation.
[c]Units are Btu/ft^2·°F (kJ/m^2·K).
[d]Walls are reinforced vertically at 32 in. (81 cm) on center.
[e]STC is calculated based on wall weight (NCMA 1990). The insulation will increase the STC, but, at this time, there are no data available to determine the amount of this increase (CDHS 1981).

Table 1 summarizes the performance characteristics of interior-insulated masonry walls. The concrete masonry wall may have vertical or horizontal reinforcement in the cores and cells without interrupting the insulation layer. The only interruption of the insulation layer is due to the furring. If wood furring is used, thermal bridging is minimized since the thermal conductance of the combined insulation and furring layer is only slightly more than the conductance of the insulation alone. This is shown in Table 1, where the R-value of the wall is slightly higher than the R-value of the insulation alone, indicating little insulation value lost due to thermal bridging. However, if the wall incorporates metal furring or studs, the effectiveness of the insulation will be greatly reduced due to the large thermal conductance of the metal framing (ASHRAE 1989).

In some applications, the furring is omitted and rigid board insulation is adhered directly to the masonry. For this installation, the use of mechanical fasteners with the appropriate adhesive is encouraged. The only thermal bridging with this insulation strategy is due to the fasteners. This option is usually chosen when minimizing the wall thickness is critical because the rigid insulation tends to be significantly more expensive than fibrous insulation (Means 1991).

The fire resistance rating of a concrete masonry wall is a function of the aggregate used in manufacturing the units and of the equivalent thickness of the unit (BOCA 1990; ICBO 1991; SBCCI 1991). The use of lightweight aggregates, such as expanded clay, shale, or slate, results in higher fire resistance ratings than units made of heavyweight aggregates, such as gravel, because of the lower conductivity of the lightweight aggregates. The equivalent thickness of a hollow masonry unit is the thickness that would result if the same volume of concrete were recast

without hollow spaces. A high equivalent thickness indicates a larger amount of concrete in the wall and, hence, a higher fire rating. Table 1 indicates a higher fire rating for 12-inch (300-mm) -thick masonry than for 8-inch (200-mm), because hollow 12-inch units, being thicker, have a larger equivalent thickness than hollow 8-inch units.

Because the insulation is located on the interior of the wall, the fire protection rating of the masonry remains unchanged. If noncombustible materials are used for furring and finishing, such as gypsum board or plaster, the fire performance increases because the thickness of the gypsum board or plaster can be added to the thickness of the masonry in determining the equivalent thickness (Allen 1970; Menzel 1934).

The acoustical properties of the masonry will generally be improved by the furring, insulation, and finish. Typically, the sound transmission class (STC) and sound absorption will increase. For example, the addition of 1/2-inch (12.7 mm) gypsum board to one side of a concrete masonry wall increases the STC about 2 points (NCMA 1990). Mounting the gypsum board on resilient channels will further increase the STC by as much as 10 points (CDHS 1981). The durability, weather resistance, and impact resistance of the exterior of the wall remain unchanged with the addition of the insulation. Impact resistance on the interior surface is limited to the performance of the interior finish.

Although thermal bridging may be minimal with this type of wall, the benefits of masonry heat storage capacity tend to also be minimized with interior insulation, since the masonry is isolated from the interior conditioned air. The designer must trade off thermal mass benefits with R-value to achieve the desired thermal performance.

Integral Insulation

Single-wythe walls may also be integrally insulated, as shown in Figure 2. Integral insulations are typically polystyrene inserts, perlite or vermiculite granular fills, or ureaformaldehyde, phenolic, or polyurethane. Table 2 summarizes the performance characteristics of integrally insulated walls with granular loose-fill insulation and with foam insulation. When using integral insulation in single-wythe walls, it is critical that the insulation fully occupies all core spaces.

Granular fills are placed in the masonry as the wall is laid up. A small amount of settlement usually occurs but has a relatively insignificant effect on overall performance. Retrofits involving penetrations into walls with granular fill insulation in the cores of the masonry units may cause problems regarding containment of the granular fill, since the fill will tend to flow out of any holes in the wall system.

