

# Mortar For Masonry

FEBRUARY, 1997

## CONSTRUCTION GUIDE MORTAR FOR MASONRY

### SCOPE

The intent of this Construction Guide is to provide general information on mortars, with primary emphasis placed on successful usage of mortars in the field. A general knowledge of mortars, in conjunction with acceptable field practices, is required to assure the successful performance of mortar. This guide will discuss in part such topics as mortar materials, mortar types and physical properties to familiarize the user with all aspects of mortar. However, there are numerous other technical documents and publications that should be consulted for more detailed information on mortar composition and specifications.

### INTRODUCTION

Mortar has been an integral part of masonry wall systems for centuries. Its primary function is simple: to successfully bond unit masonry together. Mortar's presence and performance are as crucial to a masonry wall system as the units it bonds together; yet its relevance is often overlooked by the designer and mason contractor. A thorough understanding of mortar and its application is necessary to achieve successful performance.

Mortar has developed through an evolutionary process. The Egyptians discovered that workable mortar could be produced by burning limestone at high temperatures and then soaking the byproduct (quicklime) in water after it cooled. The quicklime was then mixed with volcanic ash or river sand to produce the first lime mortars.

Lime-sand mortars remained unchanged until the development of hydraulic lime in the mid-18th century. Produced by firing limestone containing clay deposits, hydraulic lime yields a harder and more durable mortar because the clay provides additional cementitious properties.

Mortar and its usage significantly changed in the late 19th century with the advent of portland cement. The introduction of cement into mortar initially led to the development of cement-lime mortars. Eventually

other types of cement were developed and blended with sand to produce mortar.

### MORTAR MIXES

Currently three types of mortar are used for masonry construction: cement-lime, masonry cement and mortar cement. All three mortars have been used successfully, with each offering its own unique benefits.

#### Cement-Lime

Modern cement-lime mortars are produced by blending lime-sand mortar with portland cement. Combining these materials creates a mortar with well-balanced physical properties. A lime-sand mortar possesses excellent workability and high water retention, while portland cement increases setting time and provides additional strength.

Lime also possesses a healing quality that continues to affect the masonry years after construction is completed. Lime gradually gains strength by absorbing carbon dioxide from the atmosphere and converting itself back to limestone. This process is slowed by weathering and occurs over a long period of time. As the mortar cures, lime particles (calcium hydroxide crystals) migrate into the pores of the masonry unit causing the recementing of hairline cracks.

Cement-lime mortars are mixed to meet minimum physical requirements. Each ingredient is specified by volume and blended to produce a specific mortar type. Modifying the volume of each ingredient can enhance certain physical properties of mortar, such as compressive strength, bond strength, water retention and workability. The ability to vary the amount of each ingredient of cement lime mortars is advantageous.

#### Masonry Cement

Masonry cement was developed in the late 1920s with the intent of simplifying the mortar mixing process. Masonry cement mortars are produced by blending masonry cement with sand. Masonry cements are proprietary mixtures. Their ingredients will vary from one manufacturer to the next. However, most masonry

cements contain three basic ingredients:

- Portland cement for higher strength and increased setting time.
- Plasticizers, such as finely ground limestone or lime hydrate for increased workability.
- Air-entraining additives for greater durability and workability.

Masonry cement mortars are preblended and prepackaged in bags. Each bag is mixed with a specified volume of sand aggregate to meet certain minimum physical requirements. Consequently, masonry cement mortars provide consistency of mixture during construction. Furthermore, masonry cement mortars provide excellent workability, along with adequate bond and good compressive strength.

#### Mortar Cements

Mortar cement is the most recently developed mortar mixture and can be regarded as the "next generation" of masonry cement. A specification for mortar cement was first developed in 1991 and adopted by the International Conference of Building Officials in the *Uniform Building Code*.

The product was created to meet UBC flexural bond-strength requirements that masonry cement mortars could not satisfy. The ingredients in mortar cement are similar to those in masonry cement mortars. However, the ingredients have been optimized to produce lower air contents than masonry cements.

Mortar cements, like masonry cements, are prepackaged and mixed with sand and water at the job site. Mortar cement mortars provide all of the favorable properties of masonry cement mortars, in addition to higher flexural bond strengths.

## SPECIFICATION OF MORTAR

### Materials

All materials used in mortar are required to meet ASTM standards. Portland cement, masonry cement, mortar cement, hydrated lime and sand aggregates each have an ASTM specification that it must comply with.

**Portland Cement** - All modern mortars have portland cement as a principal ingredient. Portland cement is a hydraulic cement which should conform to ASTM C 150 "Standard Specification for Portland Cement." This standard states that three types of cement can be used in masonry mortars:

- Type I - for general use
- Type II - for use when moderate heat of hydration is required
- Type III - for use in attaining high early strength

**Hydrated Lime** - Hydrated lime is used primarily in cement-lime mortars. It is produced by firing (calcining) limestone to produce quicklime, which is then hydrated. Hydrated lime should conform to ASTM C 207 "Standard Specification for Hydrate Lime." Four types of hydrated lime are covered in this specification. Only type S hydrated lime should be used in masonry mortar.

**Masonry Cement** - Masonry cement is the primary material used in masonry cement mortars. Masonry cement is a hydraulic cement that usually contains some portland cement. All masonry cements must comply with the ASTM C 91 "Standard Specification for Masonry Cements." This specification lists requirements for fineness, autoclave expansion, setting time, compressive strength, air content and water retention.

**Mortar Cement** - Like masonry cement, mortar cement is a hydraulic cement that is blended with sand to produce mortar. Mortar cement must comply with ASTM C 1329 "Standard Specification for Mortar Cement." Mortar cement must meet all the physical requirements of masonry cement—with two exceptions. Mortar cements are required to have lower air content and are required to meet minimum flexural bond strengths.

**Sand Aggregates** - Sand is the principal aggregate used in all

blends of mortar. Sand fills the voids between hydrated cement particles and contributes to the structural properties of hardened mortar. Sand also reduces mortar shrinkage. Sand aggregate should conform with ASTM C 144 Standard "Specification for Aggregate for Masonry Mortar." This standard allows either natural sand or manufactured sand to be used in mortar and requires the sand to meet certain gradation limits. If the limits are not met, the sand can still be used in mortar, provided that the mortar meets the property specifications of ASTM C 270 "Standard for Mortar for Unit Masonry."

ASTM C 270 is the standard specification for mortar for unit masonry. It contains sections on scope, references, requirements, materials, test methods, construction practices and specification limitations and an appendix. The standard also contains three tables addressing mortar requirements and mortar selection. Designers and mason contractors should familiarize themselves with the entire specification, although an absolute understanding of Tables 1 and 2 is essential.

#### Mortar Types

All mortars are specified by type. Five types exist: M, S, N, O and K. (Type K is listed in the appendix). Each type must meet specific requirements that are listed in Tables 1 and 2.

Table 1 designates mortar types by listing specific proportions for each ingredient. Cement-lime mortars are usually specified in accordance with Table 1 and are required to meet the proportions listed. In this table, masonry cement mortars can also be specified by proportion but usually are specified to meet the physical requirements listed in Table 2.

Table 2 lists the minimum and maximum physical requirements for each type of mortar and contains three distinct property requirements: compressive strength, water retention

and air content. Compressive strength and water retention requirements are identical for cement-lime mortars and masonry cement mortars. However, the table allows greater air content in masonry cement mortars.

#### Property Table vs. Proportion Table

When mortars are specified to be mixed by proportion, cement-lime mortars will attain compressive strengths two to three times greater than the minimum compressive strengths listed under the property specification table. For example, a Type N cement lime mortar specified and mixed by proportion can conceivably attain minimum compressive strengths that coincide with Type S mortar listed in Table 2. Higher compressive strengths for cement lime mortars mixed by proportion have been verified through much research conducted by the masonry industry.

#### Mortar/Unit Compatibility

Mortar can constitute as much as 20% of a wall system, therefore, it must bond well to the masonry units. Bond is especially critical in wall systems directly exposed to the exterior environment. Achieving a weather-tight bond in exterior masonry facades can decrease water permeance and increase the overall durability of the wall.

Selecting a mortar that is compatible with the masonry unit will greatly enhance bond. Compatibility between mortar and unit is more critical for brick than for concrete masonry because brick and mortar consist of dissimilar components.

Mortar/unit compatibility can be achieved by selecting a mortar that produces a good chemical bond with the specified brick unit. An effective chemical bond is created when the brick absorbs just enough water and cement particles into its pores while leaving enough water in the mortar joint to allow for proper cement hydration.

TABLE 1

PROPORTION SPECIFICATION REQUIREMENTS (ASTM C 270)

Mortar	Type	Proportions by Volume (Cementitious materials)			Aggregate Ratio (Measured in damp, loose conditions)
		Portland Cement or Blended Cement	Masonry Cement	Hydrated Lime or Lime Putty	
Cement-lime	M	1	—	—	Not less than 2½% and not more than 3 times the sum of the separate volumes of cementitious materials.
	S	1	—	—	
	N	1	—	—	
	O	1	—	—	
Masonry Cement	M	1	—	1	Not less than 2½% and not more than 3 times the sum of the separate volumes of cementitious materials.
	S	—	1	—	
	N	—	1	—	
	O	—	1	—	
	S	—	—	1	
	N	—	—	1	

Note: Two air-entraining materials shall not be combined in mortar.

TABLE 2

PROPERTY SPECIFICATIONS\*

Mortar	Type	Average Compressive Strength at 28 Days, min. psi (MPa)	Water Retention, min. %	Air Content, max. %	Aggregate Ratio (Measured in damp, loose conditions)
Cement-lime	M	2500 (17.2)	75	12	Not less than 2½% and not more than 3½ times the sum of the separate volumes of cementitious materials.
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14 <sup>b</sup>	
	O	350 (2.4)	75	14 <sup>b</sup>	
Masonry Cement	M	2500 (17.2)	75	— <sup>c</sup>	Not less than 2½% and not more than 3½ times the sum of the separate volumes of cementitious materials.
	S	1800 (12.4)	75	— <sup>c</sup>	
	N	750 (5.2)	75	— <sup>c</sup>	
	O	350 (2.4)	75	— <sup>c</sup>	

\* Laboratory prepared mortar only.

<sup>b</sup> When structural reinforcement is incorporated in cement-lime mortar, the maximum air content shall be 12%.

<sup>c</sup> When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall be 18%.

A mortar's water retentivity and a brick unit's initial rate of absorption (IRA) are important physical properties that directly affect bond compatibility.

Water retentivity is a mortar's ability to retain its mixing water under suction. This property gives the mason time to lay units and make any adjustments before mortar stiffens. Water retentivity can be increased by increasing the amount of lime or air in the mortar.

A brick's IRA or suction rate is determined by measuring the amount of water absorbed when a brick is partially submerged in water for one minute. IRA is expressed in grams per 30 square inches of contact surface. The appendix of ASTM C 270 designates as moderate masonry units with IRAs of 5 to 25 at the time of laying, but notes that adequate bond can be achieved with units having IRAs beyond these values.

ASTM C 270 further notes that mortars having higher water retentivity are desirable for use with units having high suction rates; and mortars having lower water retentivity are desirable for use with units having low suction rates.

#### Compatibility Guidelines

Much more test data are needed to formulate specific compatibility requirements. However, the following guidelines can be used as a starting point to obtain more compatible mixes:

- Use a cement-lime mortar with a low lime content ( $\frac{1}{4}$  to  $\frac{1}{2}$  part by volume) or a Type S masonry cement or mortar cement for brick units with IRAs of 5 and below.
- Use a cement-lime mortar with a moderate lime content ( $\frac{1}{2}$  to 1 part by volume) or a Type N masonry cement or mortar cement mortar for brick units with IRAs ranging from 6 to 25.
- Use a cement-lime mortar with high lime proportions (1 to  $1\frac{1}{4}$  by volume) for brick units with IRAs ranging from 25 to 30.

#### MIXING MORTARS

There is no standard for mixing mortar in the field. Yet mortar is one of the few materials that a mason contractor makes at the jobsite.

ASTM C 270 provides some direction for mixing mortar. This standard requires that all materials be mixed between 3 and 5 minutes in a mechanical batch mixer with a maximum amount of water to produce a workable mortar. No direction is

given for batching procedures or for the volumetric control of water content. Ultimately, producing a workable mortar that complies with the project specifications is the responsibility of the mason contractor.

Mortar materials must first be properly batched to meet the mortar type requirements indicated in the project specifications. Quantities of mortar materials are specified by cubic foot. Portland cement, masonry cement, mortar cement and hydrated lime are packaged in 1-cubic-foot bags, whereas sand is provided in bulk. A means of volumetric measurement for sand can be established at the jobsite. This can be accomplished by providing 1-cubic-foot boxes into which the sand can be shoveled. However, pre-measurement of sand is not usually required or even necessary to produce acceptable mortar.

Understanding a mortar mixer's capacity is the key to successful batching of materials. Mortar mixers range in capacity from 4 to 16 cubic feet. The most common size of mortar mixer is 9 cubic feet.

When cementitious materials are blended with sand, they fill the voids between the sand particles. Blending 3 cubic feet of cementitious material with 9 cubic feet of sand produces approximately 9 cubic feet of mortar. The desired mortar type can be batched by adding the specified volume of cementitious material into the 9-cubic-foot mixer and subsequently filling the rest of the mixer with sand. For example, a Type S cement-lime mortar can be batched in a 9-cubic foot mixer by adding two bags of portland cement, one bag of hydrated lime and approximately 9 cubic feet of sand. Masonry cement or mortar cement mortar can be batched by adding three bags of the desired cement type and 9 cubic feet of sand into the mixer.

#### Water Content

The addition of water into a mortar mix is not governed by specific volumetric requirements. The addition of water is left to the discretion of the mason contractor. The amount of water required to produce mortar is governed by mortar type, the moisture content of the sand, the consistency desired and the suction rate of the units. Generally, just enough water is added to the mixture to produce a workable mortar that the mason can spread easily on the masonry units. Adding too little or too much water to the mixture will produce mortar that is not workable.

#### Mixing the Ingredients

Mortar mixing techniques will vary

with the contractor, but the following procedure is typical for a 9-cubic-foot mixer: Blend all of the cementitious materials with  $\frac{1}{2}$  of the sand and sufficient water. Then mix for two or three minutes. Add the remaining amount of sand and enough water to produce the desired consistency. Then mix the materials again for at least three minutes but no more than five minutes. Mixing mortar beyond these time limits can adversely affect its workability. Also, the mixer's drum should be cleaned prior to mixing.

Mortar consistency can be monitored through construction site testing. ASTM Standard C 780 "Standard Method for Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry" provides standard procedures for the measurement of mortar composition and mortar properties. ASTM C 780 provides a means of evaluating and comparing mortar that has been mixed on-site either prior to or during construction. Test results obtained by means of this standard are not required to meet the minimum compressive strength values listed in the property specifications of ASTM Standard C 270.

#### Quality-Controlled Mortar

There are several alternative methods of producing mortar that enhance quality control and ensure mortar consistency. These methods incorporate preblended mortar and eliminate the need to batch materials at the jobsite.

*Preblended/prebagged mortar* - Some cement manufacturers now provide mortar preblended with sand, proportioned to meet any desired mortar type. Preblended mortars can be purchased in individual bags or delivered to the jobsite in bulk. All a contractor needs to do is load the contents of the bag in the mixer and add the desired amount of water.

*Silo Systems* - These systems use large storage bins or silos that are loaded with preblended mortar of any specified type. The silos are delivered and stored on-site. Currently three types of silo systems are available. One type of silo contains a dual-compartment chamber that segregates cement mixtures from sand. An auger mixer at the base of the silo blends the separated materials with water at the jobsite to produce the specified mortar type.

Another type of silo system contains a single compartment chamber that is loaded by the manufacturer with all of the dry mortar materials preblended. An auger mixer attached at the base mixes the pre-

blended ingredients with water to produce the specified mortar.

Another type of silo system acts as a dispensing system and enables mason contractors to use their own mixers. In this system, the silo is loaded by the manufacturer with pre-blended mortar materials. Upon delivery, the silo is positioned over the mixer at the jobsite. The pre-blended mortar materials are then dispensed into the contractor's mixer and blended with water.

Silo and preblended packaged systems offer either cement-lime mortars, masonry mortars or masonry cement mortars in any mortar type. These systems produce more consistent mortar quality than conventional mortar mixing and reduce the contractor's amount of work and responsibility.

### MORTAR WORKABILITY

As previously discussed, workability is an important physical property of mortar. Good mortar workability is essential in forming the required mechanical bond between mortar and masonry unit.

A workable mortar should be flowable, possess good water retentivity and have a long board life, and it should be consistent from one batch to another. A workable mortar can be obtained by adding enough water to the mixture to produce a mortar that is "sticky" and adheres well to the specified masonry units.

It is impossible to gauge the exact amount of water required to produce these properties. Proper water content will vary with each mixture, depending upon the mortar type desired. Generally, proper water content is achieved through mixing experience, which includes some trial and error.

The right mixture with the right water consistency, will produce a fluffy mortar that a mason is able to spread easily. The mortar will stay workable long enough for the mason to level and tap the units into place. A mixture that is too wet will produce an unworkable mortar that puddles on the board or slips off the trowel. Conversely, a mixture that is too dry produces a stiff mortar that is difficult to spread with a trowel.

Up to 2½ hours after initial mixing, water can be added to restore the required consistency to mortar that has stiffened, (a process known as "retempering"). Mortar that is more than 2½ hours old must be discarded.

Mortar workability directly affects a mason's productivity. Maximum productivity can be achieved only when mortar is mixed to the right consistency.

### ADMIXTURES

Admixtures can be added to mortar to enhance certain desired physical properties. Admixtures should never be added to mortars unless they have been specified or approved by the designer. The use of admixtures should not be considered unless their effects on mortar are fully known and their performance is backed by manufacturer test data. Also, mortar made with admixtures must still meet the physical requirements indicated in ASTM Standard C 270. There are many types of admixtures, which perform a variety of functions. Most admixtures can be grouped as follows:

**Accelerators** - Accelerators are added to mortar in cold weather to speed up the cement hydration process. Hastening this process shortens the mortar's initial setting time and initiates early strength gain. Accelerators are not an "anti-freeze" and do not prevent mortar from freezing. However, accelerators do generate some heat within the mortar and (depending on the temperature) can reduce cold weather protection time.

Two basic types of accelerators are manufactured: chloride and non-chloride. ASTM Standard C 270 limits chloride levels in mortar to 2% by weight of portland cement or 1% by weight of masonry cement. These levels should not be exceeded because high chloride levels can contribute to corrosion of embedded metals in masonry. Non-chloride accelerators, which are nitrate-based, can be very effective and do not cause corrosion of metals.

**Retarders** - Retarders are added to mortar in hot weather to slow down the cement hydration process. Increasing hydration time enables the mortar to retain moisture, preventing rapid suction of water from the mortar by dry masonry units. Retarders can extend the working time of mortar by several hours.

**Air Entraining Admixtures** - Air-entraining admixtures enhance workability by introducing air bubbles into the mortar mix. These admixtures increase water retention and produce a mortar that is lighter in weight. Air-entraining agents increase durability and help resist freeze-thaw damage in hardened mortar. But they must be used with caution. The air content must not exceed 18% in masonry cement mortars and 14% in cement-lime mortars. Excessive air content can adversely affect mortar bond and other physical properties of mortar.

**Bond Enhancers** - Bond enhancers improve the surface

adhesion of mortar to dense-surface units such as glass block. Bond enhancers usually contain latex emulsions that increase the air content in mortar; so bond enhancers should not be used in air-entrained mortar.

**Water Repellents** - Water repellents reduce water migration through hardened mortar by sealing the pores of the mortar. Water-repellent admixtures are effective only when added to both mortar and concrete masonry units. Bond could be inhibited if a water repellent is added only to mortar.

**Color Pigments** - Color pigments can be added to mortar to alter or completely change its appearance. Most color pigments consist of black, red and yellow synthetic iron oxides. A color pigment will not affect the compressive strength of mortar unless the amount of pigment exceeds 10% of the weight of the cementitious materials. Accurate measurements and consistency in materials and mixing procedures are essential to produce uniform mortar color. Also, mortar with color pigment should never be retempered. The use of organic pigments (such as carbon black) is not recommended. Some organic pigments can affect the physical property of the mortar.

### DISCLAIMER

This document is intended to assist the industry in avoiding design and construction problems with masonry construction. It is intended for mason contractors, field personnel, architects, engineers, building officials, general contractors, construction managers, students, suppliers, manufacturers and other industry representatives. It is not the intent of this report to cover every aspect of masonry construction, but to focus on issues that may lead to problems. This document should not be used as the sole guide for designing and constructing masonry. It is imperative to refer to relevant codes and standards and other industry-related documents. As such, the IMI assumes no liability for any consequences that may follow from the use of this document.



