Structural Masonry Special Inspection

A program designed to assist in preparing for a career in the field of masonry inspection

Prepared for
MIH Masonry Institute of Hawaii
www.masonryhawaii.com
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This program is the continuation in a long series of masonry training developed and presented by:

Masonry Institute of America
Torrance, California
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International Code Council (ICC)
www.iccsafe.org

This program was developed by:

John Chrysler, P.E.
Executive Director
Masonry Institute of America

The Beginning

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The Beginning

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The Beginning

In this presentation the Masonry Standards Joint Committee's (MSJC) *Building Code Requirements for Masonry Structures* (TMS 402/ACI 530/ASCE 5) is hereafter referred to as the MSJC Code, and the MSJC's *Specification for Masonry Structures* (TMS 602/ACI 530.1/ASCE 6) is hereafter referred to as the MSJC Specification.

The Beginning

This presentation was prepared in keeping with current information and practice for the present state of the art of masonry design and construction.

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The Beginning

This presentation is based on the book, *Reinforced Concrete Masonry Construction Inspectors Handbook, 8th Edition © 2013*, published by the Masonry Institute of America and the International Code Council.

Program Contents

Program Contents

PROGRAM CONTENTS

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Program Contents

Structural Masonry Special Inspection Test References

International Building Code, 2012 Edition

Structural Masonry Special Inspection Test References

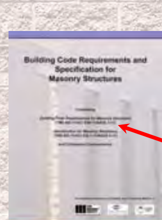
Structural Masonry Special Inspection Test References

International Building Code, 2012 Edition

Building Code Requirements for Masonry Structures
(TMS 402-11/ACI 530-11/ASCE 5-11)

Specification for Masonry Structures
(TMS 602-11/ACI 530.1-11/ASCE 6-11)

Structural Masonry Special Inspection Test References



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Structural Masonry Special Inspection Test References

International Building Code, 2012 Edition

Building Code Requirements for Masonry Structures (TMS 402-11/ACI 530-11/ASCE 5-11)

Specification for Masonry Structures (TMS 602-11/ACI 530.1-11/ASCE 6-11)

Reinforced Concrete Masonry Construction Inspectors Handbook, 8th Edition

Structural Masonry Special Inspection Test References

Structural Masonry Special Inspection Test References

International Building Code, 2012 Edition

Building Code Requirements for Masonry Structures (TMS 402-11/ACI 530-11/ASCE 5-11)

Specification for Masonry Structures (TMS 602-11/ACI 530.1-11/ASCE 6-11)

Reinforced Concrete Masonry Construction Inspectors Handbook, 8th Edition

ICC Model Program for Special Inspection

Structural Masonry Special Inspection Test References

Structural Masonry Special Inspection Test References

International Building Code, 2012 Edition

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ICC Model Program for Special Inspection

ICC ASTM Standards as referenced in the 2009 IBC

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The Beginning

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- Specification for Masonry Structures *(TMS 602-11/ACI 530.1-11/ASCE 6-11)*
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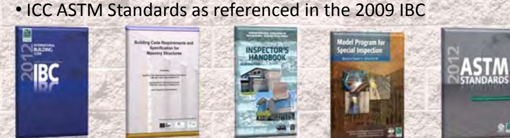
- ICC Model Program for Special Inspection
- ICC ASTM Standards as referenced in the 2009 IBC



The Beginning

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		2002
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CHAPTER 1
INTRODUCTION

1.1 GENERAL

This manual has been developed to provide the inspector with information and to serve as a general guide for **reinforced hollow unit concrete masonry construction.**

Reinforced hollow unit concrete masonry construction uses concrete blocks (also called concrete masonry units, or CMU for short) with steel reinforcement embedded in grout or mortar so that the separate materials act together to form a single effective structural system.

Introduction

Introduction

This publication has been prepared to assist masonry construction inspectors with the information needed to do a thorough professional job.

In order to understand a material and system, it is necessary to know its terminology. The first section of this book includes terms and definitions used in reinforced concrete masonry construction and Chapter 14 contains a more detailed glossary.

Since a construction project cannot begin until the proper materials are selected, materials are discussed first.

Introduction

The Materials Section is followed by Quality Control, Sampling and Testing, describing the necessary sampling and testing of masonry to assure that the materials used are in keeping with the prescribed standards and specifications.

Inspection of the actual construction follows, which specifically deals with code concerns and inspection requirements of reinforced concrete masonry.

The handbook’s last sections are on typical concrete masonry shapes, names and functions, glossary of terms and general information that relate to concrete masonry.

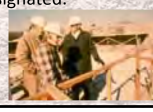
Introduction

This edition incorporates *Building Code Requirements for Masonry Structures* (TMS 402-11/ACI 530-11/ASCE 5-11) and *Specification for Masonry Structures* (TMS 602-11/ACI 530.1-11/ASCE 6-11), also known as the *Masonry Standards Joint Committee Code* referred to as the *MSJC Code* and *MSJC Specification*; and the *2012 International Building Code (IBC)*. Also contained are metric (SI) references in parenthesis after the English dimension or quantity.

Introduction

1.2 THE INSPECTOR

A vital part of any construction project is good inspection. The inspector's job is, therefore, quite important. Knowledge and good judgment are essential in obtaining the results required by the approved plans and specifications. The materials furnished on the project represent the manufacturers' efforts to supply products meeting applicable industry standards and project specifications. It is the inspector's responsibility to verify that these products are properly used to construct the project as designated.



Introduction

1.3 RESPONSIBILITIES AND DUTIES

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

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

Introduction

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

The inspector should note how many masons and laborers are on the project each day and verify the delivery of materials. Any special conditions, problems or adverse events that may take place should also be noted.

If there are project conferences, a list of attendees, what was accomplished and the decisions made should be noted.

Complete and thorough project records are invaluable and the inspector is key to maintaining the records.

Introduction

1.4 EQUIPMENT AND MATERIALS FOR THE INSPECTOR

As with all competent and skilled professionals and craft workers, construction inspectors must have tools and materials to properly carry out their inspection duties and responsibilities. Maintenance of project documents, codes and reports can be accomplished by using a laptop computer. The following is a minimum suggested list that an inspector should have:

1. A current set of plans and specifications, including all change orders.
2. Applicable building codes and standards to which the project was designed and the requirements of the governing jurisdiction.
3. A list of architects, engineers, contractors and subcontractors; names, addresses, telephone numbers and responsible person(s) in charge.
4. A laptop computer, notebook or log to keep daily notes.
5. Necessary forms for filing reports with required agencies.

Introduction

6. Pens, pencils and erasers.
7. Folding rule or retractable tape and long steel tape.
8. String to check straightness and plumbness.
9. Keel (lumber crayon) in 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.
15. Watch.

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

Introduction

1.5 TERMINOLOGY

Masonry, like all materials, systems and specialties, has its own vocabulary. Knowing and understanding the terms is a basic requirement.

IBC Section 2102 provides selected terms relative to masonry materials, design and construction with which masonry inspectors should be familiar. Also included are other definitions listed in *MSJC Code and MSJC Specification* as noted. Additional definitions are contained in the Glossary, Chapter 14.

Introduction

IBC Section 2102, except as noted

2102 DEFINITIONS

2102.1 General. The following terms are defined in Chapter 2:

AAC MASONRY. Masonry made of autoclaved aerated concrete (AAC) units, manufactured without internal reinforcement and bonded together using thin- or thick-bed mortar.

ACCEPTABLE, ACCEPTED. Acceptable to or accepted by the Architect/Engineer (*MSJC Specification*).

ADOBE CONSTRUCTION. Construction in which the exterior load-bearing and nonload-bearing walls and partitions are of unfired clay masonry units, and floors, roofs and interior framing are wholly or partly of wood or other approved materials.

Introduction

Adobe, stabilized. Unfired clay masonry units to which admixtures, such as emulsified asphalt, are added during the manufacturing process to limit the units' water absorption so as to increase their durability.

Adobe, unstabilized. Unfired clay masonry units that do not meet the definition of "Adobe, stabilized."

Introduction

ANCHOR. Metal rod, wire, or strap that secures masonry to its structural support.

Introduction

ANCHOR PULLOUT. Anchor failure defined by the anchor sliding out of the material in which it is embedded without breaking out a substantial portion of the surrounding material. (*MSJC Code*).

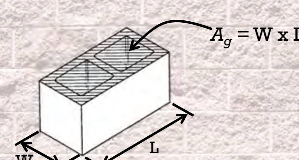
ARCHITECT/ENGINEER. The architect, engineer, architectural firm, engineering firm, or architectural and engineering firm issuing drawings and specifications, or administering the work under project specifications and project drawings, or both (*MSJC Specification*).

