MASONRY DESIGN - OZEWIEKI

MASONRY ELEMENTS MUST BE DESIGNED TO RESIST THE FOLLOWING:

I. LOADS
   A. DEAD
   B. LIVE
      1. SNOW
      2. WIND
      3. FLOOR LIVE LOADS
   D. EARTH
   E. SEISMIC
   F. HYDRAULIC
      1. ROOF PONDING

II. THERMAL
    A. THERMAL EXPANSION
    B. R-RATING
    C. FIRE RATING

III. MOISTURE
    A. SHRINKAGE - CMU
    B. EXPANSION - BRICK
    C. RAIN PENETRATION

MASONRY ELEMENTS ARE DESIGNED IN ACCORDANCE WITH THE FOLLOWING CODES:

1. OHIO BUILDING CODE (OBC)
2. ACI 530, ASCE 5, TMS 402
3. INTERNATIONAL BUILDING CODE (IBC)
4. ASCE 7 - MINIMUM DESIGN LOADS

NOTE THAT THERE ARE THREE (3) ACTIVE BUILDING CODES IN THE UNITED STATES:

1. BOCA - MIDWEST, NORTHEAST
2. UBC - WEST
3. SBC - SOUTHEAST

THE OBC IS A BOCA CODE. HOWEVER, IN THE NEAR FUTURE ALL THREE BUILDING CODES WILL EVOLVE INTO THE IBC, WHICH IS MORE LIKE THE UBC.

THE UBC HAS MORE STRINGENT DESIGN REQUIREMENTS RELATIVE TO SEISMIC LOADING. IN ADDITION, THE UBC PERMITS THE USE OF LIMIT STATE DESIGN, CURRENTLY THE OABC (BY WAY OF ACI 530) DOES NOT.
Masonry Elements are designed and manufactured in accordance with the following codes:

1. Clay Units
   - ASTM C 62
   - ASTM C 216
   - ASTM C 652

2. Concrete Masonry
   - ASTM C 55
   - ASTM C 90

3. Joint Reinforcement
   - ASTM A 185
   - ASTM A 492

4. Steel Reinforcement
   - ASTM A 615 (Rebar)
   - ASTM A 421 (Prestressed Wire)
   - ASTM A 416 (Prestressed Strand)
   - ASTM A 722 (Prestressed Bar)

5. Grout
   - ASTM C 476 (Mix Design)
   - ASTM C 143 (Slump Test)

6. Mortar

Masonry Organizations

1. American Concrete Institute (ACI)
2. The Masonry Society (TMS)
3. National Concrete Masonry Association (NCMA)
4. Brick Institute of America (BIA)
THE GENESIS OF ACI 530

DEVELOPMENT OF ACI 530 STARTED IN 1978. IT WAS AN EFFORT TO UNIFY VARIOUS STANDARDS THAT WERE AVAILABLE AT THE TIME.

ACI AND ASCE AGREED TO JOINTLY CREATE A STANDARD WITH INPUT FROM THE MASONRY INDUSTRY AND SUPPORTING ASSOCIATIONS, E.G., THE MASONRY SOCIETY.

IN 1989 AFTER 11 YEARS OF DEVELOPMENT, THE FIRST VERSION WAS PRESENTED AS

ACI 530-89 / ASCE 5-89

A COMPANION DOCUMENT REFERRED TO AS THE "SPECIFICATIONS FOR MASONRY STRUCTURES" REFERRED TO AS:

ACI 530.1-89 / ASCE 6-89

WAS ALSO PUBLISHED. SUBSEQUENT REVISIONS TO THESE DOCUMENTS APPEARED IN

- 1992
- 1996

THE 1996 EDITION WAS ACCEPTED BY THE "STANDARD BUILDING CODE" (SBC) AND "THE NATIONAL BUILDING CODE" (BONCA). THIS VERSION CONTAINED CHAPTERS ON

1. SEISMIC DESIGN

2. GRASS BLOCK

3. VENEERS


THE 1999 CODE REPRESENTS THE MOST SIGNIFICANT CHANGE TO THE ACI 530 CODE FROM AN ENGINEER'S PERSPECTIVE, FOR THE FIRST TIME THE CODE. THIS CODE RECOGNIZES TWO DESIGN FORMATS, I.E., ALLOWABLE STRESS DESIGN (ASD) AND THE LIMIT STATES DESIGN (LRFD), THE DETAILS FOR ULTIMATE STRENGTH DESIGN DID NOT APPEAR UNTIL THE 2002 CODE. THIS CODE HAD NOT CHANGED SIGNIFICANTLY.
Relation Between Code and Specification

- **Code:**
  - Design provisions are given in Chapters 1-7 and Appendix A
  - Sections 1.2.4 and 1.14 require a QA program in accordance with the specification
  - Section 1.4 invokes the specification by reference.

