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REINFORCED GROUTED BRICK MASONRY

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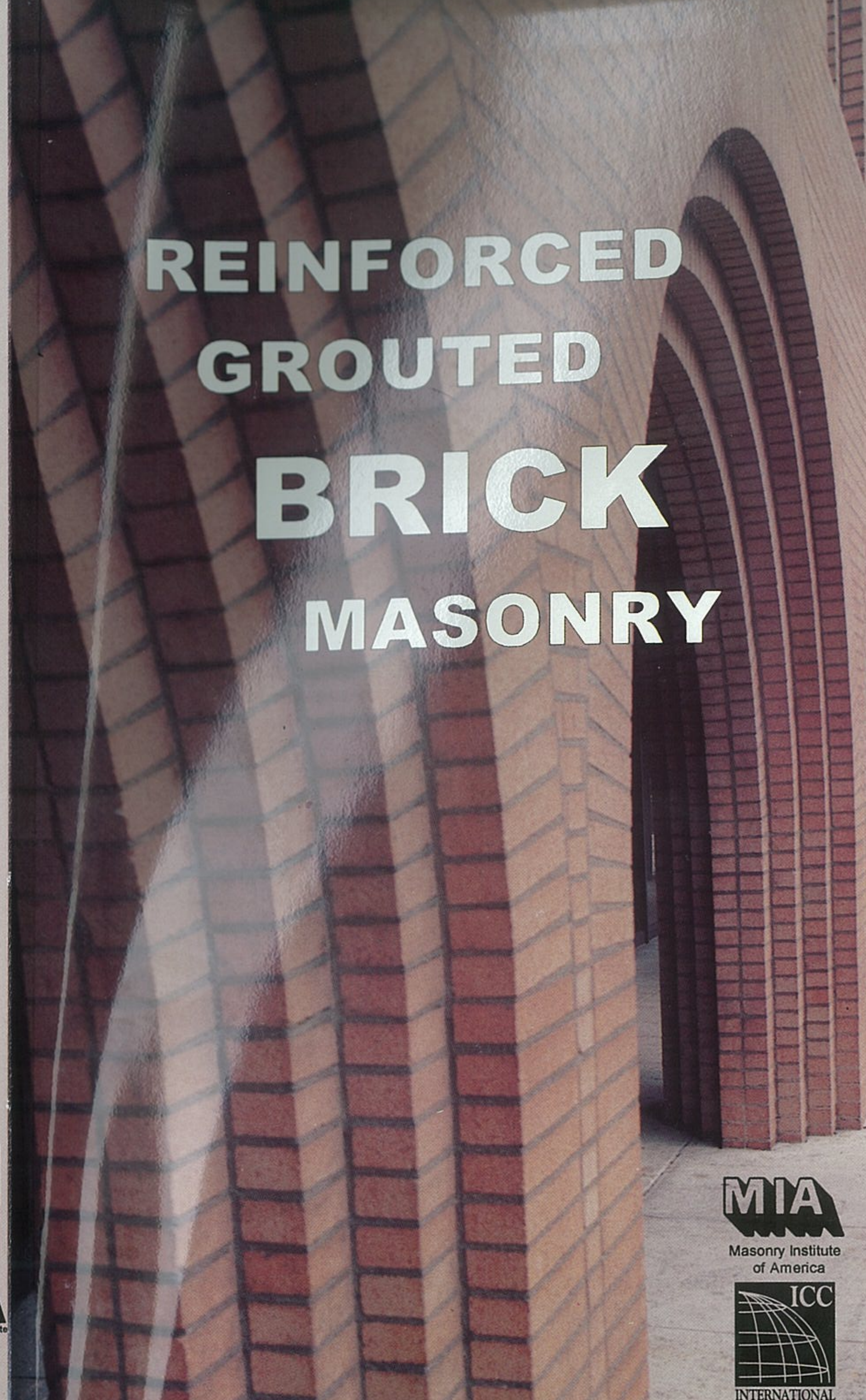

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John Chrysler, P.E.
Executive Director

in cooperation with

INTERNATIONAL CODE COUNCIL®
Setting the Standard for Building Safety™

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Building Code Requirements for Masonry Structures (ACI 530-99/ASCE 5-99/TMS 402-99)
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Reported by The Masonry Standards Joint Committee

Masonry Design Manual
Published by Masonry Industry Advancement Committee

BIA Technical Notes.
Published by Brick Industry Association

Reinforced Concrete Masonry Construction Inspector's Handbook
Informational Guide to Grouting Masonry
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Drawings by Thomas Escobar

Cover Photo:
Gerontology Center, a masonry building at the University of Southern California, Los Angeles, CA

INTRODUCTION

This handbook will serve as a guide for those interested in or concerned with the construction and inspection of reinforced grouted brick masonry (RGBM) as developed and practiced in Southern California for over 70 years. It is particularly applicable for those areas that have provisions for earthquake safety in their building codes.

Throughout this book, the California Code of Regulations (C.C.R.), Title 24 is referenced. This is a California State regulation, based on the Uniform Building Code, with certain amendments intended to bring the code to a higher threshold. C.C.R., Title 24 applies to state government buildings (primarily schools and hospitals) located within California.

There are a number of organizations, such as the Structural Engineers Associations of California (SEAOC), Washington (SEAOW), Oregon and Utah, as well as the Western States Clay Products Association (WSCPA), that are additional valuable sources of information for structural brick masonry.

The general principles of design are based on working stress design (WSD), applied to reinforced grouted brick masonry, using allowable stresses contained in building codes.

Competent, conscientious and intelligent inspection during construction is fully as important as the design of structures. The best design for earthquake safety will not insure adequacy of structures if compliance with plans and specifications is not rigid and exact.

In the design of a structure, consideration has been given to the nature of the building, its use, the materials in its construction, and the tie-in to lateral force resistance.

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The following is a list of commonly used acronyms in this publication.

Acronym	Full Name/Meaning
ACI	American Concrete Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
BIA	Brick Industry Association
C.C.R.	California Code of Regulations
DSA	(California) Division of the State Architect
IBC	International Building Code
ICBO	International Conference of Building Officials
IMI	International Masonry Institute
IRA	Initial Rate of Absorption
IRC	International Residential Code
MCAA	Masonry Contractors Association of America
MIA	Masonry Institute of America
MSJC	Masonry Standards Joint Committee
RGBM	Reinforced Grouted Brick Masonry
SDC	Seismic Design Category
SEA	Structural Engineer Association
SEAOC	Structural Engineers Association of California
SPC	Seismic Performance Category
TMS	The Masonry Society
UBC	Uniform Building Code
WSCPA	Western States Clay Products Association

SECTION 1 INTRODUCTION

1.1 BRIEF HISTORY

Reinforcing of brick masonry had its first major application in 1825 with the construction of the Thames Tunnel, which used brick caissons, 30 inches [760 mm] thick, 50 feet [15.2 m] in diameter and 70 feet [21.3 m] deep. Since then the principle has been continually used.

Widespread publicity was given to testing a reinforced brick beam at the Great Exposition in London in 1851, in which "new cement", now know as "portland cement," was used. Portland cement was so named because when made into mortar or concrete it resembled natural stone from Portland, England.

In 1923, Under-Secretary A. Brebner, Government of India, wrote, "In all, nearly 3,009,000 square feet [280,000 m^2] of reinforced brick masonry have been laid in the past three years." S. Kanamori, C.E., Imperial Japanese Government, reported in **Brick & Clay Record**, in 1930: "There is no question that reinforced brickwork should be used instead of plain brickwork when any tensile stress would be incurred in the structure. We can make them safer and stronger, saving much cost. Further, I have found that reinforced brickwork is more convenient and economical in building than reinforced concrete and, what is still more important, there is always a very appreciable saving in time."

The idea of using cement-sand grout instead of bonding brick headers to bind brick wythes or tiers together and inserting reinforcing steel in the grout space for tensile and shearing resistance was developed for practical and sound engineering use in Southern California beginning about 1935. This practice was a result of the catastrophic failure of unreinforced brick masonry in the Long Beach earthquake of 1933. Since then thousands of tests have been conducted on full size beams, slabs and walls, from which sound engineering design criteria have been established and incorporated into building codes throughout the United States.

Unreinforced masonry building after 1933 Long Beach, CA earthquake.

SECTION 2 MATERIALS

2.1 BRICK

There are three basic types of building brick; **Common Building Brick, Face Brick** and **Hollow Brick**. Building bricks are made in shades of red of the sizes shown herein with smooth or textured faces, and are made of clay just as it comes from the pit or banks.

Face brick is made from controlled mixtures of clays or shales containing certain minerals which, when fired in a kiln, produce various shades of color. No artificial colors are added.

Hollow brick materials are similar to face brick, however, hollow brick are extruded with cells that can be reinforced and grouted, similar to concrete block.

The physical difference between face brick and building or hollow brick is that the former are required to meet strict tolerances for color, size, warpage and chippage.

All local building codes including California Code of Regulations (C.C.R.), Title 24 and most project specifications require brick to be in conformance with one of American Society for Testing and Materials (ASTM) Standards; C 62, *Standard Specification for Building Brick*, C 216, *Standard Specification for Facing Brick*, for building brick and face brick, respectively and C 652, *Standard Specification for Hollow Brick* for hollow brick. Most brick throughout the United States are manufactured to meet these respective specifications.

As stated in ASTM C 62 "The brick, as delivered to the site, shall, by visual inspection, conform to the requirements specified by the purchaser or to the sample or samples approved as the standard of comparison and to the samples passing the tests for physical requirements. Minor indentations or surface cracks incidental to the usual method of manufacture or the chipping resulting from the customary methods of handling in shipment and delivery, should not be deemed grounds for rejection."

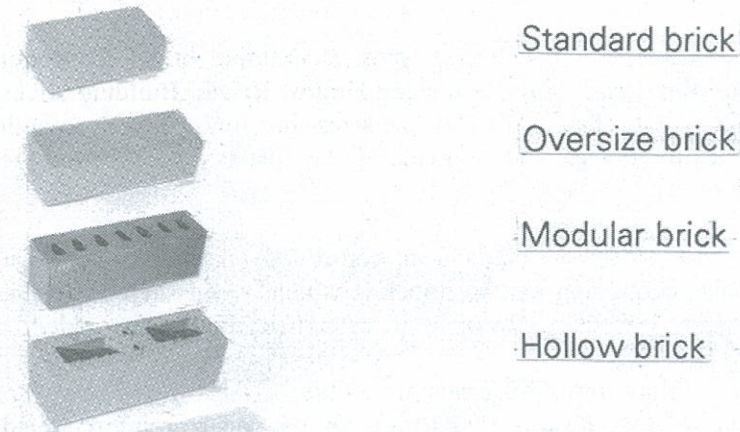


Figure 1. Building (common) brick. Standard size, available smooth or textured: Oversize, available smooth, wire cut or textured: Modular size, wire cut, smooth or textured.

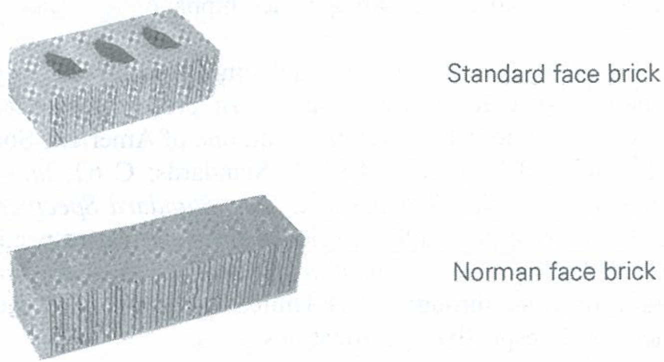


Figure 2. Face brick, standard size, smooth or textured: Norman size, smooth or textured face: Face bricks are available in many different colors.

"The brick shall be free of defects, deficiencies, and surface treatments, including coatings that would interfere with the proper setting of the brick or significantly impair the strength or performance of the construction.

Unless otherwise agreed upon by the purchaser and the seller, a delivery of brick may contain not more than 5% broken brick."

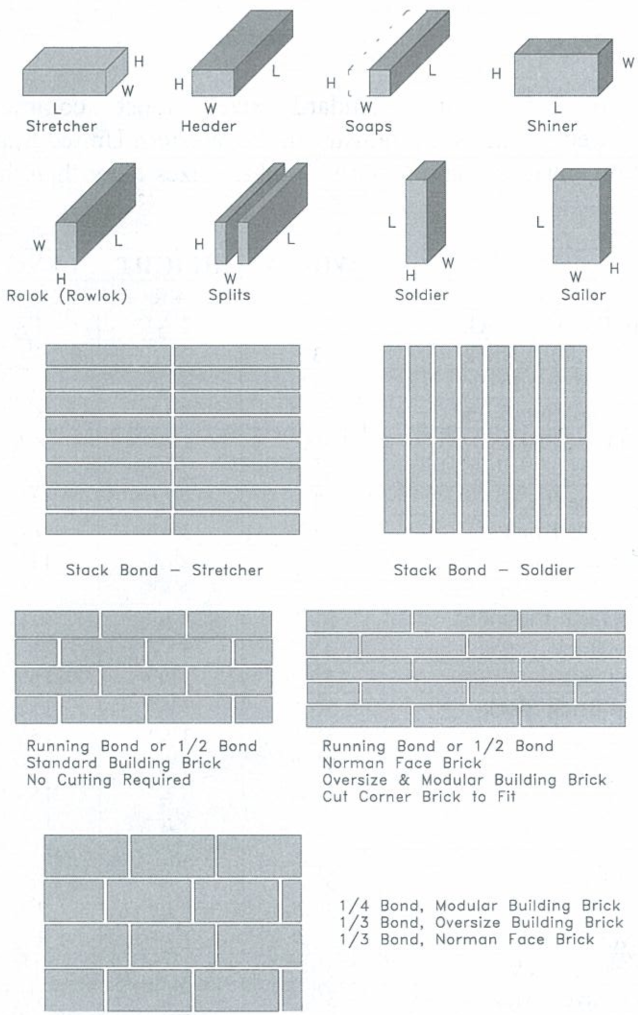
2.1.1 Sizes

Listed below are standard sizes most commonly manufactured by the brick industry in the Western United States. In addition, various manufacturers produce sizes other than these standards.

	WIDTH	HEIGHT	LENGTH
	x 25.4 for mm		
Standard Building Brick	3 1/2"	2 1/2"	7 1/2"
Oversize Building Brick	3"	3 1/2"	9 1/2"
Modular Building Brick	3"	3 3/8"	11 1/2"
Common Building Brick	3 1/8"	2 1/2"	8 1/4"
Standard Face Brick	3 7/8" 3 5/8"	2 1/4" 2 1/4"	8 1/4" 7 5/8"
Modular Face Brick	3"	3 1/2"	11 1/2"
Oversize Face Brick	3"	3 1/2"	9 1/2"
Norman Face Brick	3 1/2"	2 1/4"	11 1/2"
Continental Face Brick	3"	3 1/2"	11 1/2"
Utility Brick	3 5/8"	3 5/8"	11 5/8"
Economy Brick	3 1/2"	3 1/2"	11 1/2"
Emperor Brick	3 5/8"	3 5/8"	15 1/2"
Structural Brick Block	3 1/2" 5 1/2" 7 1/2" 7 1/2" 7 1/2" 7 1/2"	3 5/8" 3 5/8" 3 5/8" 5 1/2" 3 1/2" 5 1/2"	15 1/2" 15 1/2" 15 1/2" 15 1/2" 11 1/2" 11 1/2"
Paving Brick	3 3/4" 3 5/8"	1 1/4" 1 1/4"	8" 7 5/8"
Split Paver Brick	3 7/8"	1 1/2"	8 1/4"
Bel Air Paver Brick	5 1/2"	1 3/8"	11 1/2"
Common Paver Brick	3 7/8"	1 3/8"	8 1/4"

The Brick Industry Association (BIA) also lists other brick sizes in their *Technical Notes on Brick Construction 10B*. Since the brick manufacturer has complete latitude in determining their particular brick sizes and shapes, it is advisable to verify the brick requirements prior to delivery.

2.1.2 Nomenclature



2.1.3 Dimensional Tolerances

Building brick, ASTM C 62 lists the following permissible variations in dimensions:

Specified Dimension, in. [mm]	Maximum Permissible Variations from Specified Dimension, plus or minus, in. [mm]
Up to 3 [76] incl.	$^{3}/_{32}$ [2.4]
Over 3 to 4 [76 to 102] incl.	$^{1}/_{8}$ [3.2]
Over 4 to 6 [102 to 152] incl.	$^{3}/_{16}$ [4.8]
Over 6 to 8 [152 to 203] incl.	$^{1}/_{4}$ [6.4]
Over 8 to 12 [203 to 305] incl.	$^{5}/_{16}$ [7.9]
Over 12 to 16 [305 to 406] incl.	$^{3}/_{8}$ [9.5]

Face brick, ASTM C 216 and hollow brick, ASTM C 652, list the following tolerances on dimensions

Specified Dimension, in. [mm]	Maximum Permissible Variations from Specified Dimension, Plus or Minus, in.	
	Type FBX/HBX	Type FBS/HBS
3 [76] and under	$^{1}/_{16}$ [1.6]	$^{3}/_{32}$ [2.4]
Over 3 - 4 [76 to 102] incl.	$^{3}/_{32}$ [2.4]	$^{1}/_{8}$ [3.2]
Over 4 - 6 [102 to 152] incl.	$^{1}/_{8}$ [3.2]	$^{3}/_{16}$ [4.8]
Over 6 - 8 [152 to 203] incl.	$^{5}/_{32}$ [4.0]	$^{1}/_{4}$ [6.4]
Over 8 - 12 [203 to 305] incl.	$^{7}/_{32}$ [5.6]	$^{5}/_{16}$ [7.9]
Over 12 - 16 [305 to 406] incl.	$^{9}/_{32}$ [7.1]	$^{3}/_{8}$ [9.5]

2.1.4 Rate of Absorption, ASTM C 67

The initial rate of absorption of a brick has an important effect on the bond between brick and mortar. Maximum bond strength occurs when the suction of the brick at the time of laying is between 5 and 20 gm. per minute per 30 square inches [0.27L to 1.07L/m^2] of brick surface immersed in $^{1}/_{8}$ inch [3.2

mm] of water. Brick having a higher absorption should be moistened to reduce the suction. To check the moisture of high suction brick, the inspector should occasionally break a brick and observe the interior. Figure 3 shows typical conditions.

There is no consistent relationship between **total** absorption and **rate** of absorption. Some bricks have high total absorption and vice versa.

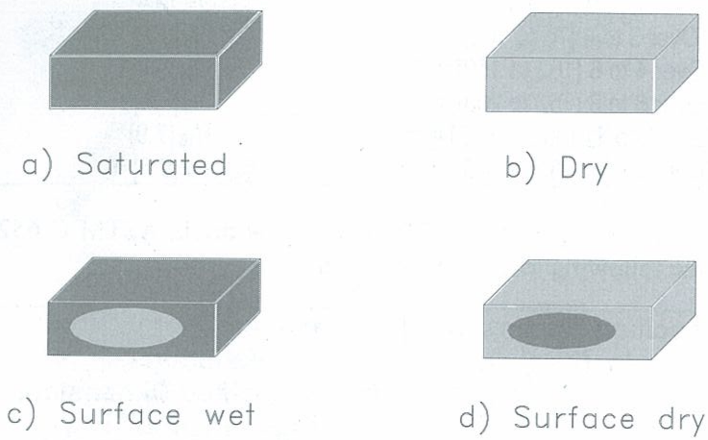


Figure 3. Moisture conditions of inside of brick.

Figure 3a shows a saturated condition where the brick has so low a suction that it will float unless the bricklaying proceeds very slowly. Figure 3b shows a dry brick. Figure 3c shows a wet surface but dry core condition, and is satisfactory if the moisture extends at least $^3/_4$ inch [19.1 mm] into the brick. The reason for the $^3/_4$ inch [19.1 mm] of moisture is that in warm weather the brick may otherwise dry out. Figure 3d shows the ideal condition where the core is wet and the surface is damp. One method to achieve this condition is to saturate the brick the day before use.

2.1.5 Field Test for Rate of Absorption

A rough but effective test for a rate of absorption is to place a quarter on a brick draw a circle around it with a pencil, then trace around the circle using a wax crayon. Using a medicine dropper, very quickly drop water within the circle, completely filling it, taking care that the water does not flow over the marked circle, and continue until 20 drops have been placed. Note the time required for all of the water to be absorbed into the brick, beginning with the time the circle is first filled. If the time exceeds $1^1/_2$ minutes, the brick need not be wetted. If the water disappears in less than $1^1/_2$ minutes, the brick should be pre-wetted.

2.1.6 Wetting of Brick

A poor bond between brick and mortar may result from either too much or too little water in both mortar and brick.

Brick must be wet with clear water. Several methods can be used in wetting brick. One is letting a hose run on the pile or pallets of brick; another is using a sprinkler that would wet a number of pallets at one time, or they may be hand sprayed by holding the hose.

Brick should be wetted several hours before they are to be laid. This allows the moisture to penetrate into the interior of the brick. The surfaces should be just damp when laid. The time of wetting and the amount of wetting will depend on weather conditions.

Some face bricks having a very low rate of absorption and need not be wetted, while others need be only dampened before laying. When brick are thoroughly soaked, as after a hard rain, they must be allowed to dry until the initial rate of absorption is restored.

2.2 SAND (ASTM C 144)

Quality. Sand for mortar should consist of hard, strong, durable uncoated mineral or rock particles free from mica, organic matters, saline, alkaline, or other deleterious substances which would impair the strength of the mortar or which would cause disintegration or efflorescence.

Ocean or beach sand should never be used, as it is not properly graded since it contains deleterious matter and salt, which contribute to efflorescence. Ocean or beach sand may also contain soap-like elements, which will cause disintegration.

Sand for mortar which may be either natural or manufactured, is the largest volume and weight constituent of the mortar. Sand acts as an inert filler, providing economy, workability and reduced shrinkage, while influencing compressive strength. An increase in sand content increases the setting time of a masonry mortar, but reduces potential cracking due to shrinkage of the mortar joint.

Well-graded sand reduces separation of materials in plastic mortar, which reduces bleeding and improves workability. Sands deficient in fines produce harsh mortars, while sands with excessive fines produce weak mortars and increase shrinkage. High lime or high air content mortars can hold more sand, even with poorly graded aggregates, and still provide adequate workability.

Field sands deficient in fines can result in the cementitious material acting as fines. Excess of fines in the sand, however, is more common and can result in over sanding, since such excess does not substantially affect workability.

Mortar properties are not seriously affected by small variations in grading, but quality is improved by careful attention to aggregate selection.

Grading. Aggregate for masonry mortar must be graded within the following limits set by ASTM C 144, whether sand is natural sand or manufactured.

Sieve Size	Percent Passing[1]	
	Natural Sand	Manufactured Sand
No. 4 [4.75 mm]	100	100
No. 8 [2.36 mm]	95 to 100	95 to 100
No. 16 [1.18 mm]	70 to 100	70 to 100
No. 30 [600 μm]	40 to 75	40 to 75
No. 50 [300 μm]	10 to 35	20 to 40
No. 100 [150 μm]	2 to 15	10 to 25
No. 200 [75 μm]	0 to 5	0 to 10

[1] ASTM C 144, Section 4.1

Fineness Modulus. A fineness modulus of mortar sand between the approximate limits of 2.25 and 2.75 is recommended. Fineness modulus is the summation of the percentages of dry sand retained on standard sieve numbers 4, 8, 16, 30, 50 and 100 divided by 100.

Figure 4. Nest of sand analysis sieves in shaking apparatus. Knocker at top taps nest while being shaken.

Voids. Voids in sand may be defined as the empty spaces among the grains of sand. If a metal cylinder is filled with sand, an amount of water may be poured into it without overflowing, since the water simply fills up the air spaces. When the sand has settled down, and is saturated without free water standing on top, the volume of water required to saturate the sand would represent the volume of voids in the sand. In commercially graded sand, this void volume is closely one third the volume of loose sand. Thus the accepted rule is 1 volume of cementitious materials to 3 volumes of sand.

A material having particles all of a uniform size and shape contains practically the same percentage of voids as a material having particles of a corresponding similar shape, but of a different uniform size.

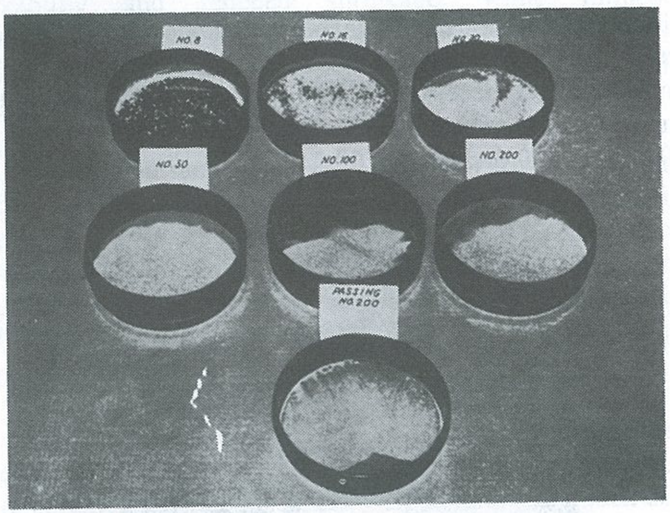


Figure 5. Sieves showing amounts of sand retained on (top, left to right) No's. 8, 16 and 30 sieves, and (2nd row) No's, 50, 100 and 200 sieves. Bottom pan, amount passing No. 200 sieve. This sand has a fineness modulus of 2.40.

In any loose or granular material, the largest percentage of voids occurs with particles all of the same size. The smallest percentage of voids occurs with particles of such different sizes that the voids of each size are filled with the largest particles, which will fill them.

Materials with round particles contain less voids than materials with angular particles screened to the same size.

1 cubic foot contains	1728 cubic inches
12 inch diameter sphere contains	904.8 cubic inches
1728 1-inch diam. stacked spheres contain	904.8 cubic inches
1 cubic foot of stacked buck shot contains	904.8 cubic inches
In each case	47.7% voids
Graded sand about	34 % voids

Requirements. Most local building codes and C.C.R. Title 24 require sand to meet ASTM Specifications C 144, which provides a definite sand gradation and limit of 2 to 15% on fine materials passing the No. 100 sieve.

In washed sand, fines are washed out producing a harsher mortar. To compensate for the lack of fines, the mortar requires more lime or cement to provide the required plasticity and water retention.

Bulking. Where the volume of sand is specified on dry, loose measurement, and the sand on the job is damp, it is necessary to allow for bulking.

A simple method of determining this is to carefully fill a 6 inch x 12 inch [152 mm x 305 mm] cylinder level full of the damp sand, without tamping, then carefully dry out this sand, after which, place it back in the cylinder. The distance the surface of the dry sand is below the top of the cylinder, divided by the depth of the sand, will give the percentage of damp sand to be added to obtain the specified volume. If this distance is, say 2 inches [50.8 mm], then (2 divided by 10) 20% bulking must be added to the sand volume.

Another method is to pour enough water into a sand-filled cylinder until the sand is completely saturated and settled and the cylinder is level full of water. The distance from the top of the cylinder to the top of the saturated sand is closely the same as in the preceding paragraph.

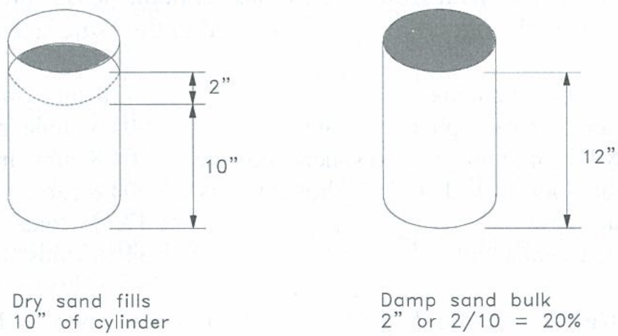


Figure 6. Bulking of damp sand.

2.3 LIME (ASTM C 5, C 207)

Of all the materials in the mortar mix, lime has the greatest capacity to retain water. This is a very important function of the lime since it aids workability and is also a cementitious material. Lime is required in masonry mortar by most local building codes, Uniform Building Code, ASTM C 270, C.C.R., Title 24 and in Federal Specifications.

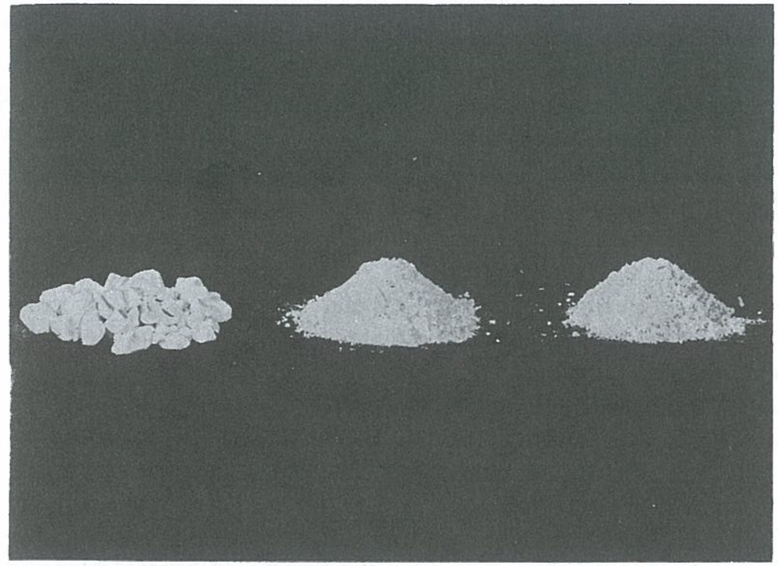


Figure 7. LIME - From left, lump quick-lime, processed quick-lime, hydrated lime.

Cycle: Limestone to Lime to Limestone.
It may be Calcium Carbonate or Magnesium Carbonate, or both.

EXAMPLE:

	$CaCO_3$	=	Calcium Carbonate (Limestone)
Minus,	CO_2	=	Carbon Dioxide (Lost in burning Limestone)
Result,	$Ca\,O$	=	Carbon Oxide (Quicklime)
Add,	H_2O	=	Water to slack Quicklime
Result,	$Ca\,(HO)_2$	=	Calcium Hydroxide (Lime Putty)
Plus,	CO_2	=	Carbon Dioxide from air
Result,	$CaCO_3$	=	Calcium Carbonate (Limestone)

Quicklime in lumps, called **lump lime**, is slaked by adding lime to the water.

Processed lime (pulverized quicklime) is slaked by adding the lime to the water.

Hydrated lime is the same, chemically, as lime putty, but only enough water is added to quicklime in manufacture to satisfy its chemical demand. Water added to hydrated lime makes lime putty in very few minutes.

Lime putty is made from quicklime or hydrated lime. If made from quicklime, other than pulverized (processed) quicklime, the lime must be properly slaked and then screened through a sieve having not less than 16 meshes per linear inch. After screening and before using, the slaked lime must be properly stored and protected for not less than 10 days or longer until entirely cooled. If made of pulverized (processed) quicklime, the lime must be properly slaked for not less than 24 hours or until the lime putty has entirely cooled. All resulting lime putty should not weigh less than 83 pounds per cubic foot [1329 kg/m^3].

The crystallization of lime not only increases the bond strength, but, over a period of many years, heals or seals fine cracks caused by shrinkage or other causes.

Whether lime putty or dry hydrated lime is used, the proportions by volume measurement are the same for either type.

2.4 CEMENTS (ASTM C 150)

Portland Cement - Portland cement is made by finely pulverizing clinker which is produced from burning a definite artificial mixture of silicious (containing silica), argillaceous (containing alumina), and calcareous (containing lime) materials to incipient fusion. Small amounts of alkalies, such as potassium oxide, sodium oxide, and sulfur trioxide are also present.

Portland cement is composed of three principal compounds: tri-calcium aluminate, tri-calcium silicate, and di-calcium silicate. As these compounds crystalize, the portland cement sets and hardens as follows:

1. Approximately $2^1/_2$ hours after mixing, the initial set will occur as the first set of crystals form.
2. Final set occurs after about 8 hours with the formation of the second crystals.
3. Hardset occurs with the formation of the last crystals. Although the portland cement will continue to harden indefinitely, hard set is usually considered to have occurred 4 weeks after mixing.

Portland cement in mortar does not chemically set up until approximately $2^1/_2$ hours after mixing and therefore, can be retempered with water up to this time without loss in strength. However, some specifications limit the retempering time to one time after mixing. Tests have been made on mortar in increments of time up to 4 hours and very little loss in compressive strength was noted. ASTM C 270, *Mortar for Unit Masonry,* requires mortar to be retempered with water to maintain workability, and to be used and placed within $2^1/_2$ hours after the original mixing. This depends on temperature.

Plastic Cement. In some of the southwestern areas of the United States, plastic cement is sometimes used for mortar. Plastic cement is a type of Portland cement specifically designed for use in plastering. It has a high air content, which makes it workable for this application. It is basically Type I portland cement with approximately 12 percent plasticizing agent added. When plastic portland cement is used in mortar, hydrated lime may be added, but not in excess of one-tenth of the volume of cement.

Plastic cement is generally used for small masonry projects and the "do it yourself" home masonry market since lime does not have to be used to obtain adequate plasticity. Mortar made with 1 part plastic cement and 3 parts sand is equivalent to a mix of 1 part portland cement, 0.14 parts plasticizer and 3.4 parts sand which is richer than type S, portland cement, lime mortar.

The Uniform Building Code prohibits the use of plastic cement in structural masonry in Seismic Zones 2, 3 and 4. ASTM C 270 does not acknowledge the use of plastic (plasterers) cement in any masonry mortar.

Masonry Cement Masonry cement is a mixture of portland cement, 30% to 60% plasticizer material, and added other chemicals. The requirements for masonry cement are contained in ASTM C 91, *Standard Specification for Masonry Cement*.

The Standard includes classification Type M, Type S and Type N masonry cements to produce mortars conforming to ASTM C 270. Additionally, Type N masonry cement may be mixed with additional portland cement to produce Type M and Type S mortars.

The building codes prohibit the use of masonry cement for structural masonry in Seismic Zones 2, 3 and 4 and Seismic Performance Categories D and E.

Mortar Cement. In response to the seismic restrictions on masonry cement, the manufacturers introduced a new type of cement, Mortar cement, in the mid 1980's. Mortar cement is also a portland cement based material which meets the requirements of Uniform Building Code. Standard 21-14, Mortar Cement and the more recently published ASTM C 1329, *Standard Specification for Mortar Cement*. Mortar cement may be used for mortar in all Seismic Zones and Seismic Performance Categories.

There are three types of mortar cement:

(1) Type N. Contains the cementitious materials used in the preparation of Type N or Type O mortars. Type N mortar cement may also be used in combination with portland or blended hydraulic cements to prepare Type S or Type M mortars in accordance with ASTM C 270, Table 1.

(2) Type S. Contains the cementitious materials used in the preparation of Type S mortar.

(3) Type M. Contains the cementitious materials used in the preparation of Type M mortar.

Preblended Mortars. In many parts of the United States, portland cement, hydrated lime and aggregates are factory blended and shipped to the project in silos or sacks. Preblended mortars may also contain pigment for colored mortar. The advantages are that this method removes some of the variables associated with mortar, such as imprecise volume measurements of all ingredients and non-contamination of materials. Blending is done in a manner similar to concrete batch plant quality control standards to produce the requirements of specified type of mortar.

This packaged mortar conforms to the requirements of Table 1 in ASTM C 270. In bulk form it is ideal for large projects and sacks are tailored to small projects and congested projects, such as parking structures.

2.5 WATER

Water used in masonry construction should be potable, suitable for drinking, and free of harmful substances such as oil, acids, alkalis, and any other non-drinkable impurities.