ARCHITECTURAL TERRA COTTA. Plain or ornamental hard-burned modified clay units, larger in size than brick, with glazed or unglazed ceramic finish.

Introduction

AREA:

Gross cross-sectional. The area delineated by the out-to-out specified dimensions of masonry in the plane under consideration.



Introduction

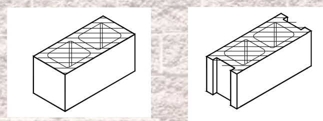
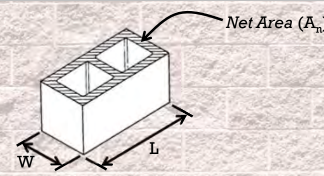


Figure 1.1 Gross cross-sectional area.

Introduction

Net cross-sectional. The area of masonry units, grout and mortar crossed by the plane under consideration based on out-to-out specified dimensions.



Introduction

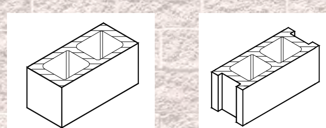


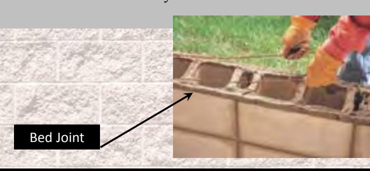
Figure 1.2 Net cross-sectional area.

Introduction

AUTOCLAVED AERATED CONCRETE (AAC). Low density cementitious product of calcium silicate hydrates, whose material specifications are defined in ASTM C1386.

BACKING. Wall or surface to which the veneer is attached. (*MSJC Code*)

BED JOINT. The horizontal layer of mortar on which a masonry unit is laid.



Introduction

BOND BEAM. A horizontal grouted element within masonry in which reinforcement is embedded.

Introduction

BONDED PRESTRESSING TENDON. Prestressing tendon that is encapsulated by prestressing grout in a corrugated duct that is bonded to the surrounding masonry through grouting. (*MSJC Code*)

Introduction

BRICK.

Calcium silicate (sand lime brick). A pressed and subsequently autoclaved unit that consists of sand lime, with or without the inclusion of other materials.

Introduction

BRICK.

Clay or shale. A solid or hollow masonry unit of clay or shale, usually formed into a rectangular prism, then burned or fired in a kiln; brick is a ceramic product.

Introduction

BRICK.

Concrete. A concrete masonry unit from Portland cement, water, and suitable aggregates, with or without the inclusion of other materials.

Introduction

BUILDING OFFICIAL. The officer or other designated authority charged with the administration and enforcement of this code, or a duly authorized representative. (*MSJC Code*)

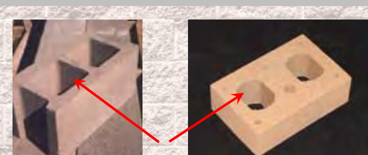
Introduction

CAST STONE. A building stone manufactured from Portland cement concrete precast and used as a trim, veneer or facing on or in buildings or structures.

Introduction

CAVITY WALL. A masonry wall consisting of two or more wythes, at least two of which are separated by a continous air space; air space(s) between wythes may contain insulation; and separated wythes must be connected by wall ties. (*MSJC Code*)

CELL. A void space having a gross cross-sectional area greater than $1^1/_2$ square inches. (967 mm^2).



Introduction

CHIMNEY. A primarily vertical enclosure containing one or more passageways for conveying flue gases to the outside atmosphere.

Introduction

CHIMNEY TYPES.

High-heat appliance type. An approved chimney for removing the products of combustion from fuel-burning, high-heat appliances producing combustion gases in excess of 2,000°F (1093°C) measured at the appliance flue outlet (see IBC Section 2113.11.3).

Low-heat appliance type. An approved chimney for removing the products of combustion from fuel-burning, low-heat appliances producing combustion gases not in excess of 1,000°F (538°C) under normal operating conditions, but capable of producing combustion gases of 1,400°F (760°C) during intermittent forces firing for periods up to 1 hour. Temperatures shall be measured at the appliance flue outlet.

Introduction

Masonry type. A field-constructed chimney of solid masonry units or stones.

Medium-heat appliance type. An approved chimney for removing the products of combustion from fuel-burning, medium-heat appliances producing combustion gases not exceeding 2,000°F (1093°C) measured at the appliance flue outlet (see IBC Section 2113.11.2).

Introduction

CLEANOUT. An opening to the bottom of a grout space of sufficient size and spacing to allow the removal of debris.

Introduction

Figure 1.3 Cleanouts.

Introduction

COLLAR JOINT. Vertical longitudinal space between wythes of masonry or between masonry wythe and backup construction that is permitted to be filled with mortar or grout.

Introduction

COLUMN. An isolated vertical member whose horizontal dimension measured at right angles to its thickness does not exceed 3 times its thickness and whose height is greater than 4 times its thickness. (*MSJC Code*)

Introduction

COMPOSITE ACTION. Transfer of stress between components of a member designed so that in resisting loads, the combined components act together as a single member. (*MSJC Code*)

COMPOSITE MASONRY. Multiwythe masonry members with wythes bonded to produce composite action. (*MSJC Code*)

Introduction

COMPRESSIVE STRENGTH OF MASONRY. Maximum compressive force resisted per unit of net cross-sectional area of masonry, determined by the testing of masonry.

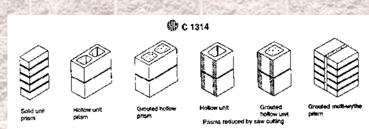


FIG. 1 Masonry Prism Construction

Introduction

CONNECTOR. A mechanical device for securing two or more pieces, parts or members together, including anchors, wall ties and fasteners.

Introduction

CONTRACT DOCUMENTS. Documents establishing the required work, and including in particular, the project drawings and project specifications. (*MSJC Code*)

CONTRACTOR. The person, firm, or corporation with whom the Owner enters into an agreement for construction of the Work. (*MSJC Specification*)

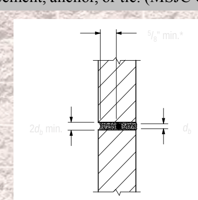
CORBEL. A projection of successive courses from the face of masonry. (*MSJC Code*)

COVER, GROUT. Thickness of grout surrounding the outer surface of embedded reinforcement, anchor, or tie. (*MSJC Code*)

Introduction

COVER, MASONRY. Thickness of masonry units, mortar, and grout surrounding the outer surface of embedded reinforcement, anchor or tie. (*MSJC Code*)

COVER, MORTAR. Thickness of mortar surrounding the outer surface of embedded reinforcement, anchor, or tie. (MSJC Code)



Introduction

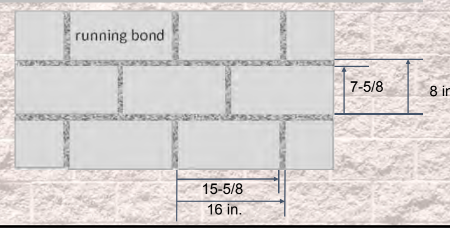
DEPTH. The dimension of a member measured in the plane of a cross section perpendicular to the neutral axis. (*MSJC Code*)

DIAPHRAGM. A roof or floor system designed to transmit lateral forces to shear walls or other lateral-force-resisting elements. (*MSJC Code*)

Introduction

DIMENSIONS.

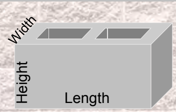
Nominal. The specified dimension plus an allowance for the joints with which the units are to be laid. Nominal dimensions are usually stated in whole numbers. Thickness is given first, followed by height and then length.



Introduction

DIMENSIONS.

Specified. Dimensions specified for the manufacture or construction of a unit, joint element.



Dimensions for CMU:
Width x Height x Length

Nominal Widths - 4", 6", 8", 10", 12"

Specified Dimensions = nominal - 3/8"

Nominal	Specified
6 x 8 x 16	5-$^5/_8$ x 7-$^5/_8$ x 15-$^5/_8$
8 x 8 x 16	7-$^5/_8$ x 7-$^5/_8$ x 15-$^5/_8$
12 x 8 x 16	5-$^5/_8$ x 7-$^5/_8$ x 15-$^5/_8$

Introduction

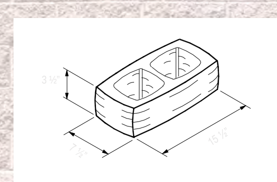
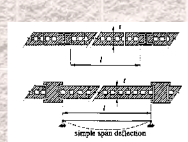


Figure 1.4 Nominal 8" x 4" x 16" (203 mm x 102 mm x 406 mm) slumped concrete block with specified dimensions of 7$^1/_2$" x 3$^1/_2$" x 15$^1/_2$" (190 mm x 89 mm x 394 mm).

