

National Concrete Masonry Association
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CONCRETE MASONRY BASEMENT WALL CONSTRUCTION

TEK 3-11

Construction (2001)

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INTRODUCTION

Basements allow a building owner to significantly increase usable living, working, or storage space at a relatively low cost. Old perceptions of basements have proven outdated by state-of-the-art waterproofing, improved drainage systems, and natural lighting features such as window wells. Other potential benefits of basements include room for expansion of usable space, increased resale value, and safe haven during storms.

Historically, plain (unreinforced) concrete masonry walls have been used to effectively resist soil loads. Currently, however, reinforced walls are becoming more popular as a way to use thinner walls to resist large backfill pressures. Regardless of whether the wall is plain or reinforced, successful performance of a basement wall relies on quality construction in accordance with the structural design and the project specifications.

MATERIALS

Concrete Masonry Units

Concrete masonry units should comply with *Standard Specification for Loadbearing Concrete Masonry Units*, ASTM C 90 (ref. 8). Specific colors and textures may be specified to provide a finished interior to the basement. Dry-wall can also be installed on furring strips, if desired. A rule of thumb for estimating the number of concrete masonry units to order is 113 units for every 100 ft² (9.3 m²) of wall area. This estimate assumes the use of 3/8 in. (9.5 mm) mortar joints.

Mortar

Mortar serves several important functions in a concrete masonry wall; it bonds the units together, seals joints against air and moisture penetration, and bonds to joint reinforcement, ties, and anchors so that all components perform as a structural element.

Mortar should comply with *Standard Specification for Mortar for Unit Masonry*, ASTM C 270 (ref. 9). In addi-

Table 1—Mortar Proportions by Volume (Ref. 12)

Mortar	Type	Proportions by volume (cementitious materials)								Aggregate measured in a damp, loose condition
		Portland cement or blended cement ^a	Masonry cement			Mortar cement			Hydrated lime or lime putty ^a	
			M	S	N	M	S	N		
Cement-lime	M	1	—	—	—	—	—	—	1/4	Not less than 2 1/4 and not more than 3 times the sum of the separate volumes of cementitious materials.
	S	1	—	—	—	—	—	—	over 1/4 to 1/2	
	N	1	—	—	—	—	—	—	over 1/2 to 1 1/4	
	O	1	—	—	—	—	—	—	over 1 1/4 to 2 1/2	
Mortar cement	M	1	—	—	—	—	—	1	—	
	M	—	—	—	—	1	—	—	—	
	S	1/2	—	—	—	—	—	1	—	
	S	—	—	—	—	—	1	—	—	
Masonry cement	N	—	—	—	—	—	—	1	—	
	M	1	—	—	1	—	—	—	—	
	M	—	1	—	—	—	—	—	—	
	S	1/2	—	—	1	—	—	—	—	
	S	—	—	1	—	—	—	—	—	
	N	—	—	—	1	—	—	—	—	
	O	—	—	—	1	—	—	—	—	

¹ When plastic cement is used in lieu of portland cement, hydrated lime or putty may be added, but not in excess of one tenth of the volume of cement.

tion, most building codes require the use of Type M or S mortar for construction of basement walls (refs. 2, 4, 5, 9, 13), because Type M and S mortars provide higher compressive strengths. Table 1 lists mortar proportions.

Typical concrete masonry construction uses about 8.5 ft³ (0.24 m³) of mortar for every 100 ft² (9.3 m²) of masonry wall area. This figure assumes 3/8 in. (9.5 mm) thick mortar joints, face shell mortar bedding, and a 10% allowance for waste.

Grout

In reinforced concrete masonry construction, grout is used to bond the reinforcement and the masonry together. Grout should conform to *Standard Specification for Grout for Masonry*, ASTM C 476 (ref. 10), with the proportions listed in Table 2. As an alternative to complying with the proportion requirements in Table 2, grout can be specified to have a minimum compressive strength of 2000 psi (13.8 MPa) at 28 days. Enough water should be added to the grout so that it will have a slump of 8 to 11 in. (203 to 279 mm). The high slump allows the grout to be fluid enough to flow around reinforcing bars and into small voids. This initially high water-to-cement ratio is reduced significantly as the masonry units absorb excess mix water. Thus, grout gains high strengths despite the initially high water-to-cement ratio.