2.6 STEEL (ASTM A 615)

Reinforcing steel is typically specified to comply with ASTM A 615, which specifies physical and chemical properties and deformations for bonds. Laboratory reports are required when steel is specified to be tested.

According to ASTM A 951, *Standard Specification for Masonry Joint Reinforcement*, the longitudinal and cross wires shall be a minimum size of 11 gage. UBC Section 2106.1.5.4 requires a minimum of 9 gage wire for joint reinforcement. The cross wires are not to project more than $^1/_8$ inch [3.2 mm] beyond the longitudinal wires and are typically spaced at 16 inches [406 mm] intervals. This spacing works well when installing 16 inches [406 mm] long masonry units.

Building Code Requirements for Masonry Structures (ACI 530-99/ASCE 5-99/TMS 402-99) allows joint reinforcement to bond two wythes of masonry together when using the cross wires of the joint reinforcement as ties. Maximum spacing of the ties shall be 2.67 square feet [0.25 m^2], except that when used in Seismic Performance Category C and above, the spacing of (longitudinal wires and) cross wires shall not exceed 16 inches [406 mm] both vertically for walls over 4 inches [102 mm] in width.

2.7 STORAGE OF MATERIALS

Brick units, cement and sacked lime should be protected from exposure to wet weather. Cement and lime may deteriorate when exposed to excessive moisture. Aggregates should also be protected from the elements. Not only can debris blow into sand and gravel piles, but rain may also erode bulk material stockpiles.

2.8 MORTAR (ASTM C 270)

The most important properties of mortar are:

...Workability and water retentivity
...Capacity to develop bond
...Weather resistance
...Minimum volume change

The recommended proportions for mortar for Reinforced Grouted Brick Masonry and brick veneer are:

1 part portland cement

$^1/_2$ part hydrated lime

$4^1/_2$ parts mortar sand, damp loose measurement

All parts must be determined by accurate volume measurements at the time of placing in the mixer. When less than one full sack of cement is used, extreme care must be taken in very accurately measuring all the parts. C.C.R Title 24 does not permit shovel measurements in the preparation of mortar.

Compressive strength is not a function of the bonding value of mortar.

Full size tests have shown that brick masonry using a mortar mix of 1 part portland cement, $^1/_2$ part lime, $4^1/_2$ parts sand has bond value in flexure much higher than when mortar of 1 part cement, $^1/_4$ part lime, 3 parts sand are used.

With any mortar mix, the softer or more plastic the mortar, the greater the bond strength. For maximum bond, the mortar must be as soft as the mason can handle without smearing the face of the brick.

Mortar must be maintained highly plastic on the mortar boards which usually requires retempering with water. This should be done only by adding water within a basin formed in the mortar and the mortar reworked into water. Water should never be dashed over mortar on the boards. Harsh, non-plastic mortar must not be retempered or used. Most building codes permit the use of mortar for up to $2^1/_2$ hours after the introduction of water since mortar will not set up chemically for that time duration. Therefore, it is amply safe to use it up to 1 hour. Once the mortar comes in contact with the unit, the hydration process begins.

2.8.1 Water Retention of Mortars

Water retentivity is the property of mortar that resists a rapid loss of mixing water to the air or to overly absorptive masonry units. Water retentivity is often related to workability since mortars with good water retention properties tend to remain soft and plastic for an ample period of time. Therefore, masonry units may be aligned, leveled and plumbed without breaking the critical bond between the mortar and the masonry unit. Conversely rapid loss of water from the mortar causes premature setting of the mortar and poor bond while excessively high water retention mortars (or non absorptive units) cause the masonry units to float so that it is difficult to properly align them. Thus, mortars should be mixed to have water retention properties within tolerable limits.

Water retention for mortar is determined in a laboratory by measuring the flow on a flow table as outlined in ASTM C 91. Mortar is placed on an apparatus which, by vacuum, sucks water out of the mortar for one minute. The mortar is then returned to the flow table and again measured. If the mortar has lost no water, the flow after suction would be 100%.

In ASTM C 91, Table 1, a 70% minimum water retention value is recommended. This is based on mortar having an original flow of 100 to 115%. Mortar, when used, however should generally have an original flow of 135 to 145%, and thus would have a higher percent flow after suction. Generally, the water retention of a mortar at the time of use should be about 85%.

Water retention determined from ASTM C 91-96, Section 20.

Cone Dimensions:
Diam. at top $2^3/_4$"
Diam. at bottom 4"
Height of cone 2"

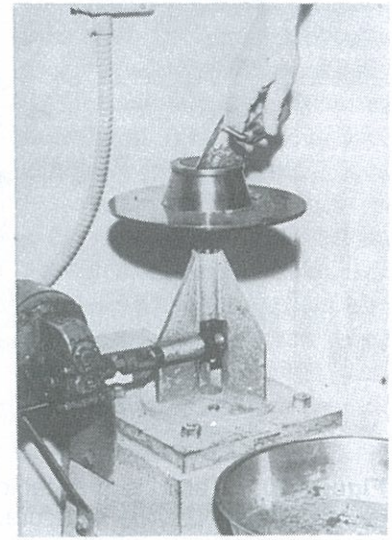


Figure 8. The "flow" and water retention of mortar is determined as follows: A truncated brass cone is placed on the flow table. Cone is filled with mortar and leveled off.

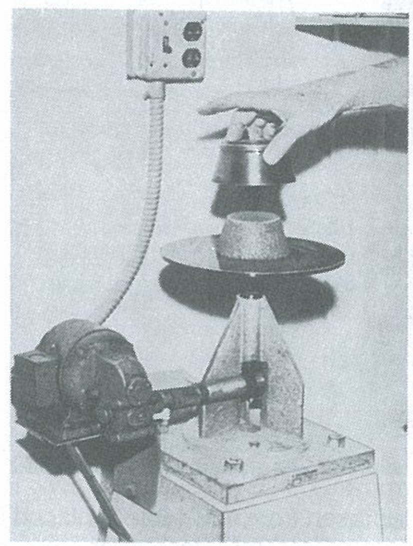


Figure 9. Cone is carefully removed

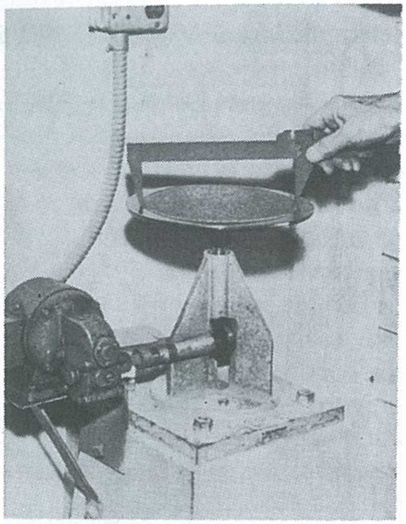


Figure 10. Table is mechanically "dropped" 25 times in 15 seconds, and "flow" is measured. Cone diameter at base is 4 inches. If mortar flows out to 9.60 inches, the increase in diameter is 5.60 inches, and the "flow" is 5.6 divided by 4, or 140 percent.

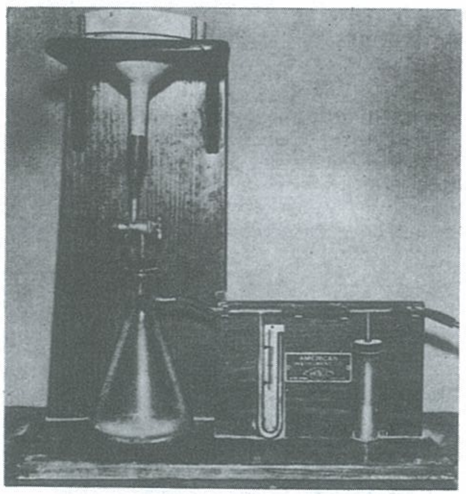


Figure 11. Mortar taken from flow table is placed into perforated dish of suction apparatus, and 2 inches of mercury sucks water from mortar for one minute.

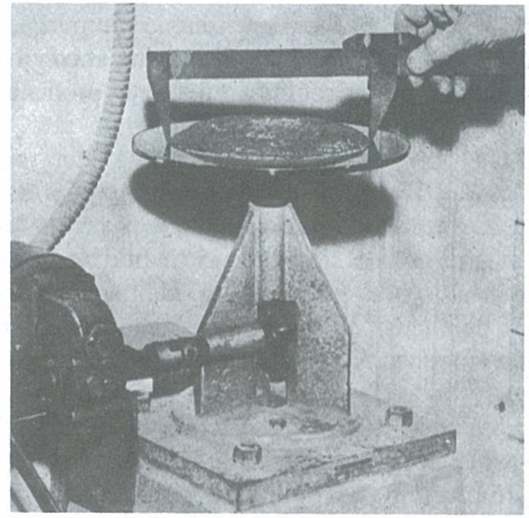


Figure 12. Mortar is returned to the flow table and measured for flow. If it then flows to 8.5 inches diameter, the increase is 4.5 inches. The flow after suction is 4.5 divided by 4, or 113 % the water retention is the ratio of 113% divided by 140, or 80% which is ideal for good brick mortar.

2.8.2 Admixtures

No admixtures should be used in mortar and grout unless approved by the governing building department and without the written approval of the architect or engineer. Tests and experience must demonstrate that the admixture will not decrease the bond strength to the brick or the reinforcing steel. Some admixtures reduce the water content or water demand, and thus may adversely affect the water retentivity of mortar.

2.8.3 Mortar Colors

Color additives for mortar may be only pure mineral oxides, carbon black or synthetic colors. The Uniform Building Code limits carbon black to a maximum 3% of the weight of the cement in the mortar. Colors for the mortar must be approved by the architect or engineer, and measured accurately into each batch after all other ingredients are in the mixer. Then all ingredients should be thoroughly mixed to produce an even color.

Specification for Masonry Structures (ACI 530.1-99/ASCE 6-99/TMS 602-99) also contains limitations on the amount of color that can be added to mortar. In portland cement-lime mortars, the limit is 10% for mineral oxide pigments and 2% for carbon black pigments. In mortar cement and masonry cement mortars, the amounts are reduced by half, for 5% and 1% respectively.

Factory blended colored mortars are available and color quantities are carefully controlled, thereby reducing field color variation.

2.9 GROUT (ASTM C 476)

Grout differs from concrete in that concrete is poured with a low water-cement ratio, into non-porous forms, while grout has a high water-cement ratio, and is poured between porous brick forms. Additionally, grout must be sufficiently fluid to flow into small grout spaces and around reinforcing steel without leaving voids. Although good mortar should stick to the bottom side of a trowel, it should be impossible for grout to do so. When introduced into the masonry, the high water-cement ratio of grout is rapidly reduced to an extremely low ratio producing a compact mass having a density about equal to that of gunite.

In construction of Reinforced Grouted Brick Masonry, building codes typically allow the two wythes of masonry to be carried up to a height listed in Uniform Building Code Table 21-C or *Building Code Requirements for Masonry Structures* Table 1.15.2. Unless very low lifts are grouted, approximately 12 inches [305 mm] or less, it is suggested that proper curing time be given to allow the brickwork to adequately set and avoid blowouts. Although not governed by the code, three days should

be adequate curing time. Grout pours over 12 inches [305 mm] are required by code to be mechanically vibrated.

C.C.R. Title 24 permits one outer tier of brickwork to be carried up not more than 12 inches [305 mm] and the other tier not more than 1 unit high prior to grouting. The grout is poured from the center of the course previously laid, to the center of the course being grouted. To insure grout flowing into all spaces between the bricks and to fully encase the reinforcing steel, it should be puddled immediately with a wood puddle stick about 1 inch x 2 inches [25.4 mm x 50.8 mm]. In early practice, grout was puddled with the point of a trowel. This left cut planes in the grout. The fresh grout normally did not flow into the trowel penetrations, leaving voids in the grout.

Grout must be well mixed before using to avoid segregation of the ingredients. It must be carefully poured, preferably with buckets containing spouts to avoid having the grout contact the bed joint surfaces of exposed brickwork, and also the face of the masonry. When grout contacts the face of finished masonry it must be thoroughly cleaned off just after the mortar has set. If done sooner, the washing and scrubbing with brushes may injure the mortar joints. If done too late, the grout may have become too hard to be removed by scrubbing or washing and may require more aggressive cleaning methods. Small drips of grout on the face of the brick may be immediately cleaned with a sponge and plain water.

It is usually preferable to pour grout from the inside face of the wall when possible. Grout pouring may be done in one or more passes. By grouting from the center of one course to the center of a course just laid, it prevents movement of the top course due to hydrostatic pressure of the grout and puddling pressure.

Where grouting is suspended for an hour or more, the grouting should be carried up to within approximately $1^1/_2$ inches [38.1 mm] below the course or courses being grouted. This allows the grout surface to be cleaned and flushed out before proceeding with the work.

Fine grout for Reinforced Grouted Brick Masonry consists of one part portland cement and 3 parts sand which is measured in a damp loose condition.

In grout spaces 2 inches [50.8 mm] or more in width the grout may contain 2 parts pea gravel, making a mix of 1 part cement, 3 parts sand, 2 parts pea gravel and is called coarse grout. The addition of pea gravel not only produces a good concrete core but it also replaces water in a given volume.

When pea gravel is used, it should not be pre-mixed with the sand, but rather, it should be measured and placed in the mechanical batch mixer directly. This does not applied to factory blended grout mix.

Where the grout space in walls, pilasters, columns and beams is wide enough to permit full brick to be inserted with at least $^3/_4$ inch [19.1 mm] grout coverage on each side, the interior brick are "floated" into the grout for a depth of not less than $^1/_2$ their height.

2.10 REINFORCEMENT

Before installation, reinforcement must be free from loose rust, mill scale, and other coatings that would destroy or reduce bond.

All reinforcement must be accurately cut to length, and bent when required, without injury to the material. All kinks or bends in the bars caused by handling incidental in delivery must also be straightened without injury to the material before placement. Splices must be made only at such points, and in such manner that the structural integrity of the member will not be reduced. Lapped splices must provide sufficient length to transfer the working stress of the bars by bond, and shear with a minimum

lap of 48 bar diameters for Grade 60 steel. Welded or mechanical connections must develop 125% of the specified yield strength of the bar in tension.

The minimum clear distance between parallel bars, except in columns, must be 1 inch [25.4 mm] or the nominal diameter of the bar, whichever is greater, except where lapped and tied.

All vertical reinforcing steel must be accurately placed and properly braced by mechanical devices to maintain correct positions shown on the plans. Local building codes and C.C.R. Title 24 do not require horizontal steel to be tied to vertical steel. Generally, a bricklayer can do a much better job by having the horizontal steel placed into fresh grout than by trying to work around horizontal steel previously tied in position.

Principal reinforcing bar spacing is limited to 4 feet [1.2 m] maximum each way by the Uniform Building Code for Seismic Zones 2 (10 feet [3 m] horizontal), 3 and 4, and by *Building Code Requirements for Masonry Structures* for Seismic Performance Categories D and E. Seismic Performance Category C allows the vertical reinforcement to be spaced up to 10 feet [3 m] apart.

C.C.R. Title 24 requires that the maximum spacing for both vertical and horizontal bars not exceed 2 feet [610 mm].

All reinforcement must be accurately cut to length, and bent when required.

SECTION 3
INSTALLATION

3.1 BRICKLAYING

Where feasible, brickwork should be started at the least conspicuous corner or wall, and the masonry contractor should request an early inspection of the work by the architect or engineer.

Horizontal surfaces that are to receive brickwork must be clean and damp to insure good bond to the mortar and also grout and concrete. All laitance must be removed. Roughness in itself is no guarantee of providing good bond.

For maximum bond, the first course on each side of a wall should be laid on the concrete, taking care that the first mortar bed joint does not extend into the grout space, then two courses are grouted to a point about $1^1/_2$ inches [38.1 mm] below the top of the courses.

In laying up leads or corners, care must be taken that these leads are not too high: not over 4 feet [1.2 m]. The most particular point to watch is the grouting of the leads. Each course in a corner lead must be grouted as laid, using a brick or other means to form a dam for the grout.

Where head joints are less than $^5/_8$ inch [15.9 mm] wide, they must be solidly filled with mortar at the time of laying.

In spreading the bed mortar, extreme care must be taken to prevent the mortar from falling into the grout spaces. This can be accomplished by keeping the grout side of the mortar joint back about $^1/_2$ inch [12.7 mm] from the inside edge of the brick so that when bricks are laid the mortar will spread to the edges of the brick in the grout space without squeezing out.

Another method more typically used, is to spread the mortar, and then draw the trowel over the mortar in an upward and outward direction, away from the grout space forming a beveled mortar bed. When the bricks are laid on such a beveled bed, the mortar will likewise be squeezed only to the grout side edges without squeezing out. Deep furrowing of bed joints should not be done, however, very light furrowing or riffling the bed joint with the point of the trowel has been found to effect solid bed joints.

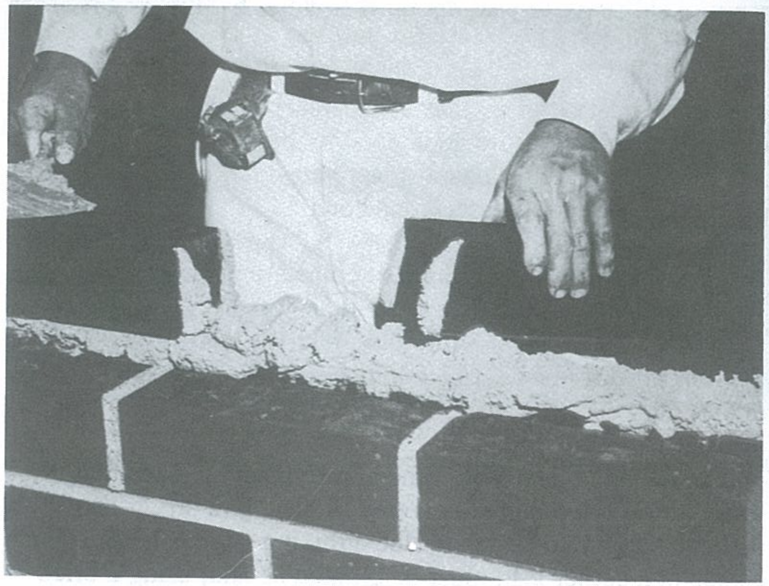


Figure 13. Insufficient head joint. Mortar is too stiff. Too much mortar in bed joint. Too much overhang in grout space. **Not recommended**.

Where the mortar squeezes out into the grout space $^5/_8$ inch [15.9 mm] or less, either in the bed or head joint, it is best to leave it alone, as the grout will bond around it when poured and puddled. When mortar does drop into the grout space, as is bound to happen occasionally, it is best to leave it until the grouting is done, at which time the puddling of the grout will

solidly mix the mortar droppings into the grout. Of course, this only applies where the grouting follows the bricklaying within a few minutes or so. C.C.R. Title 24 requires grout spaces to be kept clean of mortar droppings.

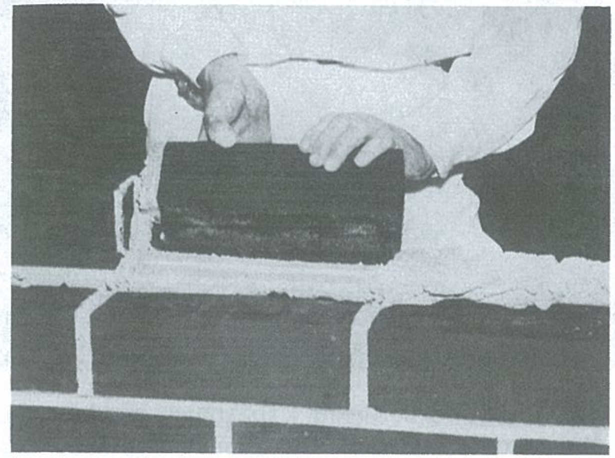


Figure 14. Deep furrowed bed joint. Note lengthwise void and no mortar in center of brick, and unfilled head joint. **Not recommended**.

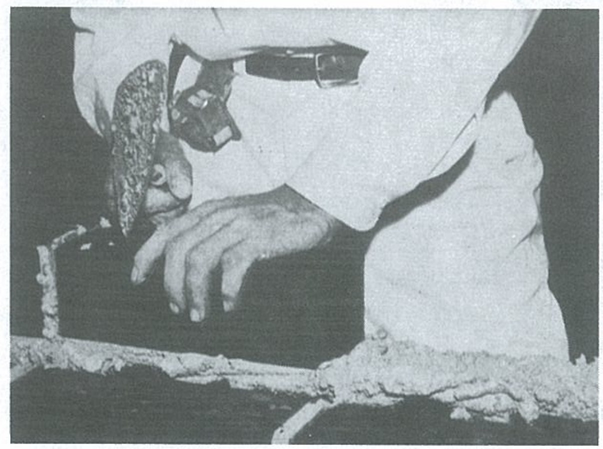


Figure 15. Furrowed bed joint. Too much overhang in grout space. **Not recommended**.

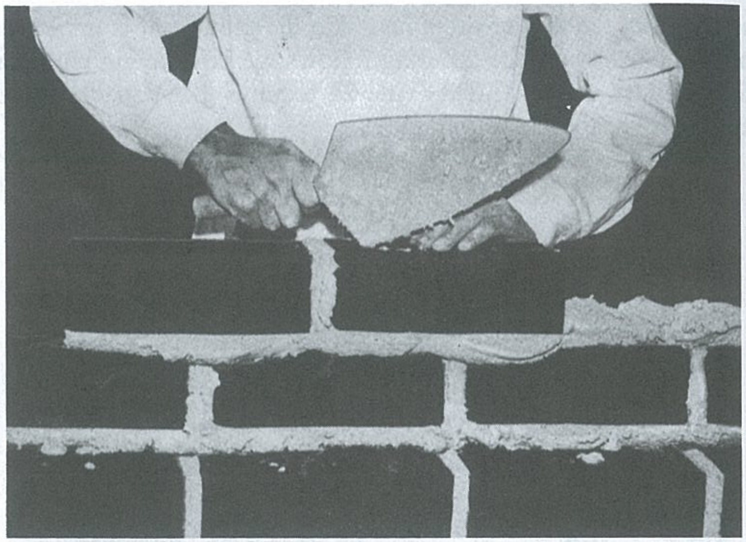


Figure 16. Furrowed bed joint. Too much overhang in grout space. **Not recommended**.

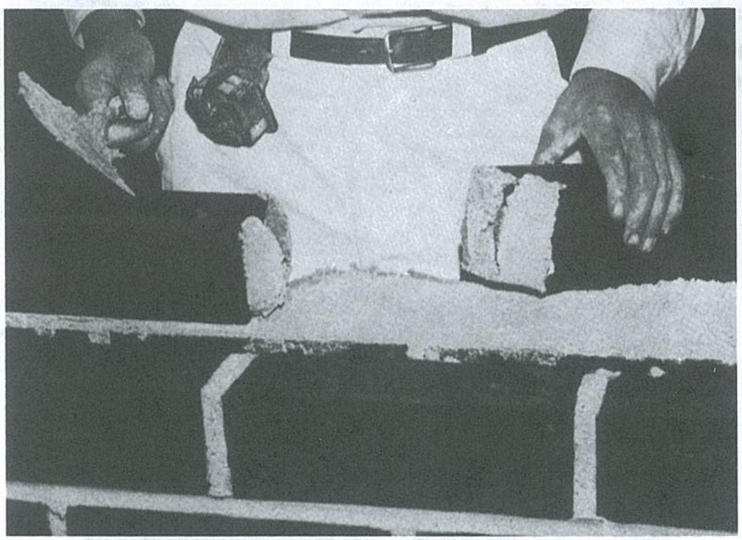


Figure 17. Full head joint. Beveled bed joint. **Recommended**.

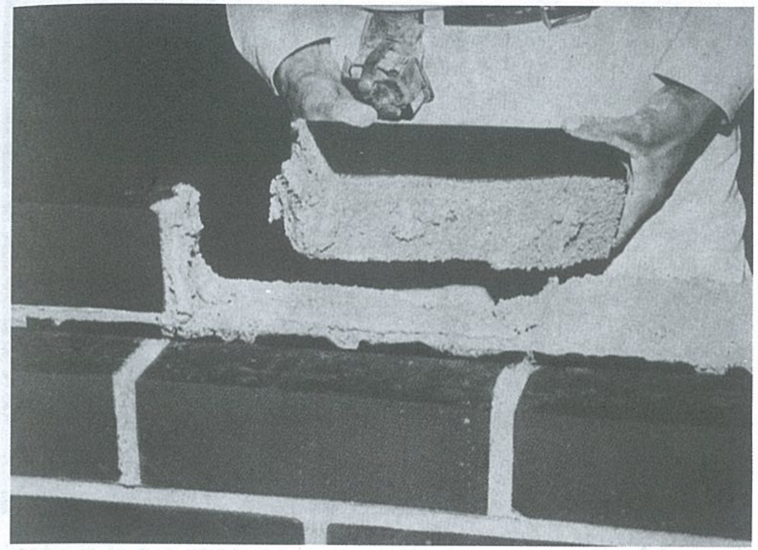


Figure 18. Full head joint. Beveled bed joint with brick lifted. Note full coverage of mortar. **Recommended**.

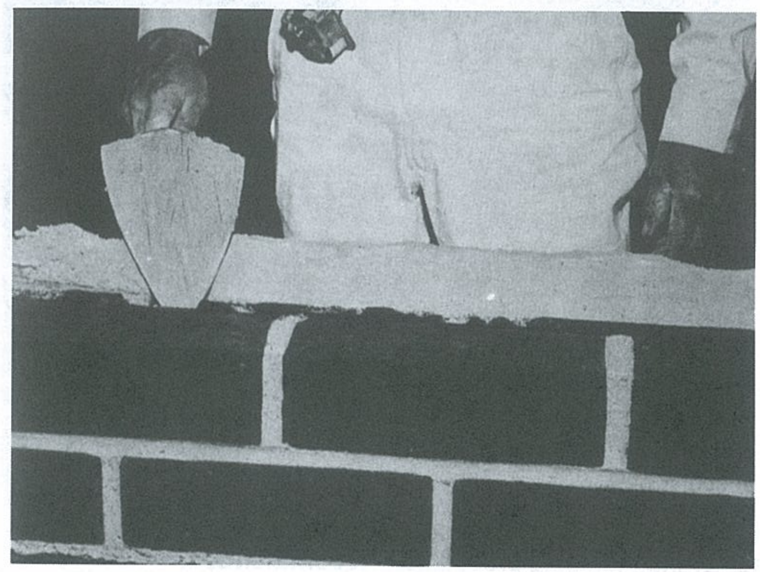


Figure 19. Beveled bed joint. **Recommended**.

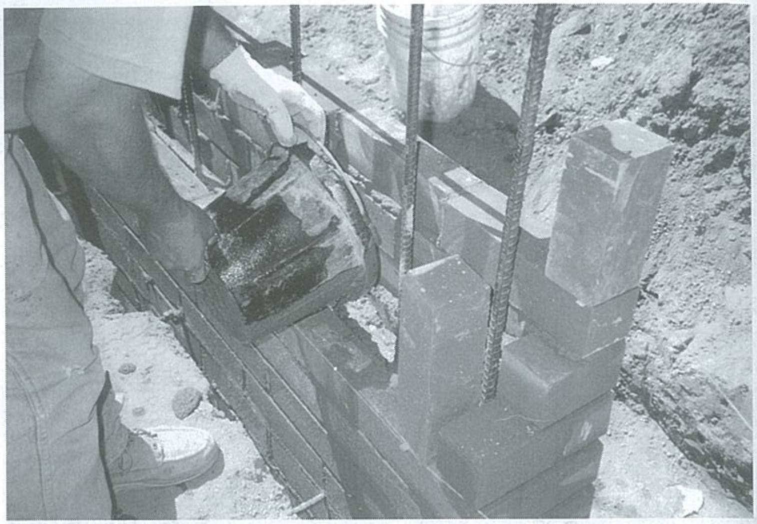


Figure 20. Pouring grout. Note ideal squeeze-out of mortar in back wall. See pages 42-50 construction procedure.

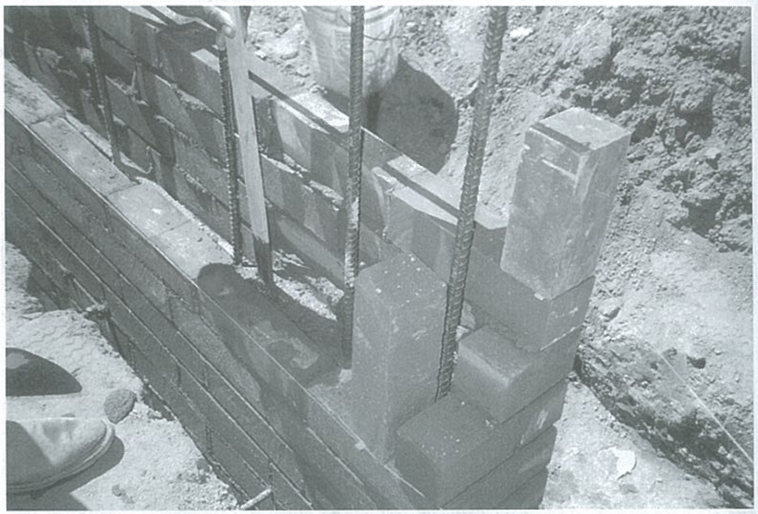


Figure 21. Puddling grout with puddle stick using swishing rather than tamping procedure. **Recommended.**

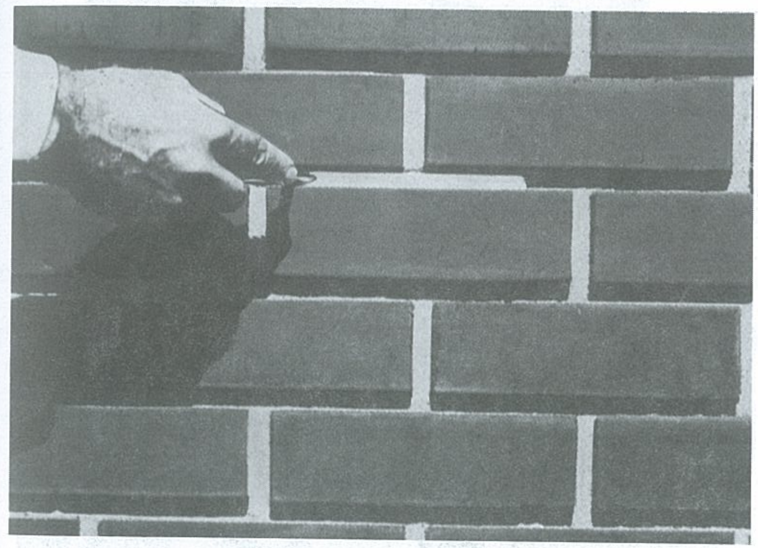


Figure 22. Raked and tooled joints.

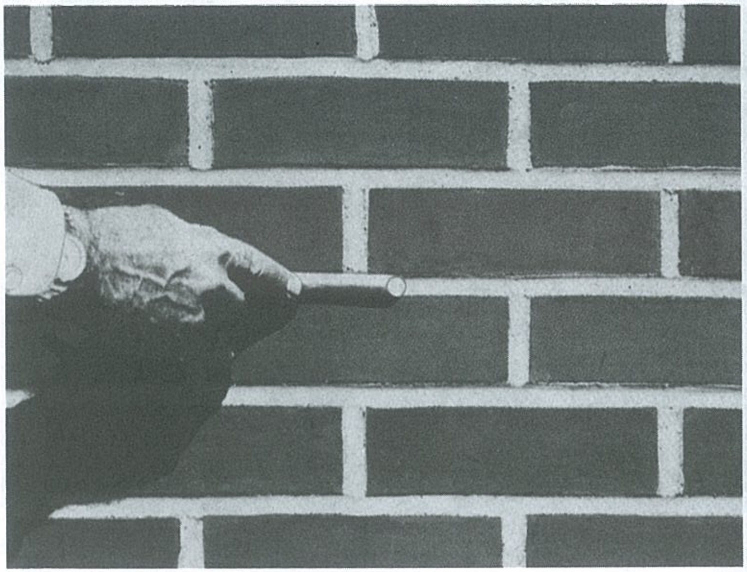


Figure 23. Tooled joints, clean.

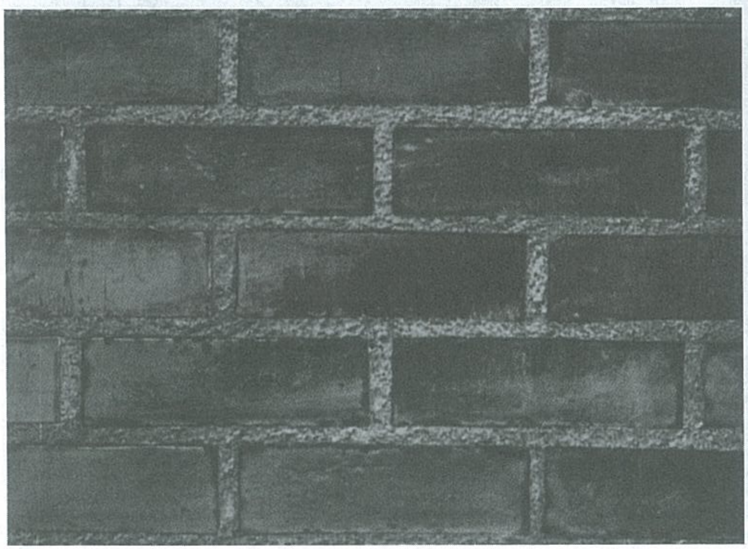


Figure 24. Flush-cut joints, sack-rubbed.

Since grouting should be left down approximately 1 inch [25.4 mm], below work, which is to be stopped for more than an hour, there should be no mortar droppings on the top of the grout. However, before continuing work previously stopped, both the brick and the grout joint must be thoroughly cleaned and their top surfaces dampened with water.

Most bricks are required by local codes and C.C.R. Title 24 to be shoved into place. This shoving may be only a fraction of an inch, but the shoving action permits the mortar in the bed joint to be rubbed into the pores of the underside of the brick being laid and at the same time tighten up the head joints.

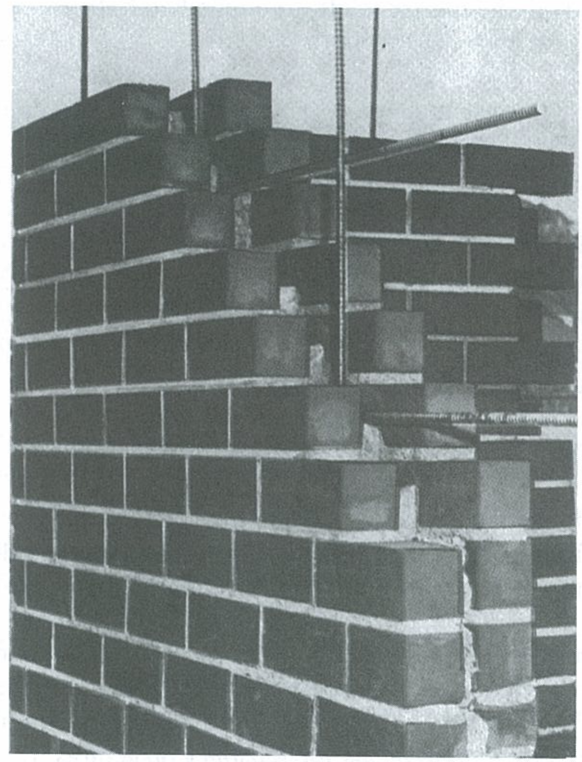


Figure 25. Racking in foreground. Toothing at right background.

When necessary to stop a longitudinal run of masonry, and at corner leads, the masonry should be racked back approximately one half brick length in each course and stopping the grout at the rack. Particular care must be taken when toothing a wall since filling the grout space is more difficult.

