



MASONRY

INFORMATION

Building Weather-Resistant Masonry Walls

In order to be competitive in today's marketplace, a wall system must be easy to build; strong enough to support all imposed loads, including wind loads and self weight; able to withstand severe weather; durable; and cost effective. It must provide good thermal and sound insulation plus fire protection, and require only minimum maintenance. Masonry walls satisfy all of these requirements.

Masonry walls that leak when subjected to driving rains, however, are a source of irritation to owners, tenants, designers, and builders. The following contains a number of design and workmanship details that are essential to preventing moisture problems in masonry walls.

Why Walls Leak

Leaky walls are not confined to any one type of masonry construction or any single cause. **The prevention of leaky walls must begin with design of the building, follow through with selection of materials and supervision of workmanship, and continue with maintenance of the structure after its completion.** All involved with each of these facets of the construction process should understand how certain key factors under their control affect the weather resistance of the finished masonry wall.

Water rarely passes through masonry units or mortar. These materials are generally too dense for water to penetrate quickly. If water enters the wall, it is typically through fine capillary passages at the masonry unit-mortar interface, through unfilled mortar joints, through cracks caused by building movements, or through cracks between masonry walls and adjoining building segments (roofs, floor, windows, doors, etc.). Problems also can occur because of condensation within the wall resulting from air leakage and differences in the temperature and humidity of outside air versus interior conditioned air.

The designer must evaluate each architectural expression and its influence on the ability of the masonry to resist water infiltration including: possible sources of exposure to moisture, suitability of the various masonry wall types being considered for the application, and integration of the masonry with other building components. Details must be properly incorporated into the design to prevent cracking, limit the entry of water into the wall, and direct moisture away from the building interior. Good design should also include evaluation of proposed materials to insure compatibility of performance in the intended application.

Improper detailing frequently results in water leakage problems in masonry buildings. Two closely related contributors to leaks are time schedules and cost limits imposed on construction. Details included in the design must

be faithfully installed. The caliber of workmanship necessary to ensure maximum resistance to rain penetration must not be sacrificed for speed. Good design and materials cannot compensate for careless installation.

Wall Types

Both solid and cavity walls consist of brick or other masonry facing units attached to a backup wall, usually of concrete masonry units. In a solid wall, the vertical space between the wythes is about 3/4 in. (19 mm) wide and should be filled solidly with mortar. In a cavity wall, the outer and inner wythes should be separated by an unfilled vertical space 2 in. (50 mm) wide. This space may be enlarged to accommodate insulation. Although solid and cavity walls may look alike externally, they behave differently in service.

Other wall types such as veneer, single wythe, solid grouted, and reinforced masonry are not specifically discussed here, although the information set forth in this publication is applicable to other wall types as well.

Solid Masonry Walls. Solid masonry can be rainwater resistant if the masonry units and mortar are compatible, the mortar joints are completely filled, and the top of the wall is covered with a properly flashed parapet and coping or an overhanging roof.

The designer often has very little information on mortar and units with which to evaluate compatibility. Extensive field testing of masonry assemblies to establish compatibility is not practical from either a cost or time standpoint on most projects. However, the project specifications should require conformance of units and mortar to appropriate standards of the American Society for Testing and Materials (ASTM) or the Canadian Standards Association (CSA). The specifier should be certain that the weathering durability of the materials selected is appropriate for the climate and exposure. Finally, the specifier should avoid selecting high-strength/low-water retentive mortars in combination with highly absorptive units. A good rule of thumb is to never select a higher strength mortar than required by structural and durability considerations.

Solid masonry walls will not be weathertight unless all of the mortar joints—including bed joints, head joints, and the collar joint—are completely filled. Wind pressure and gravity will also carry water into or through walls when the mortar laid in bed joints is too heavily furrowed with the trowel and when line-pin holes remain unfilled.

Well designed and skillfully constructed, double-wythe, solid masonry walls provide serviceable weather-resistant walls.

Cavity Walls. Although leakproof solid walls can be constructed, many designers and builders choose cavity walls, which include extra protection against leakage. Any water that penetrates the face wythe of a cavity wall runs down the inside surface of the face wythe, is diverted by flashing at shelf angles and ledges, and flows back to the outside through weepholes. Defects in the flashing and obstructions in the weepholes and cavity, such as mortar droppings, will defeat the purpose of cavity walls.

Air Leakage

Air moving in and out through cracks and openings can carry moisture through masonry walls. In high-rise buildings, air leakage is aggravated by the “stack effect”—inward (at the bottom) and outward (at the top) movement of air due to pressure differences generated by temperature and density variance between inside and outside air.