Table 2—Grout Proportions by Volume (Ref. 10)

Type	Proportions by volume (cementitious materials)		Aggregate measured in a damp, loose condition	
	portland cement or blended cement	hydrated lime or lime putty	Fine	Coarse
Fine Grout	1	0 to 1/10	2/4 to 3 times the sum of the volumes of the cementitious materials	
Coarse Grout	1	0 to 1/10	2/4 to 3 times the sum of the volumes of cementitious materials	1 to 2 times the sum of the volumes of cementitious materials

CONSTRUCTION

Prior to laying the first course of masonry, the top of the footing must be cleaned of mud, dirt, ice or other materials which reduce the bond between the mortar and the footing. This can usually be accomplished using brushes or brooms, although excessive oil or dirt may require sand blasting.

Masons typically lay the corners of a basement first so that alignment is easily maintained. This also allows the mason to plan where cuts are necessary for window openings or to fit the building's plan.

To make up for surface irregularities in the footing, the first course of masonry is set on a mortar bed joint which can range from 1/4 to 3/4 in. (6.4 to 19 mm) in thickness. This initial bed joint should fully bed the first course of masonry units, although mortar should not excessively protrude into cells that will be grouted.

All other mortar joints should be approximately 3/8 in. (9.5 mm) thick and, except for partially grouted masonry, need only provide face shell bedding for the masonry units. In partially grouted construction, webs adjacent to the grouted cells are mortared to restrict grout from flowing into ungrouted cores. Head joints must be filled solidly for a thickness equal to a face shell thickness of the units.

Tooled concave joints provide the greatest resistance to water penetration. On the exterior face of the wall, mortar joints may be cut flush if parging coats are to be applied.

When joint reinforcement is used, it should be placed directly on the block with mortar placed over the reinforcement in the usual method. A mortar cover of at least 5/8 in. (15.9 mm) should be provided between the exterior face of the wall and the joint reinforcement. A mortar cover of 1/2 in. (12.7 mm) is needed on the interior face of the wall. For added safety against corrosion, hot dipped galvanized joint reinforcement is recommended.

See Figures 1-4 for construction details.

Reinforced Masonry

For reinforced masonry construction, the reinforcing bars must be properly located to be fully functional. In most cases, vertical bars are positioned towards the interior face of basement walls to provide the greatest resistance to soil pressures. Bar positioners at the top and bottom of the wall prevent the bars from moving out of position during grouting. A space of at least 1/2 in. (12.7 mm) for coarse grout and 1/4 in. (6.4 mm) for fine grout should be maintained between the bar and the face shell of the block so that grout can flow completely around the reinforcing bars.

As mix water is absorbed by the units, voids can form in the grout. Accordingly, grout must be puddled or consolidated after placement to eliminate these voids and to increase the bond between the grout and the masonry units. Most codes permit puddling of grout when it is placed in lifts less than about 12 in. (305 mm). Lifts over 12 inches (305 mm) should be mechanically consolidated and then reconsolidated after about 3 to 10 minutes.