Foamed-in-place insulation is usually installed after the wall is completed. The installer will either fill the cores from the top of the wall or drill small holes in the masonry and pump the foam through those holes. Some foams, such as ureaformaldehyde, tend to shrink as they cure. Shrinkage

may be in the vertical direction as well as away from the edges of the cores in the concrete masonry, opening up very small gaps between the insulation and the masonry. These gaps are generally too small to significantly impact the thermal performance, but they can act as channels, allowing water to penetrate the masonry. Other foams, such as polyurethane, expand as curing occurs. These foams penetrate into the face shells and webs of the concrete masonry units, effectively sealing the pores of the masonry and impeding water penetration.

Polystyrene inserts may be placed in the cores of conventional masonry units or the inserts may be used in specially designed concrete masonry units, such as those shown in Figure 3. The specially designed concrete masonry units often incorporate cut-down webs to accommodate the insert. The cut-down webs also reduce the thermal bridging through the masonry, since the reduced web area provides a smaller cross-sectional area for heat flow through the wall. To further reduce thermal bridging, some manufacturers have developed concrete masonry units with two cross-webs, rather than three. Inserts may be installed in the masonry units at the construction site or installed at the manufacturing plant. Some inserts extend beyond the cores of the masonry to cover the mortar joint area and provide more continuous insulation coverage. The maximum thermal resistance is achieved when all mortar joint areas are covered.

The degree of water penetration resistance varies with the integral insulation strategy. If water penetrates a concrete masonry wall insulated with granular fill, the water travels down through the insulation to flashing and weep holes, where it is collected and channelled to the exterior. Polystyrene inserts also permit the wall to drain, since they generally do not fill the entire core. In a foam-insulated wall, the insulation may direct the water across the webs to the interior of the wall, since the foam is impervious to water. For most single-wythe walls exposed to the weather, the use of an integral water repellent system or exterior water repellent is generally recommended as a second line of defense against water penetration.
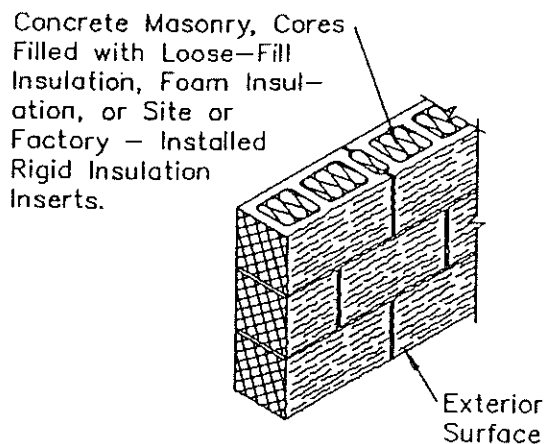

Concrete Masonry, Cores Filled with Loose—Fill Insulation, Foam Insulation, or Site or Factory — Installed Rigid Insulation Inserts.

Exterior Surface

Figure 2   *Integral insulation.*

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TABLE 2
Single-Wythe Walls
Integral Insulation

Insulation Type	Granular Loose-Fill	Foamed-in-Place
Resistivity of Insulation[a]	3.1 (0.15)	4.4 (0.21)
R-Value of Wall[b]:		
8" CMU	5.1 (0.90)	5.3 (0.93)
8" CMU, reinforced[c]	3.9 (0.69)	4.0 (0.70)
12" CMU	7.2 (1.27)	7.5 (1.32)
12" CMU, reinforced[c]	5.3 (0.93)	5.5 (0.97)
Heat Capacity[d]:		
8" CMU	8.7 (178)	8.5 (174)
8" CMU, reinforced[c]	10.7 (219)	10.5 (215)
12" CMU	12.2 (249)	11.8 (241)
12" CMU, reinforced[c]	15.5 (317)	51.2 (311)
STC[e]:		
8" CMU	48	48
8" CMU, reinforced[c]	50	50
12" CMU	51	51
12" CMU, reinforced[c]	54	53
Fire Rating (hours):		
8" CMU	4	1.5 - 2.75
12" CMU	4	2.75 - 4
Installed cost of insulation (Means 1991): dollars/ft^2		
8" CMU	$0.59	$1.18
12" CMU	$1.08	$1.89
Insulation installed per day, ft^2(m^2) (Means 1991):		
8" CMU	2400 (223)	1035 (96)
12" CMU	1200 (111)	630 (59)
Other considerations:	• Increases fire rating. • Use screens or wicks in weep holes. • Relatively expensive. • Ensure no voids in mortar joints.	
General:	• No protection or finish is required. • No increase in wall thickness due to insulation. • R-values are lowered due to insulation. • During construction, cores must be kept free of trash and debris.	