Introduction

EFFECTIVE HEIGHT. Clear height of a braced member between lateral supports and used for calculating the slenderness ratio of a member. Effective height for unbraced members shall be calculated. (*MSJC Code*)



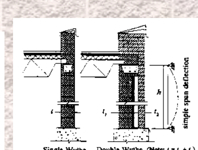


Figure 1—Lateral Support of Concrete Masonry Walls

Introduction

EFFECTIVE PRESTRESS. Stress remaining in prestressing tendons after all losses have occurred. (*MSJC Code*)

FIREPLACE. A hearth and fire chamber or similar prepared place in which a fire may be made and which is built in conjunction with a chimney.

Introduction

FIREPLACE THROAT. The opening between the top of the firebox and the smoke chamber.

FOUNDATION PIER. An isolated vertical foundation member whose horizontal dimension measured at right angles to its thickness does not exceed three times its thickness and whose height is equal to or less than four times its thickness.

Introduction

FIREPLACE THROAT. The opening between the top of the firebox and the smoke chamber.

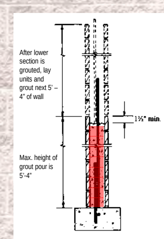
FOUNDATION PIER. An isolated vertical foundation member whose horizontal dimension measured at right angles to its thickness does not exceed three times its thickness and whose height is equal to or less than four times its thickness.

Introduction

GLASS UNIT MASONRY. Masonry composed of glass units bonded by mortar. (MSJC Code)

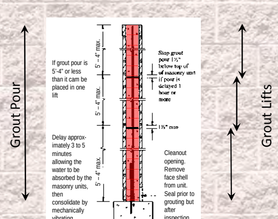
Introduction

GROUT LIFT. An increment of grout height within a total grout pour. A grout pour consists of one or more grout lifts. (*MSJC Specification*)



Introduction

GROUT POUR. The total height of masonry to be grouted prior to erection of additional masonry. A grout pour consists of one or more grout lifts. (*MSJC Specification*)



Introduction

GROUT, SELF-CONSOLIDATING. A highly fluid and stable grout typically with admixtures, that remains homogeneous when placed and does not require puddling or vibration for consolidation. (*MSJC Code*)

Introduction

HEAD JOINT. Vertical mortar joint placed between masonry units within the wythe at the time the masonry units are laid.

Introduction

Figure 1.5 Head Joints and bed joints, shell and web.

Introduction

HEADER (Bonder). A masonry unit that connects two or more adjacent wythes of masonry. (*MSJC Code*)

INSPECTION, CONTINUOUS. The Inspection Agency's full-time observation of work by being present in the area where the work is being performed. (*MSJC Code*)

INSPECTION, PERIODIC. The Inspection Agency's part-time or intermittent observation of work during construction by being present in the area where the work has been or is being performed, and observation upon completion of the work. (*MSJC Code*)

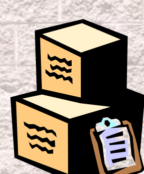
Introduction

LATERALLY RESTRAINED PRESTRESSING TENDON. Prestressing tendon that is not free to move laterally within the cross section of the member. (*MSJC Code*)

LATERALLY UNRESTRAINED PRESTRESSING TENDON. Prestressing tendon that is free to move laterally within the cross section of the member. (*MSJC Code*)

Introduction

LOAD, DEAD. Dead weight supported by a member, as defined by the legally adopted building code. (*MSJC Code*)



Introduction

LOAD, LIVE. Live load specified by the legally adopted building code. (*MSJC Code*)

Introduction

LOAD, SERVICE. Load specified by the legally adopted building code. (*MSJC Code*)

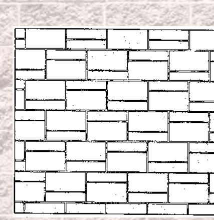
LONGITUDINAL REINFORCEMENT. Reinforcement placed parallel to the longitudinal axis of the member. (*MSJC Code*)

MASONRY. A built-up construction or combination of building units or materials of clay, shale, concrete, glass, gypsum, stone or other approved units bonded together with or without mortar or grout or other accepted methods of joining.

Ashlar masonry. Masonry composed of various sized, rectangular units having sawed, dressed or squared bed surfaces, properly bonded and laid in mortar.

Introduction

Coursed ashlar. Ashlar masonry laid in courses of stone of equal height for each course, although different courses shall be permitted to be of varying height.



Introduction

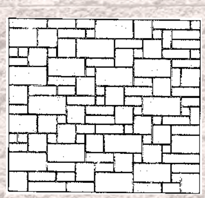
Glass unit masonry. Masonry composed of glass units bonded by mortar.

Introduction

Plain masonry. Masonry in which the tensile resistance of the masonry is taken into consideration and the effects of stresses in reinforcement are neglected.

Introduction

Random ashlar. Ashlar masonry laid in courses of stone set without continuous joints and laid up without drawn patterns. When composed of material cut into modular heights, discontinuous but aligned horizontal joints are discernible.



Introduction

Reinforced masonry. Masonry construction in which reinforcement acting in conjunction with the masonry is used to resist forces.

Solid masonry. Masonry consisting of solid masonry units laid contiguously with the joints between the units filled with mortar.

Unreinforced (plain) masonry. Masonry in which the tensile resistance of masonry is taken into consideration and the resistance of the reinforcing steel, if present, is neglected.

MASONRY BREAKOUT. Anchor failure defined by the separation of a volume of masonry, approximately conical in shape, from the member. (*MSJC Code*)

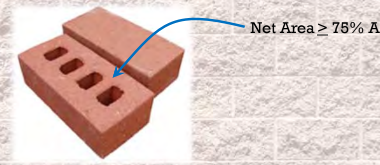
Introduction

MASONRY UNIT. Brick, tile, stone, glass block or concrete block conforming to the requirements specified in Section 2103.

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

Introduction

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

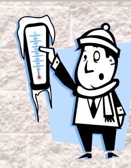


Introduction

Introduction

MEAN DAILY TEMPERATURE. The average daily temperature of temperature extremes predicted by a local weather bureau for the next 24 hours. (*MSJC Specification*)

MINIMUM DAILY TEMPERATURE. The low temperature forecast by a local weather bureau to occur within the next 24 hours. (*MSJC Specification*)



Introduction

MINIMUM/MAXIMUM (not less than.....not more than). Minimum or maximum values given in this Specification are absolute. Do not construe that tolerances allow lowering a minimum or increasing a maximum. (MSJC Specification)

MORTAR. A mixture consisting of cementitious materials, fine aggregates, water, with or without admixtures, that is used to construct unit masonry assemblies.

Introduction

MORTAR, SURFACE-BONDING. A mixture to bond concrete masonry units that contains hydraulic cement, glass fiber reinforcement with or without inorganic fillers or organic modifiers and water.

OTHERWISE REQUIRED. Specified differently in requirements supplemental to this Specification. (*MSJC Specification*)

OWNER. The public body or authority, corporation, association, partnership, or individual for whom the Work is provided. (*MSJC Specification*)

Introduction

PARTITION WALL. An interior wall without structural function. (*MSJC Specification*)

PIER. An isolated vertical member whose horizontal dimension measured at right angles to its thickness is not less than 3 times its thickness nor greater than 6 times its thickness and whose height is less than 5 times its length. (*MSJC Code*)

POST-TENSIONING. Method of prestressing in which prestressing tendon is tensioned after the masonry has been placed. (*MSJC Code*)

Introduction

PRESTRESSED MASONRY. Masonry in which internal stresses have been introduced to counteract potential tensile stresses in masonry resulting from applied loads.

PRESTRESSING GROUT. A cementitious mixture used to encapsulate bonded prestressing tendons. (*MSJC Code*)

PRESTRESSING TENDON. Steel elements such as wire, bar, or strand used to impart prestress to masonry. (*MSJC Code*)

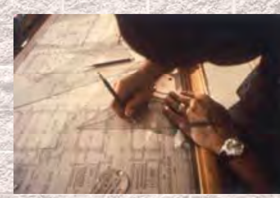
PRETENSIONING. Method of prestressing in which prestressing tendon is tensioned before the transfer of stress into the masonry. (*MSJC Code*)

Introduction

PRISM. An assemblage of masonry units and mortar with or without grout used as a test specimen for determining properties of the masonry.