Shear walls or sections are vital to a structure. Where such sections are less than about six feet [1.8 m] in length, especially at corners, they should be built in level courses with racking or corner leads not more than 12 inches [305 mm] in height, using care to solidly grout at these corners.

An inspector is to make certain that all line pinholes and other voids in the mortar joints are immediately filled before the masons leave an area of work.

Jointing must be done while the mortar is still thumbprint fresh plastic, so that the mortar will be squeezed tightly against the bricks before it has begun to set or stiffen. Carpet, sacks or rags **must never be rubbed** over the face of finished exposed brickwork. Brickwork to be painted may be sackrubbed.

Lintels and beams must be complete and grouted their full height or depth and length, in one continuous operation to avoid horizontal cold joints.

3.2 LOW LIFT AND HIGH LIFT GROUTING

Although the terms low lift and high lift grouting have been deleted from the Uniform Building Code in recent years, they are still commonly used when referring to grouting methods.

Normally, the term low lift grouting is used to refer to procedures where the grout pour is 5 feet [1.5 m] or less (see Uniform Building Code Table 21-C, Grouting Limitations, *Building Code Requirements for Masonry Structures,* (ACI 530-99/ASCE 5-99, TMS 402-99), Table 1.15.2, Grout Space Requirements, or *Specification for Masonry Structures*, (ACI

530.1-99/ASCE 6-99, TMS 602-99), Table 7, Grout Space Requirements). When masonry grout pours do not exceed 5 feet [1.5 m], cleanouts are not required. However, in high lift grouting, where the masonry is to be poured to heights greater than 5 feet [1.5 m], cleanout holes are required.

U.B.C. Table No. 21-C- Grouting Limitations[4]

Grout Type	Grout Pour Maximum Height (Feet[1])	Minimum Dimensions of the Total Clear Areas within Grout Spaces and Cells[2,3],	
		Multiwythe Masonry	Hollow-Unit Masonry
Fine	1	$\frac{3}{4}$	$1\frac{1}{2}$ x 2
Fine	5	$1\frac{1}{2}$	$1\frac{1}{2}$ x 2
Fine	8	$1\frac{1}{2}$	$1\frac{1}{2}$ x 3
Fine	12	$1\frac{1}{2}$	$1\frac{3}{4}$ x 3
Fine	24	2	3 x 3
Coarse	1	$1\frac{1}{2}$	$1\frac{1}{2}$ x 3
Coarse	5	2	$2\frac{1}{2}$ x 3
Coarse	8	2	3 x 3
Coarse	12	$2\frac{1}{2}$	3 x 3
Coarse	24	3	3 x 4

[1] See also Section 2104.6.

[2] The actual grout space or grout cell dimensions must be larger than the sum of the following items: (1) The required minimum dimensions of total clear areas in Table 21-C; (2) The width of any mortar projections within the space; and (3) The horizontal projections of the diameters of the horizontal reinforcing bars within a cross section of the grout space or cell.

[3] The minimum dimensions of the total clear areas shall be made up of one or more open areas, with at least one area being $\frac{3}{4}$ inch [19.1 mm] or greater in width.

[4] Similar to *Building Code Requirements for Masonry Structures,* Table 1.15.2 and *Specification for Masonry Structures*, Table 7.

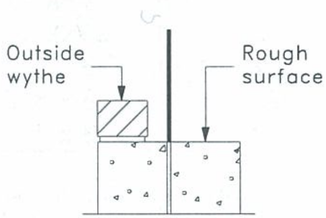
Sequence of Grouting Masonry Walls

The sequence of grouting masonry walls depends on the type of masonry wall and height of pour or lift.

Two Wythe Brick Walls, Low Lift Grouting Procedure, 12 inches or less

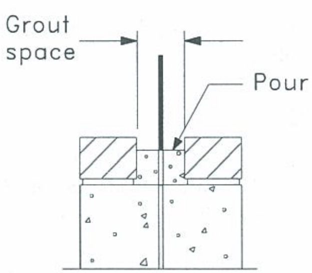
When the two wythe brick walls are constructed and grouted in pours 12 inches [305 mm] high or less, the grout can be consolidated by puddling with a puddling stick, such as a 1 inch x 2 inch [25.4 mm x 50.8 mm] piece of wood. It is ideal for small projects in which the bricklayer grouts as he lays up the masonry units.

The following procedure for low lift grouting is an expanded version of the requirements outlined in the 1982 Edition of the UBC. It has been periodically reviewed for consistency with current model building codes.

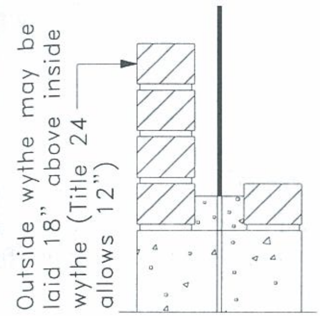


STEP 1. Check that concrete foundation ready to receive the mortar and first course of brick. The concrete surfaces must be clean, roughened and damp.

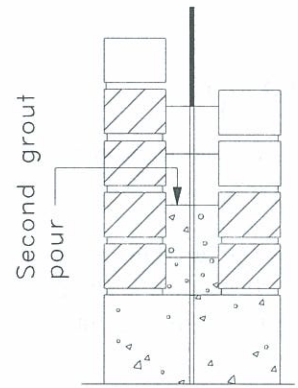
Lay one masonry course on one side with no mortar in the grout space. This wythe is called the outside wythe as it is furthest away from the mason.



STEP 2. Grout to half-height of unit and consolidate by puddling to insure grout bonding the concrete foundation, and to eliminate any voids in the grout.

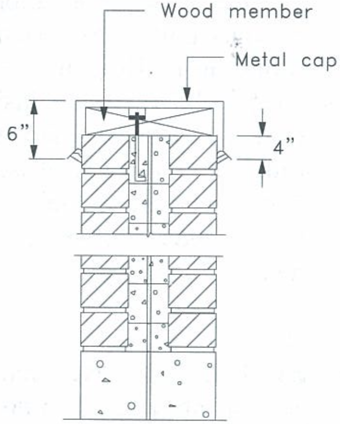


STEP 3. Lay up additional masonry units on the outside wythe up to 18 inches [457 mm] above the inside wythe. Projects for the California Division of State Architect limit the height of the outside wythe to 12 inches [305 mm].



STEP 4. Grout each course as units are laid, or in pours not to exceed 6 times the width of the grout space or a maximum of 8 inches [203 mm]. Hold grout one inch below the top of units.

It is also permitted to lay up more than one unit, up to 12 inches [305 mm] high, and then pour grout and puddle. Caution and care must be taken not to displace units in grouting and puddling as the mortar is very fresh and soft.



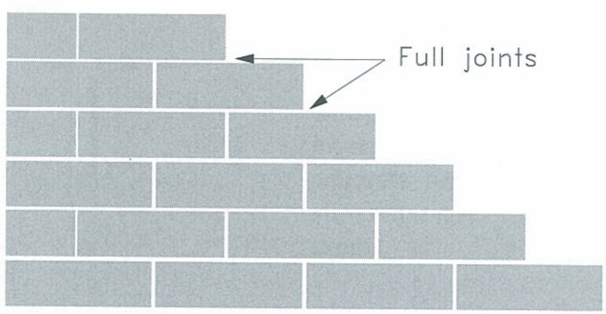
STEP 5. At completion of wall, grout flush to top of units. Puddle all grout after pouring.

More than 12 inches and up to 5 feet high

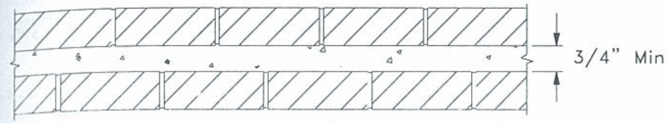
Two wythe walls may be built without cleanouts, up to 5 feet [1.5 m] high, and grouted in one pour.

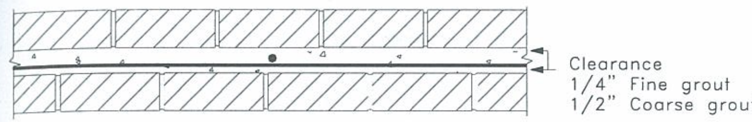
It is necessary, however, to tie the wythes together with wire ties or joint reinforcement to prevent the wythes from bulging or blowing out. In addition, the grout must be consolidated by mechanical vibration.

STEP 1. All units shall be laid with shoved heads and full bed mortar joints.



STEP 2. The grout space shall be not less than $^3/_4$ inch [19.1 mm] in width or wide enough to accommodate the vertical and horizontal reinforcing steel with proper clearance.

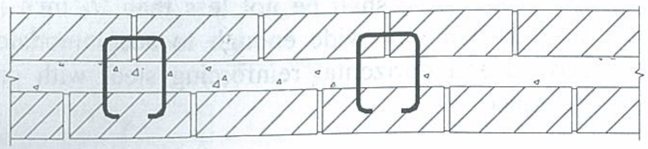


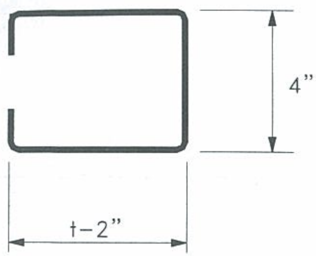


STEP 3. The two wythes shall be bonded together with rectangular wall ties of not less then 9 gage wire that are 4 inches [102 mm] long and 2 inches [50.4 mm] less in width than the thickness of the wall. If a single zee wire tie is used, it shall not be less than $^3/_{16}$ inch [4.8 mm] in diameter.

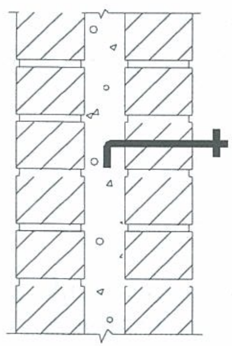
Joint reinforcement may be used to tie the wythes together provided the reinforcement is spaced vertically no more than 16 inches [406 mm] apart.

There should be one rectangular tie, one zee tie or one cross-wire of joint reinforcement for approximately two square feet [0.19 m^2] to $4^1/_2$ square feet [0.42 m^2] of wall, depending on the applicable Code.





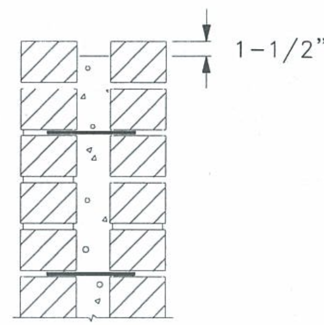
STEP 4. Prior to grouting, horizontal and vertical reinforcing steel, bolts and other embedded items must be in place.



STEP 5. Give sufficient time for mortar joints to set, approximately 12 to 18 hours. This will allow joints to gain strength, and be able to withstand the pressure of the fluid grout, which may have a hydraulic head pressure up to 5 feet [1.5 m].

STEP 6. Grout the wall and distribute the grout evenly for the full height of the pour. Consolidate as grout is poured by means of a mechanical vibrator. Reconsolidate the grout after the unit absorbs the excess water, which would be approximately 3 to 5 minutes.

STEP 7. Continue to lay up masonry units, tying the wythes together and grout in each pour and consolidate by mechanical vibrator.



STEP 8. Horizontal construction joints must be formed by stopping all wythes at the same height. The grout is then poured to $1^1/_2$ inches [38.1 mm] below the top of the masonry to form a key for the next grout pour. Where bond beams occur, stop the grout a minimum of $^1/_2$ inch [12.7 mm] above the horizontal reinforcing steel. This is to insure that the horizontal reinforcing steel is covered and a shear key is provided.

STEP 9. At completion of the wall grout flush to top of units and consolidate.

High Lift Grouting Procedure

Building a wall to its full height, and then grouting, is an economical method of constructing reinforced masonry walls. It allows the mason to continually lay masonry units without waiting for the walls to be grouted. High lift grouting procedures are used when walls and grout pours exceed 5 feet [1.5 m].

For high lift grouting construction, cleanouts must be provided and grout must be consolidated by mechanical vibration.

STEP 1. All units shall be laid with shoved heads and full bed mortar joints.

STEP 2. The width of the grout space for walls 8 feet high [2.4 m] shall be at least $1^1/_2$ inches [38.1 mm] for fine grout and 2 inches [50.8 mm] when coarse grout is used, as a minimum, but not less than necessary to accommodate the vertical and horizontal reinforcing steel with proper clearance. For wall higher than 8 feet [2.4 m] and up to 24 feet [7.3 m] high, the grout space shall be wider. See Uniform Building Code Table 21-C or *Building Code Requirements for Masonry Structure,* (ACI 530-99/ASCE 5-99/TMS 402-99), Table 1.15.2.

STEP 3. The two wythes must be bonded together with rectangular wall ties of at least 9 gage wire that are 4 inches [102 mm] long, and 2 inches [50.8 mm] less in width than the thickness of the wall. If a single zee wire tie is used, it shall not be less than $^3/_{16}$ inch [4.8 mm] in diameter.

Joint reinforcement may be used to tie the wythes together, and should be spaced apart vertically not more than 16 inches [406 mm].

There should be one rectangular tie, one zee tie or one cross-wire of joint reinforcement for approximately two square feet [0.19 m^2] to $4^1/_2$ square feet [0.42 m^2] of wall, depending on the applicable Code.

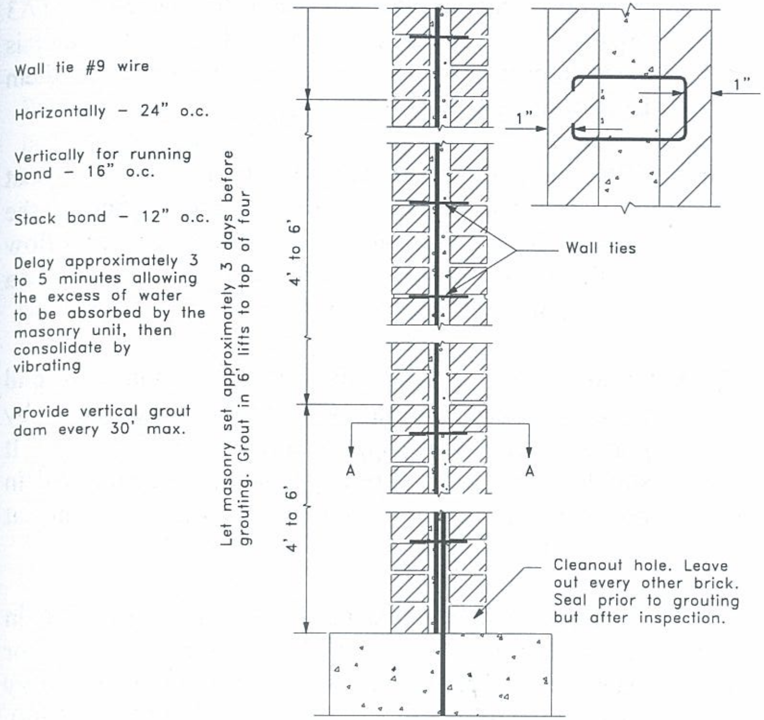


Figure 26. High lift grouting procedure for two wythe brick walls. (Cleanout holes are required)

STEP 4. Cleanouts shall be provided for each pour by leaving out brick units at the bottom of the section being poured.

STEP 5. During the work, mortar droppings and any other foreign matter shall be removed from the grout space. The cleanouts shall be sealed after inspection and before grouting.

STEP 6. Masonry walls should cure at least three days in warm weather or five days in cold weather to gain strength prior to pouring grout. This delay, which is significantly longer for high lift grouting than low lift grouting, is due to placing grout as high as 24 feet [7.3 m]. As a result, a tremendous lateral pressure is exerted on the wythes. The use of ties will keep them from bulging or blowing out.

STEP 7. UBC requires that vertical grout barriers or dams must be built of masonry units across the grout space for the entire height of the wall to control the horizontal flow of the grout. Grout barriers must be spaced a maximum of 30 feet [9.1 m] apart.

STEP 8. Grout must be a fluid mix suitable for pumping and must be mixed thoroughly. Grout can be placed by pumping or by an approved alternate method. It should be placed before any initial set occurs, and in no case more that $1^1/_2$ hours after adding the water at the jobsite

STEP 9. Grouting must be done in a continuous operation in lifts not exceeding 6 feet [1.8 m] for UBC and nor exceeding 5 feet [1.5 m] for *Specification for Masonry Structures* (ACI 530.1-99/ASCE 6-99/TMS 602-99). It must be consolidated by mechanical vibration after excess moisture has been absorbed, approximately 3 to 10 minutes. Grouting the full height of any section of wall between control barriers should be completed in one day with no interruptions between lifts greater than one hour.

3.3 BRICK VENEER

Anchorage to Wood Frame Construction - Brick veneer over wood frame construction, with sheathing is laid one inch [25.4 mm] clear from backing. Veneer is attached to the supporting wall with corrosion-resistant metal clips of not less than 22 gage, which are nailed to studs and plates. These clips must extend into the mortar bed joints. In Seismic Zones 3 and 4 as well as Seismic Performance Categories D and E, there shall

be a continuous horizontal strand of wire reinforcement in the mortar joints that contain the ties. The ties are to positively engage the wire in Seismic Zones 3 and 4 and Seismic Performance Category E. This wire reinforcement is required to be not less than 9 gage, and should be laid in the center line of the veneer bed joints. The Uniform Building Code states that metal clips support not more than two square feet [0.19 m^2] of wall area and may not be more than 24 inches [610 mm] apart horizontally. *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99) contains area and spacing requirements slightly more liberal for seismic application.

The Uniform Building Code allows the space between the veneer and the backing to be either solidly filled with slush-grout or to maintain a minimum one inch [25.4 mm] airspace. *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99), Section 6.2.2, requires a one inch [25.4 mm] airspace between the veneer and backing and does not suggest that the backing may be filled with mortar or grout. Dovetail anchors may be also used, however, there are hat channel track systems specifically designed to be surface mounted, whereas the dove tail spots are specifically designed to be embedded into concrete.

Brick veneer over wood frame construction **without** sheathing is required to be laid at least one inch [25.4 mm] clear of galvanized metal mesh backing such as K-LATH, or STEELTEX. To Avoid moisture penetration, two layers of waterproof paper are applied directly to the studs with the metal mesh. The space between the veneer and the backing must be filled with grout as each course is laid.

Anchorage to Concrete Construction - Brick veneer is required to be laid at least one inch [25.4 mm] clear from the concrete and is commonly attached by means of dovetail anchorage. Dovetail type slots are placed not more than 24 inches [610 mm] apart horizontally, according to the UBC, 32 inches [813 mm] according to *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99). The dovetail anchors are placed in the veneer mortar joints and should not be spaced more than 12 inches [305 mm] apart vertically per Uniform Building Code, 18 inches [457 mm] per *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99). These anchors engage a continuous strand of horizontal reinforcement wire of not less than No. 9 gage or equal, which is laid on the centerline of the veneer bed joints. The space between the concrete and the backing is a clear airspace, however, Uniform Building Code allows the space to be filled with grout.

3.4 VENEER

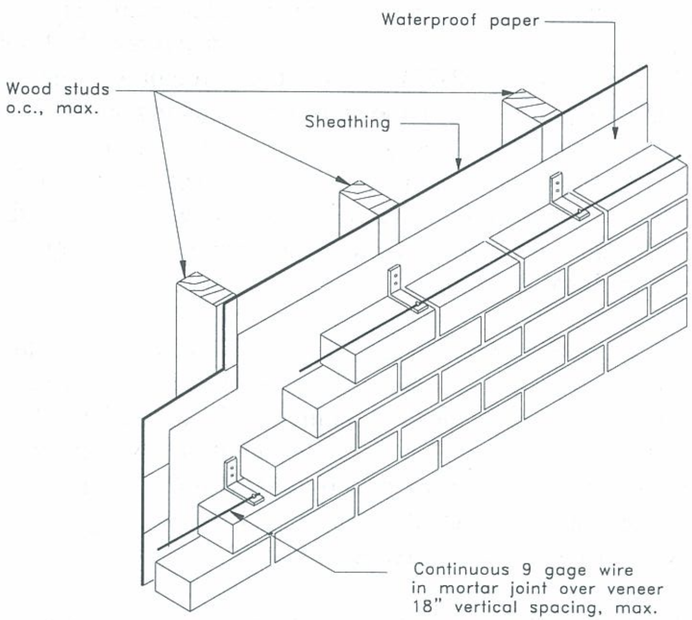


Figure 27. Anchored brick veneer to wood stud wall, Seismic Zones 3 & 4, Seismic Performance Categories D & E.

3.5 ANCHORAGE OF VENEER

1. The veneer anchors shall be 22 gage by approximately 1 inch [25.4 mm], galvanized steel brackets with 9 gage galvanized wire.
2. Anchors shall be spaced in accordance with the applicable code.

   a. Uniform Building Code.
      i. 24 inches [610 mm] on center horizontally.
      ii. 18 inches [457 mm] on center vertically.

   b. *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 4-99/TMS 402-99).
      i. 32 inches [813 mm] on center horizontally.
      ii. 18 inches [457 mm] on center vertically.
3. Joint wire may be butt spliced. Veneer anchors shall be attached to studs with 8d galvanized nails.
4. Veneer backing.

   a. Uniform Building Code
      i. Slushed portland cement filling 1 inch [25.4 mm] space *or*
      ii. Minimum 1 inch [25.4 mm] airspace permitted.

   b. *Building Code Requirements for Masonry Structures.*
      i. Minimum 1 inch [25.4 mm] airspace required.

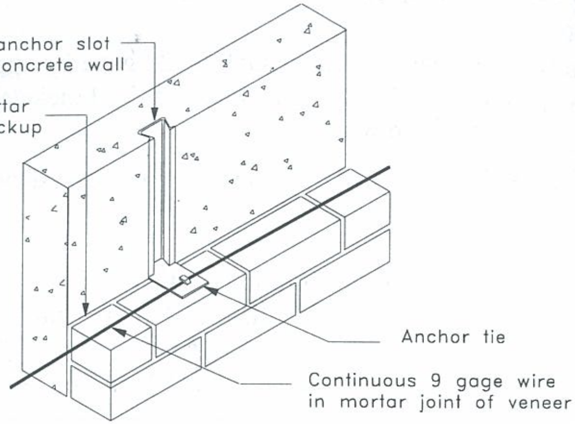


Figure 28. Anchored brick veneer to cast concrete wall.

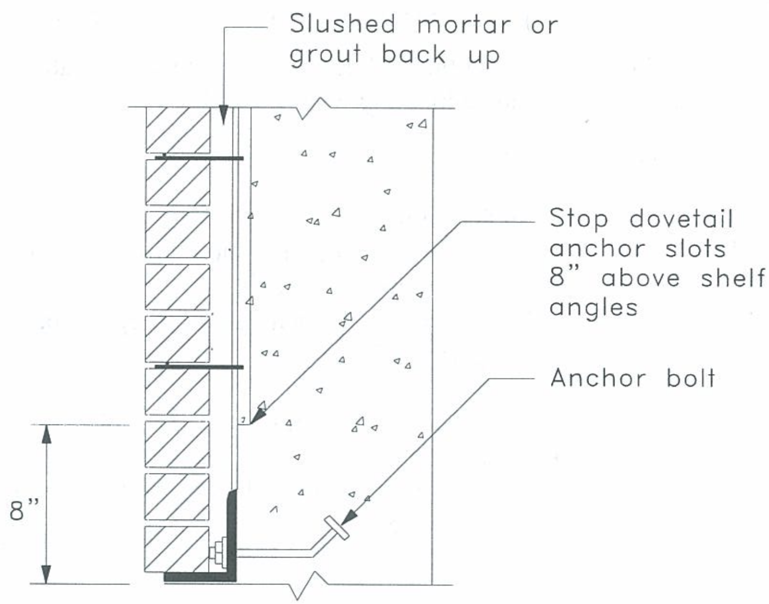


Figure 29. Shelf angle detail for brick veneer on concrete wall.

3.6 STEELTEX METHOD

No wood sheathing is required behind double thickness waterproofed paper backing, unless modified by the local jurisdiction. For example, the City of Los Angeles requires that plywood sheathing be used behind brick veneer, thereby creating a seismically resistant shear wall.

A 2 inch by 2 inch [50.8 mm by 50.8 mm], 16 gage galvanized wire mesh is anchored with 2 inch [50.8 mm] long furring nails at 4 inches [102 mm] on center. There is $1^1/_8$ inches [28.6 mm] penetration into each stud. At the top and bottom plates 8d common nails at 8 inches [203 mm] on center can be used.

For brick veneer over steel stud framing, wire Aqua K-Lath or Steeltex can be connected to metal studs or channels with standard tie wires.

3.7 AQUA K-LATH METHOD

No wood sheathing is required behind the self-furring galvanized welded wire fabric lath, which is 16 gage, 2 inch x 2 inch [50.8 mm x 50.8 mm] mesh, with waterproof paper laminated to the back side.

The K-Lath is secured to wood studs with galvanized steel wire furring nails at 4 inches [102 mm] on center or barbed galvanized nails at 6 inches [152 mm] on center with $1^1/_8$ inches [28.6 mm] minimum penetration. Attach the top and bottom of the wire mesh with 8d common nails.

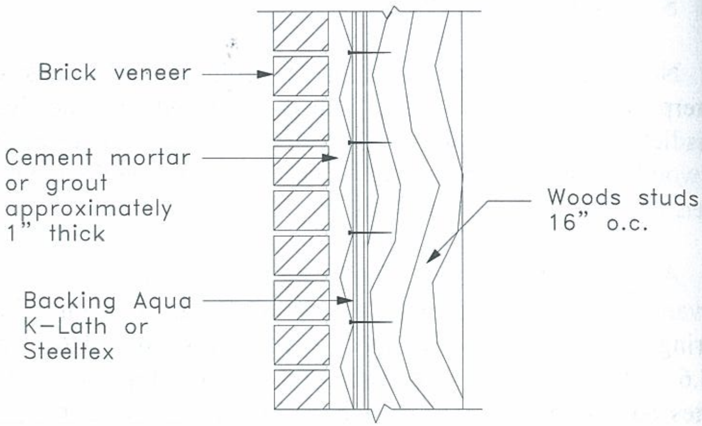


Figure 30. Anchored veneer, no wood sheathing back up required, using Steeltex or Aqua K-Lath backing.

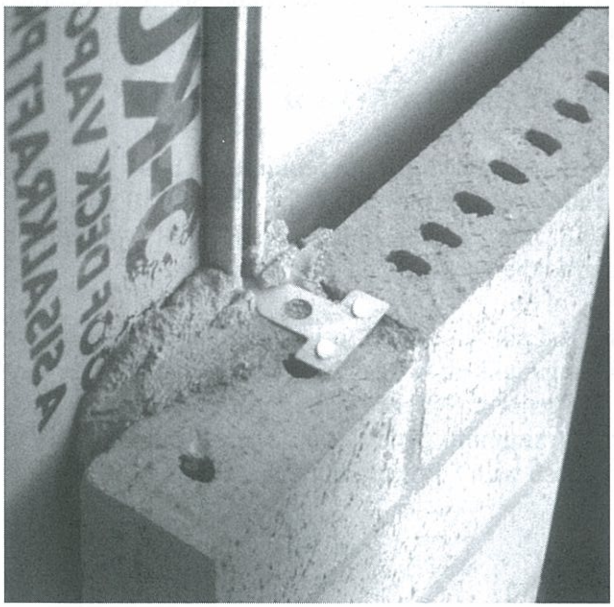


Figure 31. Sheathing, studs, using hat channel and Fleming anchors which engage wire reinforcement. See details pages 52, 54 and 56.

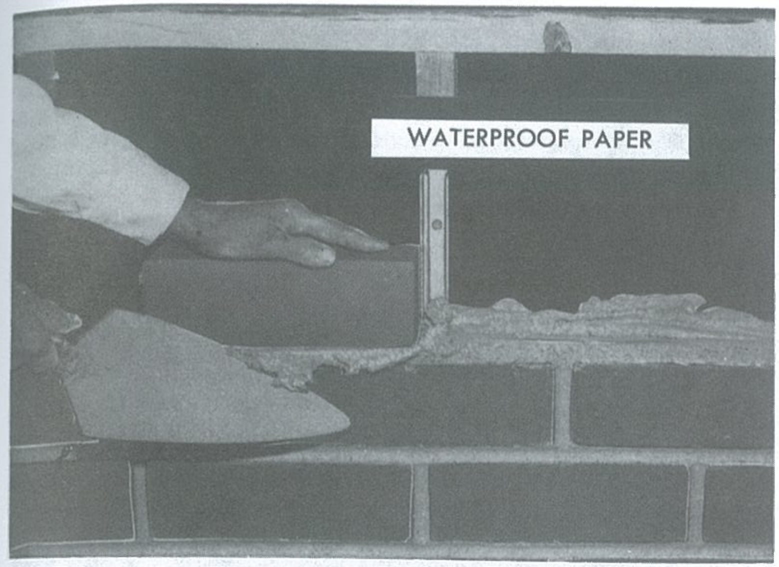


Figure 32. Placement of brick over anchor and horizontal joint reinforcement.

Figure 33. "Steeltex" or "K-Lath" on wood studs, being slush grouted.

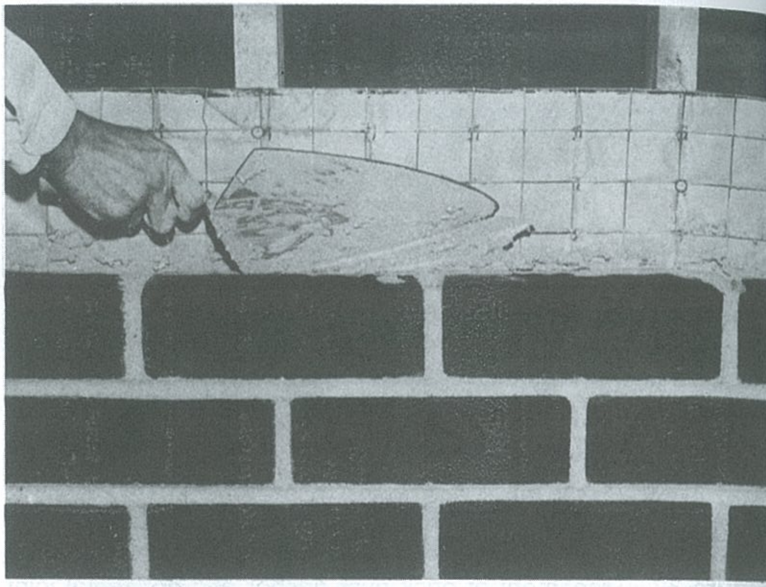


Figure 34. "K-Lath" on wood studs, being slush grouted.

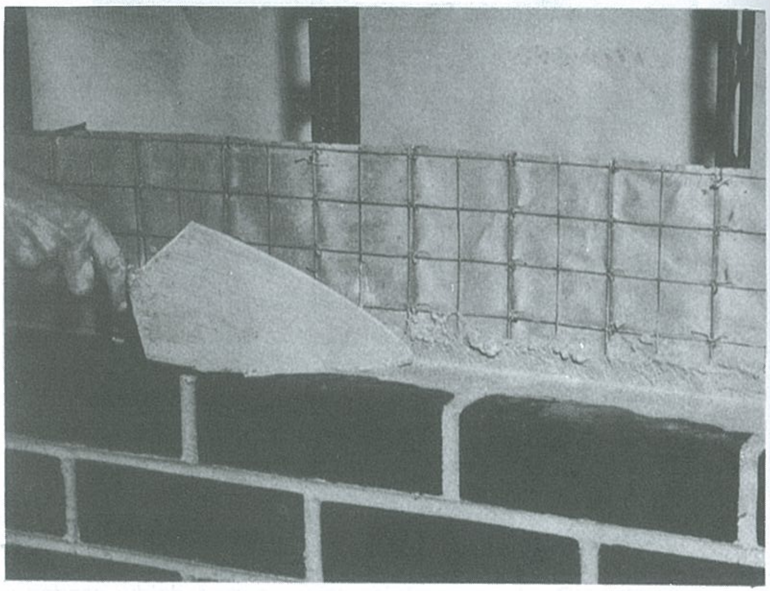


Figure 35. "Steeltex" tied to steel studs, being slush grouted.

3.8 BRACING, SHORING AND SCAFFOLDING

All scaffolding must be of safe design and not overloaded by materials, and be in accordance with national or local safety rules.

Scaffolding cannot be used to brace walls and must be maintained independent of the walls.

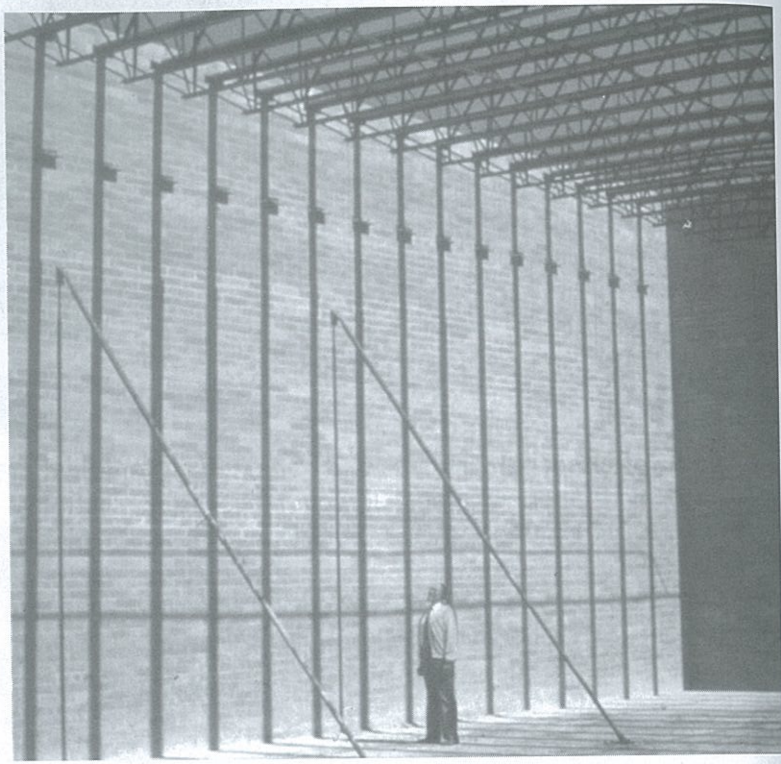
Guidelines for masonry bracing can be found in *Standard Practice for Bracing Masonry Walls Under Construction* published by MCAA, Lombard, IL (630/705-4200). This publication is based on wind conditions applied to reinforced and unreinforced masonry.

3.9 PROTECTION OF WORK

Faces of masonry must be protected from being smeared or splattered with mortar, grout or splashings from scaffolds. However, should this occur, the faces should be cleaned with clear water and fiber brushes immediately after the initial set of the mortar in the joints, or about 2 hours. All sills, ledges and offsets of brick or other materials must be protected from mortar droppings during construction. It is wise to protect the tops of all unfinished masonry from rain. No construction supports should be attached to masonry unless specifically permitted by the architect or engineer.

3.10 CURING OF FINISHED MASONRY

There is more than enough water in Reinforced Grouted Brick Masonry construction to completely hydrate the cement. It is not recommended to wet brick masonry during or after construction, except in extreme hot, dry weather where there is evidence that the bricks are absorbing water too fast from the mortar which can be seen readily as wet edges around the brick adjacent to the mortar joints (see Wetting of Brick). In such cases, the masonry walls should have their surfaces dampened only by a light fog spray, without water running down the face of the work, after the mortar has set.



Bracing of a brick masonry wall.