[a]Units are hr·ft^2·°F/Btu·in (m·K/W).
[b]Units are hr·ft^2·°F/Btu (m^2·K/W). Wall R-values were calculated using the isothermal planes calculation method, assuming a concrete density of 125 pcf (2002 kg/m^3). CMU = concrete masonry unit.
[c]Walls are reinforced vertically at 32 in. (81cm) on center.
[d]Units are Btu/ft^2·°F (kJ/m^2·K).
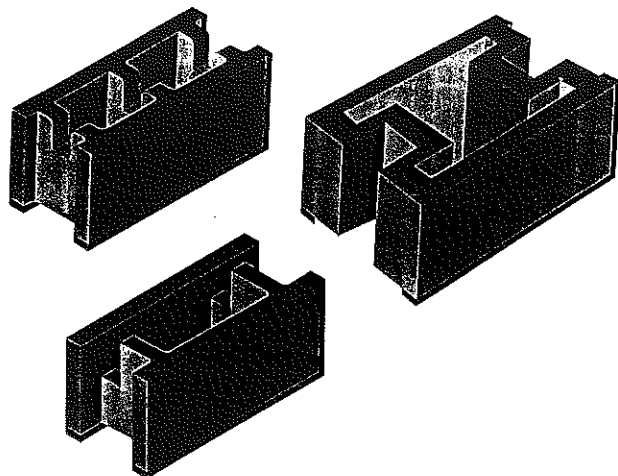[e]STC was calculated based on the wall weight in pounds per square foot (NCMA 1990).

Figure 3   *Concrete masonry units specially designed to accomodate insulation.*

The limiting factor in the fire testing of masonry walls is typically surface temperature rise, due to thermal conductance and not to the penetration of flames or smoke (Menzel 1934). Thus, as long as the insulation system is contained within the masonry, the integral insulation will improve the fire protection of the masonry. Unfortunately, very few data exist on the effects of foams and inserts on fire ratings. However, tests have been performed with loose-fill products (Menzel 1934). As a result, most building codes include special provisions for vermiculite and perlite fills. The BOCA National Building Code (BOCA 1990) allows a two-hour masonry wall to be increased to a four-hour rating when all cores are filled with vermiculite or perlite. The Standard (SBCCI 1991) and Uniform (ICBO 1991) Building Codes allow the equivalent thickness to be the actual thickness of the masonry unit, when all cores are filled with vermiculite or perlite.

This significantly increases the equivalent thickness, hence increasing the fire rating, as shown in Table 2. For example, the equivalent thickness of a typical 8 inch (200 mm) thick masonry unit increases from 4 inches (101 mm) to 7.625 inches (194 mm), increasing the fire rating from 1.5-3 hours (depending on the aggregate used in manufacture) to 4 hours.

The acoustic performance of an integrally insulated single-wythe wall is primarily dependent on wall weight (NCMA 1990). For this reason, walls built with larger or denser masonry will have higher STC ratings than those constructed of smaller or lighter units. Since integral insulation does not significantly change the weight of the wall, the insulation has a negligible effect on both the STC and sound absorption. For example, the STC of an 8-inch (200-mm) lightweight block has been shown to increase from 49 to 51 when all cores are filled with granular loose-fill insulation (CDHS 1981). This is usually significant only if the wall is required to meet an STC of 50, as in the case of partitions between living units in townhouses or condominiums (ICBO 1991). Similarly, the insulation does not

affect durability or impact resistance since both faces of the masonry are exposed.

Vertical and horizontal reinforcement grouted into the cores of the units may be required for structural performance. Cores to be grouted are isolated from cores to be insulated by placing mortar on the webs to confine the grout. Granular or foam insulation is placed in the ungrouted spaces within the wall. Thermal resistance is then determined based on the average R-value of the wall area. Most rigid inserts are configured to accommodate reinforcing steel and grout to provide both thermal protection and structural performance.