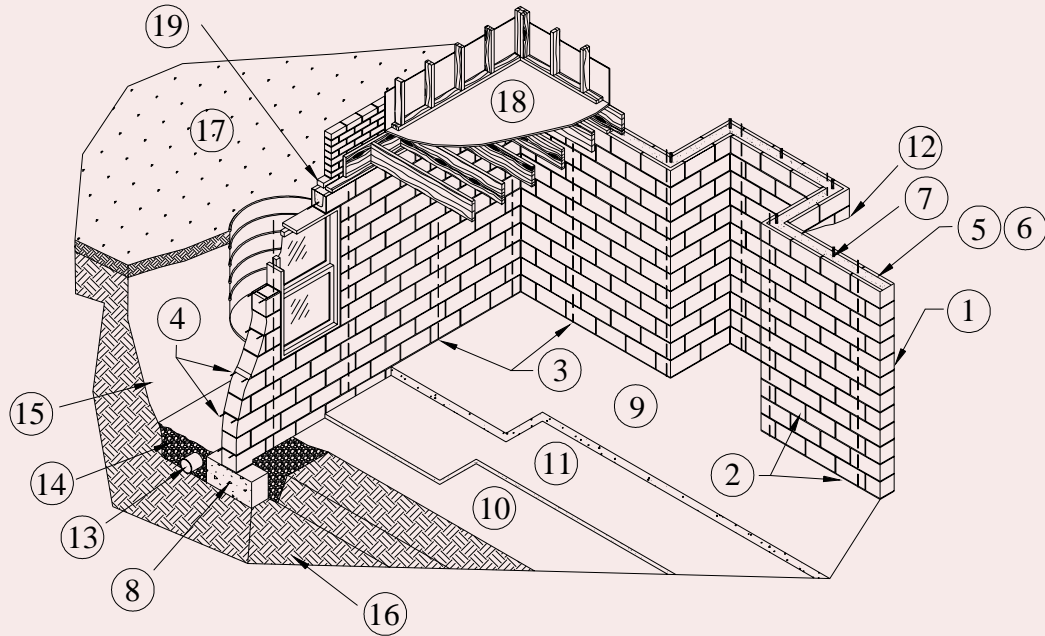
Surface Bonding

Another method of constructing concrete masonry walls is to dry stack units (without mortar) and then apply surface bonding mortar to both faces of the wall. The surface bonding mortar contains thousands of small glass fibers. When the mortar is applied properly to the required thickness, these fibers, along with the strength of the mortar itself, help produce walls of comparable strength to conventionally laid plain masonry walls. Surface bonded walls offer the benefits of excellent dampproof coatings on each face of the wall and ease of construction.

Dry-stacked walls should be laid in an initial full mortar bed to level the first course. Level coursing is maintained by using a rubbing stone to smooth small protrusions on the block surfaces and by inserting shims every two to four courses.

Water Penetration Resistance

Protecting below grade walls from water entry involves installation of a barrier to water and water vapor. An imper-



1. Concrete masonry units, typically 8-in. units. Larger sizes may be required in for some soil and backfill height conditions.
2. Mortar, generally Type S. Joints should be tooled for improved impermeability unless the exterior side is parged.
3. Vertical reinforcing bars, if required. Reinforcement should be placed adjacent to openings, in corners and at a maximum spacing determined from a structural analysis. Positioners hold the vertical bars in proper position.
4. Joint reinforcement or horizontal reinforcing bars to aid in control of shrinkage cracking and in Seismic Design Categories C, D, E, and F. See TEK 14-18 (ref. 7) for more information on seismic reinforcement requirements.
5. Grout of 2,000 psi (13.8 MPa) minimum compressive strength in cores containing reinforcement. Consolidate grout by puddling or vibration to reduce voids.
6. Solid grouted and reinforced top course to distribute loads from the walls above and increase soil gas and insect resistance.
7. Anchor bolts. Typically 7 in. (178 mm) long, 1/2 in. (12.7 mm) diameter anchor bolts are spaced no more than 4 ft (1.2 m) on center. Anchor bolts significantly increase earthquake and high wind resistance.
8. Concrete footing. Footings distribute loads to the supporting soil. Concrete should have a minimum strength of 2500 psi (17.2 MPa) and be at least 6 in. (152 mm) thick, although many designers prefer footings to be as thick as the wall thickness and twice as wide as the wall thickness. Incorporating two #4 bars (or larger) increases the ability to span weak spots.
9. Concrete slab, typically minimum 2500 psi (17.2 MPa), 4 in. (101 mm) thick. Contraction joint spacing should not exceed about 15 ft (4.6 m). Welded wire fabric located near the center of the slab increases strength and holds unplanned shrinkage cracks tightly together. Welded wire fabric should be cut at contraction joints.
10. Aggregate base. A 4 to 6 in. (102 to 152 mm) base of washed aggregate (3/4 to 1 1/2 in. (19 to 38 mm) diameter) distributes slab loads evenly to the underlying soil, provides a level, clean surface for slab placement, and allows for inclusion of a soil gas depressurization system.
11. Vapor retarder. Continuous or lapped sheets of 6 mil (152 mm) polyethylene, PVC or equivalent reduce rising dampness and block soil gas infiltration through the slab. Vapor retarders can be placed on top of the aggregate base to increase the effectiveness of the soil gas barrier system, or under the aggregate to reduce concrete placement and curing difficulties.
12. Waterproof or dampproof membrane. Dampproof where hydrostatic pressure will not occur. Where ground water levels are high, soil drainage is slow, or where radon gas levels are high, consideration of waterproof membranes such as rubberized asphalt, polymer-modified asphalt, butyl rubber and/or drainage boards should be considered.
13. Foundation drain. Perforated pipe collects and transports ground water away from the basement. Drains should be located below the top of the slab and should be sloped away from the building to natural drainage, a storm water sewer, or a sump.
14. Free draining backfill. At least 12 in. (305 mm) of washed gravel or other free draining backfill material should be placed around drains to facilitate drainage. Cover the top of the gravel with a filtering geotextile to prevent clogging.
15. Backfill. Backfill should be placed after wall has gained sufficient strength and is properly braced or supported.
16. Undisturbed soil. Soil beneath footings and slabs should be undisturbed or compacted.
17. Top of grade. Surrounding soil should slope away from building to drain water away from walls. The top 4 to 8 in. (102 to 203 mm) of soil should be of low permeability so that water is absorbed slowly into the soil.
18. Floor diaphragm. A floor diaphragm supports the tops of masonry walls and distributes loads from the superstructure to them.
19. Flashing. Flashing should be installed at the top of basement walls to prevent water from entering the wall.