SECTION 4
QUALITY CONTROL, SAMPLING AND TESTING

4.1 CORING OF WALLS

Where walls are required to be cored, the cores should be taken at least 6 feet [1.8 m] from a corner, and preferably in a full wall, rather than under a window. Normally, 2 cores on a project are sufficient. For more information on core testing, see California C.C R., Title 24, Section 2105A.3.1.

4.2 TEST SPECIMENS OF MORTAR AND GROUT

ASTM C 270, *Standard Specifications for Mortar for Unit Masonry*, contains requirements for masonry mortar based on properties of mortar, as well as on proportions of the ingredients of mortar by volume, the former being presumed to meet the requirements of the latter and vice versa. This ASTM Specification requires that the test specimens be prepared in a laboratory. In this Specification, mortar is *not* required to meet both the property and the proportion specifications. For construction, it is assumed that mortar is prepared by proportion.

The following procedures are those outlined in C.C.R. Title 24 and the 1997 Uniform Building Code and are also compatible with *Specification for Masonry Structures,* (ACI 530.1-99/ASCE 6-99/TMS 602-99):

1. Mortar used in masonry construction must be classified in accordance with the materials and proportions set forth in Table 21-A. Aggregate for mortar shall conform to ASTM C 144 as required by either UBC Section 2102.2.1.1 or ASTM C 270.

   When constructing masonry in accordance with *Specification for Masonry Structures* (ACI 530.1-99/ASCE 6-99/TMS 602-99), mortar is to be classified in accordance with the materials and proportions set forth in ASTM C 270, Table 1, which is the same as UBC Table 21-A.

2. Admixtures and mortar colors may not be added to the mortar unless approved by the building official. Provisions for such additives must be provided in the contract specifications. After the admixtures are added to the mortar, it must conform to the requirements of the property specifications.

   Only pure mineral oxide, carbon black or synthetic colors may be used.

3. The strength of mortar using cementitious materials set forth in UBC Table No. 21-A or ASTM C 270, Table 1, should meet the minimum compressive strength shown in UBC Standard 21-15, Table 1 or ASTM C 270, Table 2. The building official may require field tests to verify compliance with this section. Such tests must be made in accordance with UBC Standard No. 21-16.

   Note, however, that UBC Standard No. 21-16 is based on ASTM C 270, however, ASTM C 270, Section 7.1 of the 1996 version states: "Specification C 270 is *not* a specification to determine mortar strengths through field testing."

4. Mortar mixed to a flow suitable for use in laying masonry units is not generally required to meet the laboratory flow.

4.3 MORTAR PROPORTIONS

UBC TABLE 21-A MORTAR PROPORTIONS FOR UNIT MASONRY

Mortar	Type	Proportion by Volume (cementitious materials)[3]								Aggregate Measured In a Damp Loose Condition
		Portland Cement or Blended Cement	Masonry Cement[1]			Mortar Cement[2]			Hydrated Lime or Lime Putty	
			M	S	N	M	S	N		
Cement-lime	M	1	-	-	-	-	-	-	¼	Not less than 2¼ and not more than 3 times the sum of the separate volumes of cementitious materials
	S	1	-	-	-	-	-	-	over ¼ to ½	
	N	1	-	-	-	-	-	-	over ½ to 1¼	
	O	1	-	-	-	-	-	-	over 1¼ to 2½	
Mortar cement	M	1	-	-	-	-	-	1		
	M	-	-	-	-	1	-	-		
	S	½	-	-	-	-	-	1		
	S	-	-	-	-	-	1	-		
	N	-	-	-	-	-	-	1		
Masonry cement	M	1	-	-	1	-	-	-		
	M	-	1	-	-	-	-	-		
	S	½	-	-	1	-	-	-		
	S	-	-	1	-	-	-	-		
	N	-	-	-	1	-	-	-		
	O	-	-	-	1	-	-	-		

[1] Masonry cement conforming to the requirements of UBC Standard 21-11

[2] Mortar cement conforming to the requirements of UBC Standard 21-14.

[3] Also see ASTM C 270, Table 1.

4.4 SPECIAL SEISMIC REQUIREMENTS

When designing and constructing masonry in Seismic Zones 2, 3 and 4, the following Uniform Building Code requirements must be observed for the applicable seismic zone. This is only a partial listing of the requirements and should be used in conjunction with the complete building code.

U.B.C. Section 2106.1.12

2106.1.12.3 Special provision for Seismic Zone No. 2. Masonry structures in Seismic Zone No. 2 shall comply with the following special provisions:

2. Vertical reinforcement of at least 0.20 square inch (130 mm^2) in cross-sectional area shall be provided continuously from support to support at each corner, at each side of each opening, at the ends of walls and at a maximum spacing of 4 feet (1219 mm) apart, horizontally throughout walls.

3. Horizontal reinforcement not less than 0.2 square inch (130 mm^2) in cross-sectional area shall be provided (1) at the bottom and top of wall openings and shall extend not less than 24 inches (610 mm) or less than 40 bar diameters past the opening, (2) continuously at structurally connected roof and floor levels and at the top of walls, (3) at the bottom of walls or in the top of the foundations when dowelled in walls, (4) at maximum spacing of 10 feet (3048 mm) unless uniformly distributed joint reinforcement is provided. Reinforcement at the top and bottom of openings when continuous in walls may be used in determining the maximum spacing specified in Item 1 of this paragraph.

4. Where stack bond is used, the minimum horizontal reinforcement ratio shall be 0.0007*bt*. This ratio shall be satisfied by uniformly distributed joint reinforcement or by horizontal reinforcement spaced not over 4 feet (1219 mm) and fully embedded in grout or mortar.

5. The following materials shall not be used as part of the vertical or lateral load-resisting systems: Type O mortar, masonry cement, plastic cement, nonloadbearing masonry units and glass block.

2106.1.12.4 Special provisions for Seismic Zones 3 and 4. All masonry structures built in Seismic Zones 3 and 4 shall be designed and constructed in accordance with requirements for Seismic Zone 2 and with the following additional requirements and limitations.

EXCEPTION: One- and two-story masonry buildings of Group R, Division 3 and Group U Occupancies in Seismic

Zone 3 having masonry wall *h'/t* ratios not greater than 27 and using running bond construction when provisions of Section 2106.1.12.3 are met.

2. Shear Walls.

2.1 **Reinforcement.** The portion of the reinforcement required to resist shear shall be uniformly distributed and shall be joint reinforcement, deformed bars or a combination thereof. The spacing of reinforcement shall not exceed one half the length of the element, nor one half the height of the element, nor 48 inches (1219 mm).

Joint reinforcement used in exterior walls and considered in the determination of the shear strength of the member shall be hot-dipped galvanized in accordance with UBC Standard 21-10.

2.3 **Wall reinforcement.** All walls shall be reinforced with both vertical and horizontal reinforcement. The sum of the areas of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross-sectional area of the wall, and the minimum area of reinforcement in either direction shall not be less than 0.0007 times the gross cross-sectional area of the wall. The minimum steel requirements for Seismic Zone 2 in Section 2106.1.12.3, Items 2 and 3, may be included in the sum. The spacing of reinforcement shall not exceed 4 feet (1219 mm). The diameter of reinforcement shall not be less than $^3/_8$ inch (9.5 mm) except that joint reinforcement may be considered as part or all of the requirement for minimum reinforcement. Only reinforcement which is continuous in the wall or element shall be considered in computing the minimum area of reinforcement. Reinforcement with splices conforming to Section 2107.2.2.6 shall be considered as continuous reinforcement.

2.4 **Stack Bond.** Where stack bond is used, the minimum horizontal reinforcement ratio shall be $0.0015bt$. Where open-end units are used and grouted solid, the minimum horizontal reinforcement ratio shall be $0.0007bt$.

Reinforced hollow-unit stacked bond construction which is part of the seismic resisting system shall use open-end units so that all head joints are made solid, shall use bond-beam units to facilitate the flow of grout and shall be grouted solid.

3. **Type N mortar:** Type N mortar shall not be used as part of the vertical- or lateral load resisting system

Similarly, *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 6-99/TMS 402-99) imposes seismic requirements on masonry.

1.13.5 *Seismic Performance Category C*

1.13.5.1 Structures in Seismic Performance Category C shall comply with the requirements of Seismic Performance Category B and to the additional requirements of this section.

1.13.5.2.3 *Reinforcement requirements* - Masonry elements listed in Section 1.13.5.2.2 shall be reinforced in either the horizontal or vertical direction in accordance with the following:

(a) *Horizontal reinforcement* – Horizontal joint reinforcement shall consist of at least two longitudinal W1.7 (MW11) wires spaced not more than 16 in. (406 mm) for walls greater than 4 in. (102 mm) in width and at least one longitudinal W1.7 (MW11) wire spaced not more than 16 in. (406 mm) for walls not exceeding 4 in. (102 mm) in width; or at least one No. 4 (M #13) bar spaced not more than 48 in. (1219 mm).

Where two longitudinal wires of joint reinforcement are used, the splice between these wires shall be the widest that the mortar joint will accommodate. Horizontal reinforcement shall be provided within 16 in. (406 mm) of the top and bottom of these masonry walls.

(b) *Vertical reinforcement* – Vertical reinforcement shall consist of at least one No. 4 (M #13) bar spaced not more than 48 in. (1219 mm) . Vertical reinforcement shall be located within 16 in. (406 mm) of the ends of masonry walls.

1.13.6 *Seismic Performance Category D*

1.13.6.1 Structures in Seismic Performance Category D shall comply with the requirements of Seismic Performance Category C and to the additional requirements of this section.

1.13.6.3 *Minimum reinforcement requirements for masonry walls* – Masonry walls other than those covered by Section 1.13.5.2.3 shall be reinforced in both the vertical and horizontal direction. The sum of the cross-sectional area of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross-sectional area of the wall, and the minimum cross-sectional area in each direction shall be not less than 0.0007 times the gross cross-sectional area of the wall using specified dimensions. Reinforcement shall be uniformly distributed. The maximum spacing of reinforcement shall be 48 in. (1219 mm) except for stack bond masonry. Wythes of stack bond masonry shall be constructed of fully grouted hollow open-end units, fully grouted hollow units laid with full head joints or solid units. Maximum spacing of reinforcement for walls with stack bond masonry shall be 24 in. (610 mm).

1.13.6.4 *Shear wall reinforcement requirements* – The maximum spacing of vertical and horizontal reinforcement shall be the smallest of: one-third the length of the shear wall, one-third the height of the shear wall, or 48 in. (1219 mm). The minimum cross-sectional area of vertical reinforcement shall be one-third of the required shear reinforcement.

Shear reinforcement shall be anchored around vertical reinforcing bars with a standard hook.

1.13.7 *Seismic Performance Category E*

1.13.7.1 Structures in Seismic Performance Category E shall comply with the requirements of Seismic Performance Category D and the additional requirements of this section.

1.13.7.2 *Design of elements that are not part of the lateral force-resisting system* – Stack bond masonry that is not part of the lateral force-resisting system shall have a horizontal cross-sectional of reinforcement of at least 0.0015 times the gross cross-sectional area of masonry. These elements shall be solidly grouted and shall be constructed of hollow open-end units or two wythes of solid units.

1.13.7.3 *Design of elements that are part of the lateral force-resisting system* – Stack bond masonry that is part of the lateral force-resisting system shall have a horizontal cross-sectional area of reinforcement of at least 0.0025 times the gross cross-sectional area of masonry. The maximum spacing of horizontal reinforcement shall be 16 in. (406 mm). These elements shall be solidly grouted and shall be constructed of hollow open-end units or two wythes of solid units.

California C.C.R., Title 24 is somewhat more conservative in seismic requirements as noted in italics below. The italics portion represents additions to the Uniform Building Code. Once again, this is only a partial excerpt from the code.

C.C.R., Title 24, Section 2106A.1.12

2106.1.12.3 ***Not adopted by the State of California.***

2106.1.12.4 Special provisions for Seismic Zones 3 and 4. All masonry structures shall be *so* designed and constructed *that the unit stresses do not exceed those set forth in Section 2107A, and the* following additional requirements and limitations *are met.*

Wall reinforcement: *The total area of reinforcement in reinforced masonry walls shall not be less than 0.003 times the sectional area of the wall. Neither the horizontal nor*

the vertical reinforcement shall be less than one third of the total. Horizontal and vertical bars shall be spaced at not more than 24 inches (610 mm) center to center. The minimum reinforcing shall be No. 4, except that No. 3 bars may be used for ties and stirrups. Vertical wall steel shall have dowels of equal size and equal matched spacing for all footings. Reinforcement shall be continuous around wall corners and through intersections. Only reinforcement which is continuous in the wall shall be considered in computing the minimum area of reinforcement. Reinforcement with splices conforming to Section 2107A.2.2.6 shall be considered as continuous reinforcement.

Horizontal reinforcement shall be provided in the top of footings, at the top of wall openings, at roof and floor levels, and at the top of parapet walls. For walls 12 inches (nominal) (305 mm) or more in thickness, reinforcing shall be equally divided into two layers, except where designed as retaining walls. Where reinforcement is added to above minimum requirements, such additional reinforcement need not be so divided.

2. Shear Walls.

2.1 **Reinforcement.** The portion of the reinforcement required to resist shear shall be uniformly distributed and shall be joint reinforcement, deformed bars or a combination thereof. The spacing of reinforcement in each direction shall not exceed *24 inches (610 mm) each way.*

Joint reinforcement used in exterior walls and considered in the determination of the shear strength of the member shall be hot-dipped galvanized in accordance with UBC Standard 21-10.

2.3 **Wall reinforcement.** ***Relocated above.***

2.4 **Stack Bond.** Reinforced hollow-unit stacked bond construction which is part of the seismic resisting system shall use open-end units so that all head joints are made solid, shall use bond-beam units to facilitate the flow of grout and shall be grouted solid.

4. **Type N mortar:** Type N mortar shall not be used as part of the vertical- or lateral load resisting system.

There are also seismic provisions contained in the International Building Code (2000) which are similar to the provisions contained in *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99). There are provisions in Seismic Design Categories A and B that deal primarily with connections at roof and floor levels, and address building types.

2106.4 Seismic Design Category C. Structures assigned to Seismic Design Category C shall conform to the requirements for Seismic Design Category B and to the additional requirements of this section.

2106.4.1.3 Reinforcement requirements for masonry elements. Masonry elements listed in Section 2106.4.1.2 shall be reinforced in either the horizontal or vertical direction dependent upon the location of lateral supporting elements in accordance with the following:

1. Horizontal joint reinforcement shall consist of at least two longitudinal W1.7 wires spaced not more than 16 inches (406 mm) for walls greater than 4 inches (102 mm) in width and at least one longitudinal W1.7 wire spaced not more than 16 inches (406 mm) for walls not exceeding 4 inches (102 mm) in width; or at least one No. 4 bar spaced not more than 48 inches (1219 mm). Where two longitudinal wires of joint reinforcement are used, the splice between these wires shall be the widest that the mortar joint will accommodate. Horizontal reinforcement shall be provided within 16 inches (406 mm) of the top and bottom of these masonry walls.
2. Vertical reinforcement shall consist of at least one No. 4 bar spaced not more than 48 inches (1219 mm). Vertical reinforcement shall be located within 16 inches (406 mm) of the ends of masonry walls.

2106.4.2.3 Masonry shear walls. Masonry shear walls shall comply with the requirements for ordinary reinforced masonry shear walls or intermediate reinforced masonry shear walls.

2106.4.2.3.1 Minimum reinforcement requirements for masonry shear walls. Vertical reinforcement of at least 0.20 square inch (129 mm^2) in cross-sectional area shall be provided at corners, within 16 inches (406 mm) of each side of openings, within 8 inches (203 mm) of each side of movement joints, within 8 inches (203 mm) of the ends of walls, and at a maximum spacing of 10 feet (3048 mm).

Horizontal joint reinforcement shall consist of at least two wires of W1.7 spaced not more than 16 inches (406 mm); or bond beam reinforcement shall be provided of at least 0.2 square inch (129 mm^2) in cross-sectional area spaced not more than 10 feet (3048 mm). Horizontal reinforcement shall also be provided at the bottom and top of wall openings and shall extend not less than 24 inches (610 mm) nor less than 40 bar diameters past the opening; continuously at structurally connected roof and floor levels; and within 16 inches (406 mm) of the top of walls.

2106.5 Seismic Design Category D. Structures assigned to Seismic Design Category D shall conform to all the requirements for Seismic Design Category C and the additional requirements of this section.

2106.5.2 Minimum reinforcement requirements for masonry walls. Masonry walls other than those covered by Section 2106.4.1 shall be reinforced in both the vertical and horizontal direction. The sum of the cross-sectional area of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross-sectional area of the wall, and the minimum cross-sectional area in each direction shall be not less than 0.0007 times the gross cross-sectional area of the wall. Reinforcement shall be uniformly distributed. The maximum spacing of reinforcement shall be 48 inches (1219 mm) except for stack bond masonry. Wythes of stack bond masonry shall be constructed of fully grouted hollow open-end units, fully grouted hollow units laid with full head joints or solid units. Maximum spacing of reinforcement for walls with stack bond masonry shall be 24 inches (610 mm).

2106.5.3 Masonry shear walls. Masonry shear walls shall comply with the requirements for special reinforced masonry shear walls.

2106.5.3.1 Shear wall reinforcement requirements. Shear walls shall be reinforced in accordance with Section 2106.5.2 and the maximum spacing of vertical and horizontal reinforcement shall be the smaller of: one-third the length of the shear wall, one-third the height of the shear wall, or 48 inches (1219 mm). The minimum cross-sectional area of vertical reinforcement shall be one-third of the required shear reinforcement. Shear reinforcement shall be anchored around vertical-reinforcing bars with a standard hook.

2106.5.5 Material requirements. Neither Type N mortar nor masonry cement shall be used as part of the lateral-force-resisting system.

2106.6 Seismic Design Category E or F. Structures assigned to Seismic Design Category E or F shall conform to the requirements of Seismic Design Category D and to the additional requirements and limitations of this section.

2106.6.1 Design of elements that are not part of the lateral force-resisting system. Stack bond masonry that is not part of the lateral force-resisting system shall have a horizontal cross-sectional of reinforcement of at least 0.0015 times the gross cross-sectional area of masonry.

The maximum spacing of horizontal reinforcement shall be 24 inches (610 mm). These elements shall be solidly grouted and shall be constructed of hollow open-end units or two wythes of solid units.

2106.6.2 Design of elements that are part of the lateral force-resisting system. Stack bond masonry that is part of the lateral force-resisting system shall have a horizontal cross-sectional area of reinforcement of at least 0.0025 times the gross cross-sectional area of masonry. The maximum spacing of horizontal reinforcement shall be 16 inches (406 mm). These elements shall be solidly grouted and shall be constructed of hollow open-end units or two wythes of solid units.

4.5 FIELD TEST SPECIMENS OF MORTAR AND GROUT

While the preceding pertains to unit masonry, similar conditions occur when using grout in structural reinforced brick masonry.

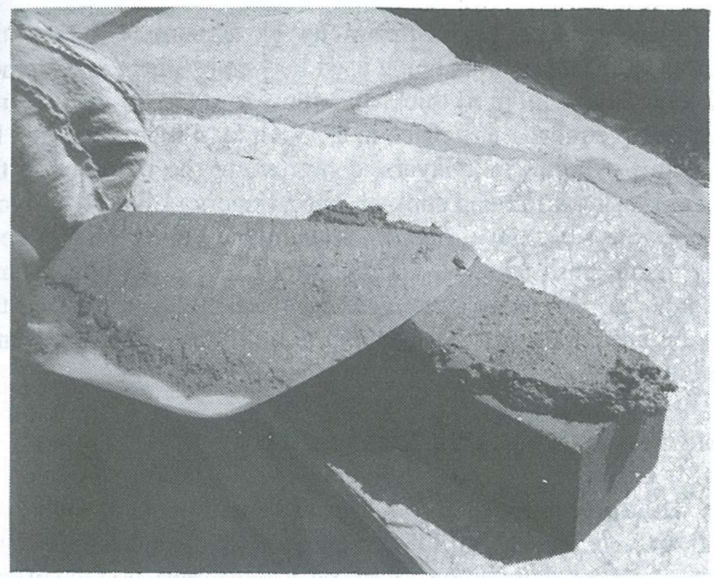


Figure 36. Spreading mortar on masonry unit.

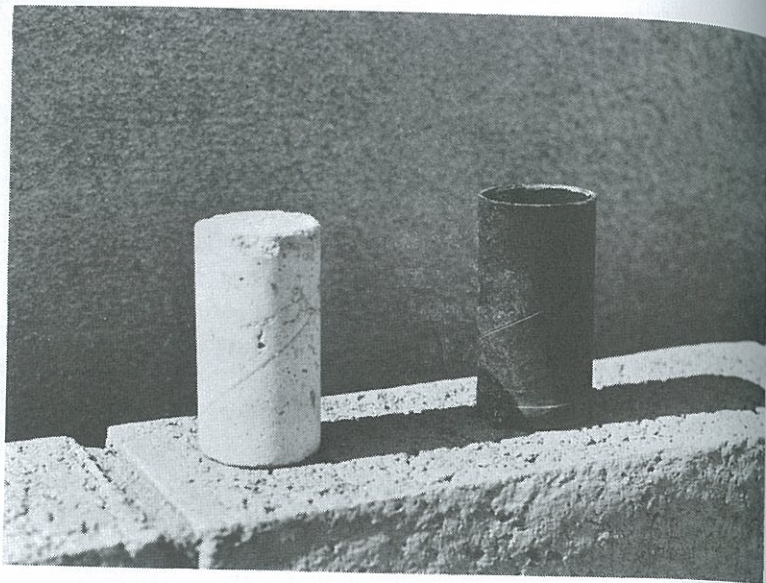


Figure 37. Mortar specimen and cardboard mold.

Field Test of Mortar, UBC Standard 21-16

Compressive Test Specimens of Mortar. Spread the mortar on masonry units being used between $^1/_2$ inch and $^5/_8$ inch [12.7 mm and 15.9 mm] thick, and allow to stand for one minute, then remove mortar and place in a 2 inch by 4 inch [50.8 mm by 102 mm] cylinder in 2 layers, compressing the mortar into the cylinder using a flat end stick or using fingers. Lightly tap mold on opposite sides, level off molds, immediately cover, and keep them damp until taken to the laboratory. After 48 hours, have the laboratory remove specimen from the molds and place the mortar specimens in the fog room until tested in the damp condition.

Field Test of Grout, UBC Standard 21-18

Slump of Grout. Use a truncated metal cone 4 inch [102 mm] diameter to 8 inch [203 mm] diameter, 12 inches [305 mm] high, and after dampening, place on a flat moist, non-absorbent base. Thoroughly mix or agitate grout before placing in cone to

obtain a full representative mix. Fill cone with grout, lightly tap cone on opposite sides, and level off, carefully lift cone and measure slump. At time of placing, grout should have a slump of 8 to 11 inches [203 mm to 279 mm].

Compressive Test Specimens of Grout. On a flat non-absorbent base, form a space approximately 3 inches x 3 inches [76.2 mm x 76.2 mm] by 6 inches [152 mm] high, using bricks having the same moisture condition as those being laid. Line the space with a permeable paper or porous separator so that water may pass through the liner into the brick. Thoroughly mix or agitate grout to obtain a full representative mix. Place grout into molds in 2 layers and puddle each layer with a 1 inch by 2 inch [25.4 mm by 50.8 mm] puddling stick to eliminate air bubbles. Level off and immediately cover molds and keep them damp until taken to the laboratory. After 48 hours, have the laboratory carefully remove bricks, and place the grout specimens in the fog room until tested in the damp condition.

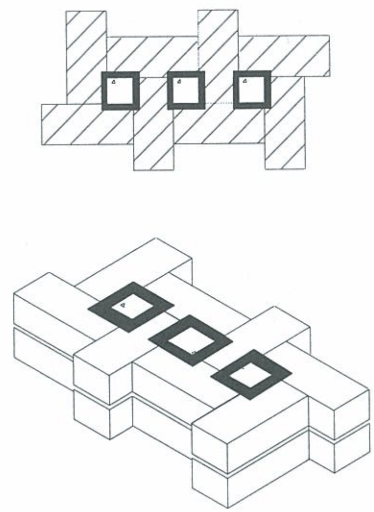


Figure 38. Brick molds lined with paper towels, for test specimens of grout, approximately 3" x 3" x 6" [76 mm x 76 mm x 152 mm] high.

Field Test Values for Compressive Strength

Following are minimum mortar and grout compressive strengths requirements according to C.C.R. Title 24 and UBC Standard 21-16. Note that the compressive strength values are minimum code values. Minimum values for grout and cores may be higher as required for a specific project.

		28 day Compressive Strength (psi)
MORTAR	1 Part portland cement $^1/_2$ part lime, and $4^1/_2$ parts dry loose sand	1500
GROUT	1 part portland cement 3 parts dry loose sand and 1 to 2 parts pea gravel	2000
CORES Cut from Walls (C.C.R.Title 24)		1500

SECTION 5
SPECIAL TOPICS AND CONDITIONS

5.1 EFFLORESCENCE

Efflorescence. This stubborn problem has caused confusion and trouble for masonry since its first appearance thousands of years ago on ancient masonry walls. Efflorescence is the white, powdery scum that often appears on masonry walls after construction. It is an undesirable, persistent and unwanted problem.

A great deal of time, money and effort has been spent trying to solve the difficulties efflorescence generates. Many test programs have been developed and numerous attempts have been made to eliminate the efflorescence problem. Unfortunately, nothing has proven 100% effective. Even though no totally effective cure has been discovered, a great deal has been learned about how efflorescence works and how to prevent it, and if preventive measures are inadequate, how to remove the efflorescence if it does appear.

What is Efflorescence?

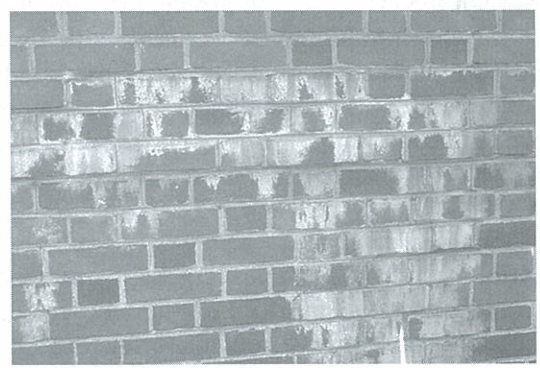


Figure 39. Typical white efflorescent salts on brick masonry.

Efflorescence is a fine, white, powdery deposit of water-soluble salts left on the surface of masonry as the water evaporates. The efflorescent salt deposits tend to appear at the worst times, usually about a month after the building is constructed, and sometimes as long as a year after completion.

Required Conditions

Efflorescence is not a simple subject. Three conditions must exist before efflorescence will occur.

First: There must be water-soluble salts present somewhere in the wall.

Second: There must be sufficient moisture in the wall to render the salts into a soluble solution.

Third: There must be a path for the soluble salts to migrate through to the surface where the moisture can evaporate, thus depositing the salts, which then crystallize, and cause efflorescence.

All three conditions must exist. If any one of these conditions is not present, then efflorescence cannot occur.

Even though the efflorescence problem is complex, it is not difficult to prevent. Although no economically feasible way exists to totally eliminate any one of these three conditions, it is quite simple to reduce all three and make it nearly impossible for efflorescence to occur.

5.2 CLEANING

The traditional method of cleaning has been sandblasting, which of course, works; unfortunately it removes just about everything else. The abrasive action of the sand erodes the surface of the brick and the tooled mortar joints along with any

deposited salts. This increases the porous qualities of the masonry and the water absorptive nature of the wall. Sandblasting will also damage the integrity of the dense tooled mortar joints. A well-tooled and compacted mortar joint readily sheds moisture and provides minimum voids for penetration. After sandblasting, the mortar is more porous, has voids for infiltration, and may even reveal cracks in the mortar. Additionally, the appearance of the masonry wall will be changed since the texture of the brick has been made slightly coarser.

Sandblasting should be use with caution and the masonry should be subsequently sealed with a waterproofing material.

A conventional chemical cleaner used for removing efflorescence is muriatic acid in a mild solution, usually one part muriatic acid, (hydrochloric acid, HC1), to 12 parts water. Several mild individual applications are better than one overpowering dose. Again, care must be taken to thoroughly presoak the wall with clean water and to thoroughly flush the wall of all remaining acids with clean water. Manufacturers are developing more environmental friendly products that remove efflorescence from masonry and the technical support available from these manufacturers is useful in the correct application of these ever changing masonry cleaners.

Cleaning efflorescence from masonry walls does not cure the problem, it only removes the symptoms. After cleaning, the efflorescence will reappear unless the natural efflorescent chain is broken. Due to the added water used when pre-soaking and post-flushing the walls when using chemical cleaners, the efflorescence will occasionally reappear, often stronger than before.

Efflorescence is a controllable condition that should not be a problem in modern masonry. Breaking the chain of conditions necessary for efflorescence can be done with attention to details, the correct materials and quality construction.

5.3 PAINTING AND WATERPROOFING

When grouted brick masonry and brick veneer walls are properly constructed, with tooled mortar joints, they are invariably waterproof, do not leak, and require no water-repellent material to be applied to exposed surfaces.

It requires many weeks of warm dry weather for a grouted brick wall to become absolutely dry throughout its interior. However, most free water comes to the surface as vapor within a few months, depending on weather conditions of temperature and humidity.

Generally, it is undesirable to paint brick masonry and may be difficult to remove once applied.

Caution

No paint or sealant should be applied to a grouted brick masonry wall until a lapse of several months after completion, or following the rainy season, or a hard rain at other times. The walls should be virtually dry. When paint or a water-repellent is to be applied to exterior brickwork, the work should be done only by qualified applicators at least ten days before landscaping is installed, and before sprinklers are turned on. Sprinklers should always be faced away from brickwork to avoid intermittent soaking of the masonry.

Before the application of any paint or water-repellent material to brick surfaces, it is recommended that a qualified representative of the manufacturer of the proposed coating material inspects the work, and verifies the type of material to be used, and also checks the moisture, temperature and surface conditions of the masonry. It is best that brick surfaces have a temperature of not less than 40° F [4.5° C] at time of painting or waterproofing. Only qualified and experienced applicators should be entrusted to apply the material or materials.

While many paint companies are not issuing guarantees, due to past misuse, they do stand behind any commitments they might make in regard to the use of their products on specific jobs.

Weather conditions play an important part in painting and waterproofing. Brick construction that has been thoroughly saturated during construction, and completed during the rainy season offers a puzzling painting problem. After a few days of warm weather the surfaces appear relatively dry; however, interior areas of the wall are invariably still wet.

Many specifications are written in the belief that it is mandatory to paint or waterproof the exteriors of brick walls prior to plastering or painting the interior surfaces. If this is done, the presence of efflorescent salts may not be too apparent, but as time goes on a disruption of the paint film by these efflorescent salts might occur. If weather conditions permit, the painting or waterproofing of the exterior surfaces should be delayed as long as possible.

Too much emphasis cannot be made on the fact that successful and lasting applications of paint or water-repellent coatings on brick masonry can be obtained only if applied after the masonry has thoroughly dried.

Before a paint or water-repellent is applied to a wall, the surface must be cleaned of all dirt, oil, grease and efflorescence, if any, and be thoroughly dry. If cement-water paint is to be used and the wall has been previously painted, the existing paint must be entirely removed. Soaps or detergents must not be used in cleaning since they will prevent adhesion of the paint unless they are completely removed from the wall surface. All cracks over $^{1}/_{32}$ inch [0.8 mm] wide must be filled or sealed separately before colorless water-repellent materials or paints are applied.

5.4 COMPOSITION OF COATINGS

The following are "breathable" types of coatings:

CEMENT-WATER paints are water reducible and usually contain about 80% white portland cement, and about 20% silica sand passing the 40 mesh sieve. Proprietary brands may, in addition, contain small percentages of titanium dioxide and a water-repellent, usually a stearate. Cement-water paints do not contain an organic binder. Resin-emulsion, oil-base and synthetic-rubber paints are referred to as organic paints.

ACRYLIC-RESIN emulsion paints are water reducible pastes of pigments ground in an acrylic vehicle which contains no oil and which have been treated with an emulsifying agent to render them miscible with water.

POLY-VINYL ACETATE emulsion paints are water reducible formulations of selected paint pigments ground in a vehicle of high polymer poly-vinyl acetate emulsion as a binder.

SILANES are typically penetrating type sealers that form a water repellent treatment by chemically bonding with siliceous minerals. Carriers may include alcohol and mineral spirits, however, some forms use water as the solvent.

SILICONE-BASE coatings are those having a silicone resin non-volatile (solid) content of not less than 5% by weight. Mineral spirits or other aromatic solvents are greatly preferred to water as a carrier for this type of coating.

ELASTOMERIC coatings are also used as both a block filler and paint finish in one application. They are usually much more water resistant than conventional paints or textured coatings and have the advantage of being able to bridge hairline cracks and still maintain integrity when the cracks open up due to shrinkage in the wall. In order to waterproof a cracked or porous wall, however, these coatings must be applied with a sufficiently thick

application in order to fill or cover all the pores. Patching over cracks with an elastomeric sealant is usually required before the coating can be applied. Finish appearance retains somewhat more of the original masonry textured coatings but less than the clear or stains.

The following are "sealer" (vapor barrier) type coatings:

SYNTHETIC-RUBBER paints are of two types: (1) The rubber-solution type in which the synthetic rubber is added to a vehicle of treated drying oils, aromatic hydrocarbons, and coal tar thinners; and (2) the rubber-emulsion type, may be breather or sealer-type, in which the synthetic-rubber resin is treated with an emulsifying agent so that the paste paints are reducible with water.

OIL-BASE paints are ready mixed, containing opaque pigments suspended in a vehicle of drying oils and thinner.

BITUMINOUS COMPOUNDS are asphalt or coal tar which are usually applied hot. Certain asphalt compounds and asphalt emulsions are applied cold. Surfaces must be THOROUGHLY DRY at time of application.

5.5 PARAPET AND FIRE WALLS

The most important parts of a structure to be waterproofed, except for the roof, are the tops and inner exposed surfaces of parapet walls or fire walls above the roof. After the masonry has thoroughly dried, these surfaces should be sealed with a coat of heavy asphalt type MASTIC compound applied from the roofing or flashing up the walls and over the tops of such walls. A positive seal may be obtained by using a fibered asphalt, or trowel-type compound of the cut-back type, rather than an emulsion type, applied in accordance with the manufacturer's specifications by a qualified waterproofing applicator. These are Asphalt compounds, naturally black, but which may be colored by using ceramic granules sprayed or rolled into the wet mastic to produce almost any desired color. Lighter colors up to white may be obtained by using an acrylic resin type paint over the black compound after the compound has dried for about a week.

5.6 CAPPING OF WALLS AND SILLS

Where cement is used to cap tops of walls or sills, it should be applied no sooner than $^1/_2$ hour after mixing, and the capping should be made as thin as practicable, about $^1/_4$ inch [6.4 mm]. The surfaces to be capped must be dampened before mortar is applied and, after application, the capping must be kept moist for at least 24 hours.

When header bricks are used for capping, the die-skin or edge surfaces of the brick, not the wire-cut surfaces, should be exposed to the weather with the top and end joints tightly tooled.

A good recommended procedure is to use a metal coping over the top of a parapet wall with the roofing material carried up under the metal coping.