International Masonry Institute  
823 15th Street, N.W.  
Suite 1001  
Washington, DC 20005

# MASONRY Information

## Masonry Cement Mortars

### Introduction

*Lime-sand mortars were in general use until the early 1900's and many buildings still stand today as proof of the durability of these early mortars. Today, mixes based only on lime and sand are rare. Virtually all masonry mortar now contains either masonry cement or portland cement mixed with lime at the jobsite.*

*Masonry cement is a cement mill formulation of materials that was developed to fill the need for a volume-stable mortar. Masonry cements improve and simplify mortar preparation because all of the necessary materials are combined in one package. This product consists of a mixture of portland cement or blended hydraulic cement and plasticizing materials (such as limestone or hydrated or hydraulic lime), together with other materials introduced to enhance one or more properties such as setting time, workability, water retention and durability. These components are proportioned at the cement plant under controlled conditions to assure uniformity of performance. Since the introduction of masonry cement over 50 years ago, acceptance and performance have narrowed the variations in properties and composition among different brands. White and colored masonry cements containing mineral oxide pigments are available in many areas.*

*Masonry cement is combined with sand and water at the jobsite to produce a workable, durable, and economical mortar that meets the strength and present-day construction requirements for use with all types of masonry units. Masonry cements are also used for parging and plaster (stucco).*

*Masonry cements are manufactured in the United States and Canada under rigid quality control standards to meet the requirements of American Society for Testing and Materials (ASTM) Designation C 91 or Canadian Standards Association (CSA) Standard CAN3-A8. This quality control produces mortar with consistent color, strength, and batch uniformity.*

### Desirable Properties

Quality mortar is necessary for good workmanship and proper structural performance of masonry construction. Since mortar must bond masonry units into strong, durable, weathertight walls, it must have the following properties as described.

© 2001 Portland Cement Association All rights reserved.

### Workability

The mason's appraisal of workability of a mortar depends on the mortar's ability to be spread easily (flow and body), to cling to vertical surfaces (adhesion), and to resist flow during placement of masonry units (cohesion). The mortar should extrude readily from the joints as units are placed, but should not drop or smear.

### Water Retention

Mortar plasticity is preserved by preventing rapid loss of mixing water. Such loss causes mortar to stiffen quickly, making it difficult to obtain good bond, adhesion, and a weathertight wall. A mortar that has good water retention remains soft and plastic long enough for the masonry units to be carefully aligned, leveled, plumbed, and adjusted to proper grade without the intimate contact and bond between mortar and units being broken. Water retention is measured in the laboratory by the water-retention test (see ASTM C 91 or CSA Standard CAN3-A8), which simulates the action of absorptive masonry units. Masonry cements are required to pass this test.



**Fig. 1. Mortar of proper workability is soft but has good body; it spreads readily and extrudes from joint without smearing or dropping.**

## Durability

The durability of mortar rests in its ability to endure exposure conditions. Although aggressive environments and use of unsound materials may contribute to the deterioration of mortar joints, the major destruction is from water entering the masonry and freezing. Damage to mortar joints and to mortar bond by frost action is of greatest importance in exposed applications such as parapet walls or exterior pavers located in climates subject to freeze-thaw cycles.

Because air-entrained mortar will withstand hundreds of freeze-thaw cycles, its use provides good protection against localized freeze-thaw damage. Masonry cement mortars generally have greater resistance to freeze-thaw deterioration than non-air-entrained mortars. This superior performance can be attributed to the controlled air content of masonry cement mortars.

When sulfates come in contact with masonry mortar, subsequent expansion can cause deterioration of the mortar. Thus resistance to sulfate expansion should be considered where seawater or sulfate-bearing soils come in contact with masonry mortar. Masonry cement mortars demonstrate excellent resistance to sulfate expansion (see Figure 2).

## Appearance

Color uniformity of mortar joints greatly improves the overall appearance of a masonry structure. Atmospheric conditions, admixtures, and moisture content of the masonry units are some of the factors affecting joint color. Other factors are uniformity of mix proportions and time of tooling the mortar joints.

Careful measurement of mortar materials and thorough mixing are important to batch uniformity. Uniform color is easy to control with masonry cement mortar. The use of masonry cement simplifies jobsite proportioning of mortar materials, eliminating many proportioning errors that would affect the color of hardened mortar joints.

Tooling the joint after the mortar has stiffened produces a darker shade than if tooled while the mortar is soft. Thus, tooling the joints at a consistent degree of mortar hardness is also important for color control.

## Consistent Rate of Hardening

The rate of hardening is the speed at which mortar develops resistance to indentation and to deformation under load. Hardening is sometimes confused with a stiffening caused by rapid loss of water, as in the case of low-water-retentive mortars on highly absorptive masonry units.

Rapid hardening interferes with the mason's use of mortar. Very slow hardening may impede progress of the work, especially in winter, when the mortar may be subjected to early damage from frost. A consistent rate of hardening allows the mason to lay the masonry units and tool the joints at the same degree of hardness, thereby obtaining uniform joint color. Masonry cement mortars are controlled to have a consistent rate of hardening.

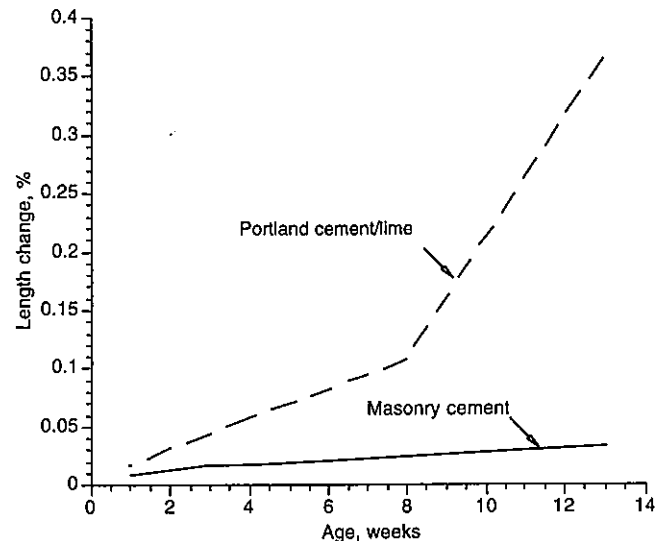


Fig. 2. Sulfate expansion of Type N masonry mortars.

## Strength

The strength of mortar commonly refers to compressive strength, not shear, tensile, or tensile bond strength. By simplifying mortar materials batching at the jobsite, the use of masonry cement assures consistent strengths between batches and jobs. Masonry cement mortars mixed according to the property specifications of ASTM C 270 provide strengths that exceed the minimum requirements of that specification. High strength Type S and Type M\* masonry cements allow the specifier to accommodate special application requirements related to load bearing masonry, masonry below grade level, and masonry for paving, without compromising the advantages of simplified batching. The compressive strength of mortar is dependent not only on the cementitious material in the mortar mix, but also on the aggregate used in preparing the mortar. Masonry cements are manufactured to meet strength requirements of present-day construction, when combined with aggregates conforming to ASTM C 144 or CSA Standard A179.

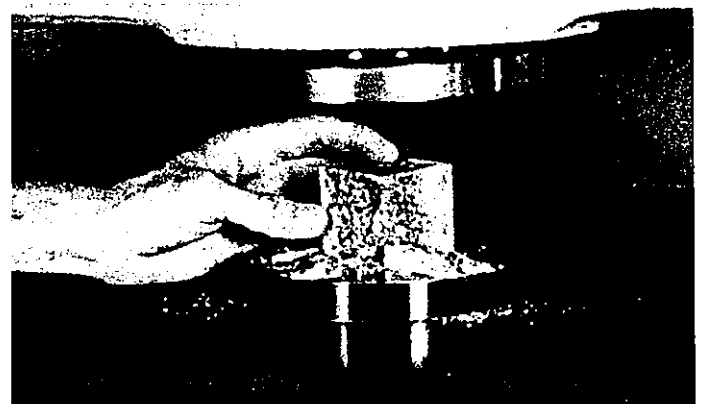


Fig. 3. Tests for compressive strength of mortar using a 2-in. (50-mm) cube specimen.

\*Not produced in Canada

## Bond

In general, the term bond refers to two different properties: (1) the extent of bond, or the degree of contact between mortar and masonry units, and (2) the tensile bond strength, or the force required to separate the units.

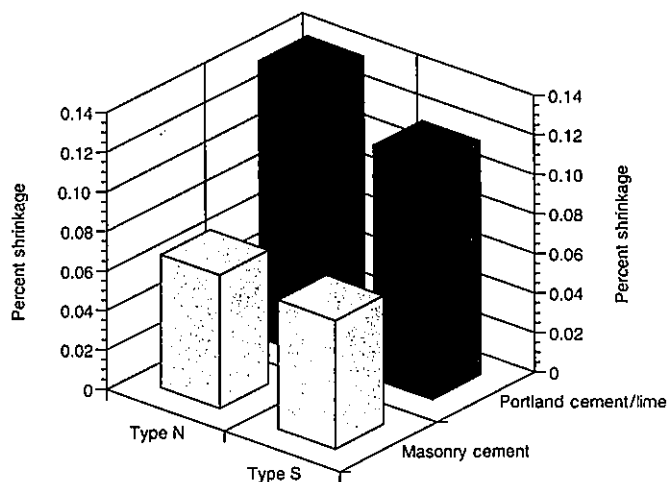
Good extent of bond means complete and intimate contact, which is important to watertightness and to tensile bond strength. Good extent of bond is obtained with a workable, water-retentive mortar, competent workmanship, full joints, and masonry units that have a medium initial rate of absorption with proper pore size and distribution. A stiff mortar will produce poor bond, whereas a wetter mortar will produce better, stronger bond, even though the compressive strength may decrease.

Neither extent of bond nor tensile bond strength is a property of the mortar alone. Both of these important aspects of masonry construction are also dependent on workmanship in laying the units, ambient conditions, and the surface characteristics of the masonry units, such as pore structure, texture, and absorption. Masonry cement mortars provide the mason with a highly plastic mortar which readily flows into the surface irregularities of the unit, assuring that the bond strength potential of the materials is realized in the field. In an extensive laboratory study of over 20 different masonry cements representing a cross section of producers throughout the United States, Ribar and Dubovoy confirmed that masonry cements yield excellent flexural bond strengths. Seventy-five percent of these masonry cement mortars tested with a brick unit having an IRA of 9 g/min·30 in<sup>2</sup> (9 g/min·194 cm<sup>2</sup>) yielded flexural bond strengths in excess of 100 psi (690 kPa). None of these masonry cement mortars produced values lower than 65 psi (450 kPa).

## Volume Change

As fresh mortar sets and cures it experiences a volume change due to the loss of free moisture from the mortar system. This volume change is known as shrinkage. Shrinkage occurs both while the mortar is in the plastic state (plastic shrinkage) and in the hardened state (drying shrinkage). One of the reasons for recommending that mortar joints be tooled with a concave jointer after the mortar is thumbprint hard is to allow most of the plastic shrinkage to occur before the tooling operation is performed. The action of the concave tool on the surface of the mortar joint then seals the mortar tight to the unit at the vulnerable face of the masonry wall.

The drying shrinkage of hardened mortar specimens may be measured using ASTM Standard Method C 1148. Several factors influence shrinkage, including water content, rate of drying, sand properties, moisture content and absorption of the masonry units, and cementitious material properties. Results of laboratory tests shown in Figure 4 indicate that the drying shrinkage of masonry cement mortars is very low. The arbitrary reduction of mixing water content of mortar is not an acceptable means of controlling drying shrinkage. The reduced workability and bond associated with using a stiff mortar far outweigh any advantage of reduced drying shrinkage. With the use of well graded sand, proper cementitious materials, good workmanship, and good design, the



**Fig. 4. Drying shrinkage of masonry mortars at 28 days.**

typical inherent shrinkage characteristics of masonry mortar will not normally compromise the performance of the masonry wall.

Expansion in mortars due to unsound ingredients can cause serious disintegration of masonry. Soundness of a cementitious material is measured by the autoclave expansion test (see ASTM C 91) or in the case of CSA Standard CAN3-A8, by either an atmospheric steam test or an autoclave test. These tests produce reactions in any unsound ingredients and simulate a long period of exposure in a wall. Any changes in length are measured to ascertain that there will be no serious expansion of the hardened mortar in the wall.

## Permeability

Water permeance of masonry is primarily related to workmanship and design. It is generally recognized that a single wythe of masonry is susceptible to water penetration and that the design and detail of the masonry construction must accommodate this fact. Important aspects of workmanship include achieving full head and bed joints, following proper tooling techniques, careful installation of flashing and weepholes, and maintaining clean cavities. The excellent workability, strength, and durability of masonry cement mortars assure that the designers' and masons' needs are met with regard to achieving watertight masonry construction. Careful laboratory research<sup>7</sup> has confirmed the excellent performance of masonry cement mortars in water penetration tests. These laboratory test results are backed up by a record of over fifty years of excellent field performance.

## Absorption

The absorption of a mortar is a measure of the amount of water the hardened mortar will absorb. While this characteristic of mortar is not directly related to the water penetration resistance of masonry, it has some significance of its own. Mortar can better resist chemical attack, staining, and freeze-thaw damage if it is less absorbent. Masonry cement mortars generally absorb only about half as much water as comparable non-air-entrained mortars.

## Time of Set

The setting time of the masonry cement affects the board life and striking time of the mortar. The test performed to measure the time of set is described in ASTM C 266, *Time of Setting of Hydraulic Cement by Gillmore Needles*, while the limits on initial and final set are given in ASTM C 91 or CSA Standard CAN3-A8. The time of set of the masonry cement as controlled by the manufacturer is not the only factor determining the board life and striking time of the mortar. These field properties of mortar are affected by the sand gradation, initial rate of absorption of the units, and ambient job conditions in addition to the setting time of the masonry cement.

## Recommended Mixing Procedures

### Proportions

The standard specification for mortar for unit masonry is ASTM C 270 or CSA Standard A179. The standards state the requirements and include two alternatives for the jobsite preparation of mortar: proportion specifications and property specifications. Proportion specifications, as indicated by the name, prescribe by volume the proportions to be used for each type of mortar. The proportions that satisfy the requirements using masonry cement are shown in Table 1.

When property specifications (Table 2) are used, the acceptability of the mortar is based on the properties of the ingredients, the water retention, and the compressive strength of a sample of mortar mixed and tested in the laboratory with jobsite sand.

It should be understood that the property requirements of the ASTM standard are for laboratory specimens and that no field testing is required. The ASTM standard presumes that the proportions developed in the laboratory, to yield the strength required, will result in satisfactory performance in the field. Unlike ASTM C 270, CSA A179 does have strength requirements (not shown in Table 2) for mortar mixed on the jobsite when the mortar is proportioned by the property specification.

### Sand

Sand for mortar should be clean and well graded, meeting *Specifications for Aggregate for Masonry Mortar*, ASTM C 144, or CSA Standard A179. For best workability the sand should contain all sizes of particles, ranging from very fine to coarse. Too much of any one particle size should be avoided. Sands deficient in fines generally produce harsh mortars, while an excess of fines—sizes passing the No. 50 sieve (300  $\mu$ m)—will yield mortars with good workability but high porosity and lower compressive strength.

### Mixing

Machine mixing should be used whenever possible. First, with mixer running, add most of the water and half the sand required.

**Table 1. Proportion Specifications for Mortar Using Masonry Cement**

A. United States (ASTM C 270)					
Mortar type	Parts by Volume				
	Portland or blended cement	Masonry cement type			Fine aggregate
		M	S	N	
M	1	—	—	1	4 1/2 to 6 2 1/4 to 3
S	1/2	—	—	1	3 3/8 to 4 1/2 2 1/4 to 3
N	—	—	—	1	2 1/4 to 3
O	—	—	—	1	2 1/4 to 3

B. Canada (CSA A179)					
Mortar type	Parts by Volume				
	Portland cement	Masonry cement		Fine aggregate	
		S	N		
S	1/2	—	1	3 3/8 to 4 1/2	
	—	1	—	2 1/4 to 3	
N	—	—	1	2 1/4 to 3	

#### Notes:

- Under both ASTM C 270, *Standard Specification for Mortar for Unit Masonry*, and CSA A179, *Mortar and Grout for Unit Masonry*, aggregate is measured in a damp, loose condition and 1 cu ft of masonry sand by damp by volume is considered equal to 80 lb of dry sand (in SI units 1 cu m of damp, loose sand is considered equal to 1280 kg of dry sand).
- Mortar should not contain more than one air-entraining material.
- The National Building Code of Canada does not allow the above mixes to be used for mortar for sand-lime brick and concrete brick. Instead, the mortar should consist of 1 part masonry cement to not less than 3 parts aggregate.

**Table 2. Property Specifications for Laboratory-Prepared Mortar Using Masonry Cement\***

A. United States (ASTM C 270)			
Mortar type	Minimum 28-day compressive strength, psi (MPa)	Minimum water retention, %	Maximum air content, %**
M	2500 (17.2)	75	18
S	1800 (12.4)	75	18
N	750 (5.2)	75	20
O	350 (2.4)	75	20

B. Canada (CSA A179)			
Mortar type	Minimum compressive strength, MPa		
	7 days†	28 days	Minimum water retention, %
S	7.5	12.5	70
N	3	5	70

\* The total aggregate shall be not less than 2 1/4 and not more than 3 1/2 times the volume of the cement used (see note 1 of Table 1).

\*\* When structural reinforcement is incorporated in the masonry cement mortar, the maximum air content is 18%.

† If the mortar fails to meet the 7-day requirement but meets the 28-day requirement, it shall be acceptable.



Next, add the masonry cement and the balance of sand. After one minute of continuous mixing, slowly add the rest of the water. Mixing should continue for at least 3 minutes. Extending the mixing time up to 5 minutes improves the mortar, resulting in better workability and water retention. In mixing, as much water should be used as practicable without impairing the workability of the mortar.

## Board Life

Mortar that has been mixed but not used immediately tends to dry out and stiffen. Loss of water by evaporation on a hot, dry day can be reduced by wetting the mortar board and covering the mortar in mortar boxes or wheelbarrows.

If necessary to restore workability, mortar should be retempered by adding water and remixing thoroughly. Although the addition of water may reduce the strength of the mortar slightly, the effect on the wall is preferable to the poor bond that would result if a dry, stiff mortar were used.

If mortar stiffens or sets because of hydration, it should be discarded. Since it is difficult to determine by sight or touch whether mortar stiffening is due to evaporation or hydration, it is more reliable to determine the suitability of mortar on the basis of time elapsed after mixing. Stiffening correlates to time and temperature, so that generally mortar that is not used within 2 1/2 hours after mixing should be discarded.

Further discussion of batching, mixing, and retempering can be found in *Mortars for Masonry Walls*, ISO40M (see "Related Publications" on page 6).

## Mortar Preparation in Hot Weather

The special problems that hot weather poses for masonry construction are often overlooked. The higher temperatures of materials and equipment coupled with more rapid evaporation rates reduce both the level of workability of a mortar and the time that it retains that workability. In fact, the mortar system may lose water to absorptive units and evaporation at such a rate that the hydration process of the cement is interrupted and normal strength development of the mortar impaired.

Some measures that can be taken to compensate for hot weather conditions are:

- Store sand, masonry units, and mixing equipment in shaded areas.
- Make certain that sand is moist. Sprinkle sand pile if needed to maintain moisture.
- Dampen high absorption brick.
- Dampen mortar boards and cover mortar boxes.
- Construct wind breaks protecting construction areas.
- Self cure masonry wall by covering with plastic at the end of the day, or fog mortar joints after they achieve initial set to compensate for evaporation.

## Mortar Preparation in Cold Weather

The ideal temperature of mortar when placed in the wall is 70 °F + 10 °F (21 °C + 5 °C). Higher temperatures may increase the rate of hardening.

Heating the mixing water is one of the easiest ways to raise the temperature of the mortar if the aggregates are not frozen. The mixing water should be heated sufficiently to produce mortar temperatures between 40 °F and 120 °F (4 °C and 49 °C) before use. Temperatures of successive mortar batches should be held to within 1 °F (5 °C) of the first batch. Temperature of mortar on mortar boards should be maintained above 40 °F (4 °C).

In freezing weather, moisture in sand will turn to ice, which must be thawed out. Never use sand that contains frost or frozen particles, or sand that has been scorched from heating. Do not heat water or sand above 120 °F (49 °C); CSA Standard CAN3-A371 requires a minimum temperature of 20 °C, a maximum temperature of 70 °C for both water and sand.