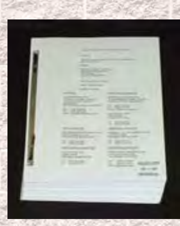
Introduction

PROJECT DRAWINGS. The drawings that, along with the project specifications, complete the descriptive information for constructing the work required by the contract documents. (*MSJC Code*)



Introduction

PROJECT SPECIFICATIONS. The written documents that specify requirements for a project in accordance with the service parameters and other specific criteria established by the owner or the owner's agent. (*MSJC Code*)



Introduction

✔ **QUALITY ASSURANCE.** The administrative and procedural requirements established by the contract documents to assure that constructed masonry is in compliance with the contract documents. (*MSJC Code*)

✔ **REINFORCEMENT.** Nonprestressed steel reinforcement. (*MSJC Code*)

Introduction

RUBBLE MASONRY. Masonry composed of roughly shaped stones.

Coursed rubble. Masonry composed of roughly shaped stones fitting approximately on level beds and well bonded.

Random rubble. Masonry composed of roughly shaped stones laid without regularity of coursing but well bonded and fitted together to form well-divided joints.

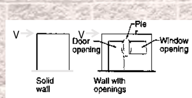
Rough or ordinary rubble. Masonry composed of unsquared field stones laid without regularity of coursing but well bonded.

Introduction

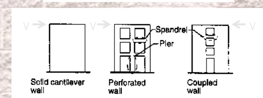
RUNNING BOND. The placement of masonry units such that head joints in successive courses are horizontally offset at least one-quarter the unit length.

Introduction

SHEAR WALL. A wall, bearing or nonbearing, designed to resist lateral forces acting in the plane of the wall (sometimes referred to as a vertical diaphragm). *(MSJC Code)*



(a) Single-Story Shear Walls



(b) Multistory Shear Walls

Introduction

SHEAR WALL.

Detailed plain (unreinforced) AAC masonry. An AAC masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, although provided with minimum reinforcement and connnections. (*MSJC Code*)

Detailed plain (unreinforced) masonry. A masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, although provided with minimum reinforcement and connections. (*MSJC Code*)

Detailed plain masonry shear wall. A masonry shear wall designed to resist lateral forces neglecting stresses in reinforcement, and designed in accordance with Section 2106.1.

Introduction

Intermediate prestressed masonry shear wall. A prestressed masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.

Intermediate reinforced masonry. A masonry shear wall designed to resist lateral forces while considering stresses in reinforcement and to satisfy specific minimum reinforcement and connection requirements. (*MSJC Code*)

Intermediate reinforced masonry shear wall. A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.

Intermediate reinforced prestressed masonry. A prestressed masonry shear wall designed to resist lateral forces while considering stresses in reinforcement and to satisfy specific minimum reinforcement and connection requirements. (*MSJC Code*)

Introduction

Ordinary plain (unreinforced) AAC masonry. An AAC masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, if present. (*MSJC Code*)

Ordinary plain (unreinforced) masonry. A masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, if present. (*MSJC Code*)

Ordinary plain masonry shear wall. A masonry shear wall designed to resist lateral forces neglecting stresses in reinforcement, and designed in accordance with Section 2106.1.

Ordinary plain (unreinforced) prestressed masonry. A prestressed masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, if present. (*MSJC Code*)

Introduction

Ordinary plain prestressed masonry shear wall. A prestressed masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.

Ordinary reinforced AAC masonry. An AAC masonry shear wall designed to resist lateral forces while considering stresses in reinforcement and satisfying prescriptive reinforcement and connection requirements. (*MSJC Code*)

Ordinary reinforced masonry. A masonry shear wall designed to resist lateral forces while considering stresses in reinforcement and satisfying prescriptive reinforcement and connection requirements. (*MSJC Code*)

Ordinary reinforced masonry shear wall. A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.

Introduction

Special prestressed masonry shear wall. A prestressed masonry shear wall designed to resist lateral forces considering stresses in reinforcement and designed in accordance with Section 2106.1 except that only grouted, laterally restrained tendons are used.

Special reinforced masonry. A masonry shear wall designed to resist lateral forces while considering stresses in reinforcement and to satisfy special reinforcement and connection requirements. (*MSJC Code*)

Special reinforced masonry shear wall. A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.

Special reinforced prestressed masonry. A prestressed masonry shear wall designed to resist lateral forces while considering stresses in reinforcement and to satisfy special reinforcement and connection requirements. (*MSJC Code*)

Introduction

SLUMP FLOW. The circular spread of plastic self-consolidating grout, which is evaluated in accordance to ASTM C1611/C1611M. *(MSJC Code)*

Introduction

SPECIFIED. Required by construction documents.

SPECIFIED COMPRESSIVE STRENGTH OF AAC MASONRY, f'_{AAC}. Minimum compressive strength, expressed as force per unit of net cross-sectional area, required of the AAC masonry used in construction by the contract documents, and upon which the project design is based. Whenever the quantity f'_{AAC} is under the radical sign, the square root of numerical value only is intended and the result has units of psi (MPa). (*MSJC Code*)

SPECIFIED COMPRESSIVE STRENGTH OF MASONRY, f'_m. Minimum compressive strength, expressed as force per unit of net cross-sectional area, required of the masonry used in construction by the construction documents, and upon which the project design is based. Whenever the quantity f'_m is under the radical sign, the square root of numerical value only is intended and the result has units of pounds per square inch (psi) (MPa).

Introduction

STACK BOND. The placement of masonry units in a bond pattern is such that head joints in successive courses are vertically aligned. For the purpose of this code, requirements for stack bond shall apply to masonry laid in other than running bond.

Introduction

STIRRUP. Reinforcement used to resist shear in a flexural member. (*MSJC Code*)

STONE MASONRY. Masonry composed of field, quarried, or cast stone units bonded by mortar.

Ashlar stone masonry. Stone masonry composed of rectangular units having sawed, dressed, or squared bed surfaces and bonded by mortar.

Rubble stone masonry. Stone masonry composed of irregular-shaped units bonded by mortar.

Introduction

STRENGTH.

Design strength. Nominal strength multiplied by a strength reduction factor.

Nominal strength. Strength of a member or cross-section calculated in accordance with these provisions before application of any strength reduction factors.

Required strength. Strength of a member or cross section required to resist factored loads.

SUBMIT, SUBMITTED. Submit, submitted to the Architect/Engineer for review. (*MSJC Specification*)

Introduction

TENDON ANCHORAGE. In post-tensioning, a device used to anchor the prestressing tendon to the masonry or concrete member; in pretensioning, a device used to anchor the prestressing tendon during hardening of masonry mortar, grout, prestressing grout, or concrete. (*MSJC Code*)

TENDON COUPLER. A device for connecting two tendon ends, thereby transferring the prestressing force from end to end. (*MSJC Code*)

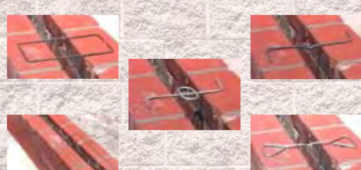
TENDON JACKING FORCE. Temporary force exerted by device that introduces tension into prestressing tendons. (*MSJC Code*)

THIN-BED MORTAR. Mortar for use in construction of AAC unit masonry with joints 0.06 inch (1.5 mm) or less.

Introduction

TIE, LATERAL. Loop of reinforcing bar or wire enclosing longitudinal reinforcement.

TIE, WALL. A connector that connects wythes of masonry walls together.



Introduction

Introduction

TILE, STRUCTURAL CLAY. A hollow masonry unit composed of burned clay, shale, fire clay or mixture thereof, and having parallel cells.

TRANSFER. Act of applying to the masonry member the force in the prestressing tendons. (*MSJC Code*)

Introduction

TRANSVERSE REINFORCEMENT. Reinforcement placed perpendicular to the longitudinal axis of the member. (*MSJC Code*)

UNBONDED PRESTRESSING TENDON. Prestressing tendon that is not bonded to masonry. (*MSJC Code*)

UNREINFORCED (PLAIN) MASONRY. Masonry in which the tensile resistance of masonry is taken into consideration and the resistance of the reinforcing steel, if present, is neglected. (*MSJC Code*)

VENEER, ADHERED. Masonry veneer secured to and supported by the backing through adhesion. (*MSJC Code*)

Introduction

VENEER, ANCHORED. Masonry veneer secured to and supported laterally by the backing through anchors and supported vertically by the foundation or other structural elements. (*MSJC Code*)

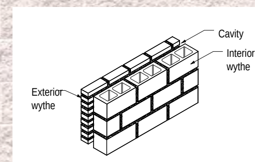
VENEER, MASONRY. A masonry wythe that provides the exterior finish of a wall system and transfers out-of-plane load directly to a backing, but is not considered to add strength or stiffness to the wall system. (*MSJC Code*)

VISUAL STABILITY INDEX (VSI). An index, defined in ASTM C1611/C1611M, that qualitatively indicates the stability of self-consolidating grout. (*MSJC Code*)

WALL. A vertical element with a horizontal length-to-thickness ratio greater than three, used to enclose space.