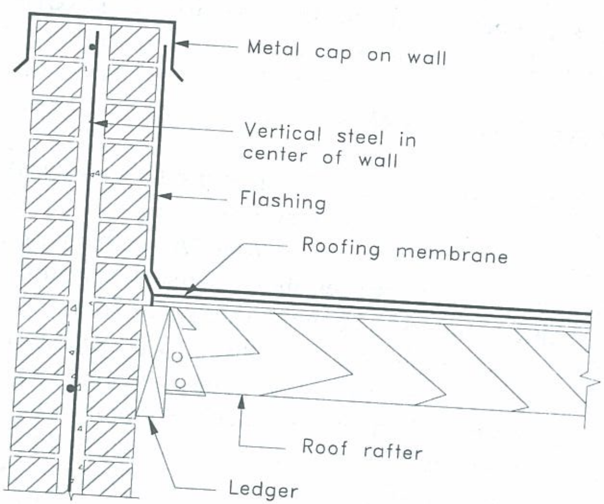


Figure 40. Parapet walls, cap and flashing detail.

5.7 PLANTERS

All types of masonry planters, whether wood or stucco, including concrete, attached to wood frame structures, are required to have a clearance of at least 2 inches [50.8 mm] from the face of a wall. Alkali salts present in the water, earth, and fertilizers are a cause of efflorescence on this type of brickwork. All mortar joints must be tool jointed on tops and both sides.

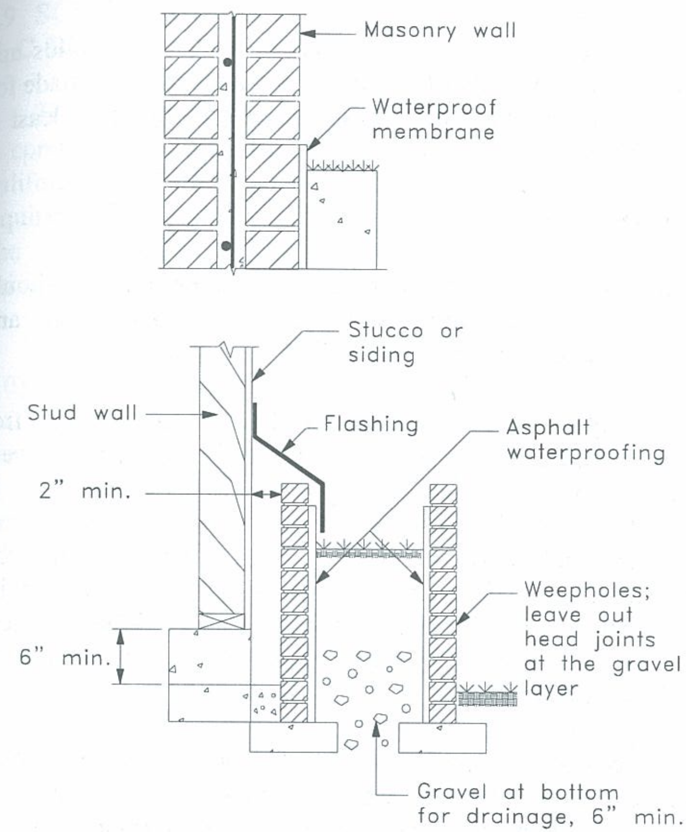


Figure 41. Planter box details. Planter boxes attached to wood framed structures are required to have a clearance of not less than 2 inches [50.8 mm] from the face of the wall, whether of stucco, wood siding, wood sheathing or wood studs.

Planters may have small weep holes through vertical joints of the lowest exposed course. All four inside surfaces of planters should be back plastered with mortar, and then waterproofed.

Before any earth, or gravel is placed in planter boxes, it is recommended that a coat of heavy mastic compound, as mentioned under Parapet and Fire Walls, be applied to all interior surfaces. Allow mastic waterproofing in planters to stand for at least one week before gravel and earth fill is placed.

It should be remembered that earth in planters "builds up" or swells, over a period of time, thus allowance must be made for the future top of the soil. Finished soil should be at least 6 inches [152 mm] below an adjacent floor level.

5.8 PLASTERING

Masonry surfaces on which suction must be reduced, should be wetted down 48 hours and again 24 hours before any plastering operations start.

Masonry joints may be struck flush. Surfaces must be free from paint, oil, dust, dirt or other material that might prevent satisfactory bond.

The surface may be given a cement-grout dash coat, composed of 1 part cement to $1^1/_2$ parts fine sand mixed with water to make a workable consistency, or a plaster bonding agent of a non-oxidizing, non-crystallizing, resinous water emulsion (non-bituminous products).

Surfaces of masonry walls must be thoroughly and evenly dampened, but not saturated, immediately preceding the application of the plaster scratch coat. The surfaces must appear slightly damp but there must be no free water on them. The plaster mortar must be forced tightly against the surfaces.

Cement-grout dash-bond coat may take the place of a scratch coat. For additional data on plastering using different materials and finishes, contact:

Plastering Information Bureau
21243 Ventura Blvd.
Woodland Hills, CA 91364
(818) 340-6767

5.9 SCHOOLS, HOSPITALS AND PUBLIC BUILDINGS, C. C. R. TITLE 24

The construction of public schools in California is required to comply with regulations of the Field Act as published in the California Code of Regulations (C.C.R.), Title 24. Many of the requirements are more rigid than those of most building codes. The following is a list of some requirements affecting Reinforced Grouted Brick Masonry.

Cement. Only Types I, II or III Portland cement (ASTM C 150), Types I-A, II-A or III-A as set forth in UBC Standard 19-1, Part I may be used. Mortar cement may be used, except that the maximum limit for flash indicated in UBC. Table 24-19-B shall be 15 percent. Masonry cement or plastic cement shall not be used in mortar or grout unless specifically approved by the enforcement agency.

Sand. Sand must conform to the requirements of ASTM C 144 for mortar and ASTM C 404 for masonry grout.

Mortar. Type S mortar, most commonly used, may be proportioned with 1 part portland cement, $^1/_4$ to $^1/_2$ part lime, and 4 parts sand based on dry loose volume. Allowance for bulking is to be made for damp sand. No admixtures are permitted unless approved by the enforcement agency, typically, the Division of the State Architect. Accurate measurement of quantities must be performed. Shovel measurements are not acceptable.

Grout. Grout may be specified by a laboratory design mix or by typical proportions contained in C.C.R. Title 24, Table 21A-C (ASTM C 476, Table 1); which are 1 part portland cement, 3 parts sand with not less than 1 part or more than 2 parts pea gravel based on dry loose volume. Minimum grout space, for low-lift grouted construction is $2^1/_2$ inches [63.5 mm] and $3^1/_2$ inches [88.9 mm] for high lift grouted construction. Approved admixtures may be added. Accurate measurement of quantities must be performed. Shovel measurements are not acceptable.

Mortar Strength. Minimum compressive strength of 2 inch by 4 inch [50.8 mm by 102 mm] cylinders, 1500 psi [10 300 kPa] at 28 days. Test mortar is taken from masonry soon after spreading (not from mortar boards).

Grout Strength. Minimum compressive strength of 3 inch x 3 inch x 6 inch [76.2 mm x 76.2 mm x 152 mm] specimens made in brick molds, 2000 psi [13 800 kPa] at 28 days, tested in vertical position. Grout to be taken from grout tub.

Absorption of Brick. At time of laying, bricks shall have a residual total absorption between 5 and 15 percent.

Steel Spacing. Maximum 2 feet [610 mm] each way, minimum splice 48 diameters.

Bricklaying. Start of work; (see drawings, page 42 through 50) Step 1, concrete surfaces must have aggregate exposed, clean and damp; Step 2, lay one course on one side, no mortar in grout space; Step 3, lay one course on other side, no mortar in grout space; Step 4, grout to half-height of brick and puddle to insure bond to concrete; Step 5, lay one side up not over 12 inches [305 mm] high; Step 6, lay courses on other side, grouting and puddling each course as laid. Keep mortar out of grout spaces. Keep brickwork damp for 3 days after laying.

Full head joints, brick shoved into place. Bed joints flat or beveled up and out from grout spaces.

Anchor Bolts. The minimum embedment depth of anchor bolts shall be at least 8 bolt diameters, but not less than 4 inches [102 mm]. The minimum center-to-center spacing between anchor bolts shall be at least 8 bolt diameters. All bolts must be accurately set with templates including bolts in tops of walls. Vertical bolts may not be forced in place into previously poured grout.

Low Lift Grouting. Low lift grouting is the construction method where the masonry wall is constructed to a limited height (5 feet [1.5 m] maximum for UBC, *Specification for Masonry Structures*), then grouted. Additional masonry units are then placed on the grouted section of wall to increase the height of the wall and the grouting process is repeated. Cleanouts are not required for the low lift grouting method.

High Lift Grouting. High lift grouting is the construction method where the masonry wall is constructed full height, subject to height limits as contained in UBC Table 21-C, *Building Code Requirements for Masonry Structures* Table 1.15.2, *Specification for Masonry Structures* Table 7 or C.C.R. Title 24, Table 21A-C, then grouted in lifts up to 6 feet [1.8 m]. High lift grouting requires cleanouts.

Masonry Core Tests
Excerpts from C.C.R. Title 24, Section 2105A.3.1

2105A.3.1 Masonry core testing. Not less than two cores having a diameter of approximately two-thirds the wall thickness shall be taken from each project. At least one core shall be taken from each building for each 5,000 square feet (465 m^2) of floor area or fraction thereof. The architect or structural engineer in responsible charge of the project or his/her representative (inspector) shall select the areas for sampling. One-half of the number of cores taken shall be tested in shear. The shear wall loadings shall test both joints between the grout core and the outside wythes of the masonry. Core samples shall not be soaked before testing. Materials and workmanship shall be such that for all masonry when tested in compression, cores shall show an ultimate strength at least equal to the f'_m assumed in design, but not less than 1,500 psi (10.34 Mpa).

For more detailed requirements refer to C.C.R. Title 24, Section 2105A.3.1 in its entirety.

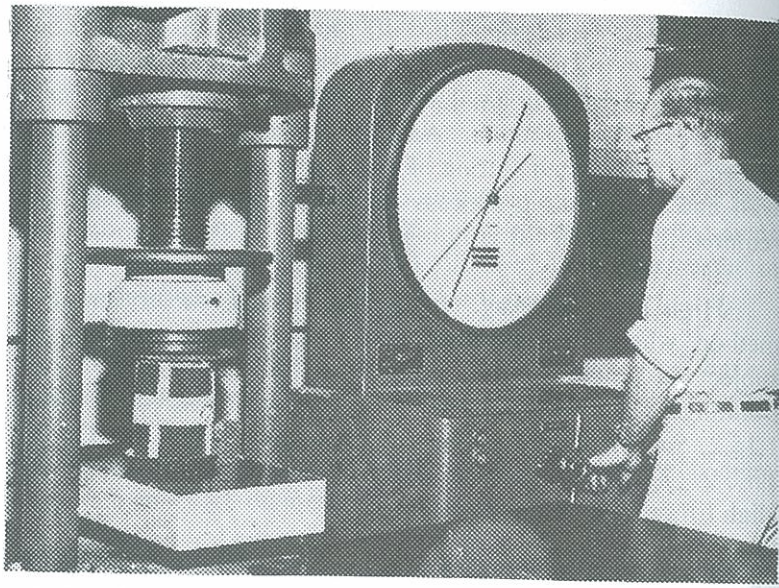


Figure 42. Compression test on core cut from wall.

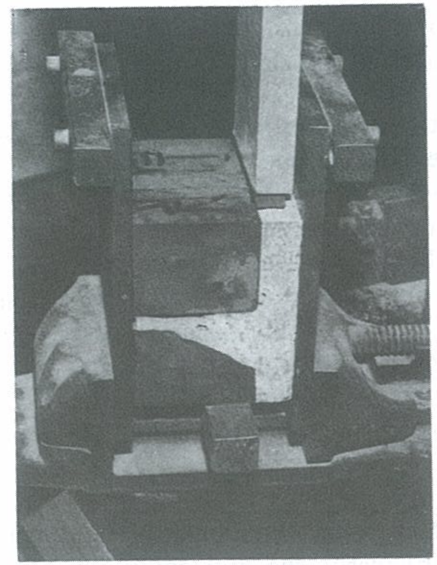


Figure 43. Testing shear strength, grout to brick.

5.10 EARTHQUAKE CONSIDERATIONS

No part of the surface of the earth is free from earthquakes. No one can predict earthquakes. Since earthquakes are vibrations transmitted as waves in the materials of the earth, they may originate from a variety of causes, including landslides, explosive volcanic activity, movements of molten rock at depth, natural or artificial explosions and abrupt movements of masses of rock along faults in the outer part (crust) of the earth. In California, the most famous fault is the San Andreas Fault, however, the most potentially damaging fault is probably the New Madrid Fault in Missouri. In 1811 and 1812, in a span of 45 days, three seismic events on the New Madrid Fault each exceeding Richter Magnitude 7.0 were felt as far away as Boston. Recently, a number of small earthquakes have been felt in places such as Tennessee and Upstate New York.

Although earthquakes are a hazard, it is interesting to note that for the past century fewer people have been killed in the United States and Canada than in some single seismic events, such as the Kobe, Japan earthquake of January 17, 1995 or some of the earthquakes in China and Turkey.

The most destructive force is caused by horizontal earth motion. When the ground underneath a structure is moved suddenly to one side, the building will tend to remain in its original position because of its inertia. Thus all parts of the building must be so connected to the frame that the building will vibrate as a unit, the connections being strong enough to overcome the inertia of the separate parts. When adjacent buildings have different periods or amplitudes, which is generally the case, they should be separated by sufficient distance to keep them from hammering one another during an earthquake.

Details of all connections must be thoroughly checked as per plans, particularly the tightening of bolts. Eccentric connections should be given special attention.

For further information on earthquakes, see publications by:

Structural Engineers Association
of Southern California
5360 Workman Mill Road
Whittier, CA 90601
Telephone (562) 908-6131
www.seaint.org/seaosc

Structural Engineers Association
of Northern California
74 New Montgomery St., #230
San Francisco, CA 94105-3411
Telephone (415) 974-5147
www.seaonc.org

Structural Engineers Association
of San Diego
P. O. Box 26500, Suite 203
San Diego, CA 92126
Telephone (619) 223-9955
www.seaint.org/seaosd

Structural Engineers Association
of Central California
P. O. Box 2590
Sacramento, CA 95628-9590
Telephone (916) 965-15368
www.seaint.org/seaocc

Earthquake Engineering
Research Institute
499 – 14th Street, #320
Oakland, CA 94612-1934
(510) 451-0905
www.eeri.org

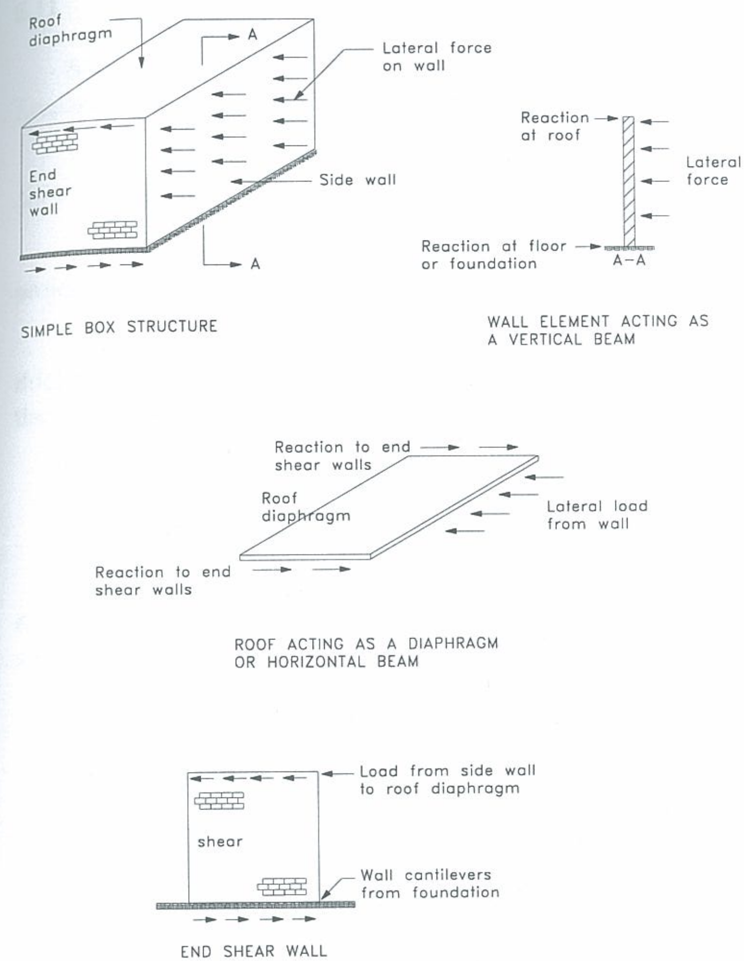


Figure 44. Lateral forces on a box structure.

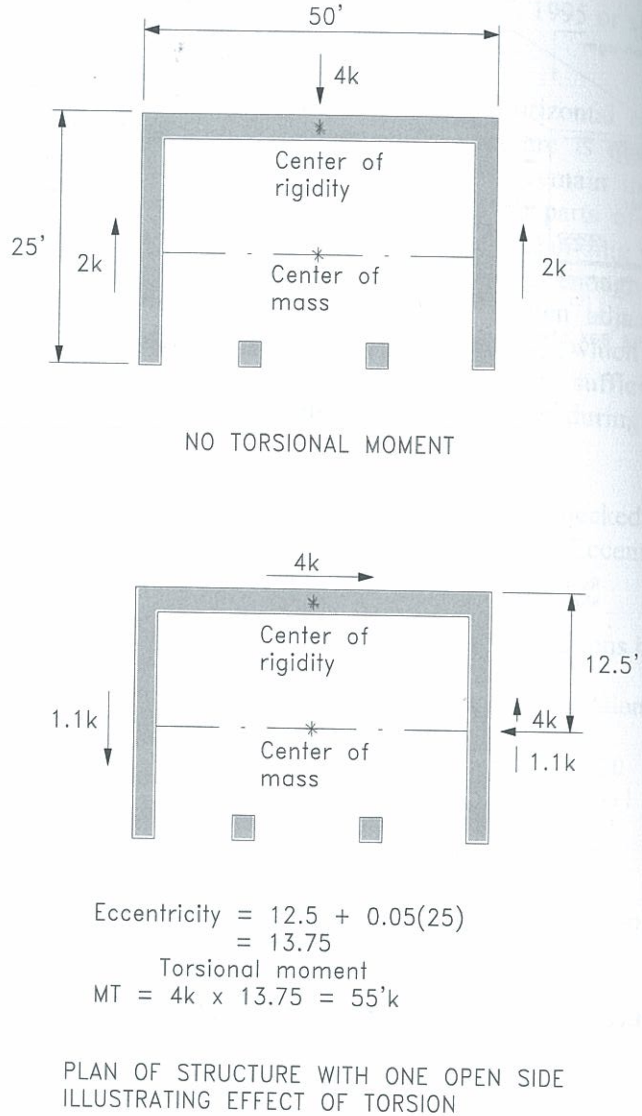


Figure 45. Seismic forces on buildings.

5.11 FIREPLACE AND CHIMNEY NOTES

Some of the issues relating to the performance of masonry fireplaces and chimneys are stated in this section.

Verify that a chimney that is not built into a masonry wall does not support any load other than its own weight.

Check footings for adequate thickness and minimum projection beyond chimney walls.

Check thickness of walls, with or without flue lining, and thickness of separation where more than one flue is contained in the same chimney.

Check mortar, grout, bricklaying and specifications.

Check fireplace opening and hearth.

Check fill-in of solid masonry behind fire-back up to about 6 inches [152 mm] below top of throat to form a depressed smoke chamber.

Check flue and throat areas.

Check minimum horizontal of $^1/_2$ inch [12.7 mm] between top of throat and inner face of flue.

Check corbelling, size and spacing of reinforcement, bond beams, anchorages, separation from combustibles, also damper and spark arrester if required.

Check height of chimney above roof.

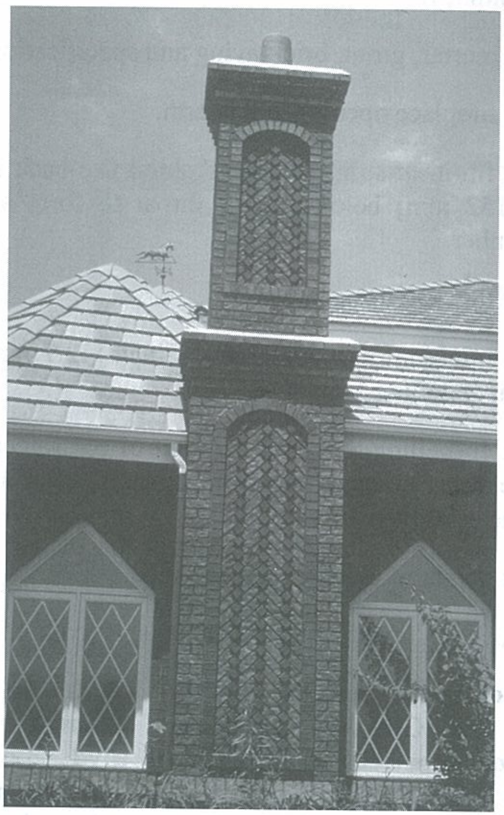
Check F.H.A. and V.A. requirements, if required.

For complete details, obtain Residential Masonry Fireplace and Chimney publication from the Masonry Institute of America, 2550 Beverly Blvd., Los Angeles, California 90057-1085. Information for Rumford type fireplaces can be obtained on the Internet at www.rumford.com.

A masonry fireplace and chimney is a beneficial energy conservation device for any home. Locating the fireplace inside, away from exterior walls, provides a thermal mass that will store and release heat energy.

During the winter when the fireplace is in use, the masonry will store much heat energy and release it slowly through the night when the surrounding air cools down.

The masonry fireplace acts as a heat sink that creates a thermal lag and reduces the extreme highs and lows of internal home temperature.



Chimney at Riverside, CA residence.

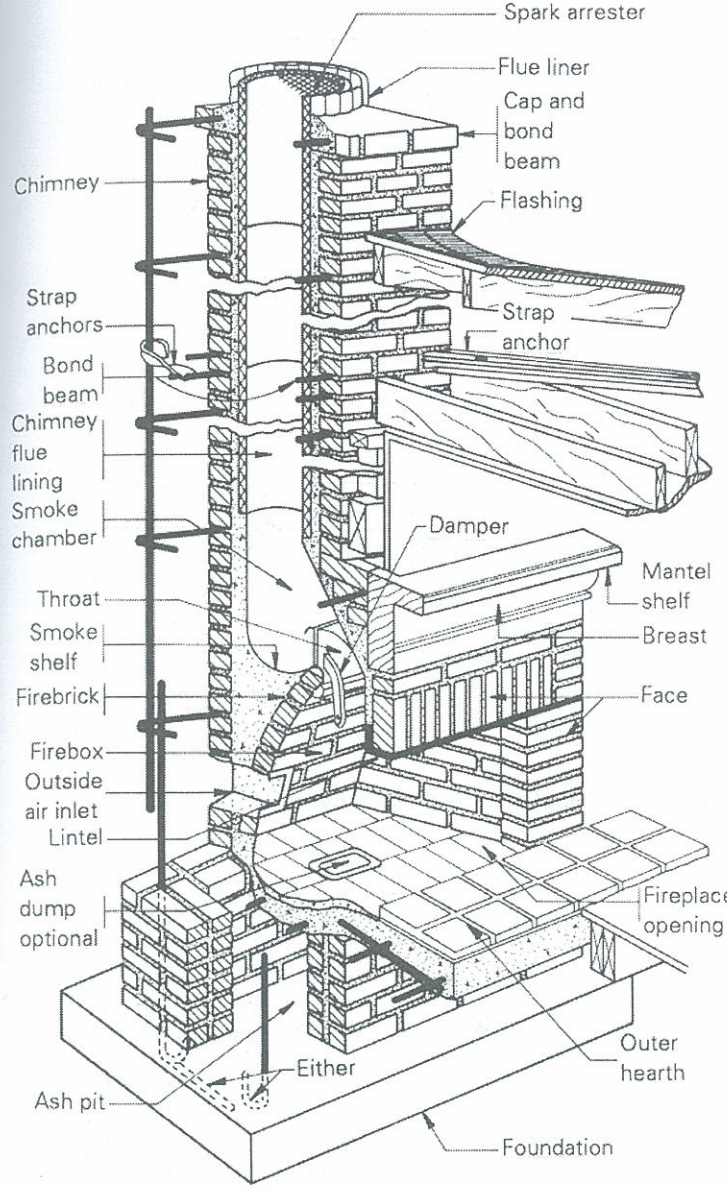


Figure 46. Parts of a fireplace and chimney

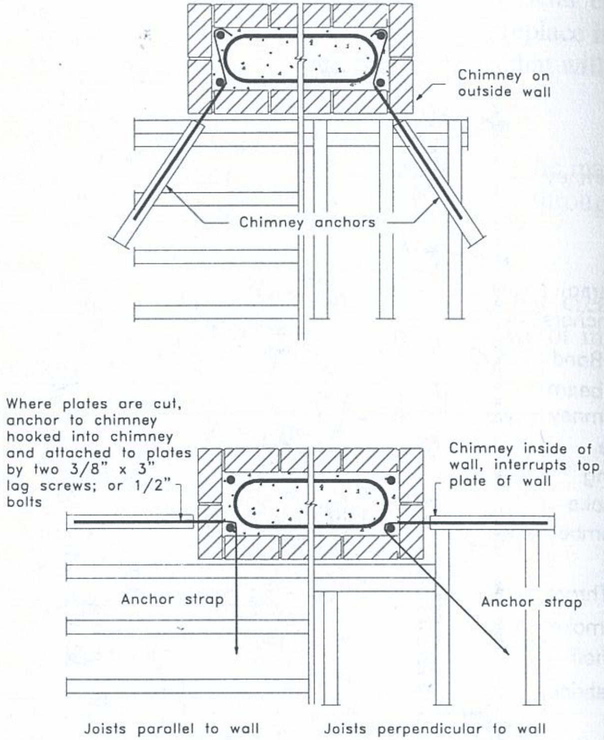


Figure 47. Anchorage of chimney

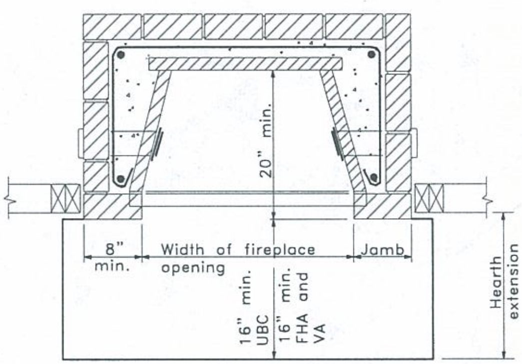


Figure 48. Plan of firebox at top of hearth.

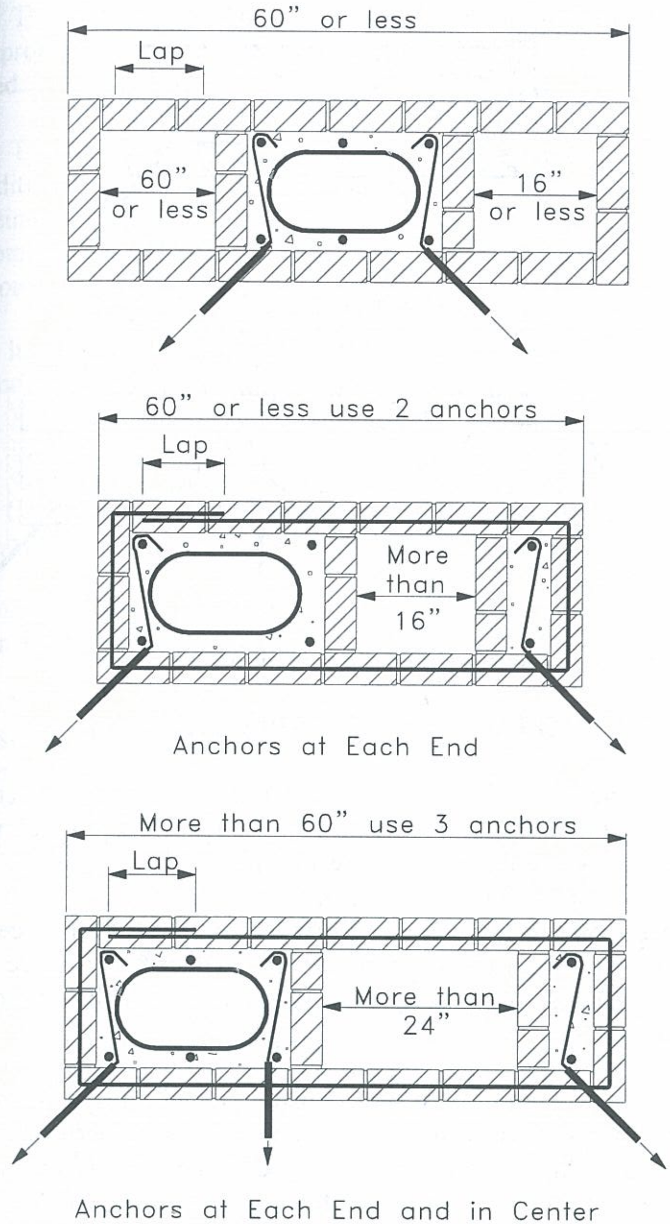


Figure 49. Anchorage of wide chimney

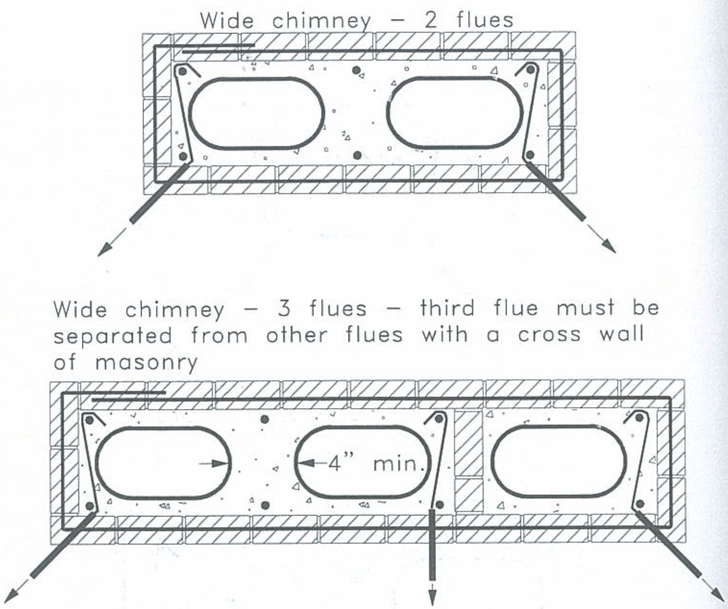


Figure 50. Anchorage of chimney with multiple flues.

5.12 TIMELY TIPS FOR INSPECTION

A vital part of any construction project is good inspection. The inspector's job is important. Knowledge and good judgment are essential in obtaining the results required by the approved plans and specifications. The materials furnished on the job represent the manufacturers' efforts to supply products meeting job specifications. It is the inspector's responsibility to see that these products are properly used to produce a quality masonry project.

Prior to starting masonry construction, the inspector must verify that necessary material testing has been performed as required. Some tests may have to be conducted well in advance of job site delivery, such as for high strength block. All materials must meet specified requirements.

The inspector should keep a daily log from his first day on the project. The status of the job from the beginning should be noted.

The daily log should record weather, temperature, and job conditions. The inspector should record all materials; test specimens and job progress, and note what work was accomplished and where it was done. This includes laying of masonry units and grout pours that are completed.

It is also suggested that the inspector note how many masons are on the job each day and the delivery of materials. Any special conditions, problems or adverse events that may take place should be noted.

If there are job conferences, a list of who attended, what was accomplished, and the decisions made should also be noted.

Complete and thorough job records are very important, and the inspector is invaluable in maintaining these.

As with all competent and skilled professionals and craftsmen, construction inspectors must have their tools and materials to properly carry out their inspection duties and responsibilities. The following is a minimum suggested list of tools an inspector should have.

1. A current set of plans and specifications, including all changed orders.
2. Applicable building codes and standards to which the project was designed and the requirements of the jurisdiction it is under.
3. A list of architects, engineers, contractors and subcontractors; names, addresses, telephone numbers and responsible persons.
4. A notebook or log to keep daily notes as described above.

5. Necessary forms for filing reports with required agencies.
6. Pens, pencils and erasers.
7. Folding rule or retractable tape and long steel.
8. String to check straightness.
9. Keel -- yellow, blue and black.
10. Permanent felt tip markers for labeling specimens.
11. Hand level and plumb bob.
12. Small trowel and smooth rod for making and rodding mortar and grout samples.
13. Sample molds obtained from testing laboratory.
14. Absorbent paper towels and masking tape to take grout specimens.

There can be more items needed, depending on the project and the scope of duties required of the inspector.

Some of the things a masonry inspector should check are listed below. A more complete checklist is contained in the *Reinforced Concrete Masonry Construction Inspectors Handbook* published by the Masonry Institute of America and the International Conference of Building Officials.

BRICK. Check brick for compliance and specifications.

MORTAR. Study the applicable Code section on mortar carefully. Check if laboratory tests are required for cement. Check volume measurements and bulking of sand (see Section on Sand). Check shovel measurements by using a cement sack for one cubic foot and check occasionally during the job. Check order and time of mixing. It is very important to see that mortar

is maintained highly plastic or 'soft' on the mortar board. Refer to bottom of page 20 on "Mortar" for proper retempering.

GROUT. Grout must be a fluid mixture, however, when grout bleeds in the tubs, water on top, chances are it was too wet when mixed. Before dipping grout from tubs, it must be re-mixed using the bucket or otherwise to obtain a thorough mix. Sand and pea gravel must not be delivered to the job pre-mixed unless premixed in quality control conditions, such as sacks or silos.

STEEL. Check if laboratory tests are required. Check position and length of dowels. Steel must be checked constantly for position and clearance from brick. When coring is required, note the location of steel so it can be avoided when cutting cores.

BRICKLAYING AND GROUTING. Don't interfere with workers or their work. Keep in the clear when inspecting. Give instructions only to foremen. Don't insist on wetting brick that are rain-soaked. Check uniformity of width of vertical and horizontal mortar joints. Report careless bricklayers to the foreman.

See that head joints are actually filled with mortar or grout. See that grout completely fills the grout space. Where excessive longitudinal shrinkage cracks occur between grout pours, check dampness of brick and amount of water in grout, and use of lime and pea gravel, and make adjustments.

See that shear walls less than 6 feet [1.8 m] wide, particularly at corners, are built level the full length with racking or corner leads not more than 12 inches [305 mm] high, and see that such leads are solidly grouted. See that jointing with jointer tool is done while mortar is still plastic enough to be pressed against edges of brick. Mortar used to form caps on walls or sills should be used not sooner than $^1/_2$ hour after original mixing to prevent shrinkage cracks. Tops of masonry must be damp while such caps are placed, and be kept covered and damp for at least 24 hours.

See that corners of finished masonry are protected against damage, especially where materials or equipment are handled through or around them. See that line pin holes, and holes between masonry and other materials are properly filled at completion.

It is far better for an inspector to be a cooperating helper in seeing that the plans and specifications are properly executed, than an antagonistic troublemaker. Bricklaying is considered an art. Artists are temperamental and so are bricklayers. However, with proper conduct, an inspector can make their own work and that of the bricklayers a cooperative, congenial experience, for the benefit of all concerned.

5.13 LAP SPLICES FOR REINFORCING STEEL

It is not reasonable to build a reinforced masonry wall using a single continuous length of reinforcing steel. Instead, the steel is placed using bars that have been cut to manageable lengths. For these shorter lengths of steel to function as continuous reinforcement, they must be connected in some fashion.

Typically, bars are lapped a specified length. The Building Codes require that reinforcing steel bars in tension have a lapped length of 40 bar diameters for Grade 40 steel and 48 bar diameters for Grade 60 steel. When the steel is in compression the required lap length is 30 bar diameters for Grade 40 steel and 36 bar diameters for Grade 60 steel.