- **Specification:**
  - Verify compliance with specified $f_m'$
  - Comply with required level of quality assurance
  - Comply with specified products and execution
Role of $f_m'$

- Concrete:
  - Designer states assumed value of $f_c'$
  - Compliance is verified by compression tests on cylinders cast in the field and cured under ideal conditions

- Masonry
  - Designer states assumed value of $f_m'$
  - Compliance is verified by “unit strength method” or by “prism test method”
BASIC TERMS AND DEFINITIONS

THE POSITIONS OF MASONRY UNITS WITHIN A WYTHE ARE GIVEN IN THE FOLLOWING FIGURE

- Stretcher
- Header
- Soldier
- Shiner
- Rowlock
- Sailor

THE FOLLOWING FIGURE DEPICTS TERMS APPLIED TO VARIOUS PARTS OF A MASONRY WALL.

- Wythe
- Stretcher
- Course
- Rowlock header
- Rowlock stretcher
- Header
- Soldier

ALTHOUGH BRICK UNITS ARE USED IN THE FIGURES ABOVE THE SAME TERMS CAN BE APPLIED TO CONCRETE MASONRY UNITS (CMU).
There are three types of mortar joints:

1. Bed joint
2. Head joint
3. Collar joints

These are depicted in the following figure:

As can be seen in the figure below, there are numerous ways to lay masonry units:

- Running bond (a)
- \( \frac{1}{2} \) Running bond (b)
- 6th Course headers Common bond (c)
- 6th Course Flemish headers Common bond (d)
- Dutch corner Flemish bond (e)
- English corner English corner English corner Dutch corner (f)
- Stack bond (g)
- English corner Dutch corner (h)
BOND STRETCH TESTS have established that the strongest bond pattern is the running bond. This pattern is used predominantly throughout Northern steel structures.

1. Running Bond

2. Other Types of Bonding

The definition of running bond is best presented in the following figure.
**Absorption** — The increase in weight of a porous solid body resulting from the penetration of a liquid into its permeable pores usually measured as a percentage of dry weight or in pounds per cubic foot.

**Admixture** — A material other than water, aggregates, and hydraulic cement, used as an ingredient of concrete, mortar, or grout and added to the batch immediately before or during its mixing.

**Aggregate** — Granular material such as natural sand, manufactured sand, expanded clay, shale or slate, pumice, volcanic scoria, bituminous or anthracite clinders, gravel, crushed gravel, crushed stone, lightweight aggregate such as magnetite or limenite, and air-cooled or expanded blast-furnace slag, which when bound together into a conglomerate mass by a matrix forms concrete, mortar, or grout.

**ASHRAE** — American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

**ASTM** — American Society for Testing and Materials.

**Bed Joint** — The horizontal layer of mortar on or in which a masonry unit is laid; may cover entire masonry unit or face shell only.

**Block, concrete** — A hollow or solid unit consisting of Portland cement and suitable aggregates combined with water. Other materials such as lime, fly ash, air-entraining agent, or other admixtures may be permitted.

**Bond** — Adhesion and grip of concrete, mortar, or grout to reinforcement or to other surfaces against which it is placed; the arrangement of units in masonry so that vertical joints are discontinuous; the pattern formed by the exposed faces of the units in masonry construction.

**Brick, concrete** — A solid unit having a rectangular prismatic shape usually not larger than 4x4x12 in. made from Portland cement and suitable aggregates, with or without the inclusion of other materials.

**Bullnose block** — A unit having one or more rounded exterior corners.

**Cavity wall** — A wall built of two or more wythes of masonry units separated by a continuous air space (with or without intervening materials) and in which the wythes are securely tied together with rigid corrosion resistant metal ties.

**Cleanout** — An opening in the first course of masonry for cleaning mortar droppings prior to grout placement in grouted masonry. Required in high lift grouting.

**Collar Joint** — The vertical longitudinal joint between wythes of masonry.

**Composite wall** — A multiple wythe wall in which at least one of the wythes is dissimilar to the other wythes with respect to type or grade of units or mortar.

**Concrete masonry unit, hollow** — A unit whose net cross-sectional area in any plane parallel to the bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane.

**Concrete masonry unit, solid** — A unit whose net cross-sectional area in every plane parallel to the bearing surface is 75 percent or more of its gross cross-sectional area measured in the same plane.

**Control Joint** — A continuous unbonded masonry joint to regulate the location and amount of separation resulting from the dimensional change of different parts of a structure so as to avoid the development of excessively high stresses.