Introduction

Cavity wall. A wall built of masonry units or of concrete, or a combination of these materials, arranged to provide an air space within the wall, and in which the inner and outer parts of the wall are tied together with metal ties.



Introduction

Introduction

Composite wall. A wall built of a combination of two or more masonry units bonded together, one forming the backup and the other forming the facing elements.

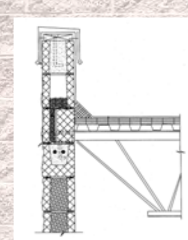
Introduction

Dry-stacked, surface-bonded walls. A wall built of concrete masonry units where the units are stacked dry, without mortar on the bed or head joints, and where both sides of the wall are coated with a surface-bonding mortar.

Masonry-bonded hollow wall. A multi-wythe wall built of masonry units arranged to provide an air space between the wythes and with the wythes bonded together with masonry units.

Introduction

Parapet wall. The part of any wall entirely above the roof line.



Introduction

WALL, LOAD-BEARING. Wall supporting vertical loads greater than 200 lb/lineal ft (2919 N/m) in addition to its own weight. (*MSJC Code*)

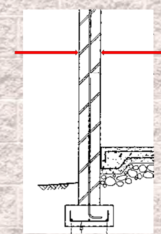
WHEN REQUIRED. Specified in requirements supplemental to this Specification. (*MSJC Specification*)

WIDTH. The dimension of a member measured in the plane of a cross section parallel to the neutral axis. (*MSJC Code*)

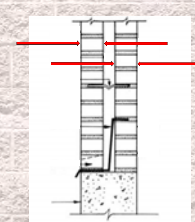
WORK. The furnishing and performance of equipment, services, labor, and materials required by the Contract Documents for the construction of masonry for the project or part of project under consideration. (*MSJC Specification*)

Introduction

WYTHE. Each continuous, vertical section of a wall, one masonry unit in thickness.



One Wythe



Two Wythes

CHAPTER 2
MATERIALS

2.1 GENERAL

All materials used in reinforced concrete masonry construction must conform to standard requirements.

2.2 MATERIAL

Materials used in masonry shall conform to the requirements stated herein. If no requirements are specified in this section for a material, or if no published material standards exist, quality shall be based on generally accepted good practice, subject to the approval of the building official.

Materials

According to 2012 International Building Code, Section 2103, and the *Specification for Masonry Structures* (TMS 602-11/ACI 530.1-11/ASCE 6-11), *Article 1.3*, masonry components shall meet the applicable industry quality Standards.

The primary masonry Standards of the American Concrete Institute (ACI), the ASTM International (ASTM) and the American National Standards Institute (ANSI) referenced in the IBC, MSJC Code and MSJC Specification are listed on the following:

Materials

2.2.1 Concrete Masonry Units

ASTM C55 Standard Specification for Concrete Building Brick.

ASTM C73 Standard Specification for Calcium Silicate Brick (Sand-Lime Brick).

ASTM C90 Standard Specification for Loadbearing Concrete Masonry Units.

ASTM C129 Standard Specification for Nonloadbearing Concrete Masonry Units.

ASTM C140 Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.

ASTM C426 Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units.

ASTM C744 Standard Specification for Prefaced Concrete and Calcium Silicate Masonry Units.

Materials

2.2.2 Clay Masonry Units

ASTM C34 Standard Specification for Structural Clay Load-Bearing Wall Tile.

ASTM C56 Standard Specification for Structural Clay Nonloadbearing Tile.

ASTM C62 Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale).

ASTM C67 Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile.

ASTM C126 Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units.

ASTM C212 Standard Specification for Structural Clay Facing Tile.

ASTM C216 Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale).

Materials

ASTM C652 Standard Specification for Hollow Brick (Hollow Masonry Units Made from Clay or Shale).

ASTM C1072 Standard Test Method for Measurement of Masonry Flexural Bond Strength.

ASTM C1088 Standard Specification for Thin Veneer Brick Units Made from Clay or Shale.

ASTM C1405 Standard Specification for Glazed Brick (Single Fired Brick Units).

ASTM E518 Standard Test Methods for Flexural Bond Strength of Masonry.

2.2.3 AAC Masonry Units

ASTM C1386 Standard Specification for Precast Autoclaved Aerated Concrete (AAC) Wall Construction Units.

Materials

2.2.4 Stone Masonry Units

ASTM C97 Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone.

ASTM C99 Standard Test Method for Modulus of Rupture of Dimension Stone.

ASTM C120 Standard Methods of Flexure Testing of Slate (Breaking Load, Modulus of Rupture, Modulus of Elasticity).

ASTM C121 Standard Test Method for Water Absorption of Slate.

ASTM C170 Standard Test Method for Compressive Strength of Dimension Stone.

ASTM C503 Standard Specification for Marble Dimension Stone (Exterior).

ASTM C568 Standard Specification for Limestone Dimension Stone.

ASTM C615 Standard Specification for Granite Dimension Stone.

ASTM C616 Standard Specification for Quartz-Based Dimension Stone.

ASTM C629 Standard Specification for Slate Dimension Stone.

Materials

2.2.5 Ceramic Tile

ANSI A108.1 Standard Specifications for Installation of Ceramic Tile

ANSI A108.4 Installation of Ceramic Tile with Organic Adhesives or Water Cleanable Tile-Setting Epoxy Adhesive.

ANSI A108.5 Installation of Ceramic Tile with Dry-Set Portland Cement Mortar or Latex-Portland Cement Mortar.

ANSI A108.6 Installation of Ceramic Tile with Chemical Resistant, Water Cleanable Tile-Setting and –Grouting Epoxy.

ANSI A108.8 Installation of Ceramic Tile with Chemical Resistant Furan Resin Mortar and Grout.

ANSI A108.9 Installation of Ceramic Tile with Modified Epoxy Emulsion Mortar/Grout.

ANSI A108.10 Installation of Grout in Tilework.

Materials

ANSI A118.1 Standard Specifications for Dry-Set Portland Cement Mortar.

ANSI A118.3 Standard Specifications for Chemical Resistant, Water Cleanable Tile-Setting and -Grouting Epoxy and Water Cleanable Tile-Setting Epoxy Adhesive.

ANSI A118.4 Standard Specifications for Latex-Portland Cement Mortar.

ANSI A118.5 Standard Specifications for Chemical Resistant Furan Mortars and Grouts for Tile Installation.

ANSI A118.6 Standard Specifications for Standard Cement Grouts for Tile Installation.

ANSI A118.8 Standard Specifications for Modified Epoxy Emulsion Mortar/Grout.

ANSI A136.1 Standard Specifications Organic Adhesives for Installation of Ceramic Tile.

ANSI A 137.1 Standard Specification for Ceramic Tile.

ASTM C482 Standard Test Method for Bond Strength of Ceramic Tile to Portland Cement Paste.

Materials

2.2.6 Glass Unit Masonry

In accordance with Project Specifications.

2.2.6 Mortar

ASTM C91 Standard Specification for Masonry Cement.

ASTM C109/C109M Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens).

ASTM C144 Standard Specification for Aggregate for Masonry Mortar.

ASTM C150 Standard Specification for Portland Cement.

ASTM C270 Standard Specification for Mortar for Unit Masonry.

ASTM C780 Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry.

Materials

ASTM C887 Standard Specification for Packaged, Dry, Combined Materials for Surface Bonding Mortar.

ASTM C946 Standard Practice for Construction of Dry-Stacked, Surface-Bonded walls.

ASTM C1329 Standard Specification for Mortar Cement.

ASTM C1586 Standard Guide for Quality Assurance of Mortars

2.2.8 Grout

ASTM C143/C143M Standard Test Method for Slump of Hydraulic-Cement Concrete.

ASTM C476 Standard Specification for Grout for Masonry.

ASTM C1019 Standard Test Method for Sampling and Testing Grout.

ASTM C1611/C1611M Standard Test Method for Slump Flow of Self-Consolidating Concrete.

Materials

2.2.9 Reinforcement

2.2.9.1 Deformed Reinforcement

ASTM A615/A615M	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
ASTM A706/A706M	Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement.
ASTM A767/A767M	Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement.