Patterns of efflorescence or dampness seen on the masonry near the tops of buildings at certain times of the year are evidence of the outward flow of air. A crack between the masonry wall and a column, slab, or crosswall is an obvious path for air leakage, as well as where window frames, door frames, and cuts penetrate the wall. A joint sealant can stop this leakage effectively.

A continuous vapor barrier installed on the warm side of the wall can prevent the accumulation of a damaging level of moisture in the masonry units or the cavity.

Dimensional Changes

The direct force of the wind is transmitted to the structural frame of a building by the masonry walls. Unit metal ties and continuous ties (joint reinforcement) specified in codes and standards should be adequate to transmit forces from the outer wythe to the backup wall, which in turn is anchored to the frame.

Dimensional changes are produced in masonry walls by variations in temperature, time exposed to weathering, and changes in moisture content. Different materials will undergo different dimensional changes under the same conditions. For example, brick units undergo a slight but irreversible expansion in-place as they absorb moisture, while in-place concrete masonry units undergo a partially reversible shrinkage as they dry. Expansion and control joints must be used to accommodate such movement without development of cracks in the masonry. Differential movement between masonry wythes and the supporting structural frame must be accommodated by proper location and installation of movement joints. Each component should move independently without damage to mortar joints or masonry units. Advice on designing and constructing such joints can be found in the *Concrete Masonry Handbook*, and in *Building Movements and Joints*, Portland Cement Association publications EB008M and EB086B, respectively.

Flashing

Flashing must be placed to guide water away from the interior of the building. Flashing is required at the bottom of all cavity spaces, over shelf angles, at foundation level, at the intersection of walls with roof decks and balcony slabs, at sills and lintels, under copings and off sets, and at parapets. All flashing laps must be sealed and the ends of flashing over a lintel must be turned up to confine water.

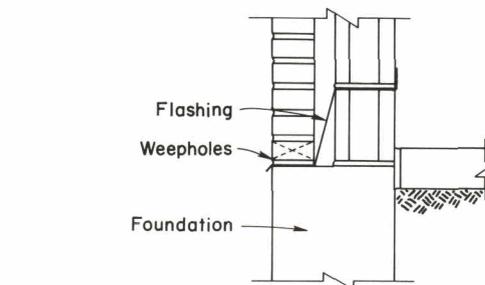
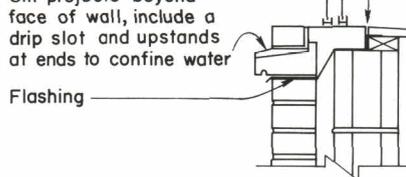
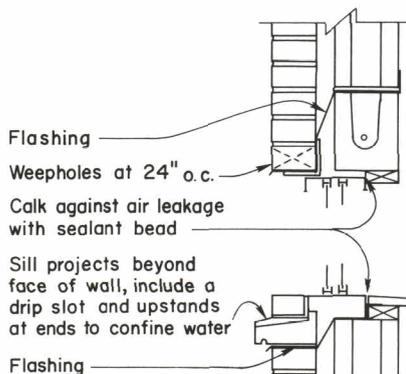
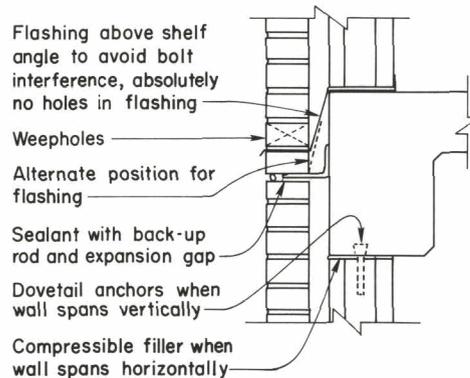
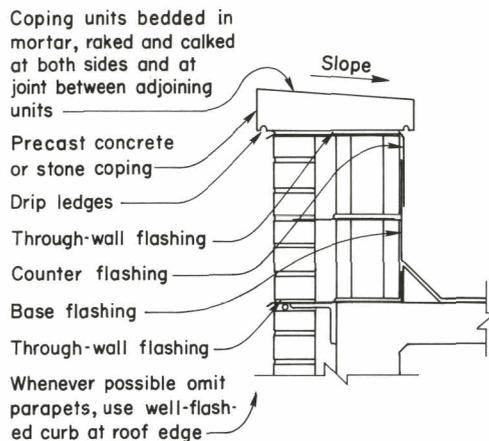


Fig. 1. Cavity wall on concrete frame showing details at foundation, window, spandrel beam, and roof. (Insulation, vapor barrier, air barrier, and interior finish are not shown.) Drawings are schematic, and illustrate factors affecting wall performance.