The use of an admixture to lower the freezing point of mortar during winter construction should not be permitted. The amount of such materials needed to significantly lower the freezing point of mortar can seriously impair mortar strength and other desirable properties.

To shorten the time required for a mortar to attain sufficient strength to resist freezing action, a non-chloride based accelerator may be used. The addition of such an admixture does not eliminate the need for protecting masonry from freezing, it simply reduces the amount of time such protection is required.

Further discussion of hot and cold weather construction is contained in chapter 5 of the *Concrete Masonry Handbook*, EB008M (see "Related Publications" on page 6).

## Specifying Mortar

The following provides a basis for preparing masonry cement mortar specifications. Some adjustments may be necessary in order to adapt the specifications to a particular project.

## Mortar

Mortar should be accepted under only one of the two alternative specifications in ASTM C 270 or CSA Standard A179. Designate either the proportion or property specifications and select mortar Type M, S, N, or O. Most guides recommend the use of the proportion specifications.

Type N mortar is commonly used in interior walls and above-grade exterior walls under normal loads. Type S mortar is used in exterior masonry structures at or below grade, such as foundation walls, retaining walls, pavements, walks, and patios. Types S and M should be considered for masonry under heavy loads and masonry exposed to severe, saturated freezing. High-strength mortar, such as Type M, should not be used indiscriminately; lower-strength mortar, such as Type N, has the advantage of greater workability, water retention, and extensibility.



## Cementitious Material

Masonry cement—ASTM C 91 (Types M, S, or N), CSA A8

Portland cement—ASTM C 150 (Types I, IA, II, IIA, III, or IIIA), CAN/CSA A5 (Types 10, 20, 30, or 50)

Blended hydraulic cement—ASTM C 595 (Types IS, IS-A, IP, IP-A, I[PM], or I[PM]-A)\*

## Sand

Aggregate for masonry mortar, ASTM C 144, or CSA Standard A179 should be used. Add special type—white crushed marble, white sand, or other—when needed.

## Water

Water should be suitable for drinking, clean, and free of harmful amounts of acid, alkalis, salts, or organic materials.

## Admixtures

Use only non-chloride based accelerators as approved by specifier. No antifreeze substances should be used to lower the freezing point of the mortar.

## Coloring Agents

Mineral oxide pigments resistant to sunlight and alkali should be used.

## Delivery, Storage, and Handling

Deliver and store manufactured products in original unopened containers. Store cements in weathertight enclosures and protect against contamination and warehouse set. Stockpile and handle aggregates to prevent segregation and contamination. Keep water free of harmful substances.

## Mixing Procedure

Measure materials by volume or equivalent weight; do not measure by shovel. Use of a container of known constant volume, such as a 1-cu ft (0.03-cu m) box, improves batching uniformity.

In clean mortar mixer, mix ingredients for 3 to 5 minutes after all materials are in the mixer. Use the maximum amount of water to produce proper workability.

## Retempering

Mortar should be used within 2 1/2 hours after initial mixing. Mortar that has stiffened within the 2 1/2 hour interval may be retempered with added water to restore workability.

\* Slag cement Types S or SA can also be used, but only with property specifications.

## References

1. Dubovoy, V.S., and Ribar, J.W., *Masonry Cement Mortars—A Laboratory Investigation*, Research and Development Bulletin RD0095, PCA, Skokie, IL, 1990, 26 pp.
2. Ribar, J.W., *Water Permeance of Masonry, a Laboratory Study*, ASTM STP 778, ASTM, Philadelphia, 1982, pp. 200–220.

## Related Publications

Readers of this publication may also be interested in the following publications available for purchase from the Portland Cement Association. For a complete listing of PCA publications, videos, and slide sets, visit our Web site at <http://www.portcement.org>, or write, call, or fax Customer Service, Portland Cement Association (phone 888.868.6733, fax 847.966.9666) and ask for the free PCA catalog, *Concrete Solutions*.

*Permeability Tests of Masonry Walls*, IS219M

*Building Weather-Resistant Masonry Walls*, IS220M

*Concrete Masonry Handbook*, EB008M

*Mortars for Masonry Walls*, IS040M

*Masonry Cement: Beauty to Last a Lifetime*, PA163M

*Recommended Practices for Laying Concrete Block*, PA043M

*Masonry Cement Mortars - A Laboratory Investigation*, RD095T

*Masonry Cement Product Data Sheet*, IS282M

---

**CAUTION:** Avoid prolonged contact between unhardened (wet) cement or cement-treated mixtures and skin surfaces. To prevent such contact, it is advisable to wear protective clothing. Skin areas that have been exposed to wet cement or cement-treated mixtures, either directly or indirectly or through saturated clothing, should be thoroughly washed with water.

This publication is based on the facts, tests, and authorities stated herein. It is intended for the use of professional personnel competent to evaluate the significance and limitations of the reported findings and who will accept responsibility for the application of the material it contains. The Portland Cement Association disclaims any and all responsibility for application of the stated principles or for the accuracy of any of the sources other than work performed or information developed by the Association.

---



5420 Old Orchard Road  
Skokie, Illinois 60077-1083  
847.966.6200  
[www.portcement.org](http://www.portcement.org)

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

**PRODUCT NAME**

Masonry Cement: Type N, Type S, and Type M

**MANUFACTURER**

Represented by:  
Portland Cement Association (PCA)  
5420 Old Orchard Road  
Skokie, IL 60077-1083  
Voice: 847.966.6200  
Fax: 847.966.9781  
Internet: [www.cement.org](http://www.cement.org)

**PRODUCT DESCRIPTION**

**Basic Use:** Masonry cement is specially formulated and manufactured to produce masonry mortar for use in brick, block, and stone masonry construction. Masonry cements are also used to produce stucco.

**Composition and Materials:** Masonry cement consists of a mixture of portland cement or blended hydraulic cement and plasticizing materials (such as lime-stone or hydrated or hydraulic lime), together with other materials introduced to enhance one or more properties such as setting time, workability, water retention, and durability. These components are proportioned at the cement plant under controlled conditions to assure uniformity of performance.

**Types.** Masonry cements are produced in Type N, Type S, and Type M strength levels for use in preparation of ASTM Specification C270 Type N, S, or M mortar, respectively, without further addition of cements.

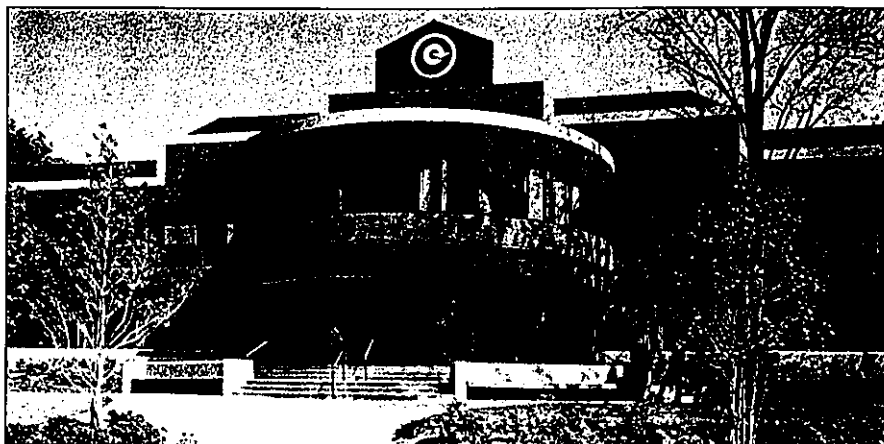
Table 1 is a general guide for selection of mortar type. Other factors, such as type and absorption of masonry unit, climate and exposure, applicable build-

Table 1. Recommended Guide for Selection of Mortar Type

Building Segment	Type
Exterior, above grade,	
load-bearing	N or S
non-load bearing	N
parapet wall	N or S
Exterior, at or below	
grade	S or M
Interior	
load-bearing	N or S
non-load bearing	N

# Masonry Information

## MASONRY CEMENT: PRODUCT DATA SHEET



*The Grump Firm, architects on the Econocom-USA Corporate Headquarters Building, used masonry cement mortar in contrasting brick masonry panels to achieve a dramatic visual effect.*

ing codes, and engineering requirements, should also be considered.

**Colors.** Masonry cements are available in a variety of colors as well as natural gray. As an alternative to the use of colored masonry cements, mineral oxide pigments may be added to the job site mixer to produce the color of mortar desired.

**Limitations.** Masonry cements are designed to be mixed with sand and water to produce a masonry mortar. The addition of hydrated lime to a masonry cement mortar at the job site is not required or recommended for conventional unit masonry construction.

**TECHNICAL DATA**

**Applicable Standards.** Masonry cements conform to ASTM C 91, the Standard Specification for Masonry Cement. Masonry cements are used to produce ASTM C 270 Type O, Type N, Type S, and Type M mortars as outlined in either the property specification or the proportion specification requirements of ASTM C 270. Requirements for sand to be used with masonry cement to produce ASTM C 270 mortars are found in ASTM C 144.

**Physical Properties.** Over the past sixty years, masonry cement has become the masonry mortar material of choice for most masonry construction in the United States because it provides the basic advantages of consistent workability, strength, color, and durability. This consistency of performance is assured by conformance to the physical property requirements for masonry cements as listed in Table 2.

Masonry cement mortars provide an excellent level of performance in the functional areas of workability, strength, durability, and appearance that are so important to the mason, owner, and designer.

**Workability.** Workability is the mason's appraisal of the mortar's ability to cling to head joints, slide smoothly off the trowel, and evenly support the placement of units. Additionally, the mortar needs to retain these properties for a reasonable length of time at whatever ambient conditions exist at the job site. That length of time that the mortar retains its workability is often termed its board life. The plasticizers contained in masonry cements contribute to their excellent workability, board life, and water retention. The importance of

workability is apparent when one considers that workmanship is a key element in achieving quality masonry construction.

**Strength.** By simplifying mortar materials batching at the job site, the use of masonry cement assures consistent strengths between batches and jobs. Masonry cement mortars prepared according to the property requirements of ASTM C 270 provide compressive strengths that exceed the values listed in Table 3. High Strength Type S and Type M masonry cements allow the specifier to accommodate special application requirements related to load bearing masonry, masonry below grade level, and masonry for paving without compromising the advantages of simplified batching.

In addition to compressive strength, bond strength is also an important consideration in masonry construction. There are many factors that affect the bond of mortar to unit in actual construction, including properties of the unit and mortar, ambient conditions, and the quality of workmanship involved. Masonry cement mortars provide the mason with a highly plastic mortar which readily flows into the surface irregularities of the unit, assuring that the bond strength potential of the materials is realized in the field when combined with good workmanship. In an extensive laboratory study of over 20 different masonry cements representing a cross section of producers throughout the United States, Ribar and Dubovoy<sup>1</sup> confirmed that masonry cements yield

Table 2. Physical Properties of Masonry Cements (ASTM C 91)

Mortar Cement Type	N	S	M
Fineness, residue on a 45- $\mu$ m (No. 325) sieve, maximum %	24	24	24
Autoclave expansion, maximum, %	1.0	1.0	1.0
Time of Setting			
Initial Set, minimum, hr.	2	1½	1½
Final Set, maximum hr.	24	24	24
Compressive strength minimum, MPa (psi)			
7 days	3.4 (500)	9.0 (1300)	12.4 (1800)
28 day	6.2 (900)	14.5 (2100)	20.0 (2900)
Air content, volume, %			
Minimum	8	8	8
Maximum	21	19	19
Water retention, flow after suction as % of original flow			
Minimum	70	70	70

Table 3. Physical Properties of Masonry Cement Mortars (ASTM C 270)

Mortar Type	Compressive Strength Minimum, MPa (psi)	Water Retention Minimum, %	Air Content Maximum, %
M	17.2 (2500)	75	18
S	12.4 (1800)	75	18
N	5.2 (750)	75	20*
O	2.4 (350)	75	20*

\*When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall be 18%.

excellent flexural bond strengths. Seventy-five percent of these masonry cement mortars tested with a brick unit having an IRA of 9 g/min-194 cm<sup>2</sup> (9 g/m-30 in<sup>2</sup>) yielded flexural bond strengths in excess of 690 kPa (100 psi). None of these masonry cement mortars produced values lower than 450 kPa (65 psi).

**Durability.** Properties of masonry mortar related to its durability include:

- Resistance to freeze thaw deterioration,
- Drying shrinkage characteristics,
- Resistance to sulfate attack,
- Water absorption characteristics, and
- Soundness

Masonry cement mortars provide significant performance advantages in these important areas.

The ability to endure the extremes of repeated freeze-thaw cycles without deterioration is critical to the long-term performance of mortar. Research<sup>2,3</sup> shows that air entrainment levels of at least 10 to 12 percent are needed to

provide effective resistance to freeze-thaw deterioration in masonry mortars. Masonry cement mortars have greater resistance to freeze-thaw deterioration than non-air-entrained-portland cement-lime mortars. This superior performance can be attributed to the controlled air content of masonry cement mortars.

Several factors influence drying shrinkage of masonry mortars, including water content, rate of drying, sand properties, moisture content and absorption of the masonry units, and cementitious material properties. Results of laboratory tests shown in Fig. 1 indi-

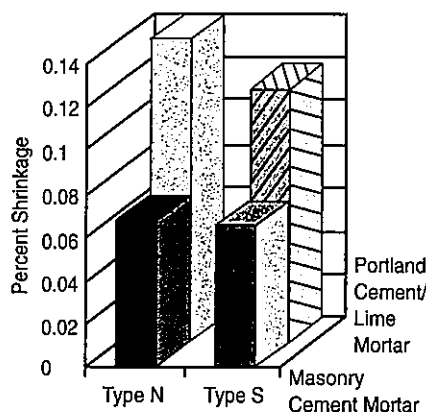


Fig. 1 - Drying shrinkage of masonry mortars at 28 days.

<sup>1</sup> Dubovoy, V. S., and Ribar, J. W., *Masonry Cement Mortars-A Laboratory Investigation*, Research and Development Bulletin RD095, PCA, Skokie, IL, 1990, 26pp.

<sup>2</sup> Davison, J. I., "Effect of Air Entrainment on Durability of Cement-Lime Mortars," *Durability of Building Materials*, Elsevier Publishing Co., Amsterdam, 1981.

<sup>3</sup> Zamatis, W. L., "Factors Affecting Performance of Unit Masonry Mortar," *ACI Journal*, Proc. Vol. 56, No. 6, American Concrete Institute, Detroit, 1959.

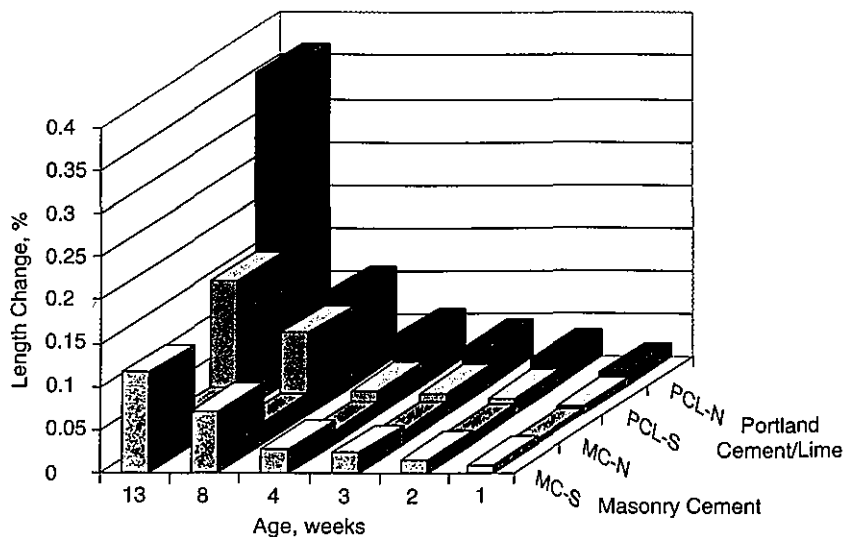


Fig. 2 - Sulfate expansion of masonry mortars.

cate that the drying shrinkage of masonry cement mortars is about half that of portland cement-lime mortars.

When sulfates come in contact with masonry mortar, subsequent expansion can cause deterioration of the mortar. Thus resistance to sulfate expansion should be considered where seawater or sulfate-bearing soils come in contact with masonry mortar. Masonry cement mortars demonstrate significantly greater sulfate resistance than portland cement-lime mortars (see Fig. 2).

Mortar can better resist chemical attack, staining, and freeze-thaw damage if it is less absorbent. Tests shown in Fig. 3 indicate that masonry cement mortars absorb only about half as much water as a comparable non-air entrained portland cement-lime mortar.

Expansion of mortars due to unsound ingredients can cause serious deterioration of masonry. Soundness of a cementitious material is measured by the autoclave expansion test. This test produces reactions in any unsound ingredient and simulates a long period of exposure for the cementitious material. Conformance of masonry cement to the autoclave expansion limits of ASTM C 91 assures that there will be no significant expansion of hardened mortar in a wall due to unsoundness.

**Water Permeance.** Water permeance of masonry is primarily related to workmanship and design. It is generally recognized that a single wythe of

masonry is susceptible to water penetration and that the design and detail of the masonry construction must accommodate this fact. Important workmanship factors include achieving full head and bed joints, following proper tooling techniques, careful installation of flashing and weepholes, and maintaining clean cavities. The excellent workability, strength, and durability of masonry cement mortars assure that the designers' and masons' needs are met in regard to achieving watertight masonry construction. Careful laboratory research has confirmed the excellent performance of masonry cement mortars in water permeance tests. These laboratory tests are backed up with a record of over sixty years of excellent field performance.

**Appearance.** The color of masonry mortar is a crucial component in the appearance of a masonry wall. Since masonry cement color is laboratory controlled and masonry cement offers the simplicity of the one-bag system of

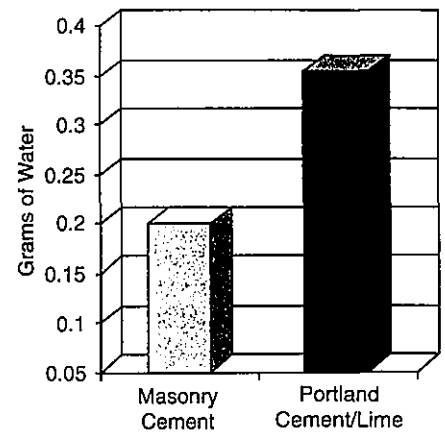


Fig. 3 - Water absorption of mortars.

batching, it is easier to achieve a consistent appearance in the finished job when using masonry cements. Colored masonry cements are also available to match, contrast, or complement the masonry units and enhance the architectural effect of the masonry.

## INSTALLATION

**Preparation.** Masonry cement mortar materials mixed according to the proportion specifications of ASTM C 270 should be accurately proportioned as indicated in Table 4. Under the property requirements of ASTM C 270, sand-to-cement proportions for the job-mixed mortar are the same as those established by laboratory tests of the mortar. The ratio of sand to cement is to be in the range of 2 1/4:1 to 3 1/2:1 by volume.

Machine mixing should be used whenever possible. First, with mixer running, add most of the water and half of the sand required. Next, add the masonry cement and the balance of sand. After one minute of continuous mixing, slowly add the rest of the water. Mixing should continue for at least 3 minutes. Extending the mixing time up

Table 4. ASTM C 270 Proportion Specification Requirements for Masonry Cement Mortars

Mortar Type	Portland or Blended Cement	Mortar Cement Type			Sand
		M	S	N	
M	—	1	—	—	2 1/4 - 3
M	1	—	—	1	4 1/2 - 6
S	—	—	1	—	2 1/4 - 3
S	1/2	—	—	1	3 3/8 - 4 1/2
N	—	—	—	1	2 1/4 - 3
O	—	—	—	1	2 1/4 - 3

to 5 minutes improves the workability and water retentivity of the mortar. In mixing, use as much water as practical without impairing the workability of the mortar.

**Application.** The practice of good workmanship principles is required for successful application. This includes proper filling of head and bed joints, careful placement of units, appropriate tooling of the joint, modification of construction procedures and/or schedules to adapt to extreme weather conditions,<sup>4,5</sup> and proper cleaning<sup>6</sup> procedures. Good workmanship coupled with proper detailing and design assures functional, durable, watertight masonry construction.

Fresh mortar should be prepared at the rate it is used, so that it does not stiffen in mortar boxes and on mortarboards. If necessary to restore workability, mortar should be retempered by adding water and remixing thoroughly. While the addition of water reduces mortar strength slightly, this effect is preferable to the poor contact between brick and mortar that will result from using dry, stiff mortar. Mortar over 2½ hours old should not be retempered or used. It should be discarded and replaced with freshly mixed mortar.