Materials

ASTM A775/A775M	Standard Specification for Epoxy-Coated Steel Reinforcing Bars.
ASTM A996/A996M	Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement.

2.2.9.2 Joint Reinforcement

ASTM A884/A884M	Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement.
ASTM A951	Standard Specification for Steel Wire for Masonry Joint Reinforcement.

Materials

2.2.9.3 Other Reinforcement/Metal Products

ASTM A36/A36M	Standard Specification for Carbon Structural Steel
ASTM A82/A82M	Standard Specification for Steel Wire, Plain, for Concrete Reinforcement.
ASTM A123/A123M	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
ASTM A153/A153M	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
ASTM A185/A185M	Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete.
ASTM A240/A240M	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.

Materials

ASTM A307	Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
ASTM A416/A416M	Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete.
ASTM A421/A421M	Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete.
ASTM A480/A480M	Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip.
ASTM A496/A496M	Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement.
ASTM A497/A497M	Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete.
ASTM A510	Standard Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel.

Materials

ASTM A580/A580M	Standard Specification for Stainless Steel Wire.
ASTM A641/A641M	Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire.
ASTM A653/A653M	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
ASTM A666	Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate and Flat Bar.
ASTM A722/A722M	Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete.
ASTM A899	Standard Specification for Steel Wire, Epoxy-Coated.
ASTM A1008/A1008M	Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Baked Hardenable.

Materials

ASTM E488	Standard Test Methods for Strength of Anchors in Concrete Elements.
ASTM F959	Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners [Metric].
AWS D 1.4	Structural Welding Code – Reinforcing Steel.

2.2.10 Other Standards

ACI 117	Standard Specifications for Tolerances for Concrete Construction and Materials (ACI 117-10) and Commentary.
ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus.
ASTM C901	Standard Specification for Prefabricated Masonry Panels.
ASTM C920	Standard Specification for Elastomeric Joint Sealants.
ASTM C1006	Standard Test Method for Splitting Tensile Strength of Masonry Units.

Materials

ASTM C1232	Standard Terminology of Masonry.
ASTM C1314	Standard Test Method for Compressive Strength of Masonry Prisms.
ASTM C1364	Standard Specification for Architectural Cast Stone.
ASTM C1386	Standard Specification for Precast Autoclaved Aerated Concrete (AAC) Wall Construction Units.
ASTM C1532	Standard Practice for Selection, Removal, and Shipment of Manufactured Masonry Units and Masonry Specimens from Existing Construction.
ASTM D994	Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type).
ASTM D1056	Standard Specification for Flexible Cellular Materials - Sponge or Expanded Rubber.
ASTM D1187	Standard Specification for Asphalt-base Emulsions for Use as Protective Coatings for Metal.
ASTM D1227	Standard Specification for Emulsified Asphalt Used as a Protective Coating for Roofing.

Materials

ASTM D2000	Standard Classification System for Rubber Products in Automotive Applications.
ASTM D2287	Standard Specification for Nonrigid Vinyl Chloride Polymer and Copolymer Molding and Extrusion Compounds.
ASTM E72	Standard Test Methods of Conducting Strength Tests of Panels for Building Construction.
ASTM E111	Standard Test Methods for Young's Modulus, Tangent Modulus, and Chord Modulus.
ASTM E119	Standard Test Methods for Fire Tests of Building Construction and Materials.
ASTM E328	Standard Test Methods for Stress Relaxation Tests for Materials and Structures.
ASTM E519	Standard Test Method for Diagonal Tension (Shear) in Masonry Assemblages.

Materials

2.3 CONCRETE MASONRY UNITS

2.3.1 General

The inspector's job site check of concrete masonry units should include a visual inspection. Significant quantities of broken or cracked units should be rejected. Unless specifically noted in the project specifications, minor cracks incidental to usual manufacturing, or minor chipping resulting from normal handling or shipping are not grounds for rejection. Inspection should also verify that colors and texture comply with the approved samples.

As an additional check, the inspector may break a unit, note the proportion of broken aggregate showing on the fractured face, and look for internal evidence of moisture. If no aggregate is broken, the inspector may recheck to be sure that the units have been tested in the laboratory and meet all required specifications. If moisture rings are apparent on the fractured face, the age of the units should be rechecked and the laboratory tests for moisture content should be verified.

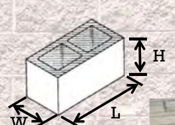
Materials

2.3.2 Dimensions

Concrete masonry units (CMU) are designated by their nominal dimensions, width, height and length (in that order), followed by a brief description, for example: 8" x 4" x 16" (203 mm x 102 mm x 406 mm) split face.

Specified unit dimensions, as defined now in IBC Section 202, MSJC Code Section 1.6, or ASTM C1232, such as 7 $^5/_8$" x 3 $^5/_8$" x 15 $^5/_8$", (194 mm x 92 mm x 397 mm) are generally $^3/_8$" (10 mm) less than the nominal dimensions, which would be 8" x 4" x 16" (203 mm x 102 mm x 406 mm). A specified dimension is equal to the nominal dimension minus the mortar joint thickness. This allows for the typical $^3/_8$" (10 mm) mortar joint used in CMU construction while retaining a modular dimension increment of 4 inches (102 mm). See Figure 2.1.

Materials



Materials

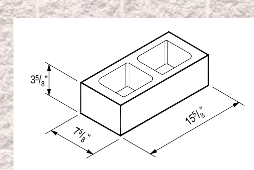


Figure 2.1 Specified dimensions of precision concrete masonry unit.

Materials

Slumped block unit dimensions, illustrated in Figure 2.2, are typically $^{1}/_{2}$" (13 mm) less than the nominal dimensions and may vary depending on the characteristics of the particular units used.

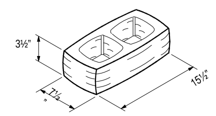


Figure 2.2 Specified dimensions of slumped concrete masonry unit.

Materials

2.3.3 Wide Selection of Units

There is also a large variety of specialty concrete masonry units that have been developed for special purposes. Specialty units have been developed for sound control, energy-efficient use of insulation, rapid placing mortarless block systems, paving blocks, pilaster units, and others. Figure 2.3 shows some of these specialty units.

Materials

Materials

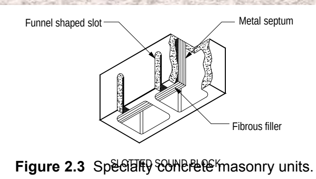


Figure 2.3 Specialty concrete masonry units.

Materials

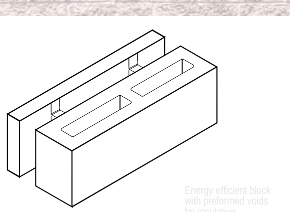


Figure 2.3 Specialty concrete masonry units.

Materials

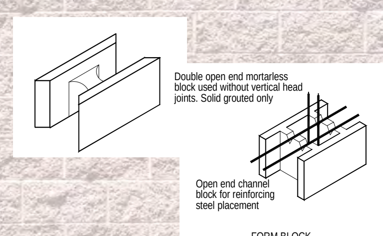


Figure 2.3 Specialty concrete masonry units.

Materials

2.3.4. Component Units

Another type of specialty concrete masonry unit configuration an inspector may encounter is known as a component system. Component systems provide added versatility for the designer and engineer by allowing the wall to be built to any desired thickness. Wall thicknesses usually range from 8 inches (203 mm) to 24 inches (610 mm) in 1 inch (25 mm) increments. See Figure 2.4.

Materials

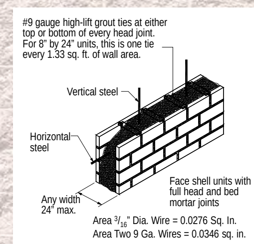


Figure 2.4 Expandable component masonry system.

Materials

This system can be used in retaining walls, subterranean walls, structural building walls, or as forms for concrete walls.

The masonry component units are solid concrete blocks conforming to ASTM C55 with a 2500 psi (17,200 kPa) minimum compressive strength or ASTM C90 with a 1900 psi (13,100 kPa) minimum compressive strength. An example of the individual unit is shown in Figure 2.5.

The components can be assembled with different architectural finishes and colors on each side. They may also be used as permanent forms for poured-in-place concrete.

Materials

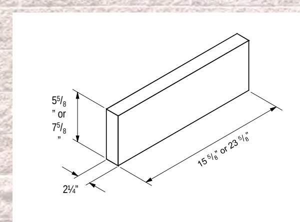


Figure 2.5 Component unit.