Parapets should be flashed through the wall just above the roof level and under the coping. Flashing should be continuous throughout the protected area and should be lapped and sealed at joints. Metal flashing requires slip joints at regular intervals to allow for expansion and contraction.

Satisfactory flashing materials must be impervious to water, durable, easily shaped, corrosion resistant, ductile at cold temperatures, dimensionally stable, and resistant to tears, or punctures. Stainless steel and copper perform well but are difficult to install. Plastics are easy to install as they are flexible and fairly tough. However, plastics often deteriorate when exposed to ultraviolet radiation and some have deteriorated in service even when protected from direct sunlight. Some combination flashing materials have been developed that provide the flexibility required for simple installation and the desired durability. Examples of combination flashing materials include rubberized asphalt fiber reinforced flashing, bonded fabric and copper sheet flashing, or metal foil coated with plastic and fiber reinforced.

Coping, caps, and sills should have slopes for drainage and overhangs with drip slots. Gutters and drains, a common source of trouble, should have ample capacity to carry away the heaviest rains without overflowing or leaking.

Storage of Materials

Stored masonry units should be isolated from ground moisture on pallets or on a clean coarse aggregate base and covered to protect from dirt, rain or snow.

Cement for mortar must be protected from moisture and contamination. Place bags of cement on pallets to avoid contact with ground moisture, and protect the bags with waterproofing covers to shed rainwater and snow.

Aggregate (sand) is also sensitive to moisture - very dry sand will absorb moisture and increase in volume (bulking). ASTM and CSA specifications for mortar are based on the assumption that the sand will be proportioned by volume and that it will be in a damp loose condition. The use of sand that is either too wet or too dry will affect the actual proportioning of the mortar. Sand, therefore, also should be protected against the weather at all times to maintain a uniform moisture content.

Mortar

Although ready mixed mortar or dry mixed mortar materials delivered to the job either packaged or in bulk silos are now available, most masonry mortar is mixed at the jobsite. Following are suggestions for proper batching, mixing, and retempering of mortar materials mixed at the jobsite.

Batching. The ideal way to batch mortar is by weight, but volume measurement remains the most practical method. Cement should be added by the bag. Sand is often batched with a shovel, but the use of a suitably sized volumetric container or gauge box is recommended. The size of the box (usually 1 cu ft) should be compatible with the volume of the batch of mortar to be prepared. It can be used to check the shovel requirements or positioned to empty directly into the mixer.

Water should be added to provide the optimum workability to the mortar mix. The amount required is best judged by an experienced mason using the materials at the jobsite.

Mixing. Start by putting about three-fourths of the required water into the mixer, then one-half the sand, followed by all of the cementitious materials. Mix these briefly, then add the remainder of the sand and water. Continue mixing until all the ingredients have been thoroughly mixed—for 3 to 5 minutes.

Ideally, mortar should be mixed for 3 to 5 minutes before being discharged, practice at the jobsite may be very different. The number of batches made and the average time for which each is mixed depends upon the mason's demand for mortar, the type of work, the weather, etc. Thus, mixing times of less than 3 minutes or in excess of 5 minutes can become commonplace. This practice leads to lack of consistency between batches and reduced mortar plasticity. Mixing times should be regulated as much as possible.

Retempering. Mortars that have stiffened by evaporation of moisture—not by advanced hydration—should be retempered to satisfactory workability by adding water. The extra water, which the mason adds, will result in some slight reduction in compressive strength. However, the improved workability will impart better bond.

IRA of Units

Absorptive clay masonry units may require wetting prior to use to achieve optimum bond. ASTM C216 recommends that units having an initial rate of absorption of 30 g/min·30 sq in. (30g/min·194 sq cm) be well wetted prior to laying. In general, if the mason encounters difficulty in achieving a proper tooled joint, wetting of the clay units to lower initial rate of absorption should be considered.

Concrete masonry units should never be wetted before use.

Importance of Workmanship

The importance of workmanship and proper construction practices cannot be overstated. Masons should:

- Use techniques that minimize any movement of the masonry unit after it has been placed in contact with the fresh mortar.
- Avoid spreading the bed mortar too far in advance of laying the next course of units.
- Carefully and completely fill head joints with mortar.
- Properly install all flashing with careful attention to forming corners and end dams.
- Keep cavities free of mortar droppings and other construction debris.
- Assure that expansion joints are free of mortar or other non-compressible materials.
- Install functional control joints where indicated.
- Carefully install all wall ties and anchors.
- Protect newly constructed masonry against rapid loss of moisture.
- Cover the top of newly completed masonry walls at the end of each working day.
- Use appropriate hot and cold weather construction procedures.
- Exercise care during construction to minimize required cleaning of masonry.
- Use approved procedures to clean masonry walls.