Figure 1— Basement/Foundation Wall (Ref. 1)

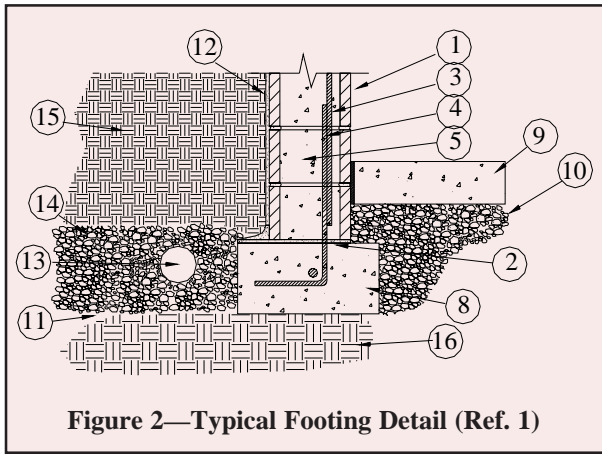


Figure 2—Typical Footing Detail (Ref. 1)

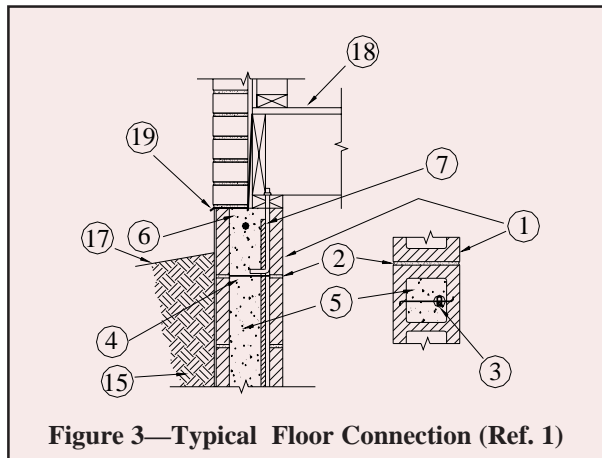


Figure 3—Typical Floor Connection (Ref. 1)

vious barrier on the exterior wall surface can prevent moisture entry. The barrier is part of a comprehensive system to prevent water penetration, which includes proper wall construction and the installation of drains, gutters, and proper grading.

Building codes (refs. 2, 4, 5, 9, 13) typically require that basement walls be dampproofed for conditions where hydrostatic pressure will not occur, and waterproofed where hydrostatic pressures may exist. Dampproofing is appropriate where groundwater drainage is good, for example where granular backfill and a subsoil drainage system are present. Hydrostatic pressure may exist due to a high water table, or due to poorly draining backfill, such as heavy clay soils. Materials used for waterproofing are generally elastic, allowing them to span small cracks and accommodate minor movements.