Emphasis should be placed in masonry construction on minimizing the amount of cleaning required. Precautions to minimize the amount of mortar splatter that is left on a wall include: the practice of good basic workmanship, dry brushing the face of the masonry wall after tooling with a soft bristle brush, and turning back the inside scaffold board at the end of the day to avoid rain splatter of mortar droppings from the board getting on the wall. Such mortar protrusions and splatters as occur should be removed before they tenaciously adhere to the masonry surface (preferably the morning after laying) using stiff nonmetallic brushes, nonmetallic scrapers, burlap, rags, or other appropriate means of removal.

If, despite efforts to maintain clean masonry during construction, it is felt that the use of masonry cleaning solutions are required, selection of cleaning technique and solution should be compatible with the units, and damage to



*William Wardlaw Center, Georgia Institute of Technology—Architect: Jova/Daniels/Busby, Inc.*

the mortar joint surface must be avoided. Follow the instructions of the manufacturer of the cleaning solution in its application on trial cleaning of inconspicuous areas to assure proper selection of method and solution. Cleaning with chemical solutions should not be attempted until the mortar has thoroughly cured. Generally, about two weeks' curing is recommended.

## AVAILABILITY

**Availability:** Masonry cements are regionally available in the United States and Canada from a network of dealers and distributors representing PCA member producers. For a complete list of PCA member masonry cement manufacturers contact PCA headquarters at 847.966.6200, by fax at 847.966.9781, or at the Web site: [www.cement.org](http://www.cement.org).

## CERTIFICATION

Masonry cement meets the requirements of ASTM C 91, The Standard Specification for Masonry Cement, for the type specified. Written manufacturer's certifications to that effect may be obtained from PCA member company producers of masonry cement upon request.

## MAINTENANCE

Avoid use of harsh chemical cleaners or strong acid solutions in cleaning masonry (refer to Installation).

## TECHNICAL SERVICES

Technical information and services are available from PCA and member manufacturers.

The following related publications are also available from PCA:

*Masonry Mortars* – IS040

*Masonry Cement Mortars* – IS181

*Trowel Tips: Hot Weather Masonry Mortar* – IS243

*Trowel Tips: Cleaning Masonry* – IS244

*Trowel Tips: Cold Weather Masonry Mortar* – IS248

*Selecting and Specifying Mortar and Grout for Unit Masonry* – IS275

*Quality Assurance for Masonry Mortar* – IS279

*Concrete Masonry Handbook* – EB008

*Recommended Practices for Laying Concrete Block* – PA043

<sup>4</sup> *Trowel Tips: Hot Weather Masonry Construction*, IS243, PCA, Skokie, IL.

<sup>5</sup> *Trowel Tips: Cold Weather Masonry Construction*, IS248, PCA Skokie, IL.

<sup>6</sup> *Trowel Tips: Cleaning Masonry*, IS244, PCA, Skokie, IL.

## PRODUCT NAME

Mortar Cement: Type N, Type S, and Type M

## MANUFACTURER

Represented by:  
Portland Cement Association (PCA)  
5420 Old Orchard Road  
Skokie, IL 60077-1083  
Voice: 847.966.6200  
Fax: 847.966.9781  
Internet: [www.cement.org](http://www.cement.org)

## PRODUCT DESCRIPTION

**Basic Use:** Mortar cement is specially formulated and manufactured to produce masonry mortar for use in brick, block, and stone masonry construction. Mortar cement mortars have similar attributes to masonry cement mortars, but they have lower air contents than masonry cements, and the mortar cement specification includes a minimum bond strength requirement. Mortar cement mortars are appropriate for use in structural applications that require masonry with high flexural bond strength.

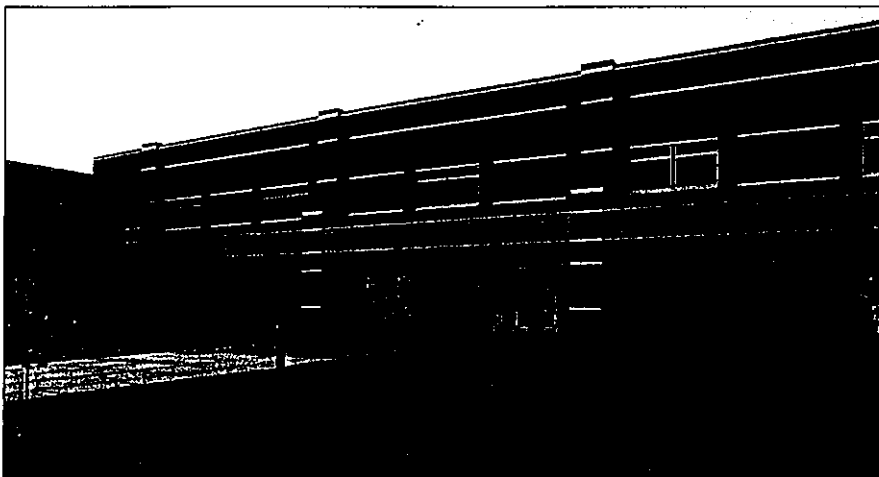
**Composition and Materials:** Mortar cement consists of a mixture of portland cement or blended hydraulic cement and plasticizing materials (such as limestone or hydrated lime), together with other materials introduced to enhance one or more properties such as setting time, workability, water retention and durability. These components are proportioned at the cement plant under controlled conditions to assure uniformity of performance.

Table 1. Recommended Guide for Selection of Mortar Type

Building Segment	Type
Exterior, above grade,	
load-bearing	N or S
non-load bearing	N
parapet wall	N or S
Exterior, at or below	
grade	S or M
Interior	
load-bearing	N or S
non-load bearing	N

# Masonry Information

## MORTAR CEMENT: PRODUCT DATA SHEET



*Masonry constructed using mortar cement mortar and three brick colors conveys a sense of security and permanence for students of the Buffalo High School in Buffalo Minnesota, designed by Abendroth, Rego & Youngquist.*

**Types:** Mortar cements are produced in Type N, Type S, and Type M classifications for use in preparation of ASTM Specification C 270 Type N, S, or M mortar, respectively, without further addition of cements.

Table 1 is a general guide for selection of mortar type. Other factors, such as type and absorption of masonry unit, climate and exposure, applicable building codes, and engineering requirements, should also be considered.

**Limitations:** Mortar cements are designed to be mixed with sand and water to produce a masonry mortar. The addition of hydrated lime to a mortar cement mortar at the job site is not required or recommended for conventional unit masonry construction.

## TECHNICAL DATA

**Applicable Standards:** Mortar cements conform to ASTM C1329, the "Standard Specification for Mortar Cement." Mortar cements are used to produce ASTM C 270 Type O, Type N, Type S, and Type M mortars as outlined in either the property specification or the proportion specification require-

ments of ASTM C 270. Requirements for sand to be used with mortar cement to produce ASTM C 270 mortars are found in ASTM C 144.

**Physical Properties:** Mortar cement mortars conform to the physical properties listed in Table 2.

These property requirements assure consistent performance of the product with respect to bond strength, compressive strength, workability, and durability.

**Bond Strength:** The mortar cement specification is the only ASTM masonry material specification that includes bond strength performance criteria. The bond strength criteria were established to assure comparable bond strength performance of the mortar cement to non-air-entrained portland cement-lime

<sup>1</sup> Melander, J. M., and Ghosh, S. K., "Development of Specifications for Mortar Cement," *Masonry: Esthetics, Engineering, and Economy*, ASTM STP 1246, D. H. Taubert and J. T. Conway, Eds., ASTM, West Conshohocken, PA, pp 88-99.

<sup>2</sup> Borchelt, J. G., and Tann, J. A., "Bond Strength and Water Penetration of Low IRA Brick and Mortar," *Proceedings of the Seventh North American Masonry Conference*, The Masonry Society, Boulder, CO, pp. 206-216.

Table 2. Physical Properties of Mortar Cements (ASTM C 1329)

Mortar Cement Type	N	S	M
Fineness, residue on a 45- $\mu$ m (No. 325) sieve, maximum %	24	24	24
Autoclave expansion, maximum, %	1.0	1.0	1.0
Time of Setting			
Initial Set, minimum, hr.	2	1½	1½
Final Set, maximum hr.	24	24	24
Compressive strength minimum, MPa (psi)			
7 days	3.4 (500)	9.0 (1300)	12.4 (1800)
28 day	6.2 (900)	14.5 (2100)	20.0 (2900)
Bond strength minimum, MPa (psi)			
28 days	0.5 (70)	0.7 (100)	0.8 (115)
Air content, volume, %			
Minimum	8	8	8
Maximum	17	15	15
Water retention, flow after suction as % of original flow			
Minimum	70	70	70

Table 3. Physical Properties of Mortar Cement Mortars (ASTM C 270)

Mortar Type	Compressive Strength Minimum, MPa (psi)	Water Retention Minimum, %	Air Content Maximum, %
M	17.2 (2500)	75	12
S	12.4 (1800)	75	12
N	5.2 (750)	75	14*
O	2.4 (350)	75	14*

\*When structural reinforcement is incorporated in (cement-lime or) mortar cement mortar, the maximum air content shall be 12%.

Note: Physical properties listed in Table 2 and Table 3 are measured in accordance with prescribed laboratory test procedures. Conformance to compressive strength, bond strength, air content, and water retention requirements of Table 2 is determined using standard testing sand (ASTM C 778). Conformance to Table 3 requirements is established using a masonry sand (ASTM C144) that is intended to be used in construction. Mortar made using masonry sand typically has lower compressive strength, lower air content, and higher water retention as compared to that achieved using standard sand. This fact is reflected in the differences between Table 2 (ASTM C 1329) and Table 3 (ASTM C 270) requirements for these properties.

combinations of equivalent mortar type designation<sup>1</sup>. As shown in Fig. 1, subsequent research has confirmed that mortar cement mortars provide excellent bond strengths<sup>2</sup>.

The procedure utilized in determining conformance of mortar cement to bond strength criteria seeks to eliminate, insofar as possible, the effects of workmanship, curing, and unit properties on measured bond strength. Therefore, standard mixing, specimen fabrication, curing, and testing procedures are outlined, including the use of standard testing units. It should be noted that there are many factors that affect the bond of mortar to unit in actual construction, including properties of the unit and mortar, ambient conditions, and the quality of workmanship involved.

**Compressive Strength:** By simplifying mortar materials batching at the job site, the use of mortar cement assures consistent strengths between batches

and jobs. Mortar cement mortars mixed according to the property requirements of ASTM C 270 provide strengths that exceed the values listed in Table 3. High strength Type S and Type M mortar cements allow the specifier to accommodate special application requirements related to load bearing masonry, masonry below grade level, and masonry for paving, without compromising the advantages of simplified batching.

**Workability:** Workability is the mason's appraisal of the mortar's ability to cling to head joints, slide smoothly off the trowel, and evenly support the placement of units. Mortar of proper workability is soft but has good body; it spreads readily and extrudes from joints without smearing or dropping. Additionally, the masonry mortar needs to retain these properties for a reasonable length of time at whatever ambient conditions exist at the job site. That length of time that the mortar retains its workability is often termed its board life. The

plasticizers contained in mortar cements contribute to their workability and board life. Fineness, time of setting, air content, and water retention requirements for mortar cements are specification properties that relate to consistent performance with respect to workability. The importance of workability is apparent when one considers that workmanship is a key element in achieving quality masonry construction.

**Durability:** Expansion of mortars due to unsound ingredients can cause serious disintegration of masonry. Soundness of a cementitious material is measured by the autoclave expansion test. This test produces reactions in any unsound ingredients and simulates a long period of exposure for the cementitious material. Conformance of mortar cement to the autoclave expansion limits of ASTM C 1329 assures that there will be no significant expansion of hardened mortar in a wall due to unsoundness.



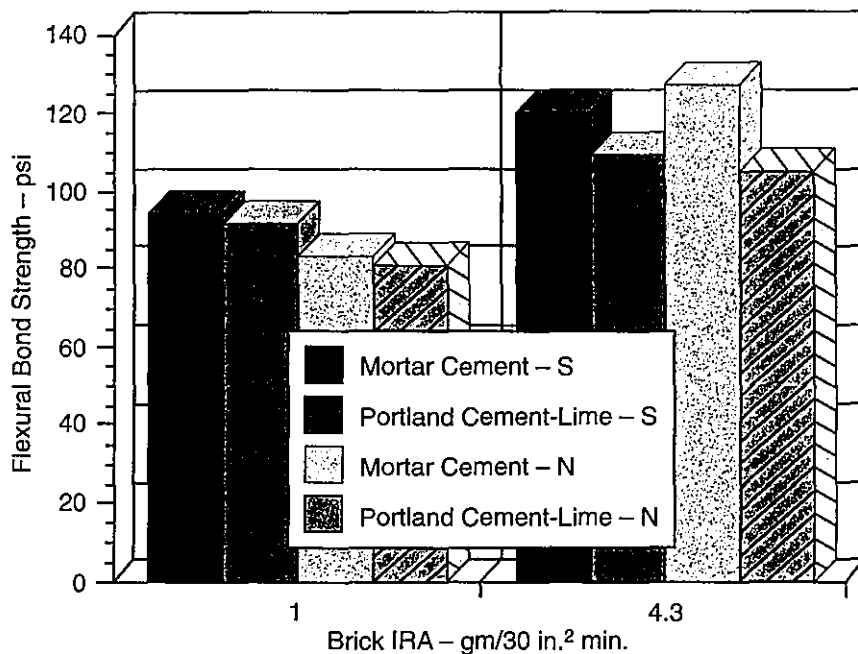


Fig. 1 - Bond Strengths of Mortar Cement and Portland Cement-Lime Mortars (Data from Ref. 2).

Mortar cements include air-entraining agents that provide advantages of improved freeze-thaw durability and workability associated with air-entrained mortars. Air content of mortar cement is limited to between 8% and 15% for Type M and S and 8% and 17% for Type N. Conformance to these limits is determined using laboratory testing procedures and standard testing sand. Air contents achieved using field sand and field mixing procedures are typically lower by one or two percent, although certain field sands may increase air content.

**Water Penetration:** Water penetration resistance of masonry is primarily related to workmanship and design. It is generally recognized that a single 4-inch wythe of masonry is susceptible to water penetration and that the design and detail of the masonry construction

must accommodate this fact. Important workmanship factors include achieving full head and bed joints, following proper tooling techniques, careful installation of flashing and weep holes, and maintaining clean cavities. The excellent workability, strength, and durability of mortar cement mortars assure that the designers' and masons' needs are met in regard to achieving watertight masonry construction. Research<sup>2</sup> has confirmed the excellent performance of mortar cement mortars in water penetration tests.

**Appearance:** The color of the masonry joint is a crucial component in the appearance of the entire wall. Since mortar cement color is laboratory-controlled and mortar cement offers the simplicity of the one bag system of batching, it is easier to achieve a consistent appearance in the finished job.

## INSTALLATION

**Preparation:** Mortar cement mortar materials mixed according to the proportion specifications of ASTM C 270 should be accurately proportioned in accordance with Table 4.

Under the property requirements of ASTM C 270, sand-to-cement proportions for the job mixed mortar are the same as those established by laboratory tests of the mortar. The ratio of sand to mortar cement is to be no less than 2¼:1 and no more than 3½:1.

Machine mixing should be used whenever possible. First, with mixer running, add most of the water and half the sand required. Next, add the mortar cement and the balance of sand. After one minute of continuous mixing, slowly add the rest of the water. Mixing should continue for at least 3 minutes. Extending the mixing time up to 5 minutes improves the mortar, resulting in better workability and water-retention. In mixing, as much water should be used as practical, without impairing the workability of the mortar.

**Application:** The practice of good workmanship principles is required for successful application. This includes proper filling of head and bed joints, careful placement of units, appropriate tooling of the joint, modification of construction procedures and/or schedules to adapt to extreme weather conditions<sup>3,4</sup>, and proper cleaning<sup>5</sup> procedures. Good workmanship coupled with proper detailing and design assures functional, durable, watertight masonry construction.

Fresh mortar should be prepared at the rate it is used, so that it does not stiffen in mortar boxes and on mortar boards. If necessary to restore workability, mortar should be retempered by adding water and remixing thoroughly. While the addition of water reduces mortar strength slightly, this effect is

Table 4. ASTM C 270 Proportion Specification Requirements for Mortar Cement Mortars

Mortar Type	Portland or Blended Cement	Mortar Cement Type			Sand
		M	S	N	
M	—	1	—	—	2¼ - 3
M	1	—	—	1	4½ - 6
S	—	—	1	—	2¼ - 3
S	½	—	—	1	3¾ - 4½
N	—	—	—	1	2¼ - 3
O	—	—	—	1	2¼ - 3

<sup>3</sup> Trowel Tips: Hot Weather Masonry Construction, PCA Publication Code IS243, PCA, Skokie, IL.

<sup>4</sup> Trowel Tips: Cold Weather Masonry Construction, PCA Publication Code IS248, PCA, Skokie, IL.

<sup>5</sup> Trowel Tips: Cleaning Masonry, PCA Publication Code IS244, PCA, Skokie, IL.

preferable to the poor contact between brick and mortar that will result from using dry stiff mortar. Mortar over 2½ hours old should not be retempered or used. It should be discarded and replaced with freshly mixed mortar.

Emphasis should be placed in masonry construction to minimize the amount of cleaning required. Precautions to minimize the amount of mortar splatter that is left on a wall include the practice of good basic workmanship, dry brushing the face of the masonry wall after tooling with a soft bristle brush, and turning back the inside scaffold board at the end of the day to avoid rain splatter of mortar droppings from the board getting on the wall. Such mortar protrusions and splatters should be removed before they adhere to the masonry surface (preferably the morning after laying) using stiff nonmetallic brushes, nonmetallic scrapers, burlap,

rag, or other appropriate means of removal.

If, despite efforts to maintain clean masonry during construction, it is felt that the use of masonry cleaning solutions are required, selection of cleaning technique and solution should be compatible with the units, and damage to the mortar joint surface must be avoided. Follow the instructions of the manufacturer of the cleaning solution in its application on trial cleaning of inconspicuous areas to assure proper selection of method and solution. Cleaning with chemical solutions should not be attempted until the mortar has thoroughly cured. Generally, about two weeks curing is recommended.

### AVAILABILITY

**Availability:** Mortar cements are regionally available in the United States and Canada from a network of dealers

and distributors representing PCA member producers. For a complete list of PCA member mortar cement manufacturers contact PCA headquarters at 847.966.6200, by fax at 847.966.9781, or at the Web site: [www.cement.org](http://www.cement.org).

### CERTIFICATION

Mortar cement meets the requirements of ASTM C 1329, The Standard Specification for Mortar Cement, for the type specified. Written manufacturer's certifications to that effect may be obtained from PCA member company producers of mortar cement upon request.

### MAINTENANCE

Avoid use of harsh chemical cleaners or strong acid solutions in cleaning masonry (refer to Installation).

### TECHNICAL SERVICES

Technical information and services are available from PCA and member manufacturers.

The following related publications are also available from PCA:

*Masonry Mortars* – IS040

*Masonry Cement Mortars* – IS181

*Trowel Tips: Hot Weather Masonry Mortar* – IS243

*Trowel Tips: Cleaning Masonry* – IS244

*Trowel Tips: Cold Weather Masonry Mortar* – IS248

*Selecting and Specifying Mortar and Grout for Unit Masonry* – IS275

*Bond Strength Testing of Masonry* – IS277

*Factors Affecting Bond Strength of Masonry* – IS278

*Quality Assurance for Masonry Mortar* – IS279

*Concrete Masonry Handbook* – EB008

*Recommended Practices for Laying Concrete Block* – PA043



*Architects Smith, Hinchman & Grylls used mortar cement mortar and brick of differing color and texture to define distinct building areas within a unified visual theme on the Veterans Administration Hospital in Detroit.*

# Pointing Masonry Construction

SEPTEMBER, 1996

*This International Masonry Institute (IMI) Masonry Construction Guide has been prepared to assist masonry contractors who bid on tuckpointing work and craftworkers who perform it.*

## Introduction

Masonry products and materials are among the most durable available for construction, especially when installed by quality contractors who employ trained, skilled craftworkers. Typically, mortar joints are serviceable for 35 years or more when properly installed. The masonry units themselves, typically brick or concrete block, may have a serviceable life of 100 years or more.

As with any building product continuously exposed to the elements, masonry is subject to weathering. Acids in the rain, seismic movement, building settlement, freezing and thawing cycles, impact damage and dirt take their toll. When visual inspection reveals that the mortar joints are cracking or otherwise deteriorated, restoration is necessary to help maintain the integrity of wall systems and products. Tuckpointing is an effective way of decreasing water entry into masonry.

## Tuckpointing

Tuckpointing is the term most often used to describe the process of cutting out deteriorated mortar joints in masonry walls to a uniform depth and filling in those joints with fresh mortar.