The watch words are "skill" and "care". Skilled masons that are careful craftsmen are key to successful installation

of masonry. It is often difficult for the designer or owner to specify or evaluate the quality of workmanship since many of the factors involved are not easily quantified. Pre-qualifying workmanship by evaluating mock-up panels that utilize required construction materials, incorporate required construction details, and use proposed cleaning procedures followed by inspection during construction is the best way to control the level of workmanship on a project. Such mock-up panels assure that all involved understand what is expected by the designer and owner and provide the specifier with some measure of the capability of the masonry contractor. These panels should be retained for reference throughout the construction process and until the job is satisfactorily completed.

Tooling Face Joints

Rain resistance is improved when joints are tooled to a concave or V-shaped profile. Tooling the joint to produce these profiles compacts the mortar against the units and produces a dense mortar joint surface. Flush, struck, raked, or extruded joints, which intercept water running down the wall, are not compacted and are not recommended for rain-exposed surfaces.

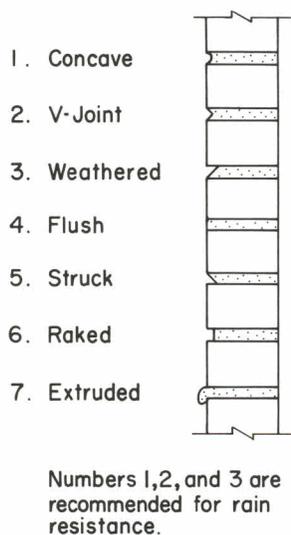


Fig. 2. Types of mortar joints.

Surface Coatings

ASTM and CSA specifications for concrete brick and block do not specify water permeability, but they do note that protective coatings may be required to prevent water penetration. Clear coatings do not contain enough solids for waterproofing and thus are classed as water repellants.

For extra protection, the application of two coats of portland cement paint to concrete masonry walls is effective for up to 8 to 10 years. The application of a portland cement plaster (stucco) may be the most economical and satisfactory method of improving the weather-tightness of an exterior masonry wall, and is recommended treatment for leaky walls when repointing and exterior wall treatment costs appear excessive.

Related Publications

Readers of this report may also be interested in the following publications available for purchase from the Portland Cement Association. A complete listing of PCA technical publications, motion pictures, videotapes, slide sets, and computer programs is given in the free catalog MS254G. To order, write or call Order Processing, Portland Cement Association, 5420 Old Orchard Road, Skokie, IL 60077-1083. Phone 708/966-6200, ext. 564.

Building Movements and Joints, EB086B
Concrete Masonry Handbook, EB008M
Masonry Cement Mortars, IS181M
Mortars for Masonry Walls, IS040M
Water Penetration Tests of Masonry Walls, IS219M
Portland Cement Plaster (Stucco) Manual, EB049M
Recommended Practices for Laying Concrete Block, PA043M
Thermal Performance of Masonry Walls, RD071M
SpecData: Masonry Cement, IS238M
Masonry Cement: Beauty to Last a Lifetime, PA163M
Masonry Cement Mortars - A Laboratory Investigation, RD095T
Air Content and Water Penetration of Masonry Walls, IS191M
Selecting and Specifying Mortar and Grout for Unit Masonry, IS275M
Trowel Tips: Efflorescence, IS239M
Trowel Tips: Tuckpointing, IS240M
Trowel Tips: Mortar Sand, IS241M

This publication is intended SOLELY for use by PROFESSIONAL PERSONNEL who are competent to evaluate the significance and limitations of the information provided herein, and who will accept total responsibility for the application of this information. The Portland Cement Association DISCLAIMS any and all RESPONSIBILITY and LIABILITY for the accuracy of and the application of the information contained in this publication to the full extent permitted by law.

CAUTION: Contact with wet (unhardened) concrete, mortar, cement, or cement mixtures can cause SKIN IRRITATION, SEVERE CHEMICAL BURNS, or SERIOUS EYE DAMAGE. Wear waterproof gloves, a long-sleeved shirt, full-length trousers, and proper eye protection when working with these materials. If you have to stand in wet concrete, use waterproof boots that are high enough to keep concrete from flowing into them. Wash wet concrete, mortar, cement, or cement mixtures from your skin immediately after contact. Indirect contact through clothing can be as serious as direct contact, so promptly rinse out wet concrete, mortar, cement, or cement mixtures from clothing. Seek immediate medical attention if you have persistent or severe discomfort.

Portland Cement Association 5420 Old Orchard Road, Skokie, Illinois 60077-1083



An organization of cement manufacturers to improve and extend the uses of portland cement and concrete through market development, engineering, research, education, and public affairs work.