When choosing a waterproof or dampproof system, consideration should be given to the degree of resistance to hydrostatic head of water, absorption characteristics, elasticity, stability in moist soil, resistance to mildew and algae, impact or puncture resistance, and abrasion resistance. A complete discussion of waterproofing, dampproofing, and drainage systems is included in TEK 19-3A (ref. 6).

All dampproofing and waterproofing systems should be applied to walls that are clean and free from dirt, mud

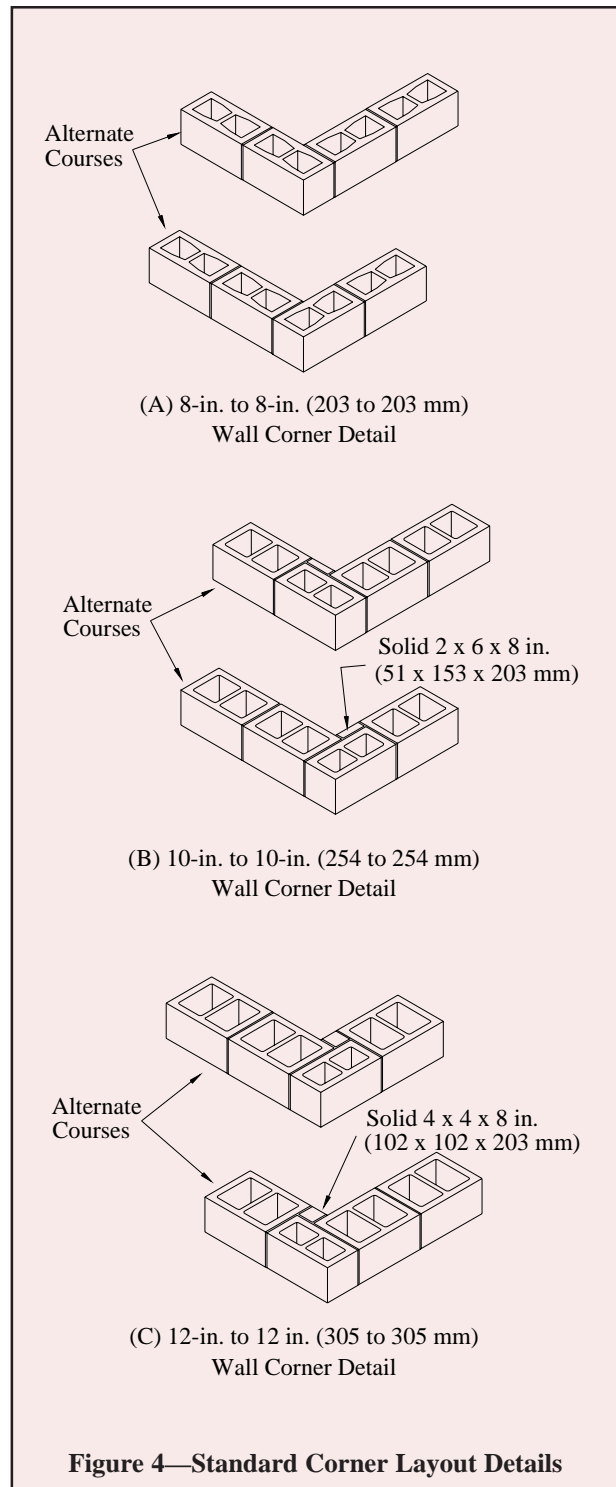


Figure 4—Standard Corner Layout Details

and other materials which may reduce bond between the coating and the concrete masonry wall.

Draining water away from basement walls significantly reduces the pressure the walls must resist and reduces the possibility of water infiltration into the basement if the waterproofing (or dampproofing) system fails. Perforated pipe has historically proven satisfactory when properly installed. When placed on the exterior side of basement walls, perforated pipes are usually laid in crushed stone to facilitate drainage. To prevent migration of fine soil into the drains, filter fabrics are often placed

over the gravel.