**Customized masonry** — Architectural masonry units having textured or sculptured surfaces. Methods used to obtain different surface textures include splitting, grinding, forming vertical striations, and causing the units to "slump." Sculpture faces are obtained by forming projecting ribs or flutes, either rounded or angular, as well as vertical and horizontal scoring, recesses, and curved faces.

**Damp-proofing** — Prevention of moisture penetration due to capillary action by the addition of one or more coatings of a compound that is impervious to water.

**Expansion Joint** — A separation between adjoining parts of a masonry structure which is provided to allow small relative movements such as those caused by thermal changes, to occur without one part affecting the adjacent part.

**Face shell** — The side wall of a hollow concrete masonry unit generally between 3/4 and 1-1/2 in. thick.

**Flashing** — A thin impervious material placed in mortar joints and through air spaces in masonry to prevent water penetration and/or provide water drainage.

**Grout** — Mixture of cementitious material and aggregate to which sufficient water is added to produce desired placing consisting without segregation of the constituents; the hardened equivalent of such mixtures.

**Head Joint** — The vertical mortar joint between ends of masonry units; sometimes called the cross joint.

**Moisture content** — The amount of water contained at the time of sampling expressed as a percentage of the total absorption.

**Parapet Wall** — That part of a wall that extends above the roof level.

**Parging** — The process of applying a coat or cement mortar to the back of the facing material, the face of the backing material, the face of rough masonry, and the earth side of foundation and basement walls (sometimes referred to as pargeting).

**Pilaster** — An integral portion of the wall which projects on one or both sides and acts as a vertical beam, a column, an architectural feature or any combination thereof.

**Prism** — A small masonry test assemblage made with masonry units, mortar, and sometimes grout. Primarily used to predict the strength of full scale masonry members.

**Shrinkage** — Volume change due to loss of moisture or decrease in temperature.

**Single wythe wall** — A wall of only one masonry unit in thickness.

**Slenderness ratio** — The ratio of effective length or height of a wall or column to effective thickness, used as a means of assessing the stability of a masonry wall or column.

**Veneer** — A masonry facing which is attached to the backup but not so bonded as to act with it under load.

**Waterproofing** — Prevention of moisture flow through masonry.

**Web** — The cross wall connecting the face shells of a hollow concrete masonry unit.

**Weep hole** — Suitably formed holes or openings placed in the masonry to permit the escape of moisture from the interior of the wall. In retaining walls, a hole through the wall to permit water to flow through the wall to prevent build up of pressure.

**Notation**

\[ f_{cm} = \text{specified compressive strength of masonry expressed as force per unit of net cross-sectional area, psi.} \]
BEAM AND LINTEL CONSTRUCTION

MASONRY BEAMS AND LINTELS CAN BE REINFORCED AS FOLLOWS

(a) Beams of Solid Units

(b) Beams of Hollow Units
TYPES OF MASONRY WALL CONSTRUCTION

Consider the following types of single wythe walls

(a) Running Bond (half bond)
(b) Grouted Wall Running Bond
(c) Third Running Bond
(d) Screen Wall Stack Pattern
(e) Screen Wall Open Bond
(f) Surface Coated Wall

Note that a wythe is a continuous vertical section of a wall, one masonry unit thick.

Hollow masonry walls are built of hollow or combined hollow and solid masonry units laid in face shell mortar bedding. All horizontal and vertical edges of the face shell are mortared together.

Hollow masonry walls are built in any thickness and in single or multiface wythes.
Next consider composite walls. These walls are constructed out of two or more wythes interconnected by header units, steel ties, or grout collars.

(a) Common Bond    (b) Flemish Bond    (c) Metal Ties

(d) Grouted Cavity  (e) Composite Wall  (f) Composite Wall
                   (Metal Ties)               (Headers)

Multiple wythe walls usually consist of two wythes, i.e.,

- FACING
- BACKUP
Previous two examples were not examples of reinforced masonry. Typically, dowel bond ties by themselves do not constitute "reinforcement." The following figure depicts several examples of reinforced masonry walls.

(a) Reinforcement in Joints  (b) Reinforcement in Cavity

(c) Reinforcement in Pockets  (d) Reinforcement in Hollow Units

Note that masonry units have more than adequate load carrying capacity in compression. Just as in concrete, steel is added to resist tensile stresses.

We will see later that when vertical steel is present, most of the axial load applied to a wall is resisted by the steel (unless the wall is lightly reinforced).
THE FOLLOWING FIGURE DEPICTS PARTIALLY REINFORCED WALLS.

**Partial Grouting** is used to save money when loads dictate that the wall must be reinforced, but not to the extent that every core must be filled.