Tuckpointing, however, is only the most common of three terms often used interchangeably in the United States and Canada to describe the complete process of restoring older masonry joints. The other two are repointing and pointing. In some areas, repointing or pointing may mean the same as tuckpointing. But they may also mean only the placing of plastic mortar in joints without first removing damaged mortar.

Tuckpointing isn't reserved for older buildings. New masonry walls may need to be tuckpointed when bee holes or voids appear in the finished joint, or when the joints have an incorrect or improperly tooled finish or when the color of the joints is incorrect.

In this Masonry Construction Guide and

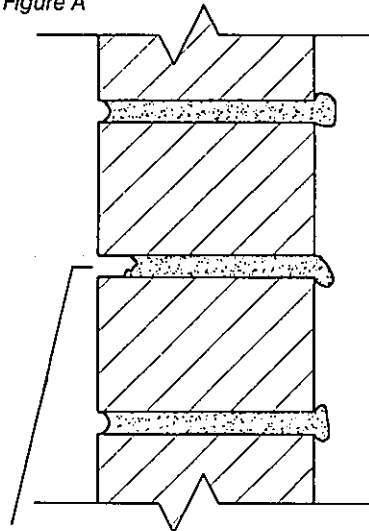
in general, IMI uses the term **tuckpointing** to refer to the process of *removing* deteriorated mortar joints and *replacing* them with new mortar.

## Procedures for Tuckpointing Preparation

Mason contractors who successfully bid tuckpointing jobs know that to be competitive, they have to employ craftworkers who have been trained in masonry restoration and who have relevant experience.

The mason contractor must determine the scope of the work. Tuckpointing is

Figure A



## DETERIORATED MORTAR JOINT

labor-intensive. To help determine the scope of the work and prepare an accurate bid, the mason contractor needs answers to a number of questions, including:

- \* Are all the mortar joints on a structure to be tuckpointed? Or only joints where the mortar has eroded to a particular depth?
- \* What about areas where there are hairline cracks between the masonry units and the mortar?
- \* Does the building need to be cleaned before the real condition of mortar joints can be observed?
- \* Is the mason contractor alone to determine which joints need restoration?

Once these questions are answered, the masonry contractor can accurately determine the area to be tuckpointed and see that it is clearly defined on the bid documents.

It is also important to determine the age of the building being scheduled for tuckpointing. If it dates back to the early part of this century or is older, more care must be taken in selecting and mixing mortar. It wasn't until after the 20th Century began that portland cement was combined with the traditional sand and lime to make mortar. Older mortars without portland cement are far weaker than modern mortars, and have far less compressive strength. A stronger repointing mortar deforms less under load than weaker older mortar, which concentrates the load in the area of the stronger mortar. The stress can lead to spalling of the masonry units.

Mortar in older buildings may contain materials to give them texture or an unusual color. These additives include oyster shells, horsehair, carbon black and others. Oyster shells, if required, can be mixed into new mortar in small quantities. If the mortar needs to be colored, use metallic oxides to match, and not organic chemicals.

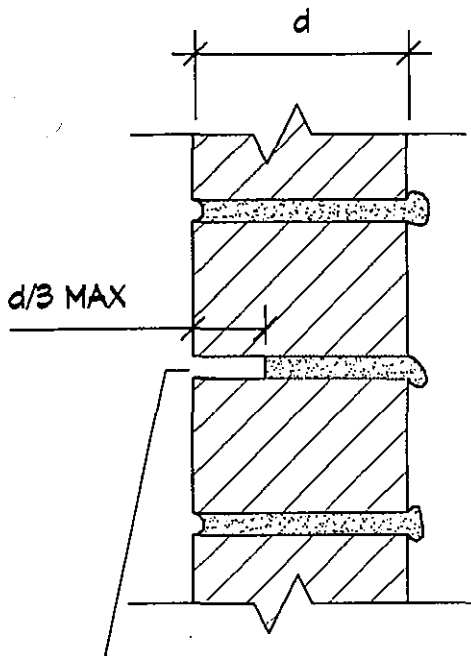
The contractor must also decide whether to use power tools, such as saws and grinders, to cut out old mortar. While the mechanical tools are faster than hammers and chisels, the power tools may damage the masonry units surrounding the mortar. Additionally, if an historical building is being restored, saws, grinders and other mechanical tools may not be allowed or, if they are, only if special permits are obtained.

## Mortar Removal and Replacement

The craftworkers should remove old mortar to a depth of  $\frac{3}{8}$ " to  $\frac{1}{2}$ ", or until sound mortar is reached. Do not remove mortar in excess of one-third the depth of masonry unit. The profile of the resulting joint should resemble Figure B, in which the mortar has been cut back to a uniform depth. Dust and debris should be removed from the joint by brushing, rinsing with water or blowing with air.

Tuckpointing mortar should be carefully selected. Use prehydrated mortar to re-

Figure B

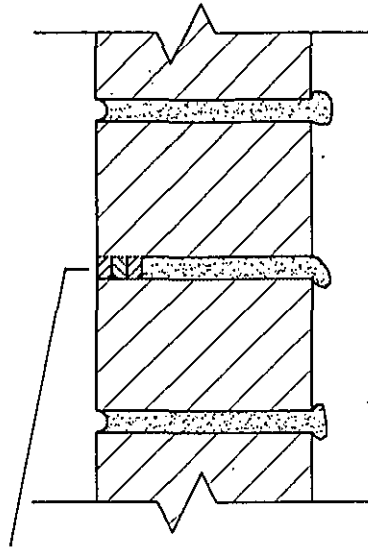


MORTAR CUT BACK  
TO A UNIFORM DEPTH

duce shrinkage. Mix in the proper additives, if any, to match the color of existing mortar. Here's how to mix a batch of mortar for tuckpointing:

1. Place all dry ingredients in a tub or mixing box
2. Thoroughly mix all dry ingredients
3. Add one-half the amount of water used in new construction
4. Mix the mortar until it will hold shape when formed into a solid ball. There should be no flow or spread of mortar

Figure C



PLACE TUCK-POINTING  
MORTAR IN THIN  
LAYERS OF 1/4" MAX

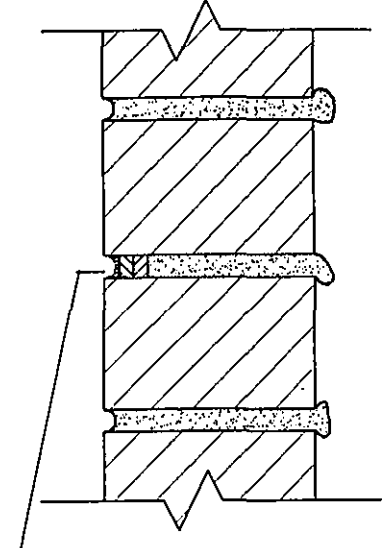
5. Let the mix hydrate for one to two hours

6. Add more water to make the mix workable, but still relatively stiff, which results in good workability and minimum smearing.

Joints to be tuckpointed should be dampened, but, to make sure the new mortar makes a good bond, the masonry units must absorb all the surface water.

A wide variety of tool widths are available to pack mortar into the prepared joints. Choose a tool with a width slightly smaller than the width of the joint. This keeps mason productivity high and keeps the wall as clean as possible. The craftworkers should force the new mortar into the joints in layers 1/4" thick or less to reduce air pockets and voids, as in Figure C. Each layer should be thumbprint hard before the next is applied. Final joint

Figure D



TOOL JOINT TO  
MATCH ORIGINAL  
PROFILE

tooling is done the same way as with new construction. The joint should be tooled to match the original profile.

Mortar tags should be brushed off after the mortar is dry, to reduce smearing. Commercial cleaning compounds can be used to clean the wall. See IMI Masonry Construction Guide 2-3, **Cleaning Masonry Walls**.

When properly done, tuckpointing provides a strong, waterproof mortar joint that matches the appearance of the original mortar joints, and helps extend the commercial life of the building.



International Masonry Institute  
823 15th Street, N.W.  
Suite 1001  
Washington, DC 20005

# FREEZE-THAW DURABILITY OF MASONRY MORTARS

Mortar durability is usually assessed on specially cast samples or pieces cut from actual mortar beds. After cycles of freezing and thawing, mortar samples are examined for changes in size, reduction in modulus of elasticity, or loss of weight and physical deterioration. Unfortunately, this type of testing does not represent real-world conditions. To counteract this shortcoming, the PCA sponsored tests by CERAM Building Technology Laboratory. Researchers used a well-established panel freezing test that simulates severe natural conditions leading to frost damage in exposed masonry.

## Mortars

Three ASTM C 270 Type S mortars (air contents from 3 to 16 percent) were studied:

- a non-air-entrained cement/lime/sand (CL) mix (ASTM C 150 Type I portland cement and ASTM C 207 Type S hydrated lime)
- an air-entrained masonry cement (ASTM C 91 Type S)
- an air-entrained mortar cement (ASTM C 1329 Type S)

## Construction of Test Panels

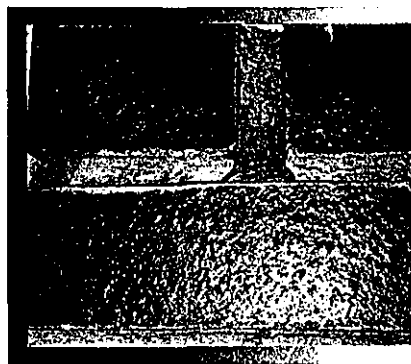
Each of the three mortars was proportioned by volume and mixed as a single batch. Three test panels—ten courses of three bricks with 10 mm (3/8 in.) tooled joints—were constructed from each mortar mix using Staffordshire Blue clay bricks. These very durable bricks have a low water absorption (5.5%) and a low initial rate of absorption (1.3kg/m<sup>2</sup>/min)—properties known to exert a strong influence on the durability of associated mortar joints. After construction, panels were cured in the laboratory atmosphere for at least 28 days prior to freeze-thaw testing.

## Test Program and Results

Cured, saturated panels were subjected to freeze-thaw cycles on their exposed faces. Testing continued until 300 cycles or until major damage to the mortar joints, whichever came first. Afterwards, panels were closely examined for signs of frost damage. None of the bricks were visibly affected by frost. Samples taken from the mortar beds were tested according to the methods given in ASTM C 1324, C 856, C 457 and C 294. Frost damage was observed to the mortar joints on panels built with non-air-entrained mortar but not to any panels where air-entrained mortar was used.

All the panels constructed with air-entrained Type S mortar cement and with air-entrained Type S masonry cement withstood 300 freeze-thaw cycles in a saturated condition without suffering frost damage to the mortar joints.

Of the three panels constructed with Type S CL mortar without air entrainment, one panel suffered no frost damage after 300 cycles, one panel suffered minor frost damage starting at 200 cycles, and one panel suffered major frost damage starting at 50



*Fig. 1. Panel No. W2904 at end of test (200 Cycles).*

cycles. On one panel, changes to the condition of the mortar joints (a pattern of fine surface cracks) were first observed after 50

cycles. At the 100-cycle stage, actual disintegration of the mortar surfaces had occurred. The condition of the joints continued to deteriorate up to the 200-cycle stage when the test was ended with considerable frost damage to the mortar, including separation at the brick/mortar interface (see Fig. 1). When the panel was partly dismantled, it was revealed that the mortar bed was cracked parallel to and 10 to 15 mm (0.4 to 0.6 in.) from the exposed surface of the panel. Poor durability was attributed to a low air content in that mortar.

## Summary and Conclusions

Masonry panels constructed from durable bricks and ASTM C 270 Type S mortars with air entrainment can withstand prolonged exposure to extremely severe freeze-thaw conditions without damage.

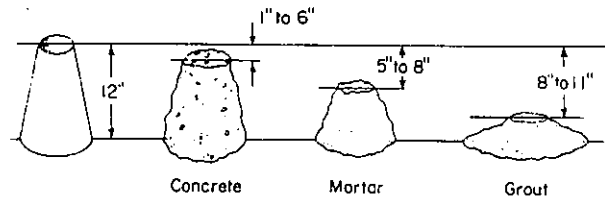
Masonry panels constructed with the same bricks and with non-air-entrained Type S CL mortar, subjected to the same severe conditions, exhibited performance ranging in degree from serious breakdown of the mortar to no detectable changes in its condition.

The program has demonstrated that Type S mortars with air entrainment are durable in extreme conditions of freezing and thawing whereas two out of three Type S mortars with low air contents suffered frost attack in the same conditions.

This article is based on PCA R&D Serial No. 2229, *Effect of Air Entrainment on Freeze-Thaw Durability of Masonry Mortars*, by G. J. Edgell, R. L. Nelson, J. L. Nicholas, J. M. Melander, and F. Peake.

## GROUT

GROUT CONSISTS OF CEMENTITIOUS MATERIAL AND AGGREGATE THOROUGHLY MIXED WITH WATER. GROUT SHOULD BE SOUPY ENOUGH TO POUR WITHOUT SEGREGATION OF THE CONSTITUENTS. TO GAIN AN APPRECIATION OF THIS CONSIDER THE FOLLOWING FIGURE WHICH DEPICTS RELATIVE SLUMPS OF CONCRETE, MORTAR AND GROUT



GROUT CAN BE USED TO BOND TWO LAYERS OF MASONRY TOGETHER (GROUT COLLARS) OR TO BOND STEEL REBAR TO MASONRY.

PORTLAND CEMENT, AGGREGATE AND WATER ARE USED TO MAKE GROUT. A SMALL AMOUNT OF LIME IS PERMITTED. THE FOLLOWING TABLE LISTS GROUT PROPORTIONS BY VOLUME

Type	Parts by volume of portland cement or blended cement	Parts by volume of hydrated lime or lime putty	Aggregate, measured in a damp loose condition	
			Fine	Coarse
Fine grout	1	0 to $\frac{1}{10}$	$2\frac{1}{4}$ to 3 times the sum of the volumes of the cementitious materials	
Coarse grout	1	0 to $\frac{1}{10}$	$2\frac{1}{4}$ to 3 times the sum of the volumes of the cementitious materials	1 to 2 times the sum of the volumes of the cementitious materials

\*Adapted from ASTM C476.

Notes: Applicable material standards: portland cement—ASTM C150; blended hydraulic cement—ASTM C595; hydrated lime—ASTM C207; lime putty—ASTM C5; aggregate—ASTM C404.

FROM THE TABLE IT IS OBVIOUS THAT TWO TYPES OF AGGREGATE ARE PERMITTED: FINE AND COARSE. THE TYPE OF AGGREGATE IS DICTATED BY

1. POUR HEIGHT
2. GROUT SPACE DIMENSIONS



THE FOLLOWING TABLE LISTS MAXIMUM POUR HEIGHTS AND SPECIFIC GROUT TYPES WITH RESPECT TO GROUT SPACE

Maximum grout pour height, ft.	Specified grout type*	Minimum width of grout space, in.**†	Minimum grout space dimensions for grouting cells of hollow units, in.‡
1	Fine	$\frac{3}{4}$	$\frac{1}{2}$ by 2
5	Fine	2	2 by 3
12	Fine	$2\frac{1}{2}$	$2\frac{1}{2}$ by 3
24	Fine	3	3 by 3
1	Coarse	$1\frac{1}{2}$	$1\frac{1}{2}$ by 3
5	Coarse	2	$2\frac{1}{2}$ by 3
12	Coarse	$2\frac{1}{2}$	3 by 3
24	Coarse	$3\frac{3}{4}$	3 by 4

\*Fine and coarse grouts and aggregates are defined in ASTM C476 and C404.

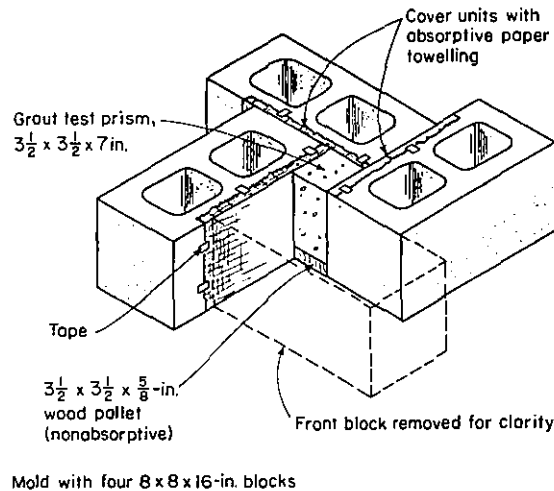
\*\*For grouting between wythes.

†Grout space dimension equals grout space width minus horizontal reinforcing bar diameter.

‡Area of vertical reinforcement shall not exceed 6% of the area of the grout space.

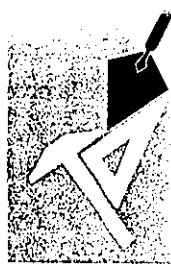
Adapted from ACI 530.1/ASCE 6 (Ref. 76).

ASTM C 1019 PROVIDES A METHOD OF USING MASONRY UNITS TO FORM A PRISM. THE PRISM IS TESTED LATER IN COMPRESSION.



NOTE THAT THIS TEST PROVIDES AN INDICATION OF THE QUALITY OF THE GROUT. TEST RESULTS CAN NOT BE USED TO ASCERTAIN THE COMPRESSIVE STRENGTH OF THE MASONRY ASSEMBLY (COMPOUND).

# Masonry Grout



## SCOPE

This Construction Guide presents general information on masonry grout, discussing such topics as grout materials, mixes, and admixtures. Knowledge of applicable standards, codes and field practices is required to thoroughly understand masonry grout. Information contained in this guide is intended to further educate the user on grout and grout materials.

## INTRODUCTION

Grout is a cementitious material, primarily composed of Portland cement, fine aggregate, possibly coarse aggregate, and, in some cases, lime. These ingredients are combined with a sufficient amount of water to produce a fluid, flowable mixture.

Grout is neither concrete nor mortar. There are distinct differences in water content and material composition between these materials.

Concrete differs from grout in that it contains a much coarser aggregate and a significantly lower water-cement ratio. Concrete is poured with a minimum amount of water into non-absorptive forms. Conversely, grout is poured with a significantly higher water-cement ratio into what are essentially absorptive forms - masonry unit cells or cores. The initially high water-cement ratio of grout is rapidly reduced because the masonry absorbs much of the water.

Mortar, on the other hand, differs from grout in that it often contains hydrated lime, additives, finer aggregates and only enough water to make it workable.

## SPECIFYING GROUT

Grout should conform to ASTM C 476, "Standard Specification for Grout for Masonry."

The Standard allows grout to be mixed according to the proportions listed (see Table 1) or by compressive strength. Research has indicated that grout mixed to the Table 1 proportions may obtain unexpectedly high compressive strengths. Therefore, it is recommended that grout be specified by strength to achieve better structural compatibility with the specified masonry units. Also, specifying grout by strength generally will produce lower material costs because the mix likely will contain less cement.

**TABLE 1 Grout Proportions by Volume**

TYPE	Parts by Volume of Portland Cement or Blended Cement	Parts by Volume of Hydrated Lime or Lime Putty	Aggregate, Measured in a Damp, Loose Condition	
			Fine	Coarse
Fine grout	1	0-1/10	2 1/4-3 times the sum of the volume of the cementitious materials	
Coarse grout	1	0-1/10	2 1/4-3 times the sum of the volumes of the cementitious materials	1-2 times the sum of the volumes of the cementitious materials

Source: Adapted from American Society For Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA

## TYPES OF GROUT

Grout is classified into two types according to ASTM C 476 - *fine grout* and *coarse grout*. Fine grout uses only fine aggregates, (natural or manufactured sand) with a maximum aggregate size of 3/8 inches. Coarse grout adds coarse aggregate to the mix (crushed stone or pea gravel) in addition to the fine aggregate. The maximum size aggregate is 1/2 inch. All aggregates - fine or coarse, must conform to ASTM C404 "Standard Specification for Aggregates for Masonry Grout".

Pour height and minimum clear grout space dimensions, as well as economics, dictate the choice of fine or coarse grout. There is no significant difference in the compressive strengths that can be attained with either type grout. Generally speaking, smaller clear grout space dimensions - spaces not exceeding 2 to 3 inches - or where the minimum clearance between the masonry unit and the reinforcing bar is only 1/4 inch, call for fine grout. When the grout spaces are larger and the clearance between the reinforcing and the unit is more than 1/2 inch, coarse grout is generally used. Pour height also effects the choice of fine or coarse grout.

## WATER CONTENT

High water content is required in grout to provide fluidity and pumpability. Fluidity allows grout to completely fill openings and to encapsulate steel reinforcement. Fluidity of grout is measured by a slump cone test. Grout must contain enough water to produce an 8 inch to 11 inch slump. The proper grout slump for the application will depend on how much water will be absorbed by the adjacent masonry. The more water the masonry units absorb from the grout, the more water the grout must contain to remain fluid. When determining the ideal grout slump, consider all of the following factors:

*Initial Rate of Absorption (IRA) of Masonry Units* - Masonry units with high IRA will absorb more water than units with low IRA.