Drainage pipes can also be placed beneath the slab and connected into a sump. Pipes through the footing or the wall drain water from the exterior side of the basement wall.

The drainage and waterproofing systems should always be inspected prior to backfilling to ensure they are adequately placed. Any questionable workmanship or materials should be repaired at this stage since repairs are difficult and expensive after backfilling.

Backfilling

One of the most crucial aspects of basement construction is how and when to properly backfill. Walls should be properly braced or have the first floor in place prior to backfilling. Otherwise, a wall which is designed to be supported at the top may crack or even fail from the large soil pressures. Figure 5 shows one bracing scheme which has been widely used for residential basement walls. More substantial bracing may be required for high walls or large backfill pressures.

The backfill material should be free-draining soil without large stones, construction debris, organic materials, and frozen earth. Saturated soils, especially saturated clays, should generally not be used as backfill materials since wet materials significantly increase the hydrostatic pressure on the walls.

Backfill materials should be placed in several lifts and each layer should be compacted with small mechanical tampers. Care should be taken when placing the backfill materials to avoid damaging the drainage, waterproofing or exterior insulation systems. Sliding boulders and soil down steep slopes should thus be avoided since the high impact loads generated can damage not only the drainage and waterproofing systems but the wall as well. Likewise, heavy equipment should not be operated within about 3 feet (0.9 m) of any basement wall system.

The top 4 to 8 in. (102 to 203 mm) of backfill materials should be low permeability soil so rain water is absorbed into the backfill slowly. Grade should be sloped away from the basement at least 6 in. (152 mm) within 10 feet (3.1 m) of the building. If the ground naturally slopes toward the building, a shallow swale can be installed to redirect runoff.

Construction Tolerances

Specifications for Masonry Structures (ref. 8) specifies tolerances for concrete masonry construction. These tolerances were developed to avoid structurally impairing a wall because of improper placement.

1. Dimension of elements in cross section or elevation-1/4 in. (6.4 mm), +1/2 in. (12.7 mm)
2. Mortar joint thickness: bed.....±1/8 in. (3.2 mm)
head.....-1/4 in (6.4 mm), +3/8 in. (9.5 mm)
3. Elements