Splices may be made only at certain locations and in such manner that the structural strength of the member will not be reduced.

Excerpt from Sections 2107.2.2.6, 2108.2.2.7 (1997 UBC)

2107.2.2.6 Splices. The amount of lap of lapped splices shall be sufficient to transfer the allowable stress of the reinforcement as specified in Sections 2106.3.4, 2107.2.2.3 and 2107.2.12. In no case shall the length of the lapped splice be less than 30 bar diameters for compression and for Grade 40 diameters for tension.

Welded or mechanical connections shall develop 125 percent of the specified yield strength of the bar in tension.

2108.2.2.7 Splices. Reinforcement splices shall conform with one of the following:

1. The minimum length of lap for bars shall be 12 inches (305 mm) or the length determined by Formula (8-14).

$$l_d = l_{de}/\phi \qquad (8\text{-}14)$$

Bars spliced by noncontact lap splices shall be spaced transversely a distance not greater than one fifth the required length of lap or more than 8 inches (203 mm).

2. A welded splice shall have the bars butted and welded to develop in tension 125 percent of the yield strength of the bar f_y.

3. Mechanical splices shall have the bars connected to develop in tension or compression, as required, at least 125 percent of the yield strength of the bar, f_y.

Similar requirements are found in *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99):

2.1.8.6.1 *Lap splices*

2.1.8.6.1.1 The minimum length of lap for bars in tension or compression shall be determined by Eq. (2-9), but not less than 12 in. (305 mm).

$$L_d = 0.002 d_b F_s \quad (2\text{-}9)$$

When epoxy-coated bars are used, lap length determined by Eq. (2-9) shall be increased by 50 percent.

2.1.8.6.1.2 Bars spliced by noncontact lap splices shall not be spaced transversely farther apart than one-fifth the required length of lap nor more than 8 in. (203 mm).

2.1.8.6.2 *Welded splices* – Welded splices shall have the bars butted and welded to develop in tension at least 125 percent or the specified yield strength of the bar.

2.1.8.6.3 *Mechanical connections* – Mechanical connections shall have the bars connected to develop in tension or compression, as required, at least 125 percent or the specified yield strength of the bar.

Table A
Length of Lap (Inches)[1]
Grade 40 Steel, F_S = 20,000 psi

Bar Size		Laps for Compression Bars			Laps for Tension Bars		
No	Dia., d_b (Inches)	30Dia.[2] Min	30x1.3[3] =39Dia	30x1.5[4] =45Dia	40Dia.[2] Min	40x1.3[3] =52 Dia	40x1.5[4] =60Dia
3	0.375	12[5]	15	18	15	20	23
4	0.500	15	20	23	20	26	30
5	0.625	19	24	29	25	33	38
6	0.750	23	29	35	30	39	45
7	0.875	26	34	39	35	46	53
8	1.000	30	39	45	40	52	60
9	1.128	34	44	51	45	59	68
10	1.270	38	50	57	51	66	77
11	1.410	42	55	63	56	73	84

[1] Based on UBC Sec. 2107.2.2.6 and 2108.2.2.7.
[2] Minimum development length, l_d, and lap splice.
[3] Use when bars are separated by 3 inches [76.2 mm] or less.
[4] Use where f_s>0.80F_S per UBC Sec. 2107.2.12.
[5] Minimum. lap length = 12" required by Code.

Table B
Length of Lap (Inches)[1]
Grade 60 Steel, F_S = 24,000 psi

Bar Size		Laps for Compression Bars			Laps for Tension Bars		
No	Dia., d_B (Inches)	36Dia.[2] Min	36x1.3[3] =39Dia	36x1.5[4] =45Dia	48Dia.[2] Min	48x1.3[3] =52 Dia	48x1.5[4] =60Dia
3	0.375	14	18	21	18	23	27
4	0.500	18	24	27	24	31	36
5	0.625	23	29	35	30	39	45
6	0.750	27	35	41	36	47	54
7	0.875	32	41	48	42	54	63
8	1.000	36	47	54	48	62	72
9	1.128	41	53	62	54	70	81
10	1.270	46	60	69	61	79	92
11	1.410	51	66	77	68	87	102

[1] Based on U.B.C. Sec. 2107.2.2.6 and 2108.2.2.7.
[2] Minimum development length, l_d, and lap splice.
[3] Use when bars are separated by 3 inches [76.2 mm] or less.
[4] Use where f_s>0.80F_S per U.B.C. Sec. 2107.2.12.

The Uniform Building Code Sec. 2107.2.2.6 requires that when adjacent bars (2 or more) are spaced 3 inches [76.2 mm] or closer apart, the required lap length must be increased 30%.

Therefore for compression, 36 bar diameters (d_b) laps (Grade 60 steel) would be required to be increased to 47 d_b and 48 d_b for tension would be increased to 62 d_b, if 2 or more bars are lapped at the same location. See Table above.

If the lapped splices are staggered, the lap lengths need not be increased.

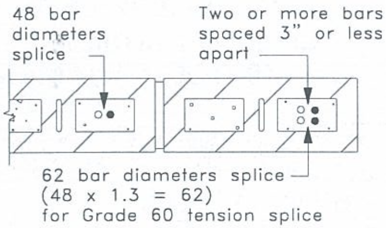


Figure 51. Lap splice of steel in cell.

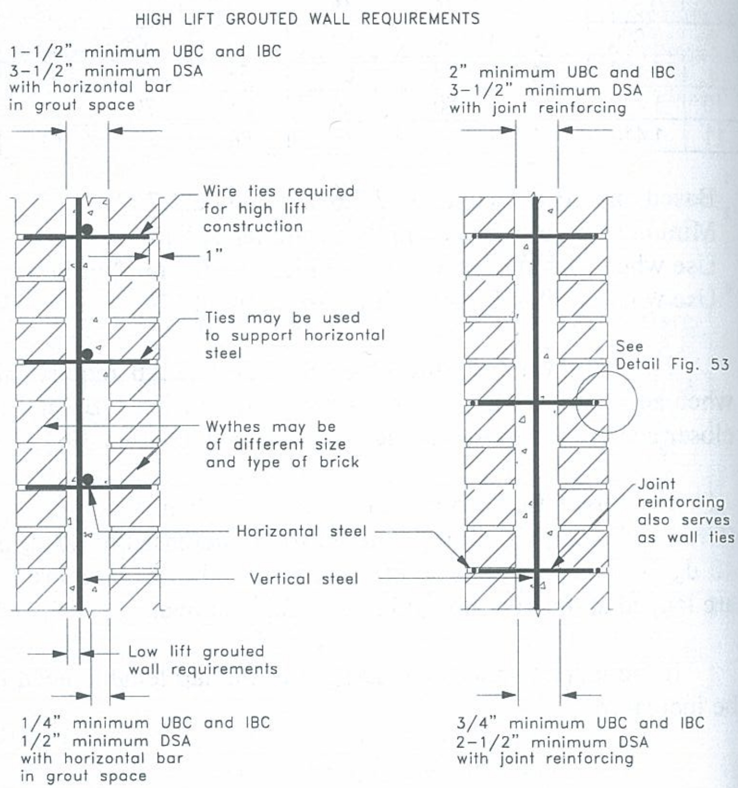


Figure 52. Wall clearances for grouted construction.

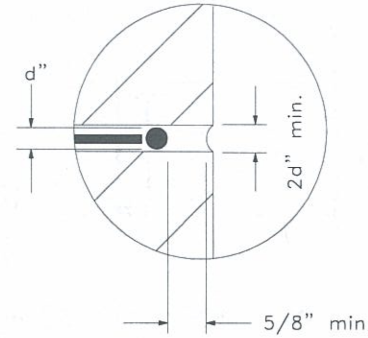


Figure 53. Detail of edge cover and clearance of joint reinforcement.

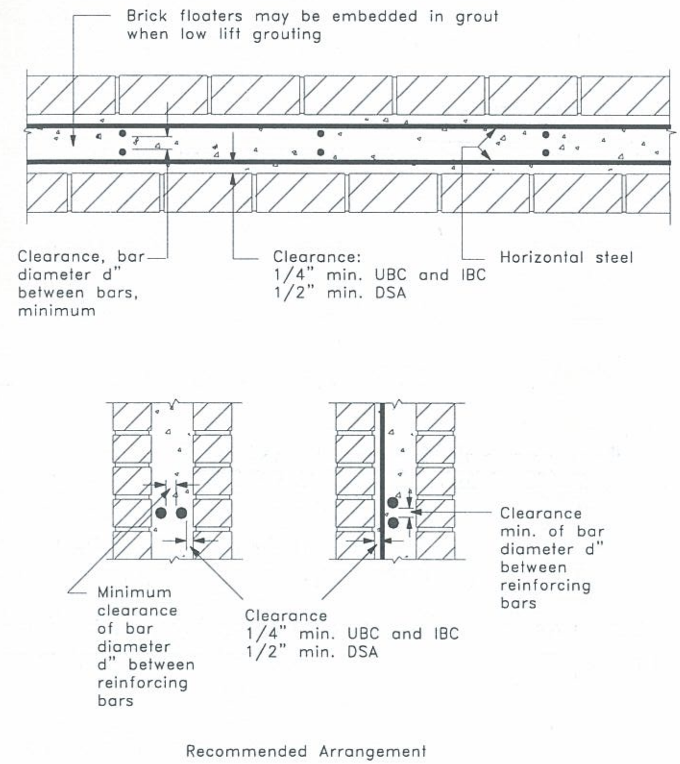


Figure 54. Clearances of steel in a beam or wall.

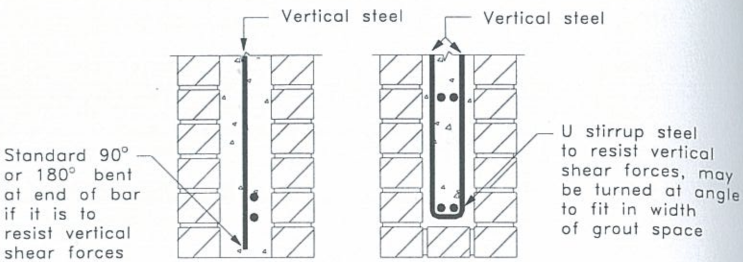


Figure 55. Vertical shear reinforcing steel arrangement for beams.

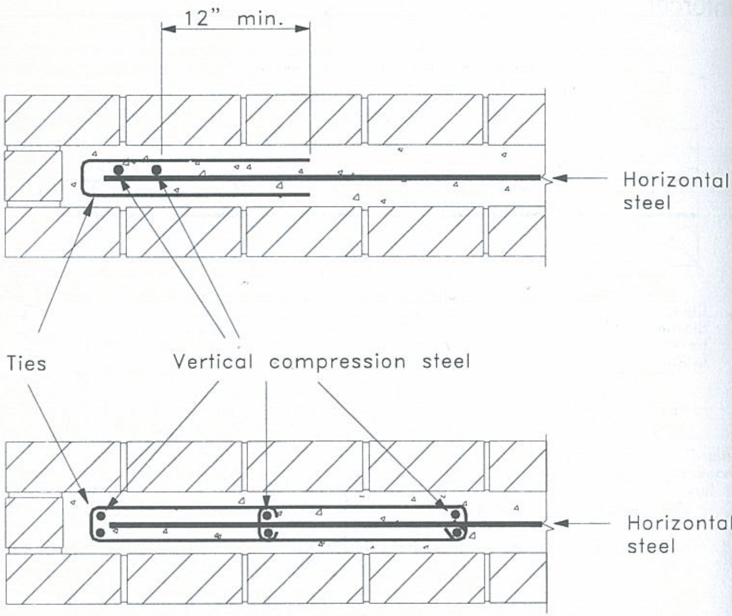


Figure 56. Ties for compression or jamb steel at the end of walls or piers.

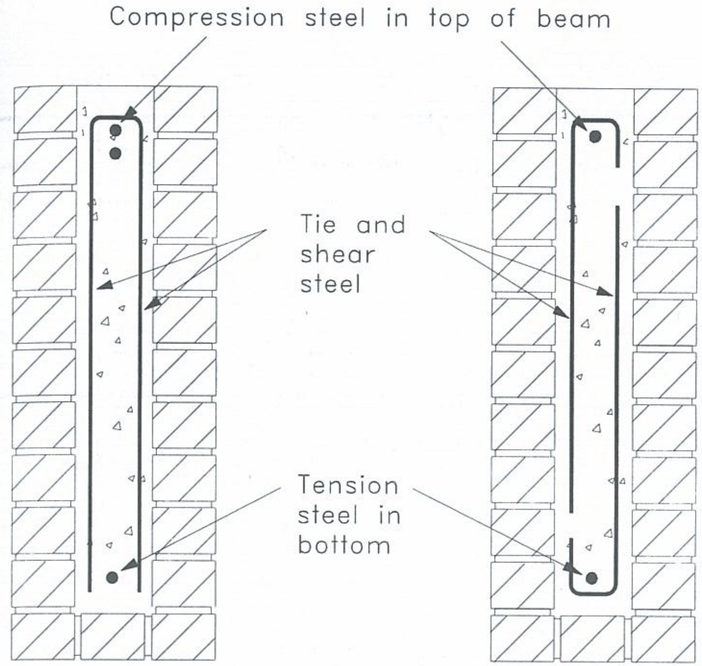


Figure 57. Ties for compression steel in beams.

5.14 FLUSH WALL COLUMNS

If engineering design permits, it is to the economic benefit of the owner and to the construction benefit of the contractor to build columns that are contained within and are flush with the wall. Wall-contained columns permit faster construction, since there are no projections from the wall and no special units are required. The reinforcing steel must be tied in accordance with the code requirements.

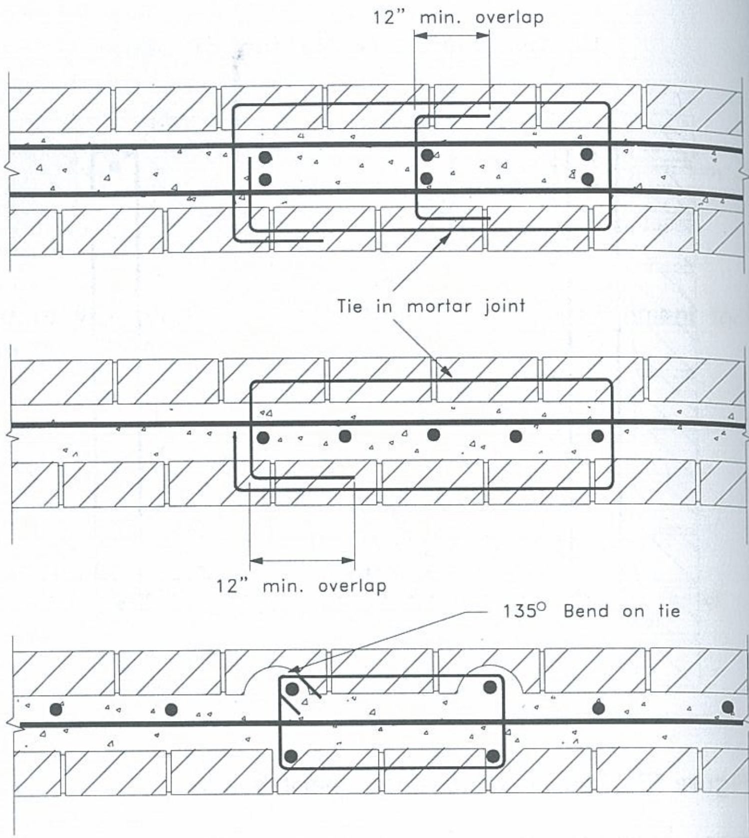


Figure 58. Flush wall brick columns with ties in mortar joint.

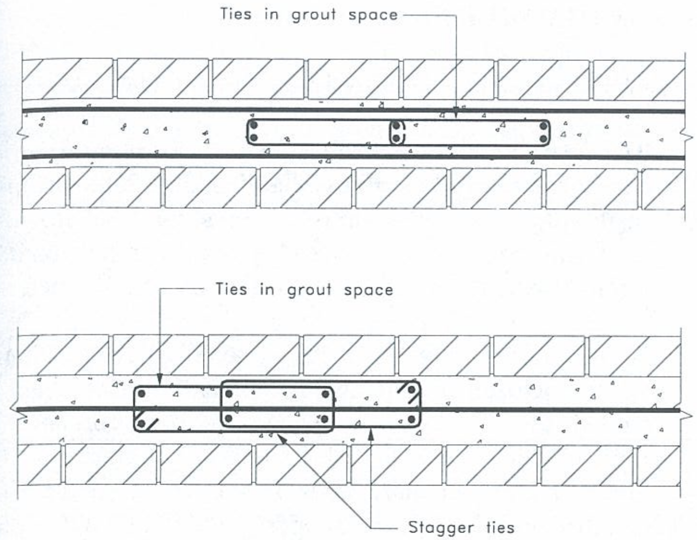


Figure 59. Flush wall brick columns with ties in grout space.

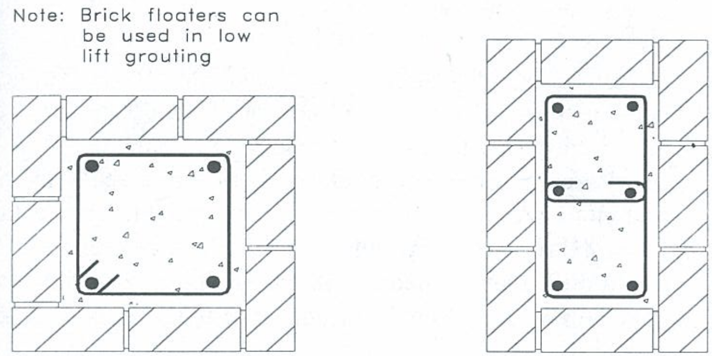


Figure 60. Brick columns showing vertical steel and ties.

5.16 COLUMN TIES

Excerpt from Sections 2107.2.13.1, 2106.3.6 (1997 UBC)

2107.2.13.1 Vertical Reinforcement. The area of vertical reinforcement shall be not less than 0.005 A_e, and not more than $0.04A_e$. At least four No. 3 bars shall be provided. The minimum clear distance between parallel bars in columns shall be two and one half times the bar diameter.

2106.3.6 Lateral ties. All longitudinal bars for columns shall be enclosed by lateral ties. Lateral support shall be provided to the longitudinal bars by the corner of a complete tie having an included angle of not more than 135 degrees or by a standard hook at the end of a tie. The corner bars shall have such support provided by a complete tie enclosing the longitudinal bars. Alternate longitudinal bars shall have such lateral support provided by ties and no bar shall be farther than 6 inches (152 mm) from such laterally supported bar.

Lateral ties and longitudinal bars shall be placed not less than $1^1/_2$ inches (38 mm) and not more than 5 inches (127 mm) from the surface of the column. Lateral ties may be placed against the longitudinal bars or placed in the horizontal bed joints where the requirements of Section 2106.1.8 are met. Spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie diameters or the least dimension of the column but not more than 18 inches (457 mm).

Ties shall be at least $^1/_4$ inch (6.4 mm) in diameter for No. 7 or smaller longitudinal bars and at least No. 3 for longitudinal bars larger than No. 7. Ties smaller than No. 3 may be used for longitudinal bars larger than No. 7, provided the total cross-sectional area of such smaller ties crossing a longitudinal plane is equal to that of the larger ties at their required spacing.

Building Code Requirements for Masonry Structures (ACI 530-99/ASCE 5-99/TMS 402-99) contains requirements for column reinforcement and ties also.

2.1.4 *Columns*

2.1.4.4 Vertical column reinforcement shall be not less than $0.0025A_n$ nor exceed $0.04A_n$. The minimum number of bars shall be four.

2.1.4.6 *Lateral ties* – Lateral ties shall conform to the following:

(a) Longitudinal reinforcement shall be enclosed by lateral ties at least $^1/_4$ in. (6.4 mm) in diameter.

(b) Vertical spacing of lateral ties shall not exceed 16 longitudinal bar diameters, 48 lateral tie bar or wire diameters, or the least cross sectional area of the column.

(c) Lateral ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a lateral tie with an included angle of not more than 135 degrees. No bar shall be farther than 6 in. (152 mm) clear on each side along the lateral tie from such a laterally supported bar. Lateral ties shall be placed in either a mortar joint or grout. Where longitudinal bars are located around the perimeter of a circle, a complete circular tie is permitted. Lap length for circular ties shall be 48 tie diameters.

Table C Tie Spacing - 16 Bar Diameters

Compression Steel Bar No	Maximum Tie Spacing, Inches [mm]
3	6 (152)
4	8 (203)
5	10 (254)
5	12 (305)
6	14 (356)
7	16 (406)
9	18 (457)
10	18 (457)
11	18 (457)

Note: Maximum tie spacing: 16 bar diameters or 18 inches [457 mm] or least dimension of column.

5.16 COLUMN TIES

Excerpt from Sections 2107.2.13.1, 2106.3.6 (1997 UBC)

2107.2.13.1 Vertical Reinforcement. The area of vertical reinforcement shall be not less than 0.005 A_e, and not more than $0.04A_e$. At least four No. 3 bars shall be provided. The minimum clear distance between parallel bars in columns shall be two and one half times the bar diameter.

2106.3.6 Lateral ties. All longitudinal bars for columns shall be enclosed by lateral ties. Lateral support shall be provided to the longitudinal bars by the corner of a complete tie having an included angle of not more than 135 degrees or by a standard hook at the end of a tie. The corner bars shall have such support provided by a complete tie enclosing the longitudinal bars. Alternate longitudinal bars shall have such lateral support provided by ties and no bar shall be farther than 6 inches (152 mm) from such laterally supported bar.

Lateral ties and longitudinal bars shall be placed not less than $1^1/_2$ inches (38 mm) and not more than 5 inches (127 mm) from the surface of the column. Lateral ties may be placed against the longitudinal bars or placed in the horizontal bed joints where the requirements of Section 2106.1.8 are met. Spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie diameters or the least dimension of the column but not more than 18 inches (457 mm).

Ties shall be at least $^1/_4$ inch (6.4 mm) in diameter for No. 7 or smaller longitudinal bars and at least No. 3 for longitudinal bars larger than No. 7. Ties smaller than No. 3 may be used for longitudinal bars larger than No. 7, provided the total cross-sectional area of such smaller ties crossing a longitudinal plane is equal to that of the larger ties at their required spacing.

Building Code Requirements for Masonry Structures (ACI 530-99/ASCE 5-99/TMS 402-99) contains requirements for column reinforcement and ties also.

2.1.4 *Columns*

2.1.4.4 Vertical column reinforcement shall be not less than $0.0025A_n$ nor exceed $0.04A_n$. The minimum number of bars shall be four.

2.1.4.6 *Lateral ties* – Lateral ties shall conform to the following:

(a) Longitudinal reinforcement shall be enclosed by lateral ties at least $^1/_4$ in. (6.4 mm) in diameter.

(b) Vertical spacing of lateral ties shall not exceed 16 longitudinal bar diameters, 48 lateral tie bar or wire diameters, or the least cross sectional area of the column.

(c) Lateral ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a lateral tie with an included angle of not more than 135 degrees. No bar shall be farther than 6 in. (152 mm) clear on each side along the lateral tie from such a laterally supported bar. Lateral ties shall be placed in either a mortar joint or grout. Where longitudinal bars are located around the perimeter of a circle, a complete circular tie is permitted. Lap length for circular ties shall be 48 tie diameters.

Table C Tie Spacing - 16 Bar Diameters

Compression Steel Bar No	Maximum Tie Spacing, Inches [mm]
3	6 (152)
4	8 (203)
5	10 (254)
5	12 (305)
6	14 (356)
7	16 (406)
9	18 (457)
10	18 (457)
11	18 (457)

Note: Maximum tie spacing: 16 bar diameters or 18 inches [457 mm] or least dimension of column.

Table D Tie Spacing -- 48 Tie Diameters

Tie Steel Bar No.	Maximum Tie Spacing, Inches (mm)
1/4" (6.4 mm)	12 (305)
3	18 (457)
4	18 (457)
5	18 (457)

Note: #2 (1/4" [6.4 mm]) ties at 8 inch [203 mm] spacing is equivalent to #3 (3/8" [9.5 mm]) ties at 16 inch [406 mm] spacing. Maximum tie spacing is the most restrictive of 16 bar diameters, 48 tie diameters, 18 inches [457 mm] or least dimension of column.

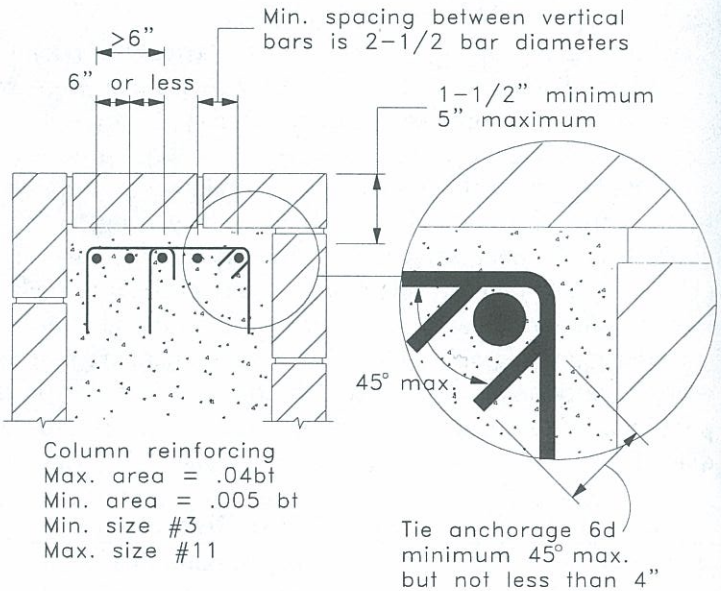


Figure 61. Reinforcing tie details for Seismic Zones 3 and 4, Seismic Performance Categories D and E.

Lateral ties shall be placed not less than $1^1/_2$ inches [38.1 mm] and not more than 5 inches [127 mm] from the surface of the column, and may be against the vertical bars or placed in the horizontal bed joints where permitted by Uniform Building Code Section 2106.1.8.

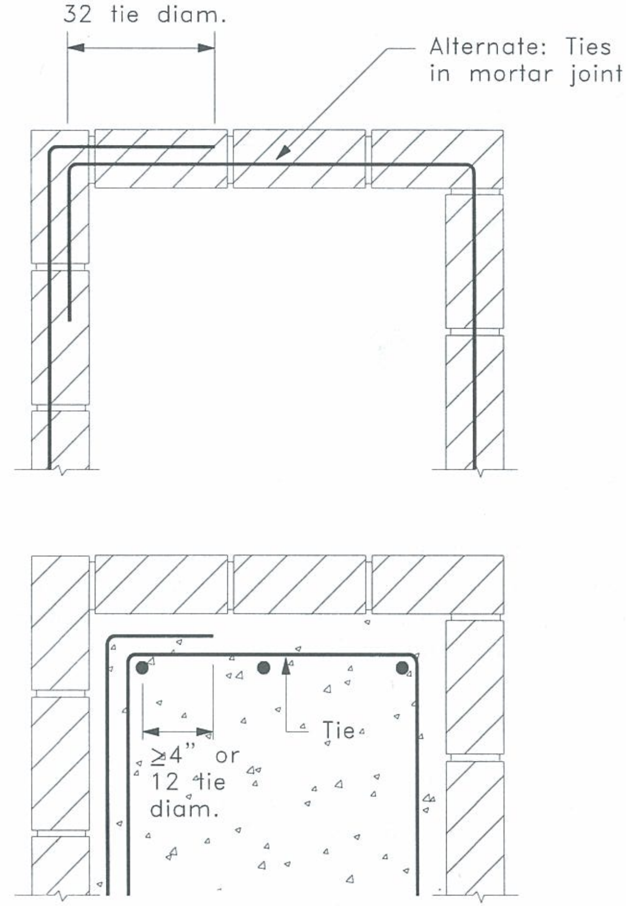


Figure 62. Tie details for Seismic Zones No. 0, 1 and 2, Seismic Performance Categories A, B and C.

Where the ties are placed in the horizontal bed joints, when permitted, the hook shall consist of a 90-degree bend having a radius of not less than four ties diameters plus an extension of 32 tie diameters.

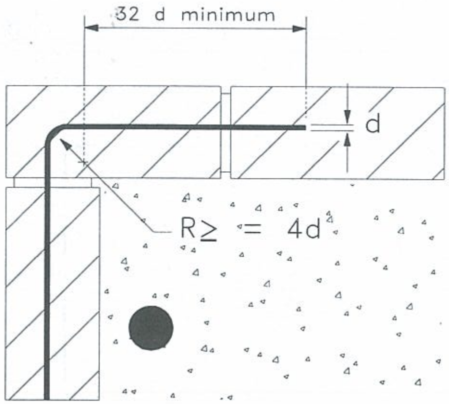


Figure 63. Tie anchorage in bed joint.

In Seismic Zones 0, 1 and 2, no intermediate ties need be provided for bars located in between the corner bars. There is no limiting distance either to the location of intermediate bars between the corner compression bars.

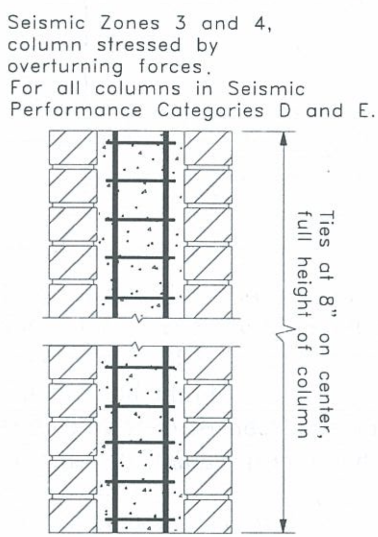


Figure 64 (a). Tie spacing in columns.

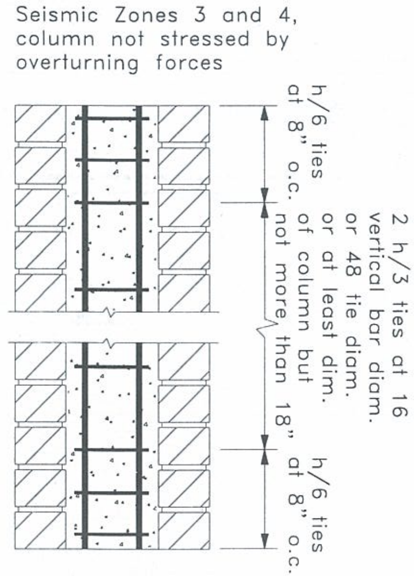


Figure 64 (b). Tie spacing in columns.

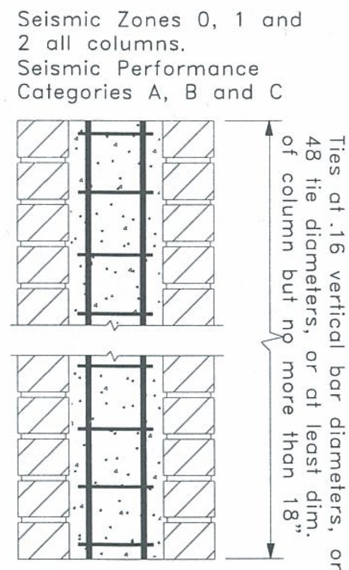


Figure 64 (c). Tie spacing in columns.

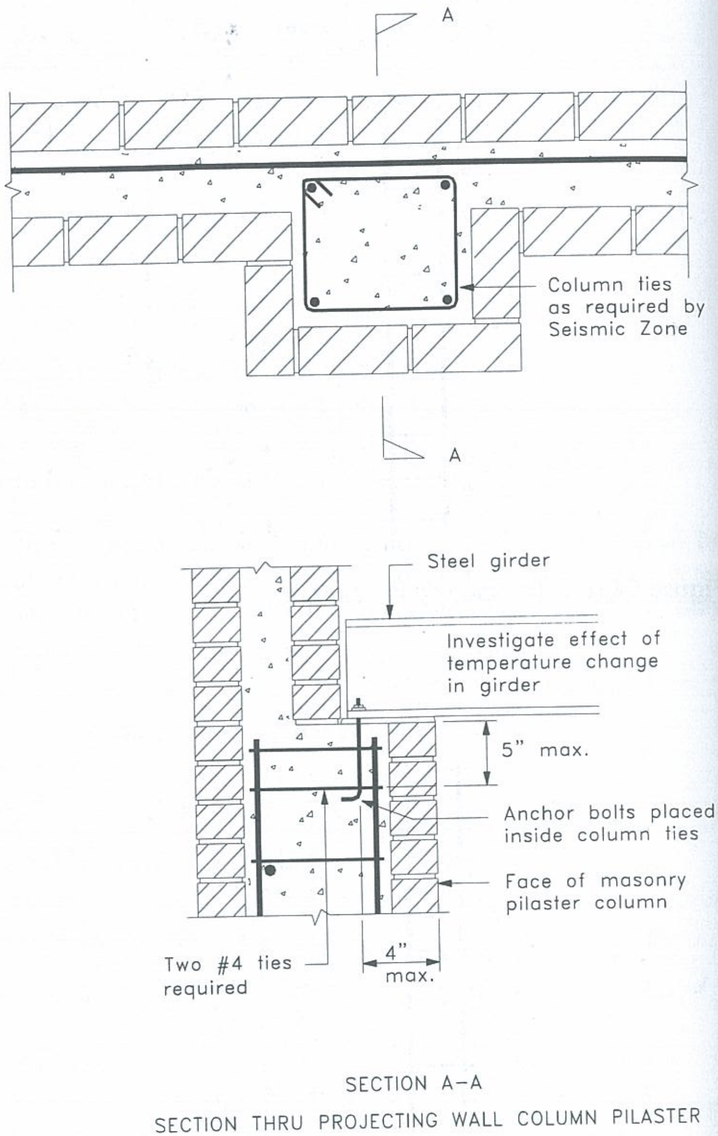


Figure 65. Projecting wall column pilaster.

Excerpt from Sections 2106.3.7 (1997 UBC)

2106.3.7 Column anchor bolt ties. Additional ties shall be provided around anchor bolts, which are set in the top of columns. Such ties shall engage at least four bolts or, alternately, at least four vertical column bars or a combination of bolts and bars totaling at least four. Such ties shall be located within the top 5 inches (127 mm) of the column and shall provide a total of 0.4 square inch (260 mm^2) or more in cross-sectional area. The uppermost tie shall be within 2 inches (51 mm) of the top of the column.

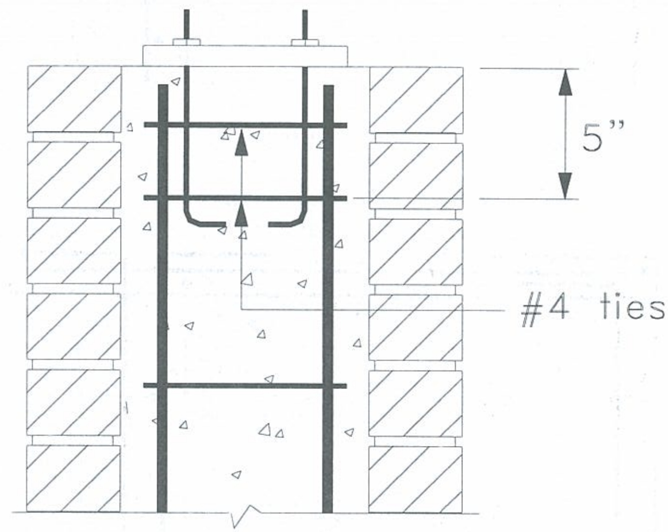


Figure 66. Ties at anchor bolts on top of columns in accordance with UBC.