Exterior Insulation

Exterior insulation of masonry walls is typically accomplished using rigid board insulation, as shown in Figure 4. The board insulation may be adhered or mechanically attached to the exterior of concrete masonry walls. The insulation should have some degree of mechanical attachment, even if the primary method of attachment is adhesion, to ensure long-term performance of the system. In addition, the insulation must be protected from weather and impact. Typically, this protection is provided by a cementitious coating, often fiber reinforced, but plywood or cementitious board is also used. Exterior insulation and finish systems (EIFS) may be used to provide both insulation and protection. The performance characteristics of walls insulated with rigid board insulation are summarized in Table 1.

The water penetration resistance of these wall systems is primarily dependent on the effectiveness of the finish system, especially at seams. Durability and impact resistance of the exterior of the wall are also dependent on the properties of the EIFS.

The fire rating of the masonry is not affected by the addition of exterior insulation, although flame spread has been cited as a concern with some EIFS systems. The use of an adequate thickness of noncombustible exterior coating
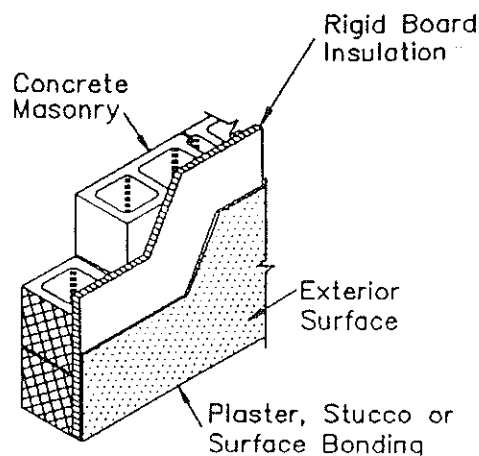

Figure 4   *Exterior insulation.*

combined with the noncombustible masonry to protect the insulation reduces these concerns about flame spread.

Acoustical performance is not significantly affected by EIFS systems. The EIFS does not substantially increase the weight of the wall or provide discontinuity of construction from the acoustical standpoint.

The structural performance of the masonry is not affected by the EIFS system. The masonry may be reinforced and grouted without interrupting the insulation. The continuous exterior insulation simply envelopes the masonry walls, minimizing the effect of thermal bridges. This places the mass inside the insulation layer and, if the masonry is left exposed, maximum heat storage is achieved.

MULTI-WYTHE WALLS

Multi-wythe masonry walls provide many design options. Composite walls (multi-wythe walls where the wythes are mortared together) may receive interior or exterior insulation strategies such as those for single-wythe walls. In addition, either or both wythes may receive insulation in the cores of the units.

Masonry cavity walls are designed with an air space, or cavity, between the two masonry wythes. With cavity wall systems, insulation is usually placed between the two

wythes of masonry. Rigid board, granular fill, or foam insulation may be used in the cavity. In addition, the masonry cores may be filled with granular fill or foam insulation.

Building codes (BOCA 1990; ICBO 1991; SBCCI 1991) require that the cavity be at least 2 inches wide, but typically the cavity is 2.75 inches (70 mm) and, without major structural considerations, may economically be increased to 4.5 inches (114 mm). This permits up to 4.5 inches (114 mm) of continuous granular fill insulation or 3.5 inches (89 mm) of rigid board insulation. Table 3 summarizes the performance characteristics of cavity walls with these insulations.

If the cavity is filled with a foamed-in-place insulation, the wall may not properly drain water. If granular fills are used, all weep holes should be covered on the interior with a screen to allow water to drain out but keep the granular fill in place. Granular loose-fill insulation provides excellent insulating values but tends to be more expensive for installation in a cavity (Means 1991).

The water penetration resistance of cavity walls with granular fills, or rigid board adhered to the back-up interior wythe, is exceptional when proper flashing and weep holes are incorporated.