*Weather conditions* - Masonry walls constructed in hot and arid conditions will absorb water more rapidly than masonry constructed under cold or humid conditions.

*Size of grout space* - Small, narrow grout spaces have larger surface-to-volume ratios than wider grout spaces and will absorb water at a greater rate.

Therefore, grout slump should be adjusted accordingly. In damper climates or when the masonry contains low-absorption units or wider grout spaces, use a grout with an 8 inch or 9 inch slump. In dryer climates or when the masonry contains high-absorption units or narrower grout spaces, use grout with a 10 inch or 11 inch slump.

## GROUT MIXES

Once a grout's required strength and slump have been determined by the designer, the contractor should contact an accredited masonry testing laboratory to acquire an appropriate grout mix. The laboratory will suggest mix proportions that meet the designer's requirements. The laboratory can then test trial batches to determine which grout mix is most economical. The laboratory will use grout proportions recommended in ASTM C 476 as a rough guideline to determine the mix design. Though grout is specified by proportion, test laboratories and readymix suppliers batch grout mix by weight. If required, volume proportions can be converted to equivalent weight proportions. Ultimately, the laboratory will determine the best mix based on test results and experience.

Once the grout mix has been determined and approved by the designer, the contractor has the option of either mixing the grout on site or ordering the grout mix from an experienced supplier. Higher quality control can be maintained if the grout

<sup>1</sup> - The "Uniform Building Code" limits the width of the grout space for fine grout to 2 inches, whereas the "Specification for Masonry Structures ACI 530 ASCE 6/T MS 602 allows a grout space width of 3 inches. Therefore, follow the guidelines of the governing code.



is ordered from a readymix manufacturer or if the grout ingredients are delivered to the jobsite pre-batched. Onsite mixing procedures for grout are described in ASTM C 476.

## GROUT TESTING

To ensure consistency of grout strength, field samples should be tested periodically in accordance with ASTM Standard C 1019 "Standard Method of Sampling and Testing Grout". This standard requires testing of field samples constructed from a mold consisting of masonry units (See Figure 1). The masonry mold extracts all excessive water from the grout, producing grout samples which are about 4 inches wide by 8 inches high, with strengths that are consistent with the actual strengths obtained in masonry walls. Plastic or metal molds should never be used to produce grout specimens because the molds do not extract water from the grout, and produce test results indicating significantly lower strengths than the grout will actually obtain.

ASTM C 1019 is specific in the methods for constructing, curing and testing masonry grout samples. It is critical that the procedures in the Standard be followed to attain accurate results. In many parts of the country, testing laboratories are not familiar with grout testing and do not follow correct procedures. Whoever produces the samples, either the mason contractor or the testing laboratory, must make sure they are formed and site-cured according to ASTM C 1019 and placed in an area where they can remain undisturbed and not exposed to excessive heat or cold. These things can have a major impact on the test results and the lower reported values would not be indicative of poor material as much as of poor testing.

Several other factors can impact the test results such as:

- not retrieving the test sample from the jobsite within the specified time,
- not properly curing or capping the specimens, and
- having testing machines with platens that are not rigid enough to spread the load evenly to the entire sample.

While this list is not comprehensive, it does include many of the most common testing errors that result in erroneous test values. Unless the ASTM C 1019 procedures are followed, it cannot be stated that the reported test values are indicative of the strength of the grout in the wall. It is imperative that the testing laboratory understands the Standard and follows it.

## GROUT ADMIXTURES

Grout admixtures should not be used unless specified by the designer and approved by the contractor. It is also good practice to have grout specimens with admixtures tested to ensure that the grout complies with the design specifications. Some common grout admixtures are:

**Superplasticizers** - Substituting superplasticizers for a portion of water in a grout mix can provide additional fluidity while maintaining a low water-cement ratio, ensuring high compressive strengths. Superplasticizers can be used when grouting masonry assemblies with very low absorption rates.

**Anti-Shrinking Agents** - These admixtures counter grout's tendency to shrink as water is absorbed from it. The quality of grout bond can be adversely affected if shrinkage is excessive. Anti-shrinking agents act as an expanding agent and are typically combined with other commonly used plasticizers.

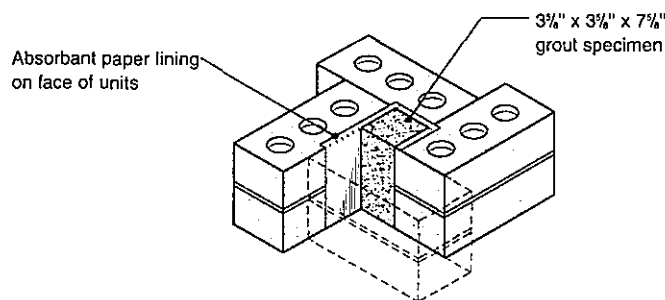
**Accelerators** - Adding accelerators to grout will hasten grout set time during cold weather construction, thereby, minimizing the amount of time the wall must be protected from freezing. Accelerators containing calcium chloride should not be used in grout that will be in contact with reinforcing steel.

**Retarders** - Adding retarders to grout will delay grout set time during hot weather construction. Retarders help extend grout fluidity keeping it workable long enough to be placed properly and consolidated sufficiently.

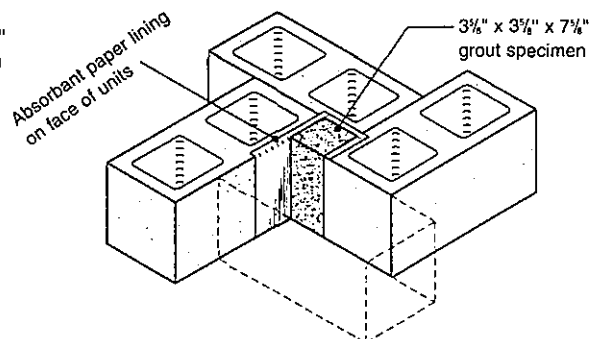
**Fly Ash** - Fly ash is a pozzolanic material produced from coal by-products. A cementitious material that is more economical than portland cement, fly ash can be added to a grout mixture as a partial substitute for portland cement. Also, fly ash helps grout maintain a given slump and improves grout pumpability.

## DISCLAIMER

This document is intended to assist the industry in avoiding design and construction problems with masonry construction. It is intended for mason contractors, field personnel, architects, engineers, building officials, general contractors, construction managers, students, suppliers, manufacturers and other industry representatives. It is not the intent of this report to cover every aspect of masonry construction, but to focus on issues that may lead to problems. This document should not be used as the sole guide for designing and constructing masonry. It is imperative to refer to relevant codes and standards and other industry-related documents. As such, the IMI assumes no liability for any consequences that may follow from the use of this document.



Grout Mold for Clay Masonry Units



Grout Mold for Concrete Masonry Units

Figure 1.



International Masonry Institute  
The James Brice House  
42 East Street  
Annapolis, MD 21401  
1-800-IMI-0988

# Grouting Masonry



## SCOPE

This Construction Guide presents information on grouting masonry walls. The intent of this guide is to provide general information on grouting methods and procedures. Knowledge of applicable codes and standards, in conjunction with acceptable field practices, is required to assure successful grouting results.

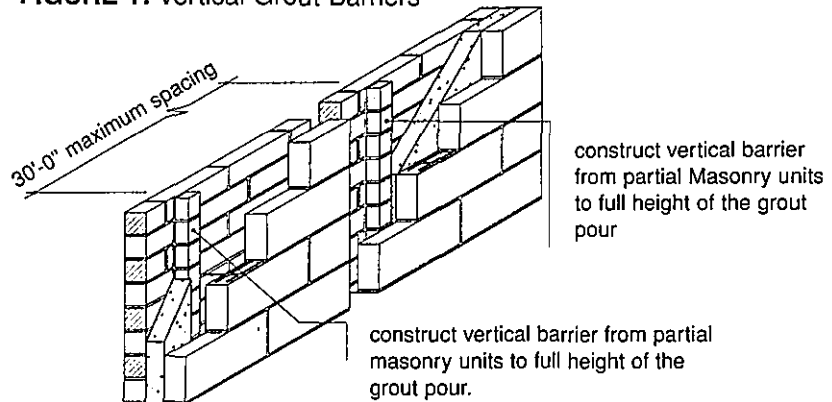
## INTRODUCTION

Masonry can be grouted and reinforced to produce efficient load-resistant structures. Reinforced masonry is used to produce taller, thinner and more economical walls. Most grouted masonry walls include reinforcing steel to provide additional lateral strength. Walls constructed in certain seismic zones are required to be reinforced and grouted to resist the dynamic forces of an earthquake.

### Placing Grout

Grout is placed in lifts either between two wythes of masonry or into the cells of masonry units. Lifts should be poured in increments not to exceed 5 feet. One or more lifts constitute a grout pour, which is the total height of grout placed in prior to the construction of additional masonry. For example, if a wall is constructed to a height of 10 feet, the total grout pour would be 10 feet, with the grout being placed in two 5-foot lifts. The maximum height of a grout pour is restricted by the size and type of grout space and the type of grout mix (fine or coarse) listed in Table 1.

FIGURE 1: Vertical Grout Barriers



## GROUTING METHODS

There are two methods of placing grout: low-lift grouting and high-lift grouting. In low-lift grouting, 5 feet or less of wall height is grouted in one day. The grout is usually placed with buckets. In high-lift grouting, grout can be placed up to a full story height in one day. Grout is usually placed with a grout pump.

The method for placing grout is usually determined by the contractor. However, the specifications can require a particular grouting method. Each of the two basic methods for placing grout—low lift grouting and high lift grouting—has its advantages. The method ultimately selected depends upon the type of masonry wall, the size of the project, the equipment available, and the experience of the contractor.

### Low-lift Grouting

The primary benefit of low lift grouting is that cleanouts are not required. Since the total grout pour cannot exceed 5 feet in one day, all visual inspections of the grout space can be made from the top of the wall. Also, low-lift grouting is better suited to smaller projects and multi-wythe construction and when construction sequencing prevents the use of high-lift grouting.

There are two procedures for low-lift grouting:

**Pours 12 inches or less** - This method involves grouting the masonry as the wall is being constructed. The grout is placed in the grout space in lifts not to exceed six times the width of the space but not more than 8-12 inches, depending on the local code. The grout lift should be terminated approximately 1 inch below the top of the uppermost units. When grout is placed between multi-wythe walls, vertical barriers must be constructed to contain grout flow. Designed to prevent excessive flow, which can cause segregation of grout materials, vertical barriers should be constructed in grout spaces at a maximum spacing of 30 feet. These barriers can be comprised of partial masonry units constructed to the full height of the wall (See Figure 1). Consolidate the grout shortly after it is placed, either by puddling or with a low velocity vibrator with a pencil head (3/4 - 1 inch diameter). Masonry units must not be displaced or dislodged while consolidating grout (See Figure 2).

TABLE 1: Grout Pour Heights and Space Requirements

Specified Grout Type	Maximum Grout Pour Height (ft.)	Minimum Width of Grout Space Between Wythes (in.)	Minimum Grout Space Dimensions for Grouting Cells of Hollow Units (In. x in.)	Cleanout Requirement
Fine	1	3/4	1 1/2x2	No
Fine	5	2	2 x 3	No
Fine	12	2 1/2	2 1/2x3	Yes
Fine	24	3	3x3	Yes
Coarse	1	1 1/2	1 1/2x3	No
Coarse	5	2	2 1/2 x 3	No
Coarse	12	2 1/2	3x3	Yes
Coarse	24	3	3x4	Yes

NOTES: The minimum grout space dimension is the distance between any masonry protrusion and shall be increased by the width of horizontal bars installed within the space.

SOURCE: Masonry Standards Joint Committee - Specification for Masonry Structures ACI530.1-99/ASCE 6-99/TMS 602-99.

**Pours greater than 12 inches and up to 5 feet** - For multi-wythe walls, first construct the masonry to a height up to 5 feet. The wythes must be bonded together with wire ties or joint reinforcement to prevent bulging or blowouts; and the masonry should be allowed to cure prior to grouting until they can withstand the hydrostatic grout pressure. A minimum 3/4 inch grout space is required between the wythes. Vertical barriers must be constructed to contain grout flow. The maximum spacing between barriers is

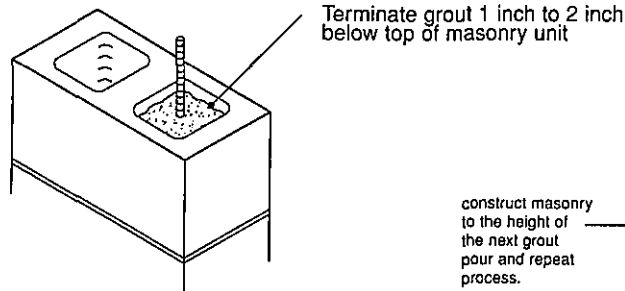


FIGURE 3D: Grout shear key

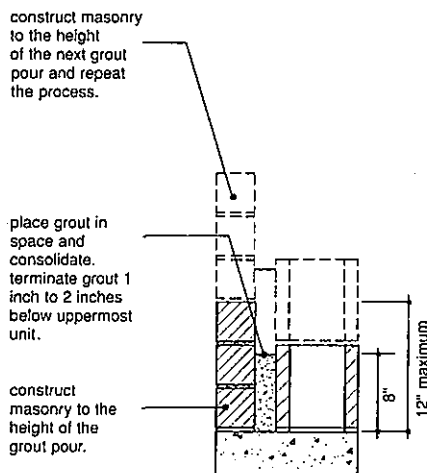


FIGURE 2A: Grout pours 12 inch or less for multi-wythe wall

30 feet. Next, install vertical reinforcement (if required); then place grout in one, two or three lifts, evenly distributing the grout throughout the space in each lift. Consolidate the grout shortly after it is placed and reconsolidate after initial water loss and settlement have occurred (See Figure 2).

For single-wythe walls, first construct the masonry to height of 4 or 5 feet with vertical cells sufficiently aligned and clear of debris and mortar obstructions. In areas where the

grout is to be confined, as in partially grouted walls, lay units with cross webs bedded. Next install vertical reinforcement (if required); then pour grout into the cells of units, terminating the grout approximately 1 to 2 inches below the top of the uppermost unit. Consolidate the grout with a low velocity vibrator with a pencil head approximately 3/4-1 inch diameter, shortly after it is placed. Reconsolidate after initial water loss and settlement has occurred (See Figure 2).

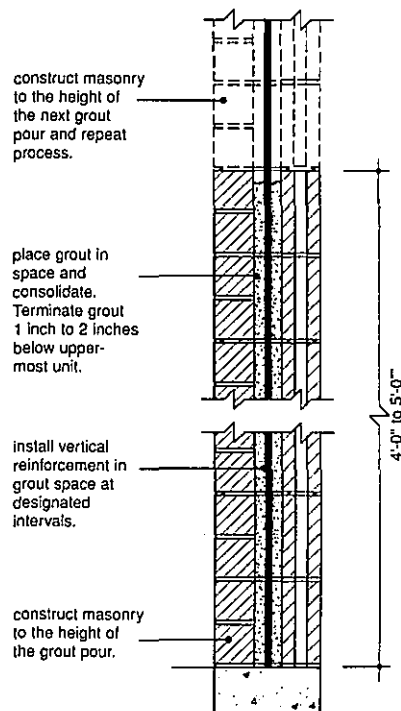


FIGURE 2B: Grout pours up to 5 feet for multi-wythe wall

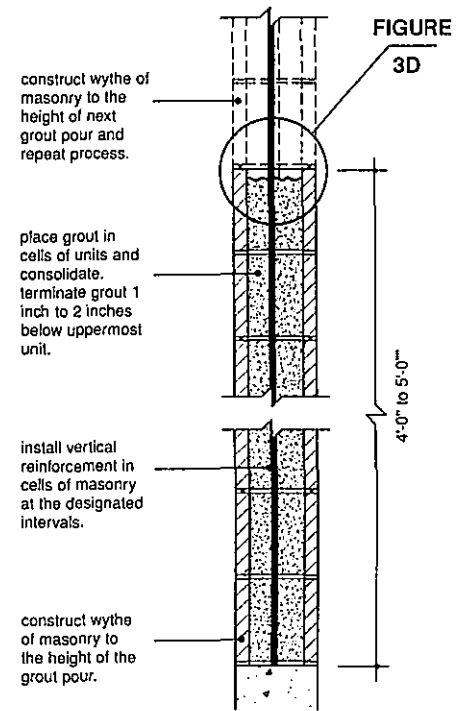


FIGURE 2C: Grout pours up to 5 feet for single-wythe wall

FIGURE 2: Methods of low-lift grouting

### High-lift Grouting

Grouting masonry walls that have been constructed to a full story height has several advantages. Reinforcement bars are placed after the masonry wall has been constructed. Productivity is increased because the mason does not have to lift and place the unit over the reinforcement bar for single-wythe grouting. Large amounts of grout can be placed at one time, which also increases productivity and produces more consistent workmanship.

Cleanout openings are required at the base of the wall for high-lift grouting. Used to remove mortar droppings and debris from the grout space, cleanouts also can be used to inspect the placement of reinforcing steel. These openings are formed by removing face shells from units, cub-

ing holes in face shells or by deleting entire units, and should be a minimum of 3 inches long by 3 inches high. Cleanouts should be located at the base of the wall every 32 inches or less in a multi-wythe wall and at

each vertical bar location when grouting cells of masonry units. Cleanouts must be covered prior to grouting - with a face shell or a form board that is braced or anchored to the wall (See Figure 3).

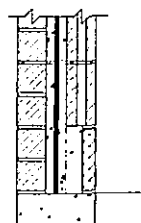


FIGURE 3A. Reinstall face shell or CMU soap

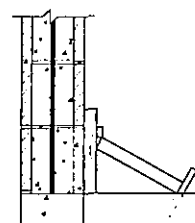


FIGURE 3B. Install 2x10 braced against masonry

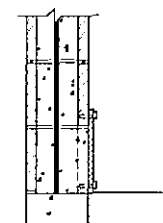


FIGURE 3C. Install plywood form board mechanically fastened to masonry

FIGURE 3: Methods for sealing cleanout openings

There are two procedures for high-lift grouting:

**Pours greater than 5 feet to 24 feet walls** - This procedure allows for the construction of the wall to its total "pour" height (not to exceed 24 feet.) First, construct the wall to its total "pour" height—with cleanouts provided at the base of the wall. The width of the grout space should conform to the minimum dimensions listed in Table 1. Clean the grout space of excessive mortar and construction debris. Remove the debris at the base of the wall through the cleanouts. Seal the cleanouts after the final inspection prior to grouting.

Next, install vertical reinforcement and place grout in uniform lifts not to exceed 5 feet. Grout should be fluid and placed before any initial set has occurred. Consolidate the grout shortly after placement and reconsolidate after initial water loss and settlement have occurred. Place the next grout lift while the existing grout is still plastic. Consolidate the grout by extending the vibrator completely through the new lift, 12 inches to 24 inches into the previous lift. Penetrating the previous lift bonds the two lifts. The full height of any

section of wall should be grouted (without extensive interruptions) in one day (See Figure 4).

For multi-wythe walls, the wythes must be bonded together with wire ties and joint reinforcement to prevent bulging or blowouts. Vertical barriers must be constructed within the grout space to contain horizontal grout flow.

For single-wythe walls, the masonry units must be laid with the cells to be grouted sufficiently aligned and with the cross-webs bedded with mortar to contain grout flow. Allow the masonry to cure 12 to 18 hours prior to grouting. If grouting is stopped for more than one hour, a shear key should be formed by terminating the grout lift 1 inch to 2 inches below the top of the uppermost grouted unit.

**Single-lift pour in cells of a single wythe wall** - This procedure is possible if approved and if it is demonstrated that the cells can be properly filled. Single-lift grouting is a quicker and more economical operation that eliminates cold joints and maximizes grout-to-rebar bond. This procedure allows the wall to be constructed to

its total "pour" height (not to exceed 24 feet) and grouted in a single lift (See Figure 4).

First, construct the wall to its total height with cleanouts provided at the base of the wall. The masonry units must be laid with the cells to be grouted sufficiently aligned and with the cross-webs bedded with mortar to contain grout flow if the grout is to be contained as in partially grouted walls. Clean the cells of excessive mortar and construction debris. Remove the debris at the base of the wall through the cleanouts. Seal the cleanouts after the final inspection prior to grouting. Allow the masonry to cure prior to grouting to avoid blowouts.