Cavity walls are utilized to keep moisture out of building.

Typically, the cavity is filled with rigid insulation to improve the thermal resistance of the wall. This can only be accomplished if the cavity space is kept clear of mortar.
Finally, consider the veneer walls depicted in the figure below:

(a) Adhered Veneer
(b) Tied Veneer (Masonry Backing)
(c) Tied Veneer (Stud Backing)

Veneered walls comprised of load-bearing CMUs with brick veneers is the most common type of multi-hyphene walls.
Question

What can we realistically expect to see in the field when we specify "clean" cavities in our masonry cavity walls?

Answer

"Clean but not pristine" says it best when it comes to debris in the cavity. The key word in your question is "realistically." It tells me you recognize that masonry is a material laid by hand in field conditions, during all kinds of weather and site situations. Keeping every single mortar dropping or protrusion out of the cavity is not cost effective and it is not necessary.

The drainage cavity should be a nominal 2" clear to allow for proper construction of the wall and to minimize mortar fins, droppings, and bridging. The purpose of the cavity is to drain any water before it can penetrate to the interior. Some mortar droppings and protrusions are to be expected, but the key point is the performance of the cavity: Is it draining the water to the flashing? If it is draining, then the cavity is clean enough. You can work out guidelines for this with the job site sample panel prior to the project start so that everyone is clear about expectations.
Preventing Water Penetration in Masonry

Introduction
Nature works overtime to create problems for architects, engineers, contractors and craftsmen. The sense of accomplishment that comes from putting up what everyone believes is a first-class building can be shattered if the owner later calls to report that the walls leak.

Water, in the form of rain, snow, ice, runoff, vapor and condensation, can enter a building through many paths. If it comes through masonry walls, the first reaction of the building owner or general contractor will be to look to the mason contractor for repairs. An inspection may reveal that the masonry walls are not the source of the leak, and that the problem will have to be resolved by a different contractor. It does happen.

On the other hand, an investigation may show that there is a problem within the wall. If there is, it needs to be addressed, because damage resulting from water penetration escalates. The water may corrode metals, stain interior walls and ruin insulation, carpeting and furniture. It will usually contribute to efflorescence. Worse, if the building is in an area where winters are cold and is therefore subject to repeated freeze-thaw cycles, the moisture that penetrates walls may lead to cracks in the masonry as the result of freezing and thawing.

Looking for Answers
Brick and concrete masonry units are porous and absorbent, but it is unlikely that water is coming through these materials. If water is penetrating a masonry wall, it is due to capillary action taking place through the natural and microscopic hairline separations between masonry units and mortar. When the water reaches the cavity of a cavity wall, it may travel up or down, depending on temperatures and humidity levels.

Causes of Leaks
Generally, water penetration in masonry walls in new buildings are caused by one or more of these factors:
1. Poor detailing
2. Substandard materials
3. Poor workmanship
4. Condensation
5. Vapor
6. Movement

Flashing
Before beginning work on a new job, carefully check the flashing details and specifications provided in the architect's working drawings and other documents for either single or double wythe walls. Report any inadequacies and inconsistencies.

There should be flashing indicated at all the following locations:
- Below copings
- Above bond beams
- At parapets
- At heads and sills of all masonry openings, such as windows
- At lintels and relief angles
- At the base of the walls

Brick and Block
It's important that the architect and building owner select brick and block for a project for reasons that go beyond aesthetics. Masonry is beautiful because of its color, size, texture and further enhanced with good workmanship. Equal attention should be paid to the characteristics of the proposed masonry materials and mortar. Generally, exterior brick should conform to ASTM C216, grades MW or SW. Concrete masonry units should be Grade N, ASTM C90, C129, or CS5.

Brick and mortar bond best when brick suction is 30g/min/30 square inches. High-suction brick will not bond well with the mortar, since the brick will draw moisture out of the mortar. The well-known "quarter" test usually will tell you what you need to know about brick suction. Using a wax pencil, draw a circle about an inch in diameter on the surface of the brick unit that will be in contact with the mortar. A 25-cent piece is about the right size. Using a medicine dropper, put 20 drops of water inside the circle and note the time required for the water to be absorbed. If the time exceeds 90 seconds, the unit need not be wetted. If it takes less than 90 seconds, wetting is recommended. An effective way to wet brick is to spray water on the brick pallets the day before they are used. Concrete masonry units should not be wetted since they will shrink.

The proper installation of brickwork requires that all the joints are completely filled with mortar. Butter the ends of the brick thoroughly and completely. Make sure the space between wythes (collar joints) is completely filled if the wall is composite.