Materials

2.3.5 Storing Masonry Units

Care must be taken when storing concrete masonry units on the job site to ensure they are clean and dry when used, as shown in Figure 2.6. Concrete masonry units should not be wetted unless otherwise approved. Wet saw cutting of units is acceptable, even immediately prior to laying the units.

During inclement weather conditions proper storage includes covering the CMU to protect from rain. Subjecting the CMU to rain does not damage the units, but they must be allowed to dry adequately before laying.

Good Rule of Thumb: Determine the difference in shading by splashing a little water on a unit. If the water does not darken the surface of the unit, then the block are too wet to install. It sounds subjective, but a good craftworker knows this limit.

Materials

Figure 2.6 Properly stored masonry units.

Materials

Materials

2.4 CEMENTITIOUS MATERIALS

For masonry units to function effectively in a wall, the units must be bonded together. This bonding is typically achieved with mortar and grout. The adhesion is obtained with the cementitious materials, cement and lime.

Materials

Attempts have been made to increase the economy of block masonry by developing mortarless block systems that can interlock and be laid without mortar. Another approach has been to manufacture the units with very uniform bearing surfaces, often achieved by grinding the edges. The blocks are then laid with very thin high bond mortars.

Materials

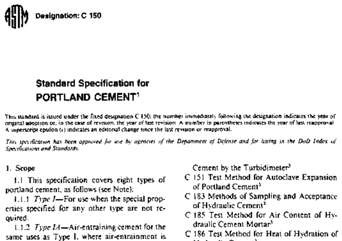
2.4.1 Portland Cement

Portland cement is defined as a hydraulic cement made by finely pulverizing the clinker produced by calcining to incipient fusion a mixture of clay and limestone or similar materials.

Portland cement is the primary bonding agent used to bind together the grains of sand and pea gravel used in mortar and grout.

Materials

Portland cement is required to conform to ASTM C150.



Designation: C 150

Standard Specification for
PORTLAND CEMENT[1]

This standard is issued under the fixed designation C 150; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers eight types of portland cement, as follows (see Note):

1.1.1 *Type I*—For use when the special properties specified for any other type are not required.

1.1.2 *Type IA*—Air-entraining cement for the same uses as Type I, where air-entrainment is desired.

Cement by the Turbidimeter[3]

C 151 Test Method for Autoclave Expansion of Portland Cement[3]

C 183 Methods of Sampling and Acceptance of Hydraulic Cement[3]

C 185 Test Method for Air Content of Hydraulic Cement Mortar[3]

C 186 Test Method for Heat of Hydration of Hydraulic Cement[3]

Materials

Portland cement needs to be properly stored off the ground and covered to prevent absorption of moisture. Sacks with hard lumps should be rejected. Usually Type I or Type II portland cement is used for mortar and grout. In some instances, low alkali portland cement, if available, can be used to reduce the possibility of efflorescence. Type III portland cement may be used in grout when extremely cold temperatures are anticipated. This will accelerate the initial curing process.

Materials

2.4.2 Plastic Cement

In some of the Southwestern areas of the United States, plastic (plasterer's) cement has been inadvisably used in mortar. This is basically Type I portland cement with approximately 12 percent plasticizing agent added.

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 basically 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 code does not recognize plastic cement as a material permitted for use in mortar. The 2012 IBC simply does not provide for the use of plastic cement, since ASTM C1328, *Standard Specification for Plastic (Stucco) Cement* is not recognized in ASTM C270, *Standard Specification for Mortar for Unit Masonry.*

Materials

2.4.3 Mortar Cement

In some parts of the United States, portland cement manufacturers and some masonry material suppliers may package a blend of cement and other proprietary materials and label the product as Mortar Cement. Unlike masonry cement, Mortar Cement is acceptable in all Seismic Design Categories. Mortar Cement msut conform to the requirements of ASTM C1329.

Mortar Cement may be the sole cement product, or it may be combined with Portland Cement when making mortar. See ASTM C270, Table 1 (page 56) for acceptable proportions. Mortar Cement is available in Types M, S, and N.

Materials

This packaged mortar cement conforms to the requirements of ASTM C1329. It can be used for projects or jobs where separate delivery of portland cement and lime is inconvenient.

Materials

2.4.4 Masonry Cement

Masonry cement is a mixture of portland cement, 30% to 60% plasticizer material, and added chemicals. This mixture is based on the requirements contained in ASTM C91 *Standard Specification for Masonry Cement*.

Materials

The standard covers three types of masonry cement for use in mortar. There are Type M, S and N masonry cements that may be used for mortar with or without the addition of more portland cement. The particular types of masonry cements are blended to produce mortar of the same type to conform to ASTM C270 *Standard Specification for Mortar for Unit Masonry.* Masonry cement is not permitted for use in the lateral load resisting system in high seismic design categories.

Materials

2.4.5 Lime

ASTM C270 permits the use of hydrated lime or lime putty in mortar. The use of lime putty is rare. Conveniently packaged hydrated lime that is delivered in sacks is most common when lime is used in mortar.

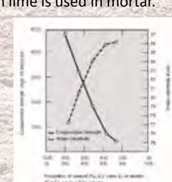


Figure 2.7 Relationship between mortar composition, compressive strength and water retentivity.

Materials

Although ASTM C207 addresses four types of hydrated lime, only Type N and Type S, are typically used in reinforced masonry construction because the other two types (NA and SA) contain more entrained air than is permitted by ASTM C270. Types N and S hydrated lime are high calcium and dolomitic, high magnesium, hydrates. Type S, special hydrated lime, is different from Type N, normal hydrated lime, principally by its ability to develop high early plasticity, higher water retentivity, and by its limitation on unhydrated oxide content.

Lime use in mortar improves the plasticity of the mix, improves water retention for longer board life, improves the watertightness of the mortar joint, increases the bond between the mortar and the masonry unit, and contributes to the cementitious materials in the mortar mix.

Materials

Increasing the portland cement content and reducing the lime content increases the compressive strength of mortar, but it also increases shrinkage, reduces workability, lowers water retentivity and causes rapid stiffening.

Conversely, increasing the lime improves workability, water retentivity and adhesion bond; it does not add to the compressive strength of mortar but it does enhance the water resistance of the mortar. Figure 2.7 shows the relationship between various proportions of cement and lime and mortar strength and water retentivity.

Materials

ASTM C476, Table 1, *Conventional Grout Proportions by Volume,* for masonry construction, allows up to one-tenth part by volume hydrated lime. This allowance is believed to be a carry-over from when mortar was used as a slushing grout material. Although lime is not generally used in grout, it may occasionally be used as a lubricant to initially charge grout pumps.

Materials

2.5 AGGREGATES FOR MORTAR AND GROUT

Aggregates for mortar and grout are composed of sand and coarse aggregate conforming to the gradation requirements of ASTM C404. This coarse aggregate is commonly referred to as "pea gravel".

Materials

Aggregates should be stored in a level, dry, clean place from which they can be measured into the mixer with minimum handling and kept free from contamination by harmful substances.

Aggregates should be delivered to the jobsite pregraded with the gradation certified by the supplier. The inspector need only check the certificate and observe the aggregate for consistent gradations. Field tests will need to be made when required by the project specifications. Field tests are generally sieve analysis tests.

Materials

2.6 REINFORCING STEEL

2.6.1 General

At the jobsite, reinforcing steel must be protected from accidental kinking or bending. It must also be kept free of dirt, mud, oil or other foreign matter detrimental to bond. Light surface rust or light mill scale is not detrimental to bond provided the unit weight (after the specimen has been cleaned) still meets minimum ASTM weight and height of deformation requirements.

Materials

Reinforcing steel must be placed as detailed on the plans and in the specifications. If, for any reason, the reinforcement cannot be placed as designed, the architect and/or engineer should be notified prior to construction.

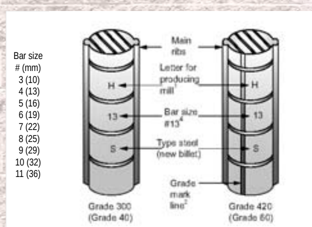
Materials

The inspector must check the reinforcing bars to assure that they are the grade and size specified. Figure 2.8 shows the markings for identification of reinforcing bars.

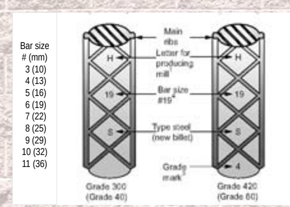
Table 2-1 and Table 2-2 provide information on the properties of reinforcing bars.

Materials

Current designation of reinforcing steel is by 'soft metric', that is, the size of reinforcement did not change from the inch designation (#3, #4, #5…..) and the metric designation (#10, #13, #16……..) correlates to the inch size designation.