Next, install vertical reinforcement and place the grout in a single lift. The grout should be fluid and placed before any initial set has occurred. Consolidate the grout shortly after placement. Insert the vibrator approximately 2/3 down into the cell of the grouted unit and vibrate briefly.

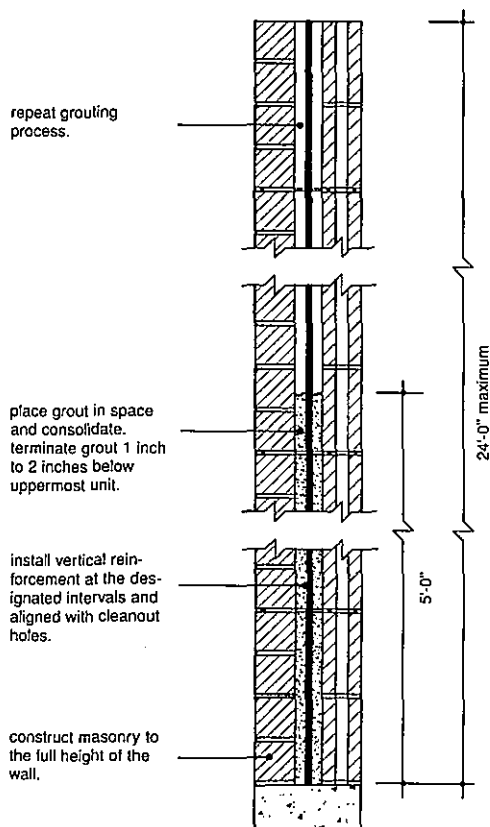


FIGURE 4A. Grout pours 6 feet to 24 feet for multi-wythe wall

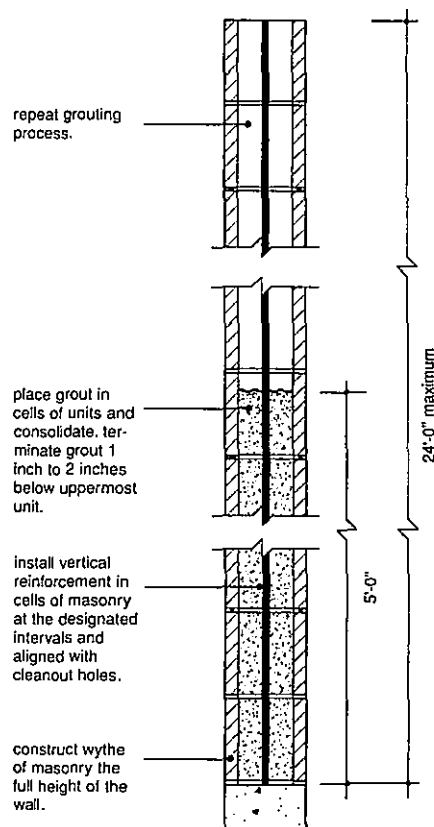


FIGURE 4B. Grout pours 6 feet to 24 feet for single wythe wall

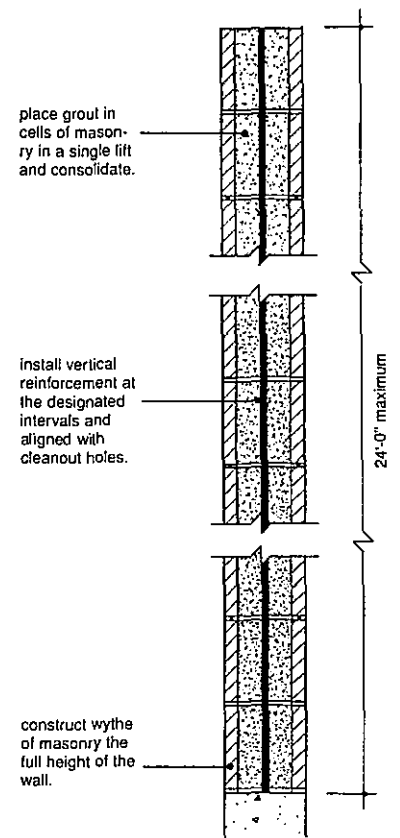


FIGURE 4C. Single lift grout pour up to 24 feet

FIGURE 4. Methods of high-lift grouting

## PRECAUTIONARY MEASURES

Certain precautions must be taken to assure successful grouting of masonry.

### Keeping Grout Space Clean

Certain provisions must be met to keep the grout space clear of mortar while the masonry is being constructed. In multi-wythe walls, beveling the mortar bed joints back and upward slightly from the grout space eliminates most mortar extrusions. If the grout space is wide enough, the mason can pick out excess mortar extrusions with his trowel. When the cells of masonry units are to be grouted, mortar extrusions (mortar fins) in the cells should be removed with a trowel while the masonry is being constructed, or the mortar fins should be knocked off with a piece of wood or rebar down to the base of the cell shortly after the mortar begins to set. Also, it is good practice to clean the grout space with high-pressure air or water to remove mortar build-up.

### Preventing Blowouts

Blowouts of mortar joints occur when the hydrostatic grout pressure exceeds the strength of the mortar joint. These blowouts can be prevented by providing proper curing time for the masonry prior to placing grout.

Additional precautions against blowouts should be taken for grouting multi-wythe walls.

- Bond wythes of masonry together with a 9-gauge rectangular wall tie and a 3/16 inch diameter wire tie, or joint reinforcement. Place a minimum of one rectangular tie, one-tie or one cross-wire of joint reinforcement every 2 square feet of wall.
- Sufficiently embed masonry ties to ensure proper bonding of the wythes. Masonry ties and joint reinforcement should be at least 2 inches less in width than the actual thickness of the wall.
- Consolidate grout properly to help prevent build-up of high-pressure. Do not continue to grout at one location, forcing the grout to flow throughout the space. Shift grout placement to other locations.

### INSTALLING REINFORCEMENT

Methods for installing rebar are dictated by code requirements. Some codes require reinforcement to be installed prior to units being laid. Given this requirement, the only productive way to construct masonry would be with open-ended units (A-

or H shaped), so that the units would not have to be lifted and placed over the reinforcement.

If the code allows for placement of reinforcement after wall construction but before grout placement, there are two installation methods available to the contractor. One method is to install full-length reinforcement bars into masonry after the units have been laid. Rebar positioners can be installed into the masonry units during construction to assure proper bar location.

Reinforcement bars also can be installed in shorter lengths as the wall is being constructed. In this method, masonry can be constructed to a height of 4 feet and allowed to cure properly. Then, a 6-foot reinforcement bar can be inserted into the masonry and grouted to an approximate height of 4 feet, leaving an adequate length of reinforcement bar exposed to provide a lap splice. This process is repeated until the wall is complete.

### PARTIAL GROUTING

Single-wythe masonry walls may be partially grouted, confining grout to areas of the wall containing vertical or horizontal reinforcement. Place hardware cloth or plastic mesh material below and sometimes above bond beam units containing horizontal reinforcement to confine grout to the units or cells that form the bond beam. Bed cross-webs with mortar to confine grout only to those areas that contain vertical reinforcement.

### WEATHER PROTECTION

When constructing and grouting masonry under adverse conditions, follow recommendations and procedures stated within the applicable masonry code. However, consider additional means of protection when grouting masonry under the following conditions:

## Grout Consolidation

Grout must be consolidated (vibrated) as it is being placed to minimize the voids that are left when water is absorbed by the masonry units. Grout consolidation, which usually takes place 5 to 10 minutes after placement, can be accomplished by puddling the grout if grout lifts do not exceed 12 inches. Lifts greater than 12 inches must be consolidated with a low velocity, mechanical vibrator fitted with a small diameter vibrator head (3/4 inch to 1 inch diameter). Mechanically vibrate grout placed in cells of masonry units for only several seconds at a given location. Leaving the vibrator head stationary at one location may cause mortar or face-shell blowouts.

Lifts greater than 12 inches should be reconsolidated after the grout has lost its initial water, but prior to setting to assure proper bond. Reconsolidation prevents separations from developing between the grout and masonry by eliminating water build-up between the two materials.

- When the climatic conditions are extremely hot and arid, moisten the exterior of the masonry with water prior to grouting. This will cool down the wall and help prevent the grout from setting prematurely.
- When climatic conditions are extremely cold, construct and grout the masonry within an adequately heated enclosure to assure that all excessive water is extracted from the grout. Keeping the newly constructed masonry warm will allow proper curing and prevent the masonry from freezing. Heat the masonry until it has thoroughly dried and cured.

### DISCLAIMER

This document is intended to assist the industry in avoiding design and construction problems sometimes associated with masonry construction. It is intended for mason contractors, field personnel, architects, engineers, building officials, general contractors, construction managers, students, suppliers, manufacturers and other industry representatives. It is not the intent of this report to cover every aspect of masonry construction, but to focus on issues that may lead to problems. This document should not be used as the sole guide for designing and constructing masonry. It is imperative to refer to relevant codes and standards and other industry-related documents. As such, the IMI assumes no liability for any consequences that may follow from the use of this document.



International Masonry Institute  
The James Brice House  
42 East Street  
Annapolis, MD 21401  
800-464-0988  
www.imiweb.org

# IMI EXPLAINS

INTERNATIONAL MASONRY INSTITUTE

## Question

*Can fly ash be used in masonry grout?*

## Answer

Yes. In 1999, fly ash was added to the material list within ASTM C476-99 Standard Specification for Grout for Masonry. This means it is an approved material for inclusion in grout. What is not obvious in this standard is the maximum amount of fly ash that is permissible. The maximum amount of fly ash allowed, when used with Portland cement, is 40%. This is derived from the blended cement standard, which allows up to 40% replacement of the Portland cement with fly ash. While this isn't clear from an initial reading of the ASTM C476 standard, it is the correct interpretation. The mix does not have to include the full 40% of fly ash, but it can contain no more than 40% if approved by the specifier.

The International Masonry Institute is a labor/management cooperative serving the interests of the International Union of Bricklayers and Allied Craftworkers and the contractors who employ its members.

The International Masonry Institute presents programs in four broad categories: apprenticeship and training, market development and technical services, research and development, and labor/management relations.

To reach the IMI office nearest you in North America, call 800.464.0988.



**The  
International  
Masonry  
Institute**

*The James Brice House*  
42 East Street, Annapolis, MD 21401  
1-800-IMI-0988, Fax 301-261-2855  
[www.imiweb.org](http://www.imiweb.org)

## ADDING WATER TO PRE-MIXED GROUT

2.2-4 Can grout be retempered after the initial mix water is added? We have a running debate in the office regarding this issue, with some saying that if the mix truck comes out with grout with a low slump, you can still add water to the grout produce slump of 8 to 11 inches (203 to 279 mm). They also say that you can add water even after this as long as the cement has not started to hydrate. Is this correct? If so are there any references so we can tell when the cement has started to hydrate?

Response by John M. Melander, Portland Cement Association

I do not think it is often called retempering, but adding water to grout at the site to achieve required slump is certainly good practice. Section 5.2.2.2 of ASTM C 476<sup>7</sup> addresses this question by stating:

“Wet-mixed grout shall arrive at the job site in a ready-mixed condition. Slump shall be adjusted as necessary, and grout shall be remixed at mixing speed for at least 1 minute before discharging to achieve the desired consistency.”

I would note that, unlike concrete, the common error in grout mixing is in not adding enough water to the mix rather than adding too much water. It is important to provide a grout that flows readily into grout spaces and around reinforcement. The excess water used to achieve that flowable consistency is absorbed by the masonry units reducing the water cement ratio of the grout in-place prior to setting. Don't make the mistake of assuming that reducing water and slump will improve the quality of a masonry grout job.

There are no easy ways of measuring how much hydration has occurred in freshly mixed grout. Therefore, limits are placed on the time interval between adding the initial mixing water to the grout and placement to assure that detrimental levels of cement hydration have not occurred. Article 3.5 A of the 2002 MSJC *Specification for Masonry Structures*<sup>8</sup> (ACI 530.1/ASCE 6/TMS 602) states:

“Place grout within 1 1/2 hour from introducing water in the mixture and prior to initial set.”

### Disclaimer

This document is intended to provide explanation of typical and not-so-typical questions regarding masonry design, construction, evaluation and repair. It is intended for masonry design professionals, architects, engineers, inspectors, contractors, manufacturers, building officials, students, and others interested in masonry. It is not intended to cover every aspect of the discussed topics, but rather to focus on key issues that should be considered and addressed. This document should not be used as the sole guide for designing, constructing, evaluating or repairing masonry. It is imperative to refer to relevant building codes, standards and other industry-related documents. As such, TMS assumes no liability for any consequences that may follow from the use of this document. In addition, the opinions, ideas and suggestions given herein are those of the respondent, and not necessarily those of The Masonry Society.

This document is produced bimonthly by:



### The Masonry Society

3970 Broadway, Suite 201-D  
Boulder, CO 80304-1135

Phone: (303) 939-9700

Fax: (303) 541-9215

Website: [www.masonrysociety.org](http://www.masonrysociety.org)

Oversight: TMS Design Practices Committee, William A. Wood, chair  
Editors: Edwin T. Huston, Vilas Mujumdar, Phillip J. Samblanet and William A. Wood

Questions, ideas, suggestions and differing opinions may be sent to TMS for consideration for inclusion in future issues of *TMS Responds*.

## STEEL

STEEL IS USED TO REINFORCE MASONRY IN ONE OF THREE WAYS

1. REBAR - GROUT SPACES AND BOND BEAMS
2. TIES - CONNECTIONS BETWEEN WYTHES
3. PRESTRESSING - TENDONS OR RODS THAT INDUCE COMPRESSIVE STRESSES IN THE MASONRY UNITS

REBAR IS THE STANDARD REBAR USED TO REINFORCE CONCRETE. THREE GRADES OF REBAR ARE AVAILABLE

GRADE 40 -  $G_y = 40 \text{ KSI}$

GRADE 50 -  $G_y = 50 \text{ KSI}$

GRADE 60 -  $G_y = 60 \text{ KSI}$

NOTE THAT ACI 308-99 LIMITS THE ALLOWABLE TENSILE STRESS IN THE DIFFERENT GRADES OF STEEL AS FOLLOWS (SECTION 2.3.2.1)

GRADE 40 & 50 -  $\sigma_{\text{ALLOW}} = 20 \text{ KSI}$

GRADE 60 -  $\sigma_{\text{ALLOW}} = 24 \text{ KSI}$

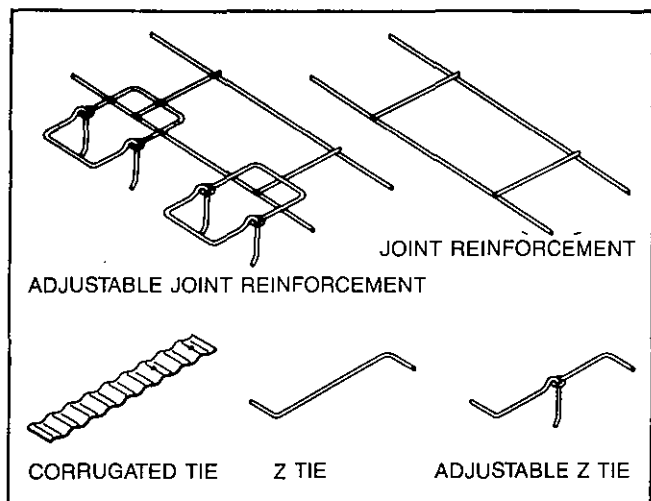
SIZE OF BARS ARE LISTED IN TERMS OF THEIR DIAMETERS. THEY RANGE FROM #3 THROUGH #11. THE NUMBER REPRESENTS THE DIAMETER OF THE BAR IN EIGHTHS OF INCHES. THUS

$$\begin{aligned} \text{DIAMETER \#8 BAR} &= 8/8" \\ &= 1.0 \text{ INCH} \end{aligned}$$

CROSS SECTIONAL AREAS ARE LISTED IN TABLE 1.12.1 OF THE CODE COMMENTARY.

METAL TIES ARE USED TO CONNECT MULTIPLE WYTHES.

JOINT REINFORCEMENT IS USED TO SATISFY SEISMIC CODE REQUIREMENTS AND MINIMUM REINFORCING STANDARDS





SUGGESTED (NOT REQUIRED) TIE SPACING IS GIVEN IN THE FOLLOWING TABLE

Wall Type	Cavity or Air Space Width in (mm)	Tie System	Maximum Area Per Tie (sq ft) (sq m)	Maximum Vertical Spacing in (mm)	Maximum Horizontal Spacing in (mm)
Cavity	$\leq 4$ (100)	#9 Gage Tie	2 2/3 (0.25)	24 (610)	36 (915)
		3/16" Diameter Tie	4 1/2 (0.42)	24 (610)	36 (915)
		Adj. Unit Tie	1.77 (0.16)	16 (410)	16 (410)
		Std. Joint Reinforcement	—	16 (410)	—
Veneer/ Wood Stud	1 (25)	Corrugated	3 1/4 <sup>b</sup> (0.35) 2 2/3 <sup>c</sup> (0.25)	24 (610) 24 (610)	24 (610) 24 (610)
Veneer/ Steel Stud	2 but $\leq 3$ (50 but $\leq 75$ )	Adj. Unit Veneer Ties	2 (0.19)	18 (460)	24 (610)
Veneer/ Concrete or CMU Backup	$\leq 2$ ( $\leq 50$ )	Adj. Unit	2 2/3 (0.25)	24 (610)	24 (610)
Multi-Wythe Brick	—	Unit Ties	4 1/2 (0.42)	24 (610)	36 (915)
		Std. Joint Reinforcement	—	16 (410)	—
Brick/Block Composite	—	Unit Ties	4 1/2 (0.42)	24 (610)	36 (915)
		Std. Joint Reinforcement	—	16 (410)	—
Two-Wythe Grouted	—	Unit Ties	2 2/3 <sup>d</sup> (0.25)	16 (410)	24 (610)
		Std. Joint Reinforcement	—	16 (410)	—

<sup>a</sup> Masonry laid in running bond. Consult applicable building code for special bond patterns such as stack bond.

<sup>b</sup> One and two-family wood frame construction not over 2 stories in height.

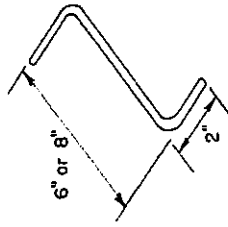
<sup>c</sup> Wood frame construction over 2 stories in height.

<sup>d</sup> For high-lift grouted walls. Masonry laid in running bond.

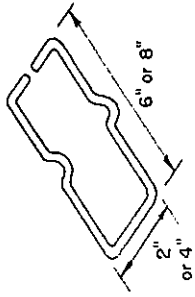
LADDER AND TRUSS TYPE JOINT REINFORCEMENT ARE VERY COMMON. THE NEXT SEVERAL PAGES DEPICT APPLICATIONS THAT UTILIZE UNIT METAL TIES, AND CONTINUOUS METAL TIES (LADDER AND TRUSS).