Time, tide and mortar wait for no man. After the mortar is placed, the brick should be laid on the bed within one minute. Keep the wall cavity free of mortar. To help prevent mortar from falling into the cavity, the bed of mortar should be spayed or bevilled away from the cavity itself. In some parts of the country, a wood strip is placed on top of the ties as brick is being laid. The wood strip protects the cavity. A string attached to the strip makes its removal easier (See Figure A).

When work is finished for the day, protect the masonry walls with tarps. Also protect all masonry left at the site for the next day's work.

Mortar
A good bond between the mortar and the masonry units helps reduce water infiltration through masonry walls.

Mortar should be mixed with as much water as possible to increase its workability. A journeyman bricklayer knows instinctively if the mix is right by how it feels on the trowel and how it "throws." Mortar should be used within two and a half hours of mixing and, obviously, if it has begun to set, it should not be used at all. Never oversand when mixing grout, because too much sand causes a weak bond between the mortar and the units, allowing for water to pass through the hairline separations. Sand should not be measured by shoveling. Instead, follow exact batching methods. Temperature and humidity levels will cause the amount of moisture in sand to vary during the day, so the sand should be checked regularly. The "dry-batch" method simplifies mixing in the field, because the mortar is premixed in a controlled environment and then sent to the site. All the bricklayer has to do is add water and mix. Dry batching usually is cost-effective on larger projects.

Select mortars that are "weaker" than the overall structural characteristics of the project. Portland cement-lime mortars have great bonding abilities. Type N generally is adequate for above-grade work, but Type S has greater bond strength. Type M is for below-grade work and
high-strength wall-bearing projects.
Only "V" and "Concave" tooled joints are acceptable for exterior applications. Struck or raked joints should not be used. Tooling of the joint is important since it tends to seal the hairline separations between the masonry units and the mortar as the mortar compacts due to shrinkage and compression.

Weep Holes
The purpose of flashing is to divert moisture that has penetrated the first wythe of masonry to the building's exterior. Water is diverted to weep holes at the head joints of all flashing locations. It's a good idea to space weep holes at 16" centers or to have two rows of staggered weeps at the base of the wall or floor line. A most attractive method is to eliminate the mortar at every second or third course and allow the open head joint to act as a natural weep hole. Placing pea gravel at the bottom of a wall cavity at a level above the weeps will help prevent drops of falling mortar from blocking the holes. (See Figure A).
Oilied ropes used to form weeps should be removed afterwards. Some journeymen put fibrous glass in the weeps to act as wicks. If possible, cover weeps with insect screening on the cavity side to keep out pests.
Final grading is another problem. Many times a mason has erected a perfectly fine wall with proper flashing and weep holes, only to have the weeps buried during the final grading. Weep holes below grade get clogged and, in cold climates, freeze solid.

Flashings
There are many kinds of flashings materials, but the contractor should make sure lead flashing never comes in contact with brick masonry. And, while copper is an excellent flashing material, in some cases it may stain adjacent walls green. Because of electrolysis, uncoated aluminum flashing should also be avoided. Galvanized zinc is a good material for flashing, especially in an alloy form. PVC and bituminous membranes have been popular in recent years.

Make sure that flashing materials are not punctured by bolts, ties or rebars. If flashing is punctured, seal the opening with heavy mastic. Flashing should rest on a thin mortar bed and be topped with additional mortar so that a standard joint height is achieved.

Mason contractors should keep in mind that "flashing boots" are available pre-cut from most manufacturers for inside and outside corners. These can save a lot of time.

Be careful that wall flashing at sills is turned up into head joints so as to form an end dam (see Figure B). When flashing lintels, such as steel angles, bend the flashing material down to a 45 degree angle to form an exterior drip.

Reinforcing
Proper wall reinforcing helps reduce water penetration. Continuous horizontal joint reinforcing or ties or both, placed every 16 inches or at every other CMU course, reduce cracking caused by shrinkage as the materials dry. Wall cracks are a major contributor to masonry water problems.

Sealants
Water filtration at control and expansion joints can be prevented with good sealant and backer rods. Here are some rules the use of sealants:
- Use solvent-based acrylic sealants at masonry openings where little movement is expected.
- Use elastomeric-type sealants (urethane, silicones and polysulfides) at expansion joints and other joints where movement is anticipated.
- Never use oil-based caulk on masonry.

Coatings
Do not take the word "waterproofing" seriously when it is used in connection with sealants or coatings. These materials will repel water, but they will not be waterproof.

So-called "waterproof" coatings are not necessarily a desirable method of controlling water penetration in masonry. For one thing, they can change the color of brick. For another, they might prevent the removal of efflorescence, and may also hinder the future tuck-pointing of mortar. These repellents also may prevent moisture from escaping the walls to the outside air.