Because the insulation is enclosed within two wythes of

TABLE 3 Cavity Walls Insulated Cavity (4" masonry, 8" masonry backup)		
Insulation Type	**Granular Loose-Fill**	**3" Rigid Board**
Resistivity of Insulation[a]	3.1 (0.15)	4.0 (0.21)
R-Value o Wall[b]	15.6 (2.75)	16.1 (2.84)
Heat Capacity[c]: Integral Insulation Exterior Insulation	14 (286) 8.9 (182)	13.6 (278) 8.5 (174)
STC[d]	52	52
Fire Rating (hours)	4	4
Installed cost of insulation (Means 1991): dollars/ft^2	$3.92	$2.01
Insulation installed per day, ft^2 (m^2) (Means 1991):	250 (23)	730 (68)
Other considerations:	• Cavity should be kept free of mortar droppings. • No additional protection required for the insulation. • Excellent weather resistance, fire rating, and acoustic performance.	

[a]Units are hr·ft^2·°F/Btu (m·K/W).
[b]Units are hr·ft^2·°F/Btu (m^2·K/W). Wall R-values were calculated using the isothermal planes calculation method, assuming a concrete density of 125 pcf (2002 kg/m^3).
[c]Units are Btu/ft^2·°F (kJ/m^2·K). Integral insulation value is calculated using the heat capacities of both wythes of masonry. Exterior insulation is calculated using only the heat capacity of the interior wythe of masonry.
[d]STC was calculated based on the wall weight in pounds per square foot, accounting for the weights of both wythes of masonry (NCMA 1990). In reality, the cavity and insulation will increase the STC, but, at this time, there is no calculation method available to estimate the amount of this increase (CDHS 1981).

masonry, excellent fire protection, durability, and impact resistance are provided. The acoustical properties of cavity walls are superb because of the mass of each wythe and the discontinuity of construction (CDHS 1981).

When the two wythes have similar heat capacities, the wall may be considered as an integrally insulated wall. However, by using only the heat capacity of the interior wythe, the wall may be considered as having exterior insulation. If this assumption is made, the actual performance of the wall will be better than predicted because of the exterior mass, which is not accounted for in the calculations. However, for use in simplified design tools and building codes such as CABO (1992), approximating the performance by only considering the thermal mass of the backup wythe is acceptable. For example, the cavity wall described in Table 3 has a heat capacity of 14 Btu/ft^2·°F (286 kJ/m^2·K) if both wythes of the masonry are included in the calculation. Since both wythes are included, the insulation strategy is integral. If we ignore the outer wythe and consider only the insulation and inner wythe, the insulation strategy is exterior, but the heat capacity decreases to 8.9 Btu/ft^2·°F (182 kJ/m^2·K). With the integral insulation strategy, the thermal mass credit is less, but this is traded off with a higher heat capacity than the exterior insulation strategy, so that the mass credit will be about the same for both strategies.

Below-Grade Applications

Below-grade masonry walls are typically single-wythe wall construction that can accommodate interior, integral, or exterior insulation. With walls that are completely, or primarily, below grade, thermal mass benefits are limited because of the nearly constant soil temperature. However, when exterior insulation is used, the masonry is effective at moderating interior temperatures and at shifting peak loads. The typical framing used with interior insulation strategies provides a place to run electric and plumbing lines, as well as a convenient method to hang drywall or other interior finish.

When using exterior or integral insulation strategies, the wall may be constructed of architectural units to provide a finished face on the interior. By using smooth molded units at the base of the wall, screeding the slab is facilitated and the space may be used to install an electric race as a molding strip. The remainder of the wall may be constructed of smooth, split-face, split-ribbed, ground face, scored, or other architectural concrete masonry units.

When insulation is installed on the exterior, the below-grade portions of the insulation only need to be held in place by adhesives because the backfill will provide support. The rigid board that extends above grade must be mechanically attached and protected. Special protection provisions are eliminated by placing the insulation in the cores of the concrete masonry. Polystyrene and fibrous glass rigid board insulation may also serve as a drainage board.

SUMMARY

Many factors are used in selecting proper building wall designs. Exterior walls are typically required to satisfy structural, durability, impact resistance, fire protection, acoustical, water penetration resistance and energy-efficiency requirements. This information is offered to aid designers and contractors in selecting appropriate insulation strategies for concrete masonry wall systems and economically satisfying other design requirements for building envelopes.

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