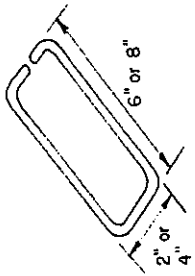
22-141 50 SHEETS  
22-142 100 SHEETS  
22-144 200 SHEETS



Z bar for solid masonry

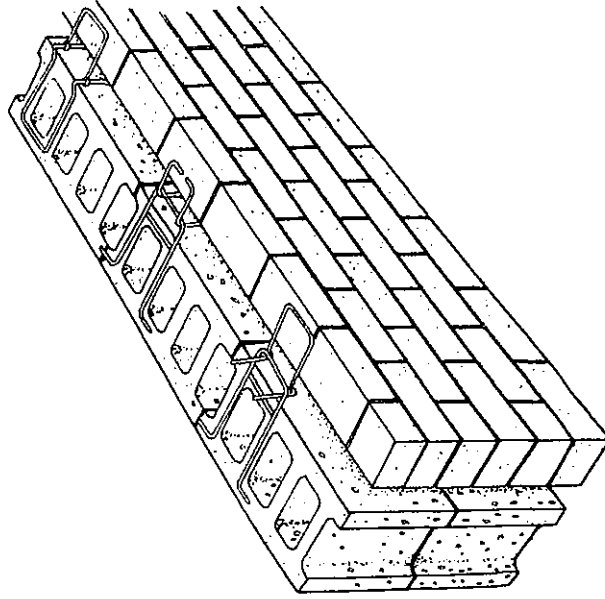


Rectangular tie with crimp for cavity walls (not recommended)

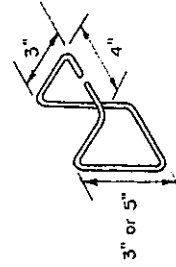
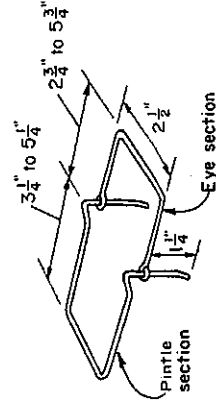
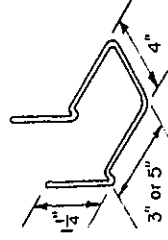
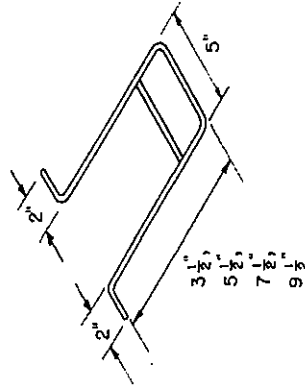


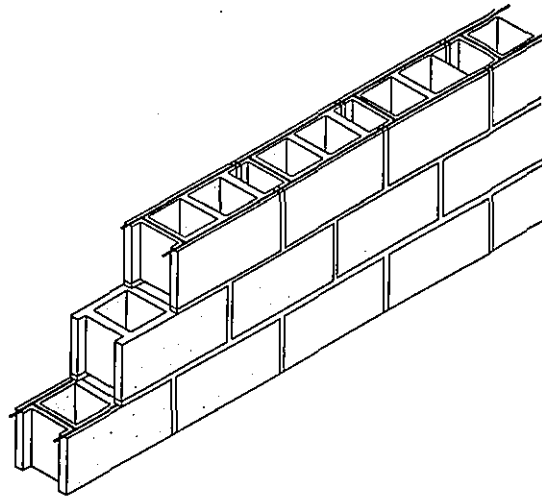
Rectangular tie for solid, composite, reinforced, or grouted walls

(a) Regular ties

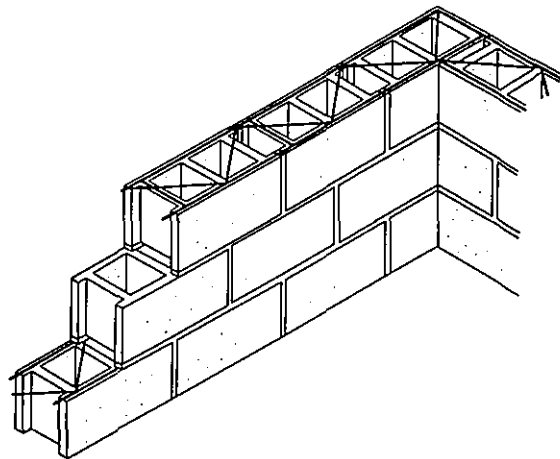


(b) Adjustable ties

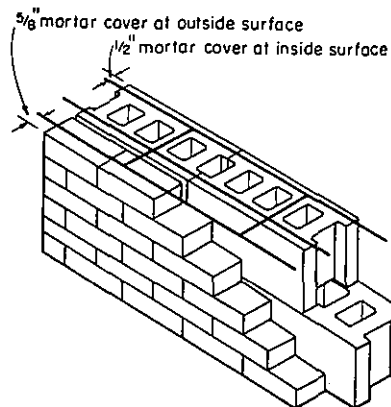




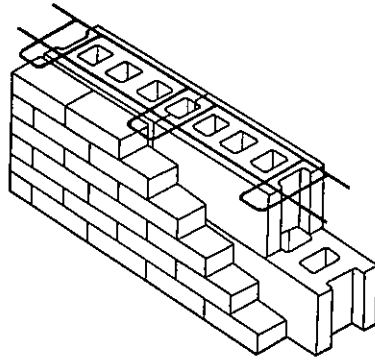
(a) Ladder type joint reinforcement for single-wythe wall



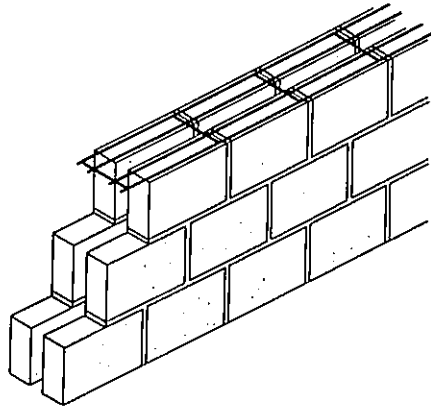
(b) Truss type joint reinforcement for single-wythe wall



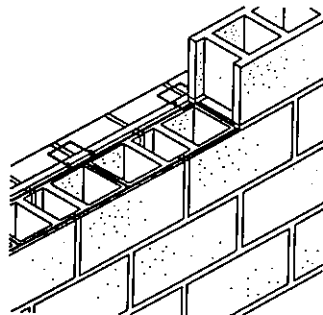
(c) Ladder tie for multi-wythe wall



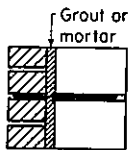
(d) Tab tie for multi-wythe wall



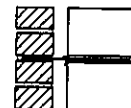
(e) Double ladder tie for multi-wythe wall



(f) Adjustable ladder tie

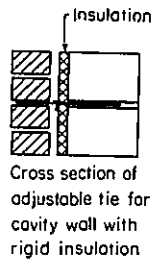
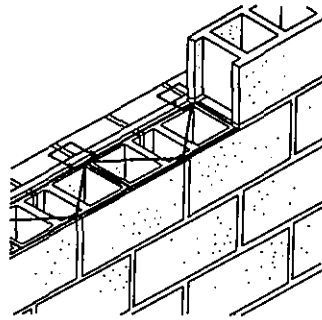


Cross section of  
adjustable tie for  
composite action  
wall

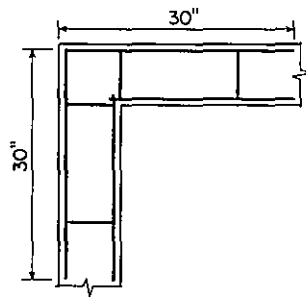


Cross section of  
adjustable tie for  
cavity wall (non-  
composite action)

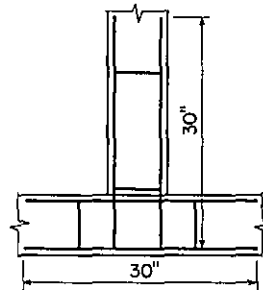
22-141 50 SHEETS  
 22-142 100 SHEETS  
 22-144 200 SHEETS



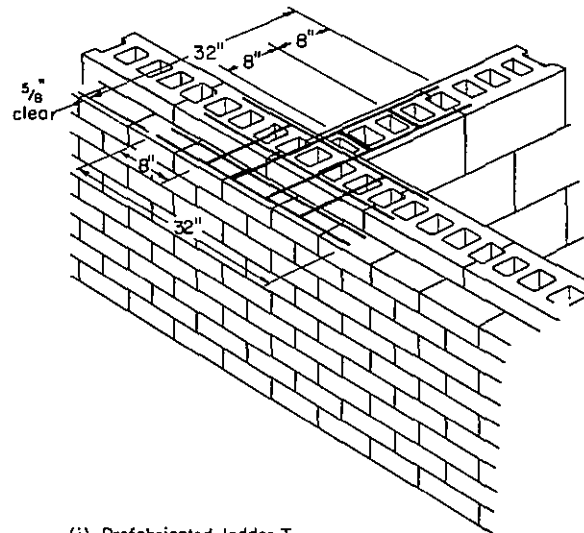
(g) Adjustable truss tie



(h) Prefabricated ladder corner



(i) Prefabricated ladder T



(j) Prefabricated ladder T

FINALLY, THE FOLLOWING TABLE LISTS GEOMETRIC AND WEIGHT PROPERTIES FOR CONTINUOUS JOINT REINFORCEMENT

Ladder Type		No. 4 (for 4 in. wall)	No. 6 (for 6 in. wall)	No. 8 (for 8 in. wall)	No. 12 (for 12 in. wall)
<b>STANDARD</b> No. 9 Gage Side Rods No. 9 Gage Cross Rods	Weight per 1000 lin. ft. (lbs.)	118	125	133	148
	Effective Steel Area (sq. in.)*	.0346	.0346	.0346	.0346
<b>MEDIUM</b> No. 8 Gage Side Rods No. 9 Gage Cross Rods	Weight per 1000 lin. ft. (lbs.)	147	161	161	177
	Effective Steel Area (sq. in.)*	.0412	.0412	.0412	.0412
<b>EXTRA HEAVY</b> 3/16" Side Rods No. 9 Gage Cross Rods	Weight per 1000 lin. ft. (lbs.)	195	202	210	224
	Effective Steel Area (sq. in.)*	.0554	.0554	.0554	.0554
<b>STANDARD</b> No. 9 Gage Side Rods No. 9 Gage Cross Rods	Weight per 1000 lin. ft. (lbs.)	172	175	180	196
	Effective Steel Area (sq. in.)**	.051	.050	.048	.045
<b>EXTRA HEAVY</b> 3/16" Side Rods No. 9 Gage Cross Rods	Weight per 1000 lin. ft. (lbs.)	247	250	257	276
	Effective Steel Area (sq. in.)**	.072	.071	.069	.066

1 in. = 25.4 mm    1 lb. = 4.448 N

\*area of two side rods

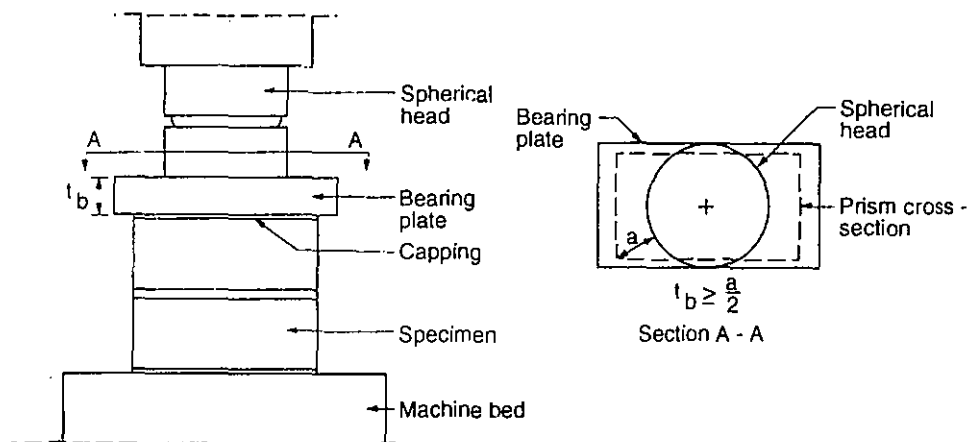
\*\*area of two side rods plus an allowance for the tensile resistance of the diagonal cross rods

22-141 50 SHEETS  
22-142 100 SHEETS  
22-144 200 SHEETS



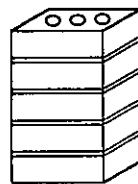
## PRISM TESTS

COMPRESSION TESTS ARE USED TO ESTABLISH  $f_m'$  FOR MASONRY ASSEMBLAGES. ASTM E447 CONTROLS TESTING OF PRISMS. TEST EQUIPMENT IS SIMILAR TO THAT USED IN ESTABLISHING  $f_c$  FOR CONCRETE. A SKETCH IS PROVIDED BELOW

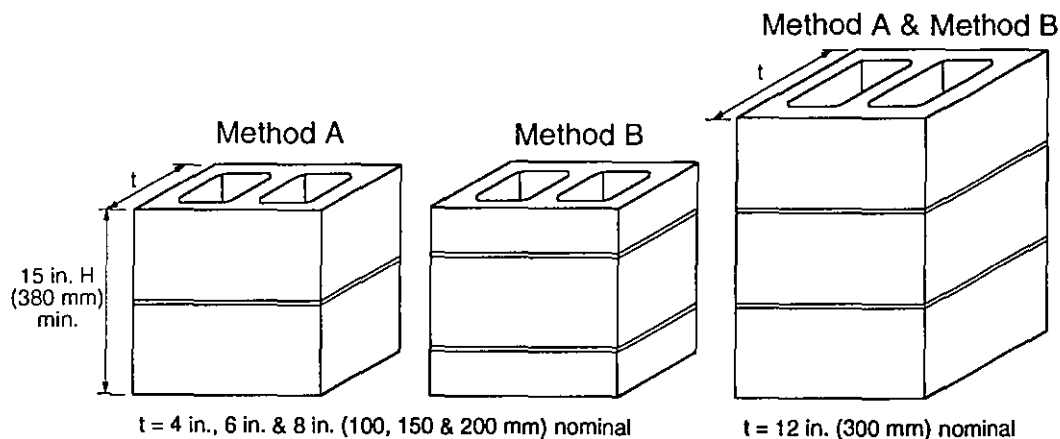


PRISM TESTS CAN BE PART OF THE DESIGN PROCESS AND MATERIALS SELECTION PROCESS.

STANDARD PRISMS ARE ONE MASONRY UNIT IN LENGTH. TYPICAL SPECIMENS FOR BRICK AND BLOCK UNITS ARE DEPICTED IN THE FIGURE BELOW



(a) Brick Masonry



(b) Block Masonry

NOTE THAT PRISMS ARE FABRICATED IN A STACK BOND CONFIGURATION, EVEN THOUGH THE DESIGN MAY CALL FOR RUNNING BOND.

IN PERFORMING PRISM TESTS, ASSEMBLAGES ARE LOADED CONCENTRICALLY. TEST SPECIMEN SIZE AND SHAPE INFLUENCE THE COMPRESSIVE STRENGTH. THUS SPECIMEN STRENGTH IS CORRECTED BASED ON A STANDARD HEIGHT TO THICKNESS RATIO. TEST SPECIMENS WITH LOWER HEIGHT TO THICKNESS RATIOS YIELD HIGHER STRENGTHS. CORRECTION FACTORS ARE LISTED IN THE FOLLOWING TABLE.

$h/t$	CORRECTION FACTOR
1.5	0.86
2.0	1.00
3.0	1.20
4.0	1.30
5.0	1.37

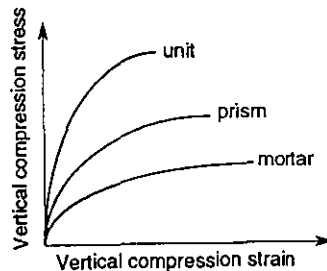
FOR LARGE JOBS QUALITY ASSURANCE SPECIFICATIONS SHOULD BE ESTABLISHED THAT INDICATE A PROCEDURE WHEN PRISM TESTS ARE OUT OF COMPLIANCE



## STRESS STRAIN RELATIONSHIPS

BECAUSE MASONRY ASSEMBLAGES ARE NOT HOMOGENEOUS STRAINS FROM PRISM TESTS MUST BE ESTABLISHED OVER RELATIVELY LONG GAGE LENGTHS. TYPICALLY GAGE LENGTHS ARE 3" IN LENGTH. THUS A CROSS STRAIN IS RECORDED.

THE FOLLOWING FIGURE DEPICTS RELATIVE STRESS-STRAIN CURVES



TYPICALLY MORTARS ARE WEAKER THAN BLOCKS.

FAILURE MODELS AND CONSTITUTIVE MODELS HAVE BEEN PROPOSED BASED ON CONSTITUENT PROPERTIES, BUT NONE HAVE FOUND THEIR WAY INTO PRACTICE. ACI 530 ADOPTS THE FOLLOWING RELATIONSHIP TO ESTABLISH YOUNG'S MODULUS FOR THE MASONRY ASSEMBLAGE

$$E_m = k f_m'$$

WHERE

$$k = 700 \quad (\text{CLAY})$$

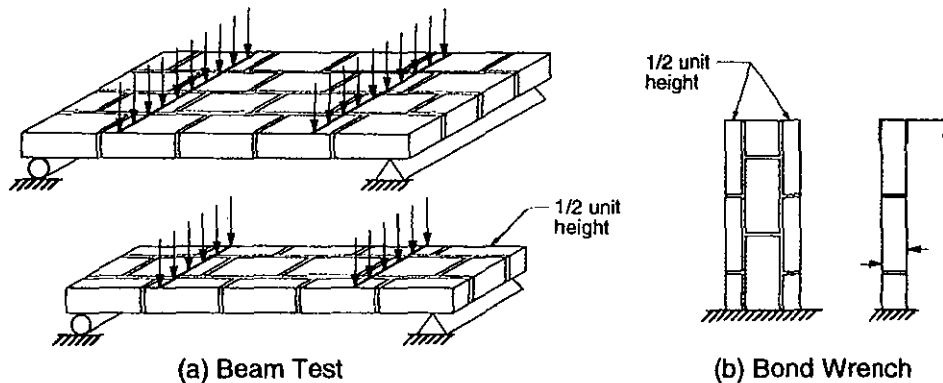
$$k = 900 \quad (\text{CONCRETE})$$

## TENSILE STRENGTH

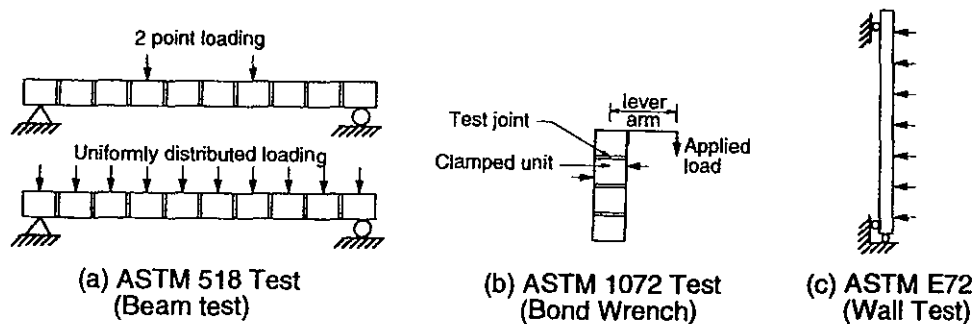
TENSILE STRENGTH IS QUANTIFIED IN TWO DIRECTIONS

- PARALLEL TO THE BED JOINT
- NORMAL TO THE BED JOINT

TESTS THAT ESTABLISH TENSILE STRENGTH PARALLEL TO THE BED JOINT ARE DEPICTED IN THE FOLLOWING FIGURE



IN ESSENCE THIS ESTABLISHES THE TENSILE STRENGTH OF THE HEAD JOINTS. TESTS THAT ESTABLISH TENSILE STRENGTH NORMAL TO THE BED JOINT ARE DEPICTED IN THE FOLLOWING FIGURE



THIS TEST INTERLOCATES THE STRENGTH OF THE BED JOINT.

TABLE 2.2.3.1 IN ACI 530 ESTABLISHES ALLOWABLE TENSILE STRENGTH VALUES FOR FLEXURE. THE ALLOWABLE TENSILE STRENGTH FOR AXIAL LOADING IS ZERO (SPEC 2.2.4)

# IMI EXPLAINS

INTERNATIONAL MASONRY INSTITUTE

## Question

*We're designing a college dormitory and are concerned with fire safety for the residents. We've heard of "balanced design" but would like to understand it better.*

## Answer

Fire safety is especially critical in group living arrangements such as dormitories and senior housing where an accidental fire started in one living space can spread to the adjoining residences and impact both life and property. Balanced design means using a four step system to minimize impact to both life and property.

**PREVENTION:** Reduce the chances of fires occurring through good housekeeping, education and building layout.

**DETECTION AND ALARM:** Early warning devices such as smoke detectors to warn of fires as soon as possible.

**SUPPRESSION:** Sprinklers, fire extinguishers or other suppression systems to help put out fires quickly and effectively.

**COMPARTMENTATION:** Use of building construction features like masonry fire walls to isolate and contain the spread of fire and toxic smoke and gases while maintaining the structural integrity of the building. This is necessary to allow for safe evacuation of the residents and to provide fire fighters with sound and safe areas from which to fight fires.

In balanced design these four strategies are used together as a system, not traded one for another. Active systems such as sprinklers and alarms work well but only for as long as the mechanical systems that support them work. They can not provide the building structural integrity needed for safe evacuation and fire fighting. Passive systems like compartmentation with non-combustible masonry fire walls work 24 hours a day regardless of mechanical systems. Masonry walls are capable of containing toxic fumes and remain structurally sound allowing fire fighters to combat fire and for evacuation.

The International Masonry Institute is a labor/management cooperative serving the interests of the International Union of Bricklayers and Allied Craftworkers and the contractors who employ its members.

The International Masonry Institute presents programs in four broad categories: apprenticeship and training, market development and technical services, research and development, and labor/management relations.

To reach the IMI office nearest you in North America, call 800.464.0988.



**The  
International  
Masonry  
Institute**

*The James Brice House*  
42 East Street, Annapolis, MD 21401  
1-800-IMI-0988, Fax 301-261-2855  
[www.imiweb.org](http://www.imiweb.org)