Coatings should be used as a last resort after much research and testing. They can be effective in protecting single wythe concrete masonry walls and are more appropriate for existing walls than new construction. Keep in mind that sealed walls have to be resealed every three to five years.

All masonry walls below grade need to be damp-proofed. In many cases, a bituminous coating over the parging will do the job in the absence of a high water table. If you encounter a hydrostatic situation, membranes of felt or fabric in conjunction with bituminous coats may
further inhibit water infiltration. The job is
finished by applying rigid insulation
boards that will protect the assembly
from gravel and backfilling and, in addi-
tion, will add an "R" insulation value.
Another method is to "wrap" the below-
grade walls in a neoprene sheet, over-
lapped at the joints and taped together
to ensure the integrity of the seal.

Waterproofing the inside face of base-
ment walls is akin to waterproofing the
inside of hunting boots.

A main function of any building is to
protect its occupants from the elements.
Buildings that leak do not perform that
function. Careful application of flashing
and waterproofing, provision of the proper
number of clear weep holes, selection of
proper materials, the right mortar mix,
proper placement of expansion joints-
these are the elements that make a
quality building that can fulfill its function
of protecting the interior as well as those
who work or live inside.
COLUMN AND PILASTRE CONSTRUCTION

Several column configurations are presented in the following figure:

![Column and Pilaster Construction Diagrams]

Columns are reinforced in the following manner:

(a) Pocket Formed by Solid or Cored Units

(b) Reinforced Hollow Units
Pilasters are columns that are constructed integrally with a masonry wall. Several configurations are presented below.

- Bonded brick
- Unbonded single projection
- Bonded double projection
- Bonded block
- Unbonded
- Pilaster block
- Tie

Pilasters are sometimes referred to as "engaged columns." Pilasters can perform the following tasks:

1. Act as a column.
2. Increase buckling resistance of the wall.
PRESTRESSED CONSTRUCTION

STRUCTURAL MEMBERS CAN BE PRE-STRESSED OR POST-TENSIONED IN THE FOLLOWING MANNER.

(a) Hollow Block Wall   (b) Cavity Wall   (c) Prefabricated Lintel Beam
Cleaning Masonry

Introduction

Cleaning is usually the last operation performed on newly constructed masonry. Unfortunately, it is sometimes performed as an afterthought, without proper planning or selection of cleaning procedures and techniques. Improper cleaning can virtually destroy the appearance and serviceability of new masonry. Usually, problems associated with the cleaning of masonry relate to: using the wrong kind of cleaning procedure for the specific masonry materials being cleaned, overcleaning in an attempt to compensate for poor workmanship during construction, or improper execution of recommended cleaning procedures. With careful planning, preparation, and application, these kinds of mistakes can be avoided and satisfactory cleaning accomplished.

Throughout the process, cleaning should be guided by the principle that “less is better”—meaning that it is better to underclean than overclean. Minor mortar smears and efflorescence associated with new masonry construction will often weather away as the building ages. In contrast, damage to the masonry from overcleaning can be virtually irreparable.

Planning

Attention to cleaning requirements should begin with preparation of the contract documents. Evaluate proposed cleaning procedures and techniques giving consideration to: the masonry materials used in the construction, the effect on adjacent materials (such as metal, wood, or glass), the logistics of the construction project, and any other site-specific factors that may affect the cleaning process. Next, perform the selected cleaning procedure(s) on a mock-up panel to verify suitability. The mock-up should be of the same materials intended for use in the construction and built with the level of workmanship expected on the project.

Acceptability of procedures selected based on evaluation of a mock-up should finally be confirmed on a trial section of the completed masonry before cleaning the whole project. The same individuals who will clean the entire masonry should first employ the proposed cleaning procedure on an inconspicuous area of the masonry. Not only will this step allow modification of the procedure to accommodate actual job conditions, but it will assure that all involved understand what is expected.

Materials

Mortar is usually the primary substance being cleaned from the face of masonry units in new construction. High-strength mortars (Type S and Type M) are generally more difficult to remove than lower-strength mortars. Unfortunately most methods that will remove mortar from the face of masonry units will also remove mortar from the surface of mortar joints. This fact can result in significant deterioration of mortar joints during the cleaning operation, particularly when less labor-intensive procedures such as acid cleaning, high pressure spray cleaning, or abrasive cleaning are employed. Measures need to be taken to minimize the effect of the cleaning operation on the surface of mortar joints. Focus scrubbing efforts on unit surfaces, not mortar joint surfaces. If acid solutions are used, the mortar should be allowed to cure at moderate temperatures for about seven days prior to cleaning. Pressure water sprays should only be used with extreme caution. Keep pressure sprays moving over the masonry surface. Angle sprays to avoid hitting the surface of mortar joints with a perpendicular stream of water.