5.16 DETAILS OF BRICK CONSTRUCTION

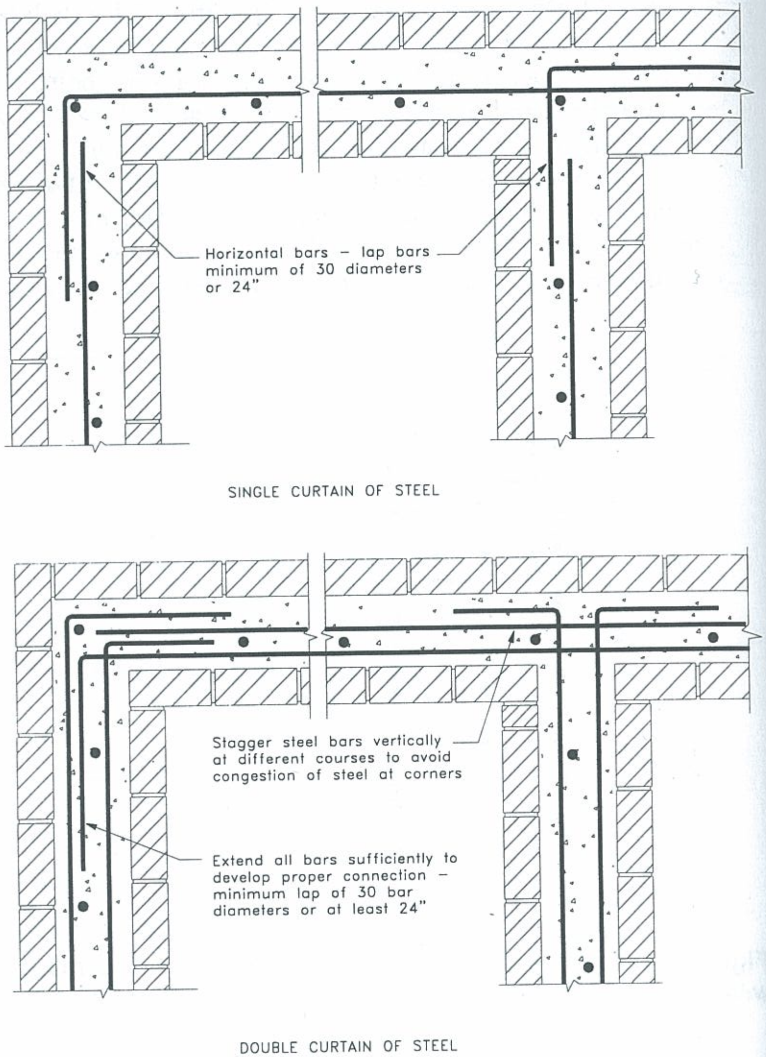


Figure 67. Typical wall connections.

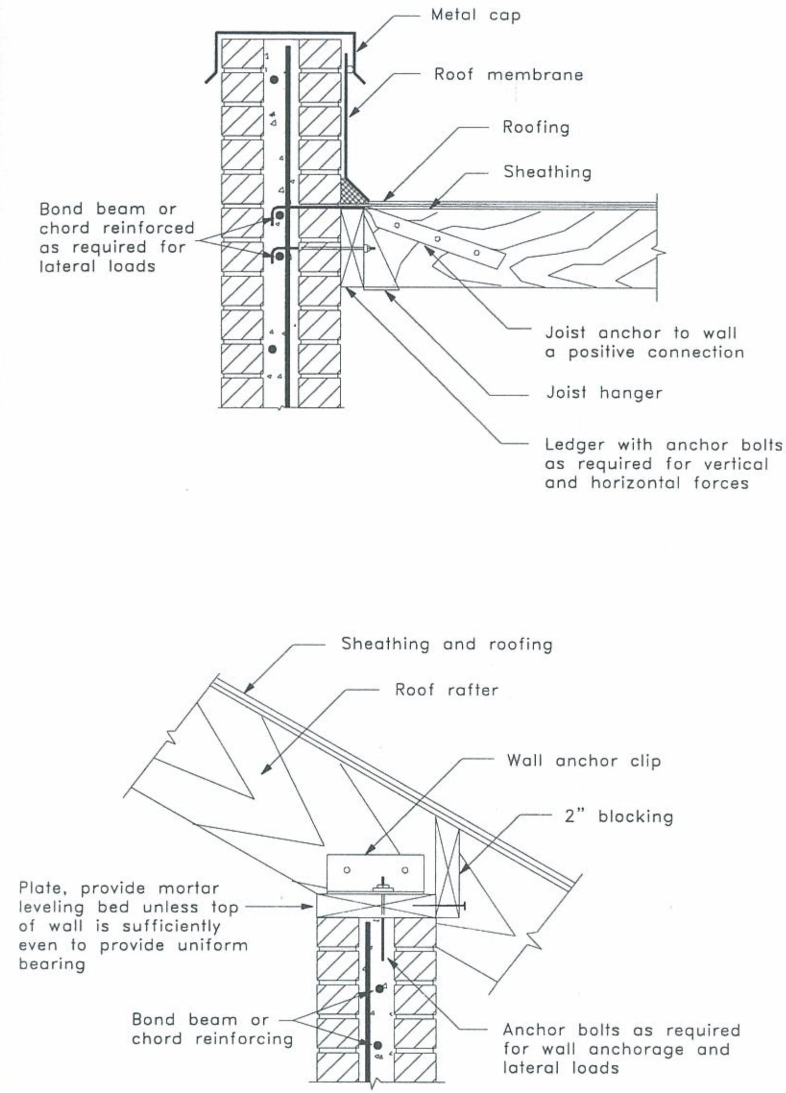


Figure 68. Connection details to wood roof.

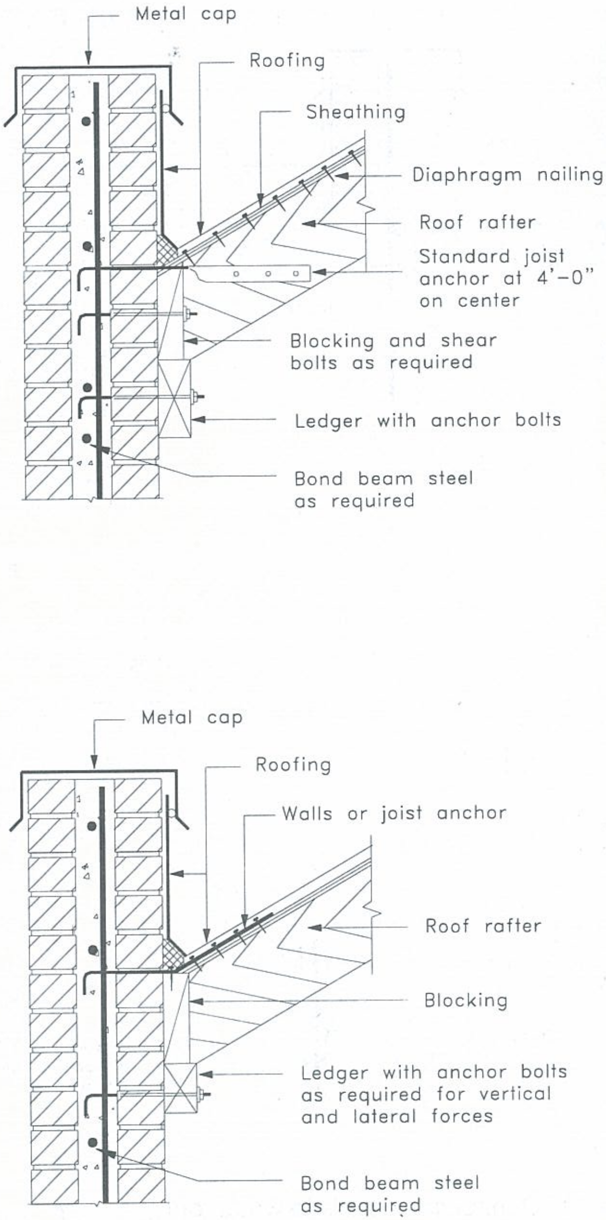


Figure 69. Connection detail to wood roof.

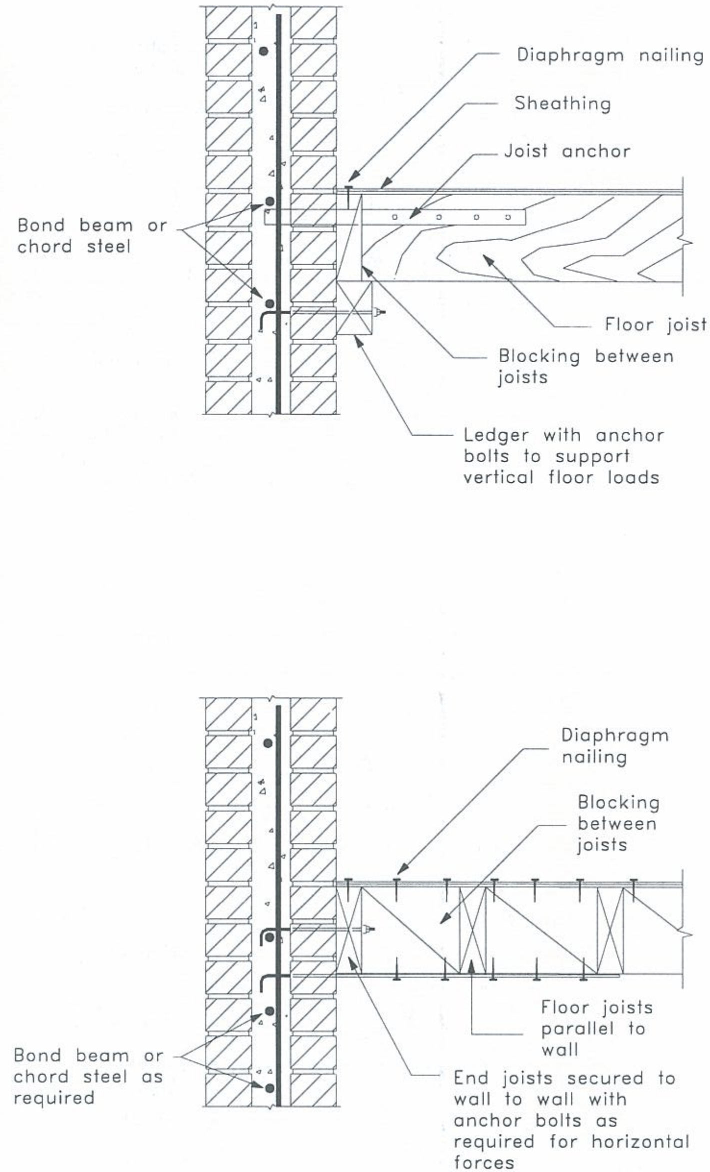


Figure 70. Connection details to wood floor.

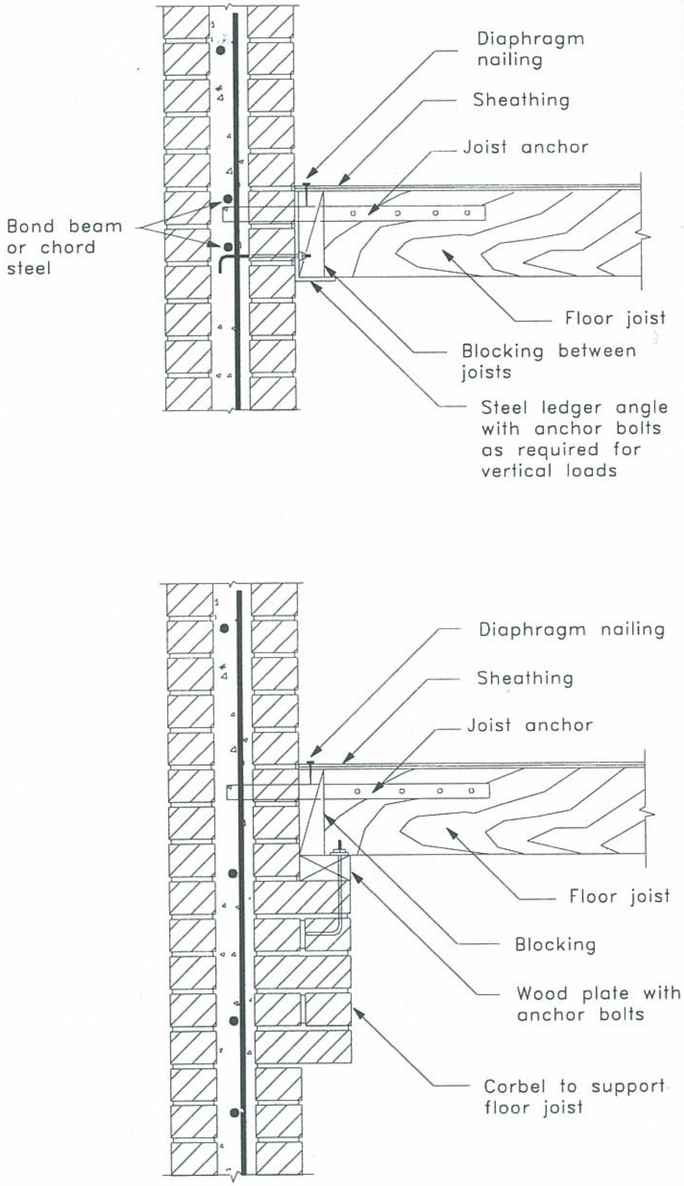


Figure 71. Connection details to wood floor.

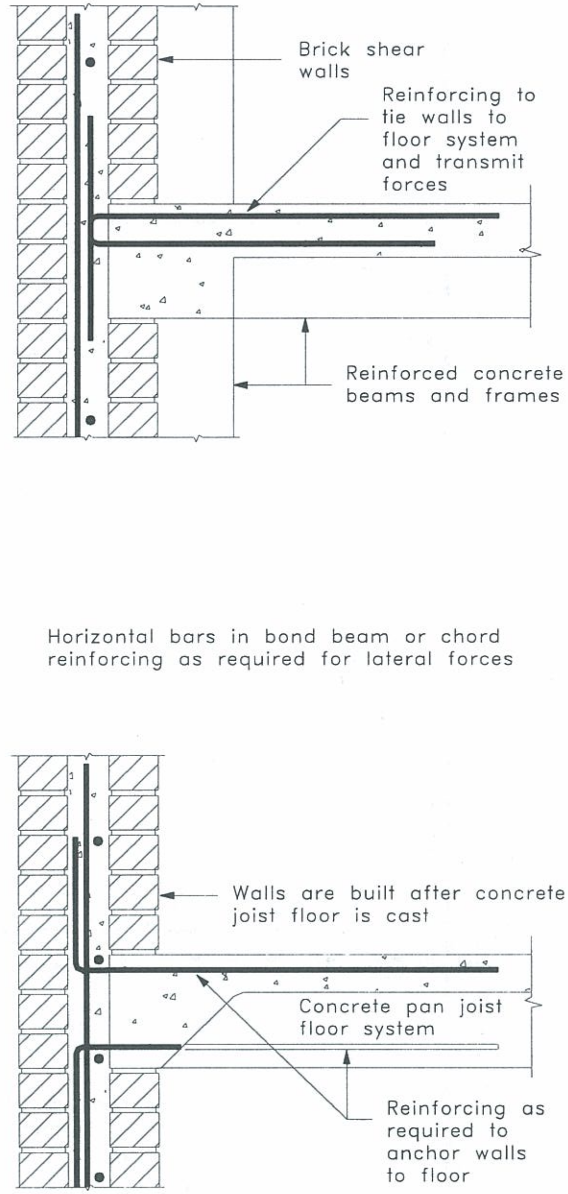


Figure 72. Masonry to concrete connection details.

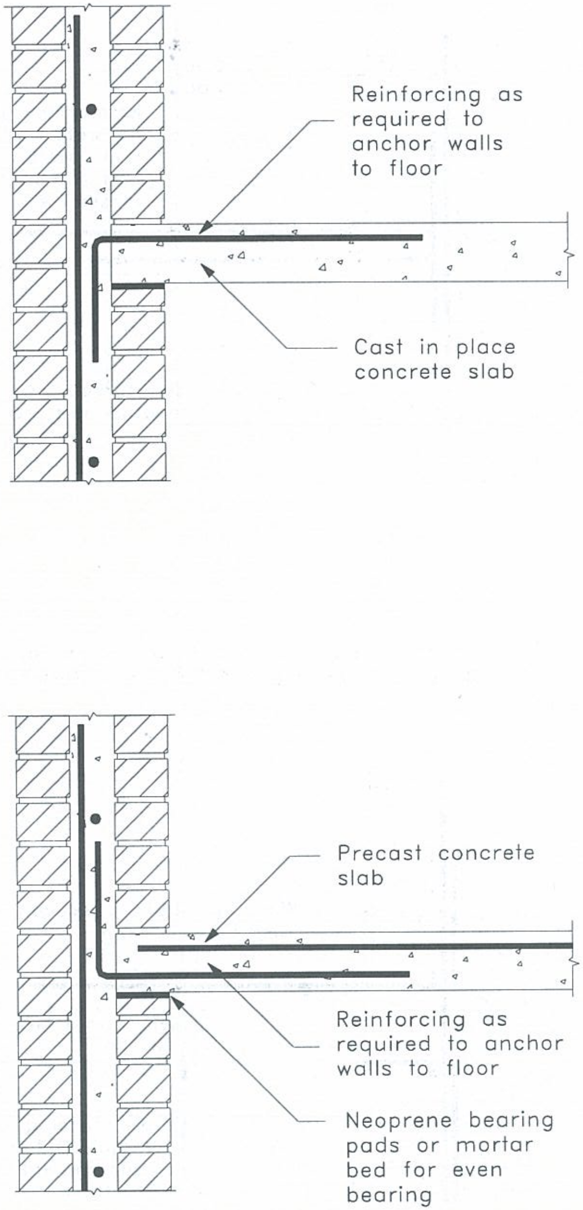


Figure 73. Masonry to concrete connection details.

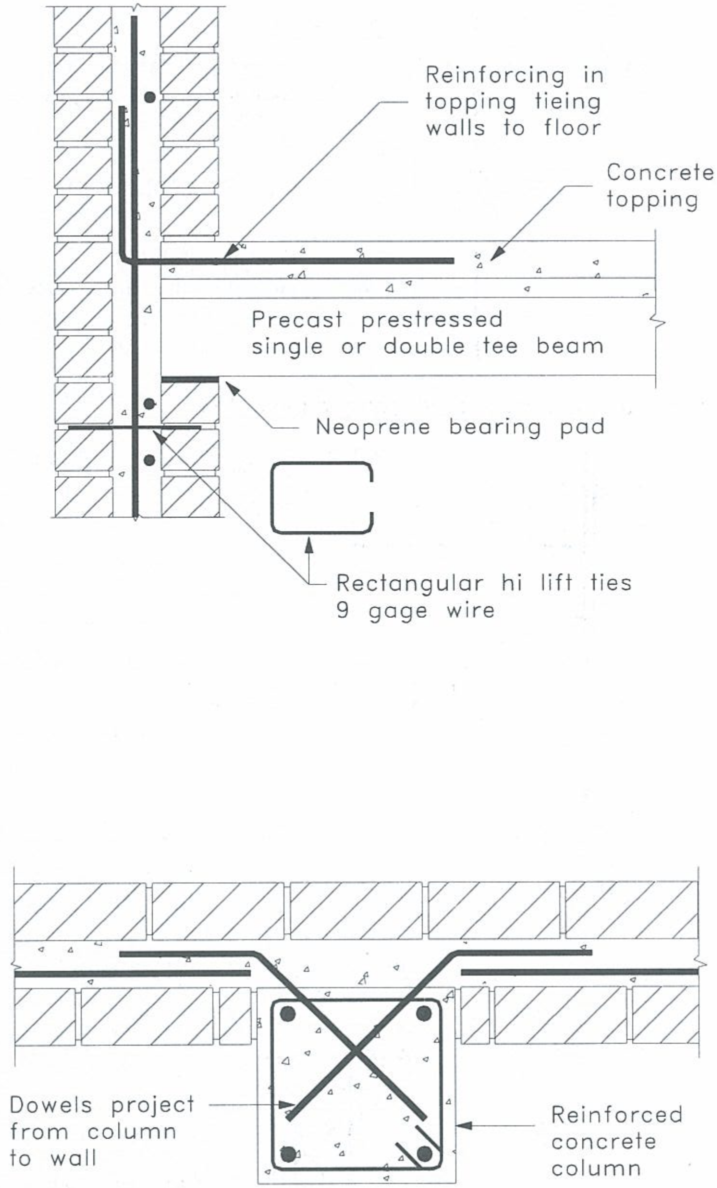


Figure 74. Masonry to concrete connection details.

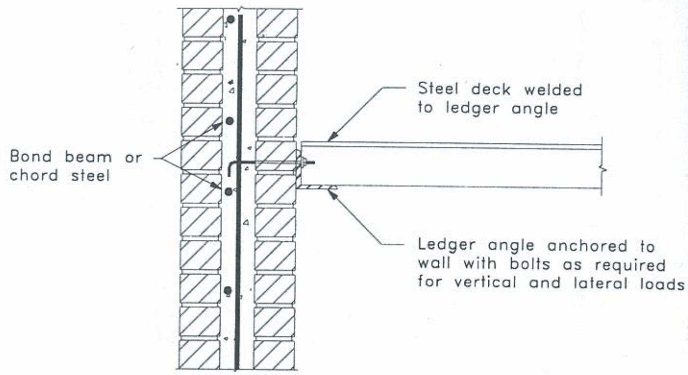


Figure 75. Masonry to steel connection detail.

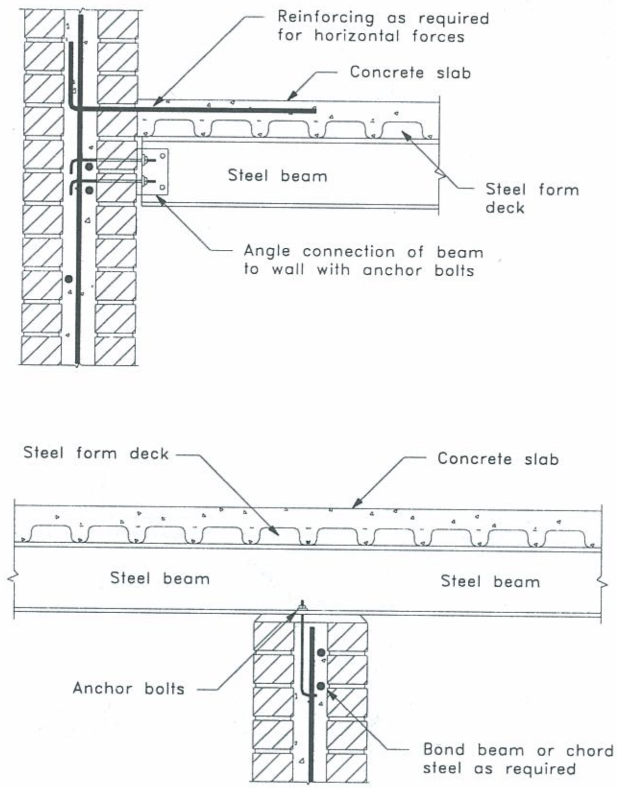


Figure 76. Steel to masonry connection details.

SECTION 6
SUPPLEMENTAL INFORMATION

6.1 GLOSSARY OF TERMS RELATING TO BRICK MASONRY

Absorption. The amount of water, by weight, absorbed by a brick when totally immersed in water, expressed as a percentage of its dry weight. Absorption is determined by immersion in cold water for 24 hours or in boiling water for 5 hours.

Absorption Rate, Initial Rate of Absorption, or Rate of Suction. The amount of water, by weight, absorbed by a brick in one minute when held in $^1/_8$ inch [3.2 mm] of water, expressed in grams or ounces per square inch of the lower surface.

Admixtures. Materials added to mortar or grout as water repellent or to retard or speed up setting.

ASTM. American Society for Testing and Materials.

Backup. That part of a masonry wall, which is behind the exterior facing. Backup masonry may be finished facing. Specifications should clearly indicate types and locations of backup materials.

Bat. A piece of brick, usually $^1/_2$ brick or less.

Batter. Recessing or sloping a wall or buttress back in successive courses; the opposite of corbelling.

Bearing Partition or Wall. A wall supporting a vertical load in addition to its own weight.

Bed Joint. The horizontal layer or mortar on or in which a masonry unit is laid.

Bond. (Adhesion) The tensile strength between brick and mortar or grout.

Bond. (Pattern) The arrangement of units to provide strength and stability.

English Cross (or Dutch) **Bond**. Alternate courses of stretchers and headers offset 2 inches [50.8 mm] by corners starting with 2 inch [50.8 mm], 4 inch [102 mm], 6 inch [152 mm], 4 inch [102 mm], 2 inch [50.8 mm] etc. Stretchers continue from 2 inch [50.8 mm] and 6 inch [152 mm] corners, headers continue from 4 inches [102 mm] corners. Used with standard size brick.

Flemish Bond. Courses of alternating stretcher, header, stretcher, header, with headers centered over stretchers in alternate courses. Used with standard size brick.

Running Bond. Brick laid so that the vertical mortar joints are centered over the brick below. Sometimes called center bond or half bond.

Stack Bond. Vertical mortar joints in continuous vertical alignment. Also called plumb joint bond, straight stack, jack bond and jack on jack.

Third Bond and Quarter Bond. Brick laid so that the wall corners show alternate headers and stretchers, and the stretchers continue from this point and the vertical mortar joints occur over about one-third or one-fourth the length of the stretchers.

Bond Beam. The course or courses of masonry units reinforced with longitudinal horizontal bars and designed to take the longitudinal flexural and tensile forces that may be induced in a masonry wall. It typically occurs at floor and roof levels.

Breaking Joints. The arrangement of masonry units to prevent continuous vertical joints in adjacent courses.

Brick:

Building Brick. A solid masonry unit made from clay or shale, dried and burned or fired at about 1850° F [1010° C], usually without special attention to color with smooth, textured, or designed surfaces.

Cored Brick. Bricks which have holes (any shape) through them. When the gross cross-sectional area of cores does not exceed 25% of the cross-sectional area of a brick, it is classified by ASTM as a solid unit.

Dry-Pressed Brick. Brick produced by a process of forming relatively dry clay in molds at pressures of from 550 to 1500 psi [3,800 to 10,300 kPa].

Face Brick. A solid masonry unit made from a scientific and controlled mixture of natural clays or shales only, and specially processed during manufacture to produce desired colors and textures, regularity in shape and uniformity, and made in modular sizes. Also called Facing Brick.

Fire Brick. Brick made from refractory clay which resist heat shock and high temperatures; not cored.

Paving Brick. A brick which is not cored and normally used for horizontal applications such as pedestrian or vehicular traffic.

Salmon Brick. A relatively soft underburned brick, so called because of its color.

Sewer Brick. A brick, low in absorption, high in compressive strength, which resists action of sewer gas and abrasion.

Soft-Mud Brick. Brick produced by a process of forming relatively wet clay in molds. When the inside of the molds are sanded, the product is called "sand-struck" or "sand-mold" brick. When molds are wetted with water to prevent sticking of the clay, the brick are called "water-struck."

Stiff-Mud Brick. Brick produced by extruding a plastic clay through a die.

Buttering. Placing mortar on brick with a trowel before laying.

Cavity Wall. Not permitted by codes in areas subject to earthquake probability. A wall built of masonry units constructed to provide a continuous center air space, usually 2 inches (50.8 mm) wide, within the wall. The wythes, or tiers, of masonry are tied together with rigid non-corrosive metal ties at specified intervals.

Cementitious Materials. Portland cement, plastic or waterproof cement, masonry cement, and lime. Low alkali portland cement is recommended to reduce efflorescence.

Ceramic Veneer. A type of architectural terra cotta, characterized by larger face dimensions and thinner sections ranging from about $1^1/_8$ inch [28.8 mm] to $2^1/_2$ inches [63.5 mm] in thickness.

Adhesion type. Ceramic slabs approximately $1^1/_8$ inch [28.8 mm] in thickness (C.C.R. Title 24, 1 inch [25.4 mm] maximum), held in place by the adhesion of the mortar to the ceramic veneer and to the backing wall. No metal anchors are required.

Anchored Type. Ceramic slabs approximately 2 to $2^1/_2$ inches [50.8 to 63.5 mm] in thickness held in place by wire anchors and a grout space in which vertical pencil rods are placed. The slabs are anchored to the rods, which in turn, are anchored to the backing wall.

Chase. A continuous recess built into a wall to receive pipes, ducts or any other continuous mechanical or electrical element.

Closer. The last brick laid in a course. A closer may be a whole unit or one that is shorter and usually appears in the field (between the ends) of the wall.

C/B Ratio. See **Saturation Coefficient**.

Collar Joint. The interior longitudinal vertical cavity in a brick masonry wall. In Reinforced Grouted Brick Masonry, it is the grout space.

Column. A vertical isolated structural compression member whose ratio of unsupported length to least width is greater than four and the horizontal dimension does not exceed three times the thickness.

Coping. The material or units used to form a cap or finish on top of a wall, pier or pilaster to protect the masonry below from penetration of water from the above.

Corbel. A shelf or ledge formed by projecting successive courses of masonry out from the face of the wall or an offset in vertical alignment as in an offset chimney.

Course. One of the continuous horizontal layers of masonry bonded together with mortar, forming the masonry structure.

Cross Joint. See Head Joint.

Curtain Wall. A non-bearing wall built between columns or piers for the enclosure of a building.

Cut Sides or Faces. The cut sides or cut faces of clay brick are the two sides which have been cut by wires as the clay column is extruded from the brick making machine. The distance between the cutting wires determines the thickness of the bricks. The other four sides are the die-skin sides, which may be smooth or textured.

Dwarf Wall. A wall or partition that does not extend to the ceiling.

Efflorescence. A whitish powder, sometimes found on the surface of masonry or concrete due to deposits of water-soluble salts that travel to the surface and crystallize.

Exfoliation. Scaling or flaking of the surfaces.

Facing. Any material forming an integral part of a wall, used as a finishing surface contrasted with veneer which is not integral with the wall.

Faced Wall. A wall in which the facing and backing are bonded with masonry, or otherwise tied, as to exert common action under load.

Fat Mortar. A sticky mortar that adheres to the trowel.

Fire Clay. A finely ground refractory clay used mortar to resist fireplace heat. Fire clay is predominately used in residential construction.

Fire Wall. Any wall which subdivides a building to resist the spread of fire, starting at the foundation and extending continuously through all stories to, or above, the roof.

Flaking. See **Exfoliation**.

Flow of Mortar. Measured on a steel circular plate upon which mortar has been placed into a small, truncated cone, the cone removed, and the plate "dropped" 25 times in 15 seconds. The "flow" is the increase in diameter of the mortar pat over the original diameter of the base of the cone. (Laboratory work).

Mortar for masonry should have a flow between 135% and 145% at time of use.

Flow After Suction. First the "flow" is determined, and then the mortar is placed in an apparatus whereby a 2 inch [50.8 mm] vacuum is pulled on the mortar through a perforated dish for one minute. Then the mortar is again measured for "flow." Flow after suction is expressed as a percentage of original flow (Laboratory work). Good mortar should have not less than 85% flow after suction at time of use.

Frog. A depression in the bed surface of a brick. The name of the brick manufacturer is often stamped into the frog.

Furrowing. The practice of striking a "V"-shaped trough in a bed of mortar.

Grade SW (Severe Weather). Brick intended for use where a high degree of resistance to frost action is desired and the exposure is such that the brick may be frozen when permeated with water.

Grade MW (Moderate Weather). Brick intended for use where exposed to temperatures below freezing but unlikely to be permeated with water, or where a moderate and somewhat non-uniform degree of resistance to frost action is permissible.

Grade NW (Negligible Weather). Brick intended for use as back-up or interior masonry.

Grout. A fluid mixture of portland cement, sand and water, with or without the addition of pea gravel or lime, poured into place in masonry cells or cavities.

Harsh Mortar. A mortar that, due to an improper measure of materials, is difficult to spread.

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

Header. A Masonry unit laid flat with its greatest dimension at right angle to the face of the wall. Generally used to tie two wythes of masonry together. Not permitted in Reinforced Grouted Brick Masonry Construction.

High Lift Grout. See pages 47 to 50.

Hog (in a wall). A wall that is hogged is one in which, for any given height at both ends, there is a different number of courses, necessitating adjustment of mortar bed joints or the use of supplementary height units in the field.

Hollow Unit. Masonry units in which the voids (cells or cores) exceed 25% of the gross cross-sectional area of the unit.

Hydrated Lime. Quicklime to which, in manufacture, only sufficient water is added to stabilize the lime's chemical affinity for water, and is used in powdered form. Water added to hydrated lime makes lime putty.

Jointer. A metal tool used to finish the surfaces of mortar joints, producing concave, flat, V, beaded, or any other tooled joint.

Jointing. The process of finishing mortar joints with a jointer, trowel, or any other suitable device.

Kiln Run. Clay bricks from a single kiln which have not been sorted or graded for size or color variation.

Lead. The section of a wall built up and racked back on successive courses at the corners ends or middle of a wall. The masons line is attached to the leads and the wall then built to the line between the leads.

Lean Mortar. A mortar that is low in cementitious material.

Lime Putty. Quicklime to which sufficient water has been added to make a plastic paste ready for use in mortar.

Line-Pin Holes. Small surface voids in the mortar left by pins that hold bricklayers coursing lines.

Lintel. A horizontal structural member placed over an opening in a wall to carry the superimposed weight above.

Modular Masonry Unit. A masonry unit with nominal dimensions based on a 4 inch [102 mm] module.

Mortar. A plastic mixture of cementitious material, sand and water to bind bricks together and prevent water penetration.

Nominal Dimension. The actual dimension of the unit plus the thickness of a mortar joint.

Panel Wall. A non-bearing wall in skeleton frame multi-story construction, built between columns or piers, and wholly supported at each story.

Parapet Wall. That part of an exterior wall entirely above the roof line.

Parging. The process of applying a coat of cement mortar to the back of the facing material or the face of the backing material.

Party Wall. A common wall separating adjoining buildings or separating adjacent units in the same building.

Pea Gravel. Mineral aggregate, well graded, with not more than 5% passing the No. 8 sieve and with 100% passing the $^3/_8$ inch [9.5 mm] sieve.

Pick and Dip. A method of laying brick by which the bricklayer simultaneously picks up a brick with one hand and, with his other hand, captures enough mortar on the trowel from the mortar board to lay one brick. Usually done only on special ornamental design work.

Pier. A vertical isolated structural compression member whose ratio of unsupported length to least width is four or less. A pier whose width is less than three times its thickness must be designed and constructed as required for a column.

Pilaster. A portion of a wall that projects on one or both sides of a wall and acts as a vertical beam, column or both.

Plasticizing Agent. Material which will cause mortar or grout to become plastic or workable. Lime is not only the best plasticizing material for mortar or grout but is also a cementitious material.

Pointing. Filling mortar into a joint or hole in masonry after the masonry unit is laid.

Processed Lime. Pulverized quicklime.

Quarter Bond. See **Third Bond**.

Racking. A method of building the end of a wall by stepping back each course, so that it can be built onto and against other brick courses without toothing; also used in corner leads.

Raggle. A grove or channel in a mortar joint, or in a special masonry unit (raggle block), to receive roofing, flashing or other material which is to be sealed into the masonry.

Rate of Absorption. See **Absorption Rate**.

Reinforced Grouted Brick Masonry. (RGBM). Reinforced brick masonry in which the continuous longitudinal vertical or collar joint is filled with reinforcing steel and grout. No masonry headers are used in this type of construction.

Retempering. The process of adding water and remixing mortar after original mixing, to the proper consistency for use.

Rowlock. A brick laid on its face edge, laid in the wall with its long dimension at right angle to the wall face. Frequently spelled rolok.