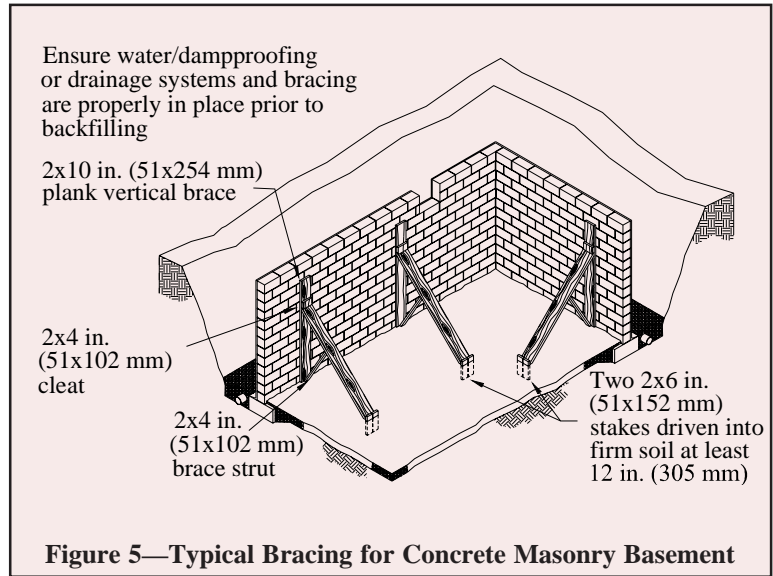


Figure 5—Typical Bracing for Concrete Masonry Basement

- a. Variation from level: bed joints..... ±1/4 in. (6.4 mm) in 10 ft (3.1 m), ±1/2 in. (12.7 mm) max
top surface of bearing walls..... ±1/4 in.(6.4 mm), +3/8 in.(9.5 mm), ±1/2 in.(12.7mm) max
- b. Variation from plumb.....±1/4 in. (6.4 mm) 10 ft (3.1 m)
.....±3/8 in. (9.5 mm) in 20 ft (6.1 m)
.....±1/2 in. (12.7 mm) maximum
- c. True to a line.....±1/4 in. (6.4 mm) in 10 ft (3.1 m)
.....±3/8 in. (9.5 mm) in 20 ft (6.1 m)
.....±1/2 in. (12.7 mm) maximum
- d. Alignment of columns and bearing walls (bottom versus top).....±1/2 in (12.7 mm)
4. Location of elements
 - a. Indicated in plan.....±1/2 in (12.7 mm) in 20 ft (6.1 m)
.....±3/4 in. (19.1 mm) maximum
 - b. Indicated in elevation
.....±1/4 in. (6.4 mm) in story height
.....±3/4 in. (19.1 mm) maximum

Insulation

The thermal performance of a masonry wall depends on its R-value as well as the thermal mass of the wall. R-value describes the ability to resist heat flow; higher R-values give better insulating performance. The R-value is determined by the size and type of masonry unit, type and amount of insulation, and finish materials. Depending on the particular site conditions and owner’s preference, insulation may be placed on the outside of block walls, in the cores of hollow units, or on the interior of the walls.

Thermal mass describes the ability of materials like concrete masonry to store heat. Masonry walls remain warm or cool long after the heat or air-conditioning has shut off, keeping the interior comfortable. Thermal mass is most effective when insulation is placed on the exterior or in the cores of the block, where the masonry is in direct contact with the interior conditioned air.

Exterior insulated masonry walls typically use rigid board insulation adhered to the soil side of the wall. The insulation requires a protective finish where it is exposed above grade to maintain durability, integrity, and effectiveness.

Concrete masonry cores may be insulated with molded polystyrene inserts, expanded perlite or vermiculite granular fills, or foamed-in-place insulation. Inserts may be placed in the cores of conventional masonry units, or they may be used in block specifically designed to provide higher R-values.

Interior insulation typically consists of insulation installed between furring strips, finished with gypsum wall board or panelling. The insulation may be fibrous batt, rigid board, or fibrous blown-in insulation.

DESIGN FEATURES

Interior Finishes

Split faced, scored, burnished, and fluted block give

owners and designers added options to standard block surfaces. Colored units can be used in the entire wall or in sections to achieve specific patterns.

Although construction with staggered vertical mortar joints (running bond) is standard for basement construction, the appearance of continuous vertical mortar joints (stacked bond pattern) can be achieved by using of scored units or reinforced masonry construction.

Natural Lighting

Because of the modular nature of concrete masonry, windows and window wells of a variety of shapes and sizes can be easily accommodated, giving basements warm, natural lighting. For additional protection and privacy, glass blocks can be incorporated in lieu of traditional glass windows.

REFERENCES

1. *Basement Manual-Design and Construction Using Concrete Masonry*, TR-68A, National Concrete Masonry Association, 2001.
2. *BOCA National Building Code*. Country Club Hills, IL: Building Officials and Code Administrators International, Inc. (BOCA), 1999.
3. *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.
4. *International Residential Code*. Falls Church, VA: International Code Council, 2000.
5. *International Building Code*. Falls Church, VA: International Code Council, 2000.
6. *Preventing Water Penetration in Below-Grade Concrete Masonry Walls*, TEK 19-3A. National Concrete Masonry Association, 2001.
7. *Seismic Design Provisions for Masonry Structures*, TEK 14-18, National Concrete Masonry Association, 1996.
8. *Specifications for Masonry Structures*, ACI 530.1-02/ASCE 6-99/TMS 602-02. Reported by the Masonry Standards Joint Committee, 2002.
9. *Standard Building Code*. Birmingham, AL: Southern Building Code Congress International, Inc. (SBCCI), 1999.
10. *Standard Specification for Grout for Masonry*, ASTM C 476-01. American Society for Testing and Materials, 2001.
11. *Standard Specification for Load-Bearing Concrete Masonry Units*, ASTM C 90-01. American Society for Testing and Materials, 2001.
12. *Standard Specification for Mortar for Unit Masonry*, ASTM C 270-00. American Society for Testing and Materials, 2000.
13. *Uniform Building Code*. Whittier, CA: International Conference of Building Officials (ICBO), 1997.