Note 1: The use of cleaning solutions (particularly acidic solutions), high pressure spray cleaning, and abrasive cleaning techniques require special safety precautions for workers (such as eye protection and protective gloves and clothing) that are not discussed in this publication. Consult appropriate product labels, product information literature, and material safety data sheets for information on products and equipment used to clean masonry.

The principles involved in cleaning of masonry constructed using white or colored mortars are fundamentally the same as those for masonry using natural gray mortars. However, effects of cleaning that are not noticeable in gray mortar joints may be strikingly obvious on a white or colored mortar joint. As noted above, cleaning procedures can remove the surface layer of a mortar joint. Often the cement paste is dissolved, leaving exposed sand particles at the surface. In addition to creating a more porous joint surface, this can result in a change in the appearance—particularly if the sand color is significantly different from that of the cement paste. Overcleaning of masonry should always be avoided, but this is especially critical.
when colored mortars are used. Manufacturers of proprietary cleaning solutions often provide different products for application on projects using dark-colored mortars than for projects using light- or white-colored mortars. The manufacturers of both the cleaning solution and the colored mortar materials should be consulted prior to selecting a cleaning procedure or solution. Cleaning procedures should then be evaluated as indicated in the previous discussion.

Masonry constructed using concrete masonry units usually requires no further cleaning than what is outlined in the construction section of this document. Mortar color is typically similar to that of concrete block. In addition, the block masonry surface is often either painted or plastered (stuccoed) to provide the desired finished appearance. If further cleaning is required where colored or architectural units are used, the manufacturer of those units should be consulted before selecting a cleaning procedure. Acidic cleaning solutions can dissolve cement paste from the face of concrete masonry units, altering the appearance and texture.

Consideration must be given to unit characteristics when selecting a cleaning procedure for masonry constructed with clay masonry. Once again, the manufacturer of the unit should be consulted for recommendations. Generally, a range of cleaning options is appropriate. Bucket and brush cleaning with a dilute acid or proprietary cleaning solution can be used on red/red flashed brick. High pressure water cleaning may also be used but is not recommended on sand finish or surface coated brick. Dilute hydrochloric acid (muriatic) cleaning solutions, including proprietary cleaners containing hydrochloric acid, are not to be used with brick that contains manganese or vanadium.

**Construction**

Good construction is integral to obtaining a clean masonry job. Excessive mortar smears are often a symptom of poor overall workmanship. They should trigger closer scrutiny of the masonry construction by the mason contractor's project supervisor or other members of the construction management team. An accomplished mason will construct masonry with a minimum of mortar droppings or smears on the face of units. The mason should take the following steps to reduce cleaning requirements:

- **Keep Units Clean:** Protect stored units from mud, dirt, or other contaminants.
- **Cover the Bottom:** Use straw, sand, or plastic to protect the base of the wall from rain splashed mud and mortar splatter.
- **Minimize Mortar Droppings:** Carefully cut excess mortar off with trowel as units are laid. Minimize amount of mortar droppings and smears on face of wall.

- **Time the Tooling:** Allow mortar joints to stiffen to “thumbprint hardness” before tooling. Tooling at the proper time will help to minimize mortar smears. (IMG13632)

- **Trim with Trowel:** After tooling, use trowel to trim mortar burns off flush with the face of the wall. (IMG13633)

- **Brush after Tooling:** Remove dust and loose mortar from face of masonry with a soft brush. (IMG13634)

- **Clean As-You-Go:** Remove mortar protrusions or droppings from masonry surface after mortar has set to avoid smearing mortar into masonry, but do not leave mortar droppings on masonry for an extended time as they will become difficult to remove. Non-metallic scrapers may be required to avoid damaging the surface of clay masonry units or architectural block units. Often a small piece of a similar unit will function as a satisfactory scraper. (IMG13635)
• Cover the Top: Prevent rain from entering walls by covering the tops of walls at the end of each working day. This practice helps reduce the possibility of efflorescence. (IMG13636)

• Put the Inside Edge Up: Turn the inside scaffold board on edge at the end of each working day to prevent rain from splashing mortar and dirt onto the masonry wall.

• Spot-Clean Smears: When practical and compatible with the masonry unit, use a stiff fiber brush and water (with or without sand) to scrub mortar smears off the masonry surface. This is most effective when performed within a day or two of the occurrence of the smear.