Sailor. A brick laid on its end so that its greatest dimension is vertical and the bedding edge is exposed.

Saturation Coefficient. A measure of the resistance to freezing and thawing of a brick. It is the ratio of the weight of water absorbed by cold immersion in 24 hours to the weight absorbed by immersion in boiling water in 5 hours. Not required in mild climates, such as the Southwest United States, except in high mountainous areas subject to frost action.

Shiner. A brick laid on its edge so that its greatest dimension is horizontal and parallel to the face and its wider side exposed.

Shoved Joints. Produced by placing a brick on a mortar bed and then immediately shoving it a fraction of an inch horizontally against the mortar in the head joints to effect solid, tight joints.

Slushed Joints. Collar joints filled by "throwing" mortar in with the edge of a trowel after units are laid.

Soap. A brick manufactured or cut on the job so that its width is less than standard. Usually supplied by manufacturer in $^1/_2$ standard width.

Soldier. A brick laid on its end so that its greatest dimension is vertical and the face edge is exposed.

Solid Masonry Unit. Bricks are established in ASTM specifications as solid when core holes or hollow spaces do not exceed 25% of the bearing area of the brick. Tests have shown that such cored bricks are as strong as non-cored bricks made in the same way from the same clay. The steel coring pins around which the clay passes while being extruded from the brick machine, tightens or squeezes the surrounding clay, hence such cored bricks are usually of equal compressive strength to those not cored.

Spall. A small fragment removed from the face of a masonry unit.

Spandrel Wall. That part of a panel wall above the top of a window in one story and below the sill of the window in the story above.

Story Pole. A rod or stick marked by the bricklayer showing each course and used to measure vertical heights during the construction of the wall. Story poles are usually mounted at the ends of walls for quality control purposes.

Stretcher. A masonry unit laid with its longest dimension horizontal and parallel to the face of the wall, with its face edge exposed.

Stringing Mortar. The procedure of spreading enough mortar on the bed joint to lay several masonry units.

Struck Joint. Any mortar joint finished smooth, typically with a trowel.

Temper. See **Retempering**.

Tier. Each vertical 4 inches [102 mm] or single unit section or thickness of masonry.

Tolerance. The dimensional imperfection allowed in a masonry unit as determined by ASTM Standards.

Tooling. Compressing and shaping the face of a mortar joint with a special tool other than a trowel.

Toothing. The temporary ending of a wall wherein the units in alternate courses project in vertical alignment. Should be used in structural walls only when approved by Architect or Engineer.

Tuck Pointing. The filling in with fresh mortar of cut-out or defective mortar joints in masonry.

Veneer. Exposed masonry attached to backing but not structurally bonded to the backing to sustain loads. Only lateral loads should be imposed on veneer.

Vitrified. That characteristic of a clay product resulting when the temperature in the kiln is sufficient to fuse all the grains and close all the pores of the clay, making the mass impervious.

Voids. Empty spaces, such as in mortar, grout or masonry units.

Water Retentivity. An important property of a mortar that prevents its rapid loss of water into masonry units. (See text on **Flow after Suction and Water Retentivity**.)

Wire Cut Sides. See **Cut Sides**.

Wythe or Withe. See **Tier**.

6.2 04211 GUIDE SPECIFICATIONS FOR HOLLOW CLAY MASONRY

NOTE: These guide specifications follow Uniform Building Code and *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS-402-99) requirements. Some modifications may be required for special code or project requirements. These Guide Specifications are based on Architect's Guide to Masonry, published by the Arizona Masonry Guild. More information can be obtained by contacting AMG at (602/265-5999).

SCOPE OF WORK

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: Hollow clay masonry units with vertical cells to receive reinforcement and grout.

B. Products Installed But Not Furnished Under This Section:
1. Section 04100 - Mortar and Grout
2. Section 04150 - Masonry Accessories
3. Section 04160 - Masonry Reinforcement
4. Section 04300 - Granular Insulation Wall Fill

C. Related Sections:
1. Section 04210 - Brick Masonry
2. Section 04220 - Concrete Masonry Units
3. Section 04270 - Glass Masonry Units
4. Section 04510 - Cleaning and Pointing
5. Section 05120 - Structural Steel
6. Section 05500 - Metal Fabrications
7. Section 07600 - Flashing and Sheet Metal

NOTES TO SPECIFIER

Section 04211 – Hollow Clay Masonry – includes the specification requirements that are specific to 'jumbo' brick laid up using methods similar to concrete masonry unit construction.

Although this section is identified as a 'specific unit type', it is not necessary to use Section 04210, Brick Masonry, with this section.

The listing of this section should be edited to include only those items applicable on the project.

The listing of this section should be edited to include only those items applicable on the project. Refer to local practices for standard exclusions stated in masonry subcontractor's bid.

Section 05120 typically includes anchorage devices for the structural steel framing to the brick wall.

Section 05500 typically includes anchor bolts for attachment of wood and steel items built into the brick wall.

Section 07600 includes reglets and flashings built into the brick wall for roof and waterproofing systems.

GUIDE SPECIFICATIONS

8. Section 07900 - Sealants
9. Section 08100 - Metal Doors and Frames
10. Section 15050 - Basic Mechanical Materials and Methods
11. Section 16050 - Basic Electrical Materials and Methods

1.02 REFERENCES

A. ASTM:
   1. C 67-99a - Standard Methods of Sampling and Testing Brick and Structural Clay Tile.
   2. C 652-00 - Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale).

B. Uniform Building Code Standards (UBC-1997):
   1. 21-1 - Section 21.107 Hollow Brick

C. Masonry Institute of America
   1. *Reinforced Grouted Brick Masonry,* (2000).

D. Mason Contractors Association of America
   1. *Standard Practice for Bracing Masonry Walls Under Construction,* (1999).

1.03 DEFINITIONS

1.04 SUBMITTALS

A. Submit [product data, detail drawings and] samples to the Architect for approval prior to constructing job-site mock-ups, delivering materials to the site or commencing the work in this section [in accordance with Section 01300].
   1. Brick Samples: Provide ___ samples of brick units, [stretcher units], to be used on the project

NOTES TO SPECIFIER

Section 07900 includes sealants used at control joints.

Section 08100 includes hollow metal frames for doors and windows built into the brick wall.

Section 15050 includes sleeves and plumbing pipes to allow for the installation of plumbing and HVAC systems.

Section 16050 includes sleeves and electrical conduits built into the brick wall to allow for installation of electrical systems.

Edit the listing of Standards to only those applicable to the specific project

Definitions contained in the applicable code or standards should not be restated here. If there are any unique definitions applicable to the project, they should be stated here.

The use of product data and detail drawing submittals should be limited to projects with complex shapes, sizes or special product requirements. Coordinate this section with Section 01300 – Submittals.

Select what is required for the project. Typically, samples satisfy the architectural requirements.

Samples should include extreme ranges in texture and color so that all parties are aware of material variations. These variations

GUIDE SPECIFICATIONS

showing range of texture and/or color variations of the exposed surfaces for units. Units provided to the project shall match these samples.

2. Mortar Color Samples: In accordance with Section 04100.

B. Submit hot weather protection procedures prior to start of work in accordance with Section 01300 if project will require the implementation of such procedures.

1.05 QUALITY ASSURANCE

A. Regulatory Requirements: Masonry materials and workmanship shall meet the requirements of the building codes which are applicable to the jurisdiction in which the project is located.

C. Mock-Ups: Prior to start of work, construct a sample panel from the approved materials, containing each different kind or color of brick units, approximately 4'-0" x 4'-0" (1.2 m x 1.2 m), [or as required to illustrate wall design under the direction of the Architect]. The sample wall shall provide a standard of workmanship, bond, thickness and tooling of joints. Construct successive sample panels until the standard is approved. When accepted, sample wall shall be the standard of comparison for the remainder of the masonry work. Upon completion of the project, remove the sample wall from the site and dispose in a legal manner.

1.06 DELIVERY, STORAGE AND HANDLING

A. Packing and Shipping: Transport and handle masonry units in such a manner as to prevent chipping and breakage.

B. Storage and Protection: Locate storage piles, pallets, stacks or bins to avoid or protect material from heavy or unnecessary traffic.

NOTES TO SPECIFIER

are inherent in the product and are desirable by most users.

Mortar should be specified in Section 04100.

Requirements for hot weather masonry construction can be found in Section 1.8 D of *Specification for Masonry Structures* (ACI 530.1-99/ASCE6-99/TMS 602-99). The designer may reference this Standard in lieu of hot weather submittal.

All parties should understand the difference between a sample panel and a mock-up. A sample panel is a small wall section, typically 4 feet square (1.2 m^2). A mock-up is normally larger and contains interface components, such as doors and windows, to depict the wall *and* connected hardware. Sample panels are recommended for all projects. The architect must provide an inspection of the sample panel or mock-up by an individual who has the authority to make the approval. Mock-ups or sample panels that use a portion of the 'in-place' masonry are discouraged since rejection of these walls will delay the work. Typical projects may require one or two sample wall reconstructions. Sample panels should not be partially approved and excessive building of sample panels is costly and inefficient.

GUIDE SPECIFICATIONS

1.07 PROJECT/SITE CONDITIONS

A. Cold Weather Requirements:
   1. Fully protect brick units against freezing by a weather-tight covering which shall also prevent accumulation of ice.
   2. When necessary to remove frost or excessive moisture, heat units to a temperature not over 120° F (49° C).
   3. Do not lay brick units when the temperature of the surrounding atmosphere is below 40° F (4.4° C) or is likely to fall below 40° F (4.4° C) in the 24 hour period after laying, unless adequate protection is provided.

B. Hot Weather Requirements:
   1. When the ambient air temperature exceeds 100° F (38° C), or when the ambient air temperature exceeds 90° F (32° C) and the wind velocity is greater than 8 mph (12.9 km/h), the masonry contractor shall implement hot weather protection procedures as submitted to the Architect.
   2. Do not spread mortar beds more than 4'-0" (1.2 m) ahead of placing brick units.
   3. Place brick units within one minute of spreading mortar.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Brick masonry unit as manufactured by the following manufacturers are acceptable
   1.______________________________.
   2.______________________________.
   3.______________________________.
   4.______________________________.

B. Substitution of Manufacturers: In accordance with Prior

NOTES TO SPECIFIER

Omit this section if climate at project site does not warrant cold weather considerations.

Heating of masonry units would be necessary only in severe weather areas. For more information see *Hot & Cold Weather Masonry Construction* published by the Masonry Industry Council (1999).

Requirements for hot weather masonry construction can be found in Section 1.8 D of *Specification for Masonry Structures* (ACI 530.1-99/ASCE6-99/TMS 602-99).

Insert names, addresses and telephone numbers of acceptable manufacturers. For assistance, contact the local masonry promotion and technical support institute. Where a local agent represents the manufacturer, it is desirable to include the agent's name, address and telephone number immediately after the manufacturer's name and insert the words "Locally represented by".

GUIDE SPECIFICATIONS

Approval requirements of Section 00100 - Instructions to Bidders.

2.02 MATERIALS

A. General Requirements for Hollow Brick:
   1. Surface of units shall be clean and free from dirt when laid in walls.
   2. Units not complying with [ASTM/UBC] Standards shall not be laid in the wall where exposed to view.

B. Hollow Clay Masonry Units:

   1. ASTM C 652, Grade [SW, MW], Type [HBX. HBS, HBA, HBB], Class [H40V, H60V].

NOTES TO SPECIFIER

Chipped corners and edges of brick probably cause more distress between the Builder and Owner than any other single item. It is important for all parties involved to understand that material standards allow for a certain amount of material imperfection.

Both ASTM and UBC Standards are included in this specification. The two Standards are similar, however, they differ on the methods used to specify Type. It is more common for the specifier to use ASTM.

Specifier must select GRADE, TYPE and CLASS.

GRADE

Grade SW is for Hollow Brick intended for use where a high and uniform degree of resistance to frost action and disintegration by weathering is desired and the exposure is such that the hollow brick may be frozen when permeated with water. Reference may be made to the Weathering Index figure contained in ASTM C 216 to help determine brick grade.

Grade MW is for Hollow Brick intended for use where a moderate and somewhat nonuniform degree of resistance to frost action is permissible or where there are unlikely to be permeated with water when exposed to temperature below freezing. Usually specified as "Grade SW or MW" to allow the SW grade as well as the MW Grade.

TYPE

Type HBX applies to Hollow Brick for general use in exposed exterior and interior masonry walls and partitions and for use where a high degree of mechanical perfection, narrow color range and minimum permissible variation on size is desired.

Type HBS applies to Hollow Brick suitable for general use in exposed exterior and interior masonry and partitions where a wider variation in size is permitted or desired than is specified for

GUIDE SPECIFICATIONS

2. UBC Std. 21-1, Grade [SW, MW], Type [H40V, H60V].
3. The variations in color and texture shall not exceed those of the samples approved by the Architect.
4. Unit Features:
   a. Texture:__________________________.
   b. Color:____________________________

5. Size of Brick Units: Provide the following standard nominal unit sizes and other sizes as indicated on the drawings:
   a. ___" x ___" x ___"
   b. ___" x ___" x ___"
   c. ___" x ___" x ___"

NOTES TO SPECIFIER

Type HBX.

Type HBA applies to Hollow Brick manufactured and selected to produce characteristic architectural effects resulting from non-uniformity in size, color and texture of the individual units.

Type HBB applies to Hollow Brick for general use in masonry walls and partitions where color and texture are not a consideration and a greater variation in size is permitted than is specified for Type HBX.

If no type is specified, then Type HBS will be furnished.

CLASS

Class H40V is specified for hollow brick with void areas greater than 25%, but not greater than 40% of cross sectional area.

Class H60V is specified for hollow brick with void areas greater than 40%, but not greater than 60% of cross sectional area.

If no class is specified, then Class H40V will be furnished.

Note that additional requirements for shell thickness and coring limitations apply to each class of hollow brick. Consult ASTM C 652.

Note that UBC Standard 21-1 uses a different "type" system.

Specify the desired features of the brick units. Individual manufacturers should be contacted regarding the availability of textures and colors.

Texture names or numbers are typically proprietary to a particular manufacturer. In some cases, specifying a particular manufacturer's product name would be appropriate.

The natural available clay dictates colors and aggregate colors. If colored mortar is required, verify that it is specified in Section 04100. Individual manufacturers should be contacted regarding the availability of colors.

List the sizes of common units required for the project under this section. Consult manufacturer's catalogs for drawings and descriptions. Sizes should be clearly stated as width x height x length. If a particular unit has a name (e.g. Norman), include with unit size. Be aware that different manufacturers may have different sizes for brick of the same name.

GUIDE SPECIFICATIONS

6. Special Shaped Units: Provide as required by the design of the structure in color and texture to match standard units.

7. Accessory Units: Provide units as required for window sills and jambs, doors, control joints, bond beams, lintels and other locations as indicated on drawings with a minimum of brick cutting.

2.02 ACCESSORIES

A. Precast Concrete Lintels: [______________] type, [____x____] inch size, [________] psi strength at 28 days as manufactured by [____________________].
B. Control Joint, Strap Anchors, Wall Ties, Dovetail Anchors, Through-Wall Flashings, Weep Holes, Cavity Vents: See Section 04150.
C. Horizontal and Vertical Reinforcement: See Section 04160.
D. Nailing Strips: See Section 06100.
E. Sheet Metal Flashings: See Section 07600.
F. Steel Lintels: As indicated or scheduled on structural drawings.

PART 3 EXECUTION

3.01 PREPARATION

A. Protection: Protect sills, ledges, offsets and other projections from dropping of mortar and grout.

3.02 ERECTION

A. General Requirements for Brick Walls:

1. Lay units in uniform and true courses, level and plumb to height indicated on drawings.
2. Adjusting Units:
   a. Units shall be adjusted to be level, plumb and straightened into final position in the wall

NOTES TO SPECIFIER

It is important that the Specifier verifies that special units shown on the drawings are available (i.e. solid units without cores to cap a planter wall if no special cap is shown). If the types of units can be specified, include a listing.

Drawings should carefully detail the types of accessory units required.

This is an example only. Verify with Structural Engineer. If special finishes are required, specify.

Verify that steel lintels are scheduled or indicated. In some cases, expensive masonry lintels are assumed to be required if steel lintels are not indicated.

Double faced walls constructed with hollow clay units will typically have a 'good' and a 'bad' face due to the allowable size tolerances of the units.

GUIDE SPECIFICATIONS

while the mortar is still soft and plastic enough to ensure a good bond.

b. Avoid over-plumbing and pounding of the corners and jambs to fit stretcher units after they are set in position.

c. If the position of the unit is shifted after the mortar has stiffened, or bond is broken or cracks are formed, re-lay unit in new mortar.

4. Bearings on Walls: Provide 3 courses of solid units or grouted hollow masonry units below steel bearing plates or beams bearing on walls. Extend bearings each side of contact with load as required to properly transfer loads into the wall.
5. Openings: Provide openings in masonry walls where required or indicated. Steel lintels to be provided unless otherwise noted.
6. Weep Holes: If required, shall be provided in the head joints of the first course and be at a maximum of 24 inches (610 mm) on center.
7. Cutting of masonry: When required, exposed hollow clay masonry units shall be cut with a power driven diamond disc or carborundum blade saw. When using "wet" cutting methods, clean water shall be used on exposed units.

B. Wetting of Units:

1. Brick having initial rate of absorption, (I.R.A. or suction), as determined in accordance with ASTM C 67 in excess of 30 g/min-30in^2 shall be wetted sufficiently so that the rate of absorption when laid does not exceed this amount.
2. Methods of Wetting: As to ensure that each unit is nearly saturated, surface dry when laid.

C. Bonding:

1. Bond pattern shall be ________________ as indicated on the drawings.

-or-

NOTES TO SPECIFIER

This item is an example of requirements included in the engineering design of a project. Verify with Structural Engineer.

Wherever possible, full masonry units should be used in the building design and construction. The use of full units avoids material staining associated with the cutting procedure and it is also more economical.

Brick units may be wetted immediately before they are laid but it is preferable to wet the brick thoroughly 3 to 24 hours prior to installation in the wall. A rough, but effective, jobsite test to determine if the brick should be wetted prior to laying is to draw a circle around a quarter with a wax pencil on the flat side of a brick. Using a medicine dropper, apply 20 drops of water within the circle. If the water is completely absorbed by the brick in less than $1^1/_2$ minutes, then the brick should be wetted.

If special bonding, such as stacked bond, is to be used throughout the project, it should be specified in this section. If regular running bond is to be used throughout the project, use the second option for C.1. If different bonding is desired at different locations, specify the bonding for the particular locations. Preferably provide an inset detail or note on the drawings

GUIDE SPECIFICATIONS

1. Bond pattern shall be regular running bond unless indicated otherwise on the drawings.
2. Bond shall be plumb throughout face of wall in exposed masonry.

D. Bearing Wall Intersections:
1. Intersecting brick bearing walls shall not be tied together in a masonry bond, except at corners.
2. One wall shall terminate at the face of the other wall with a control joint at the intersection.
3. Tie the intersecting wall together with a metal tie bar, $^1/_4$" x $1^1/_4$" x 2'-4" (6.4 mm x 31.2 mm x 711 mm) long with a 2" (50.4 mm) right angle bend at each end of bar, spaced vertically at 2'-0" (610 mm) on center.
4. The bends at the ends of tie bars shall be embedded in grouted cells.
5. Rake out the vertical mortar joint between the intersecting walls to a depth of $^3/_4$" (19.1 mm) after the mortar has stiffened.
6. Provide caulking of control joint as specified in Section 07900.

E. Non-Bearing Wall Intersections:
1. Tie non-bearing walls together with strips of metal lath or galvanized $^1/_4$" (6.4 mm) mesh hardware cloth placed across the joint between the 2 walls placed in alternate horizontal brick courses.
2. Rake out the vertical joint between the intersecting walls to a depth of $^3/_4$" (19.1 mm) after the mortar has stiffened.
3. Provide caulking of control joint as specified in Section 07900.

F. Joining of Work:
1. Where fresh masonry joins partially set masonry

NOTES TO SPECIFIER

indicating the total number of courses in a given height, story panel, module, etc., which will enable the mason to provide for more uniformity of joints and a more aesthetically pleasing wall.

If regular running bond is to be consistently used throughout the project, use this option and delete the first option of item C.1.

This section is an example only and should be reviewed by the Structural Engineer.

This section is an example only and should be reviewed by the Structural Engineer.

GUIDE SPECIFICATIONS

the exposed surface of the set masonry shall be cleaned and lightly wetted so as to obtain the best possible bond.

2. Remove loose brick and mortar.
3. Stop-off a horizontal run of masonry by racking back $^1/_2$ brick length in each course and, if grout is used, stopping the grout 4 inches (102 mm) back of the rack.
4. Toothing will not be permitted, except upon written approval of the Architect.

G. Mortar Joints:

1. Exposed vertical and horizontal joints shall be ____________ as indicated on the drawings.

-or-

1. Exposed vertical and horizontal joints shall be tooled when mortar is "thumbprint" hard with a round or other approved jointer, slightly larger than the width of the joints to produce a dense, slightly concave surface which is well bonded to the brick at edges.
2. Trowel point or tool exterior joints below grade.
3. Unexposed joints above grade shall be struck flush.
4. Joints shall be straight, clean and a uniform [$^3/_8$", $^1/_2$"] (9.5 mm, 12.7 mm) thickness on exposed wall face.
5. Solidly fill joints from the face of the unit to the depth of the face shell, except where specified otherwise.
6. Full bedding to be provided for the first course on the foundation and wherever maximum strength is

NOTES TO SPECIFIER

If special joint finishes (e.g. struck, flush, weathered, raked) are to be used throughout the project, they should be specified in this section. If different treatments will be used in different locations, specify in this section. Joints must consider the effect of weathering. If concave tooled joints are used consistently throughout the project, delete this item and use the second option for G.1.

If concave tooled joints are to be used consistently throughout the project, use this item and delete the first option for G.1. Concave tooled joints are recommended for best weather resistant performance.

This item is applicable when a $^3/_8$" or $^1/_2$" (9.5 mm or 12.7 mm) mortar joint is desired and used consistently throughout the project. Select the appropriate joint thickness. If different mortar joint thicknesses are to be used, delete this paragraph and specify the joint thicknesses within the specification sections for the different types of units. If a different thickness is to be used consistently throughout the project, edit this section accordingly.

The term 'solid fill' and 'full' when applied to mortaring of hollow unit head joints means full trough the thickness of the face shell only.

When structural requirements call for a completely filled solid wall, namely, where no voids in hollow unit construction that might normally occur at face shell mortared head joints, it is recommen-

GUIDE SPECIFICATIONS

required.

7. Butter vertical head joints well and shove these joints tight so that the mortar bonds well to both units.
8. Full coverage to be provided on face shells and webs surrounding cells to be filled.
9. Bee-holes or other open joints shall be filled and tooled with mortar while mortar is still fresh.
10. Joints to be tuck pointed shall be raked back at least $^1/_2$ inch (12.7 mm) and wetted prior to pointing. Pointing of mortar joints upon completion of work shall be in accordance with Section 04510.

H. Control Joints:

1. Provide control joints at locations indicated, as detailed.
2. Control joint materials shall be held back from finished surface as required to allow for caulking and back-up materials.

I. Horizontal Joint Reinforcement:

1. Place horizontal joint reinforcement every 16 inches (406 mm) vertically throughout wall construction.
2. Provide reinforcement in second bed joint above and below openings which extends 2'-0" (610 mm) beyond each side of opening.
3. Lap joint reinforcement a minimum of 6 inches (152 mm) at splices.
4. Cut and bend reinforcement at corners.
5. Provide #4 bar minimum in bond beam (required for Seismic Zones 2, 3 and 4, Seismic Performance Categories C, D and E).

NOTES TO SPECIFIER

ded that the designer consider open-end hollow masonry units that will allow grout to completely fill the voids. The practice of completely mortaring the ends of hollow masonry units is costly, impractical and not recommended.

Drawings must indicate control joint location and spacing. Joints should be carefully detailed. Structural Engineer should verify spacing and location of joints. Control joints are typically required for walls that exceed 40 feet (10.2 m) in length. In long lengths of walls, joints are typically required at least every 30 feet (7.7 m). Additional information on control and expansion joints is available from BIA Technical Notes 18A.

Preformed rubber or plastic control joints, which finish flush with the surface of the wall, are not recommended since they cannot be caulked.

Verify the requirements for each project. If horizontal joint reinforcement is not used, this section should be deleted. This section is representative of typical requirements and should be verified by the Structural Engineer.

GUIDE SPECIFICATIONS

J. Vertical Reinforcement and Bond Beam Reinforcement:
1. Place in accordance with requirements of drawings.
2. Vertical Reinforcement: Provide continuous reinforcement full height of wall at wall ends, corners, intersections, jambs of openings and each side of control joints. Vertical reinforcement shall match and lap dowels which are at top of foundation walls and precast concrete beams.
3. Bond Beams: Provide horizontal reinforcement of 2 bars in minimum 8 inch (203 mm) deep grouted continuous bond beam at roof and elevated floor lines.
4. Parapets: Provide horizontal reinforcement of 1 bar in minimum 8 inch (203 mm) deep grouted continuous bond beam at top of parapets.
5. Bond Beam and Parapet Reinforcement at Vertical Control Joints: Place bars continuous through control joint and wrap mastic tape around bars for 18 inches (457 mm) each side of control joint.
6. Bond Beam and Parapet Reinforcement at Corners and Wall Intersections: Provide bent bars to match reinforcement at corners and wall intersections.
7. Lap splices in reinforcement not less than 40 bar diameters for Grade 40 bars; 48 bar diameters for Grade 60 bars.
8. Use wire spacers to position reinforcing steel in center of grout at center of wall [as indicated on the drawings] as required by code.

K. Grouting:
1. Reinforcing steel is to be in place and inspected before grouting starts.
2. Vertical cells to be filled shall have vertical alignment to maintain a continuous cell area.
3. Keep cell to be grouted free from mortar.
4. Fill cells solidly with grout in lifts not to exceed 5'-0" (1.3 m) unless clean-outs are provided.

NOTES TO SPECIFIER

Verify the requirements for each project. This section is representative of typical requirements and should be verified by the Structural Engineer.

This section should be reviewed with the building code that applies to the project. The stated requirements for grouting are contained in the 1997 Uniform Building Code and *Specifications for Masonry Structures* (ACI 530.1-99/ASCE 6-99/TMS 602-99)

GUIDE SPECIFICATIONS

5. Grout may be poured by hand bucket, concrete hopper or through a grout pump.
6. Do not wet down grout space prior to pouring of grout.
7. Stop pours $1^1/_2$ inches (38.1 mm) below the top of the cell to form a key at pour points.
8. Grout shall be consolidated during placing before loss of plasticity in a manner to fill the grout space. Grout pours greater than 12 inches (305 mm) shall be reconsolidated by mechanical vibration to minimize voids due to water loss. Grout pours 12 inches (305 mm) or less in height shall be mechanically vibrated, or puddled.
9. Grout barrier below bond beams shall be continuous wire lath or other approved material.
10. Grout beams over openings and bond beams in a continuous operation.
11. Solidly grout in place bolts, anchors and other items within wall construction.
12. Fully grout jambs and head of metal door frames connected to masonry. Filling of frames shall be done as each 2'-0" (610 mm) of masonry is laid.
13. Use extreme care to prevent any grout or mortar from staining the face of the masonry.
14. Immediately remove grout or mortar which is visible on the face of masonry.

L. Provisions for Other Trades and Built-in Items:
1. Build in items required and indicated, including; but not limited to, anchors, flashings, sleeves, frames, structural steel, loose lintels, anchor bolts, and miscellaneous iron.
2. Enclosures for pipes, stacks, ducts and conduits: Construct slots, chases, cavities, and similar spaces as required.

M. Tolerances: In accordance with *Specification for Masonry Structures* (ACI 530.1-99/ASCE 6-99/TMS 602-99).

NOTES TO SPECIFIER

Edit this section as required for the project. Add any special built-in items such as waterstops that are not universally considered normal to a project.

GUIDE SPECIFICATIONS

3.03 ADJUSTING

A. Patching: If approved by the Architect, patching of exposed masonry walls shall be done at the conclusion of the general work and shall conform as closely as possible to similar surrounding or adjoining work.

3.04 CLEANING

A. Daily Cleaning: Masonry which will exposed to view at the completion of the project shall be cleaned with stiff fiber brushes until the wall is free of dropped or spattered mortar.

B. See Section 04510 for cleaning and pointing upon completion of work.

3.05 PROTECTION

A. Furnish temporary protection for exposed masonry corners subject to injury.

B. Carefully cover tops of walls left incomplete at the conclusion of the day's work with tarpaulins or other approved covering.

C. In hot and dry weather, protect masonry against too rapid drying.

D. Protect finished work against freezing for a period of not less than 24 hours by means of enclosures, artificial heat, or such other protective methods as may be required.

E. Bracing and Safety Requirements:
   1. Bracing:
      a. Masonry walls over 8'-0" (2.4 m) in height shall be adequately braced to prevent over

NOTES TO SPECIFIER

This section applies to exposed hollow clay masonry units. If unexposed, less stringent criteria (or perhaps no patching) would apply. Patching may not be an acceptable option for certain types of exposed work.

This application of section is intended for inclement weather conditions.

This section may be omitted if climate at site does not warrant hot weather considerations. Guidelines for hot weather construction are contained in *Hot & Cold Weather Masonry Construction* published by the Masonry Industry Council (1999).

This section may be omitted if climate at site does not warrant cold weather considerations. Guidelines for cold weather construction are contained in *Hot & Cold Weather Masonry Construction* published by the Masonry Industry Council (1999).

The requirements of this section are found in OSHA Requirements for Concrete and Masonry Construction Safety Standard, Section 1926.706.
Additional guidelines for wall bracing requirements are contained

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turning and to prevent collapse unless the wall is adequately supported so that it will not overturn or collapse.

   b. The bracing shall remain in place until permanent supporting elements of the structure are in place.

2. Safety: A limited access zone shall be established and shall conform to the following:
   a. The limited access zone shall be established prior to the start of construction of the wall.
   b. The limited access zone shall be equal to the height of the wall to be constructed plus 4'-0" (1.2 m), and shall run the entire length of the wall.
   c. The limited access zone shall be established on the side of the wall which will be unscaffolded.
   d. The limited access zone shall be restricted to entry by employees actively engaged in constructing the wall. No other employees shall be permitted to enter the zone.
   e. The limited access zone shall remain in place until the wall is adequately supported to prevent overturning and to prevent collapse unless the height of wall is over 8'-0" (2.4 m), in which case, the limited access zone shall remain in place until the wall is braced as specified herein.

END OF SECTION

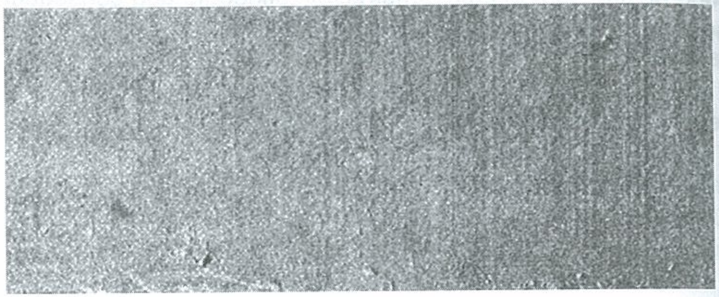
NOTES TO SPECIFIER

in *Standard Practice for Bracing Masonry Walls Under Construction,* published by Mason Contractors Association of America (1999). Most agreements for masonry construction may assign temporary shoring and bracing to the General Contractor since he/she controls the construction schedule and consequently the duration of shoring and bracing.

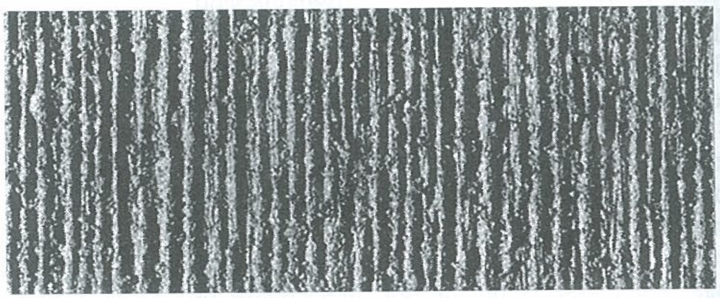
END OF SECTION

6.3 CLAY BUILDING BRICK TEXTURES

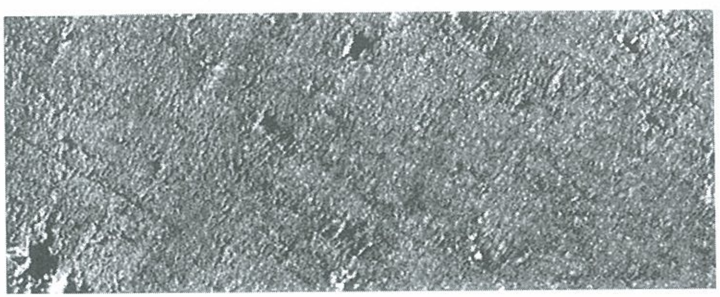
The following names have been adopted by the brick manufacturers of Southern California as standards to aid in the design of better masonry. All textures are shown actual size.



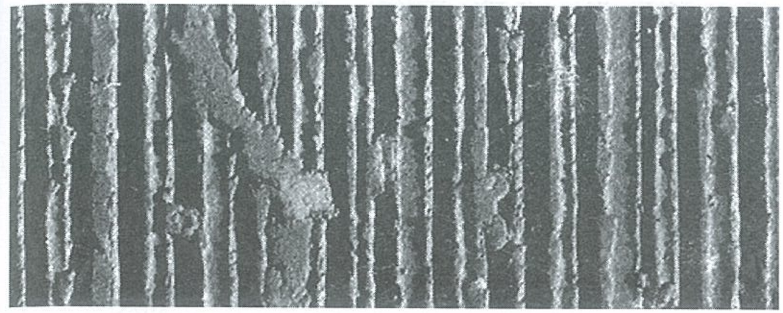
SMOOTH



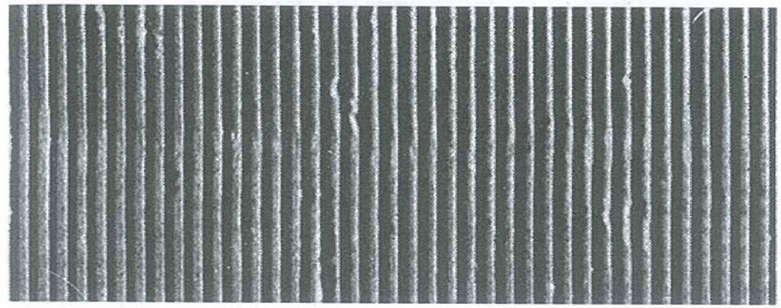
SCRATCH



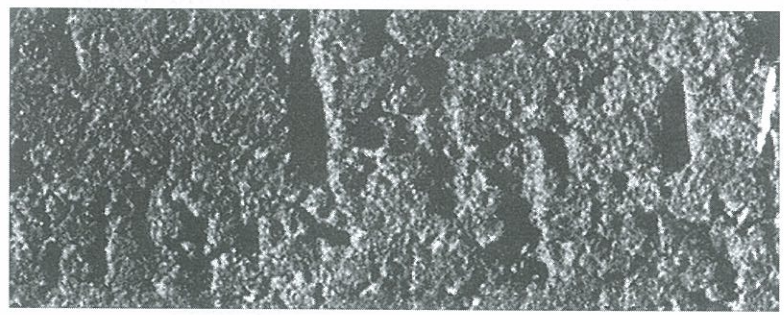
WIRECUT



RUG



COMB



ANTIQUE

BARK

STONEFACE

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