Cleaning Procedures

Dry brushing is perhaps the least aggressive cleaning procedure available. It is effective in removing loose dust, sand, and some types of efflorescence from the surface of newly constructed masonry. On small projects, or where meticulous care has been taken to limit and remove mortar smears during construction, dry brushing is often adequate. Dry brushing is not sufficient on larger projects with more demanding cleaning requirements. The use of "bucket-and-brush" with a cleaning agent may provide the best alternative. The cleaning agent can be water, detergent and water, a dilute acidic solution, or proprietary solutions manufactured specifically for masonry cleaning. Selection of an appropriate cleaning solution requires: consideration of the masonry units, evaluation of the substance(s) intended to be removed from the surface, and consideration of building elements and materials next to the masonry. Select the cleaning solution that will provide adequate cleaning without significantly eroding the surface of either the units or mortar. Obviously, if cleaning with water, or water and a detergent, will satisfactorily remove objectionable substances from the masonry, acidic solutions (including acidic proprietary solutions) should be avoided.

A dilute solution of hydrochloric (muriatic) acid is often used to clean mortar smears from the face of clay masonry construction. Some architectural concrete masonry may be cleaned in the same way. Mix the acid with water in a non-metallic container at a ratio of 1:19 (5% solution) or 1:9 (10% solution). Never add water to concentrated acid. As an alternative, proprietary acid-based masonry cleaning solutions may be used. Such cleaning solutions often incorporate detergents and wetting agents in their formulation. They are usually sold as concentrates and must be carefully mixed with water in accordance with the manufacturer’s recommendations. Before using an acid or proprietary cleaning solution, always check with the manufacturer of the masonry units to confirm that the proposed solution will not damage those units.

Adjacent building elements and materials that could be etched or stained by the cleaning solution must be protected. In particular, metallic and painted surfaces should be covered with polyethylene or another effective barrier to the cleaning solution.

Thoroughly wet masonry surfaces with clean water before applying a detergent or acid based cleaning solution to the masonry. This pre-soaking will prevent the cleaning solution from being absorbed deep into the pores of the masonry where it may react with masonry materials, resulting in chronic efflorescence or staining. The cleaning solution should be applied liberally with a stiff bristle brush (non-metallic) and allowed to stand for approximately five minutes. Start at the top of the wall and work down. Make sure that masonry below is pre-wet and other surfaces are protected. Work with small sections, concentrating on removing smears from the face of units, not on the surface of mortar joints. The cleaning solution must be thoroughly rinsed from the masonry with clean water before it starts to dry into the masonry. Failure to adequately wet the masonry prior to application of the cleaning solution, and failure to completely rinse the masonry after application of the cleaning solution often result in a white scum residue on the surface of the masonry.

Compounds dissolved by the cleaning solution when dried into the masonry surface may no longer be soluble in a conventional acidic cleaning solution and can be virtually impossible to remove without damaging the masonry.
Prewetting and careful rinsing are key steps for successful cleaning with a cleaning solution.

(IMG13639)

Apply cleaning solution to small sections of masonry with a stiff bristle brush.

(IMG13640)

Pressure water cleaning should be used only with extreme caution. Too much water or pressure can saturate a wall, causing efflorescence. Improper use of pressure water sprays can also damage the face of masonry units and erode mortar joints. When used in conjunction with a cleaning solution, the same preparation is required as with the bucket-and-brush method outlined previously. The masonry must be presoaked with clean water prior to application of the appropriate cleaning solution. The cleaning solution may be applied to the masonry surface under pressure just sufficient to carry the solution to the masonry face. After the cleaning agent has been on the wall for about five minutes, the pressure water spray may be used to clean and rinse the wall. Nozzle pressures should be limited to less than 700 psi. Use a fan nozzle to produce a flat spray. Keep stream of high pressure water moving over the surface. Angle spray to avoid hitting the surface of the masonry with a perpendicular stream of water.

Abrasive cleaning techniques include dry and wet abrasive blasting. The abrasive material most often used is sand. While wet blasting tends to be less destructive than dry, both methods function on the principle of cleaning by eroding the surface of the masonry. Neither is generally recommended for cleaning new masonry construction. For additional information on abrasive cleaning techniques and cleaning special stains see the references listed below.

References


2. Removal of Stains from Concrete Masonry Walls, NCMA-TEK 8-2, National Concrete Masonry Association, Herndon, VA, 1972.


WARNING: Contact with wet (unhardened) concrete, mortar, cement, or cement mixtures can cause SKIN IRRITATION, SEVERE CHEMICAL BURNS (THIRD DEGREE), or SERIOUS EYE DAMAGE. Frequent exposure may be associated with irritant and/or allergic contact dermatitis. 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.

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