Materials



1. Bar identification marks may also be oriented to read horizontally (at 90° to those illustrated above).
2. Grade mark lines must be continued at least five deformation spaces.
3. Grade mark numbers may be placed within separate consecutive deformation spaces to read vertically or horizontally.
4. #13 = $^1/_2$" bar and #19 = $^3/_4$" bar.

Note: Grade 520 (75) steel also available for masonry.
Bar size markings are given in metric which is indicated on reinforcement supplied for masonry use.

Figure 2.8 Identification marks, line system of grade marks.

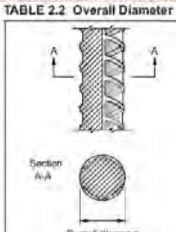
Materials

TABLE 2.1 Properties of ASTM A615/A615M for Steel Reinforcing Bars

Bar Designation No.[A]	Nominal Weight, lb/ft [Nominal Mass, kg/m]	Nominal Dimensions[B]			Deformation Requirements, in. (mm)		
		Diameter, in. [mm]	Cross-Sectional Area, in.^{2} [mm^2]	Perimeter, in. [mm]	Maximum Average Spacing	Minimum Average Height	Maximum Gap (Chord of 12.5% of Nominal Perimeter)
3 [10]	0.376 [0.560]	0.375 [9.5]	0.11 [71]	1.178 [29.9]	0.262 [6.7]	0.015 [0.38]	0.143 [3.6]
4 [13]	0.668 [0.994]	0.500 [12.7]	0.20 [129]	1.571 [39.9]	0.350 [8.9]	0.020 [0.51]	0.191 [4.9]
5 [16]	1.043 [1.552]	0.625 [15.9]	0.31 [199]	1.963 [49.9]	0.437 [11.1]	0.028 [0.71]	0.239 [6.1]
6 [19]	1.502 [2.235]	0.750 [19.1]	0.44 [284]	2.356 [59.8]	0.525 [13.3]	0.038 [0.97]	0.286 [7.3]
7 [22]	2.044 [3.042]	0.875 [22.2]	0.60 [387]	2.749 [69.8]	0.612 [15.5]	0.044 [1.12]	0.334 [8.5]
8 [25]	2.670 [3.973]	1.000 [25.4]	0.79 [510]	3.142 [79.8]	0.700 [17.8]	0.050 [1.27]	0.383 [9.7]
9 [29]	3.400 [5.060]	1.128 [28.7]	1.00 [645]	3.544 [90.0]	0.790 [20.1]	0.056 [1.42]	0.431 [10.9]
10 [32]	4.303 [6.404]	1.270 [32.3]	1.27 [819]	3.990 [101.3]	0.889 [22.6]	0.064 [1.63]	0.487 [12.4]
11 [36]	5.313 [7.907]	1.410 [35.8]	1.56 [1006]	4.430 [112.5]	0.987 [25.1]	0.071 [1.80]	0.540 [13.7]

Materials

TABLE 2.2 Overall Diameter of Bars



Bar Size	Approx. dia outside Deformations in. (mm)
#3 (#10)	$^7/_{16}$ (11)
#4 (#13)	$^9/_{16}$ (14)
#5 (#16)	$^{11}/_{16}$ (18)
#6 (#19)	$^7/_8$ (22)
#7 (#22)	1 (25)
#8 (#25)	1$^1/_8$ (28)
#9 (#29)	1$^1/_4$ (32)
#10 (#32)	1$^7/_{16}$ (36)
#11 (#36)	1$^5/_8$ (40)

NOTE that diameters tabulated are approximate size outside of deformations, so clearance should be added for holes.

Materials

2.6.2 Reinforcing Bars

In the Western United States and particularly in California, deformed bars make up the majority of reinforcing steel used in masonry. The deformed bars range from #3 ($^3/_8$ inch (10 mm) in diameter) to a maximum of #11 bars ($1^3/_8$ inch (36 mm) in diameter). **Exception:** The maximum size of reinforcement is #9 ($1^1/_8$ inch (29 mm)) for strength design of masonry in accordance with MSJC Code Section 3.3.3.1.

Most reinforcing steel conforms to ASTM A615, A706, or A996, which specifies the physical characteristics of the reinforcing steel. Reinforcing steel may be either Grade 40 (300) with a minimum yield strength of 40,000 psi (300 MPa) or Grade 60 (420) with a minimum yield strength of 60,000 psi (420 MPa).

Grade 40 (300) steel bars are furnished in sizes 3, 4, 5 and 6. However, currently, Grade 60 (420) steel is furnished in all sizes, and if Grade 40 (300) is required, a special note must be made to assure delivery.

Materials

Materials

2.6.3 Identification Marks

The ASTM specifications covering new billet steel, rail steel, axle steel and low alloy reinforcing bars (A615, A706 and A996) require identification marks to be rolled into the surface of one side of the bar to indicate the producer's mill designation, bar size and type of steel and for Grade 60 (420), grade marks indicating yield strength. See Figure 2.8.

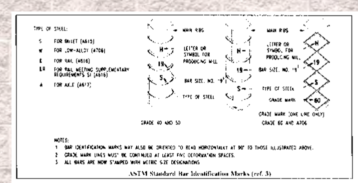
Grade 40 (300) bars are required to have only the first three marks (no grade mark) in the following order:

- 1st - Producing Mill (usually a letter)
- 2nd - Bar Size Number (metric)
- 3rd - Type S for New Billet, A for Axle, I for Rail, W for Low Alloy

Materials

Grade 60 (420) bars must also show grade marks:
The stamped number 4 or one (1) grade line for 60,000 psi (420 MPa) strength

Grade mark lines are smaller and between the two main longitudinal ribs which are on opposite sides of all U.S. made bars. Number grade marks are fourth in order.



Materials

2.6.4 Overall Bar Diameters

Bar diameters are nominal, with the actual diameter outside of deformations being somewhat greater. The outside diameter may be important when punching holes in structural steel members to accommodate bars. Approximately $^1/_{16}$ inch (1.6 mm) for #3, #4, #5 bars, $^1/_8$ inch (3.2 mm) for #6, #7, #8, #9 bars, $^3/_{16}$ inch (5 mm) for #10 and #11 bars should be added to the nominal bar diameter to account for the height of the deformations. See Table 2-2.

Materials

2.7 JOINT REINFORCING STEEL

2.7.1 General

When high strength steel wire, in ladder or truss type configuration, is placed in the horizontal bed joints, it is called joint reinforcement.

Materials

High strength steel wire fabricated in ladder or truss systems, as illustrated in Figure 2.9a and 2.9b, is placed in the bed joints to reinforce the wall in the horizontal direction. The most common uses of joint reinforcement are:

(1) to control shrinkage cracking in concrete masonry walls;

(2) to satisfy minimum prescriptive reinforcement requirements of the code. Not appropriate for structural steel resistance in higher Seismic Design Categories or for certain wall types;

(3) as designed reinforcing steel that resists forces in the masonry, such as tension and shear. It can also be used in all types of masonry walls as a continuous tie system for veneer and cavity walls.

Materials

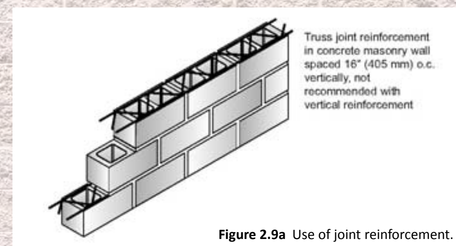


Figure 2.9a Use of joint reinforcement.

Materials

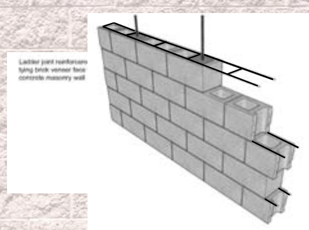


Figure 2.9b Use of joint reinforcement.

Materials

2.7.2 Description

Joint reinforcement consists of deformed longitudinal wires welded to cross wire in sizes suitable for placement in mortar joints between masonry courses.

2.7.3 Configuration and Size of Longitudinal and Cross Wires

The requirements for configuration and size of longitudinal and cross wires are described in ASTM A951.

The distance between longitudinal wires and the configuration of cross wires connecting the longitudinal wires must conform to the design and requirements.

Materials

Longitudinal wires must not have a diameter of less than W1.1 (11 gage) or more than one-half the mortar joint thickness, although heavier 9 gage wire is commonly supplied.

Cross wires must have a diameter of at least W1.1 (11 gage), however the heavier (No. 9 gage) 0.148 in. (3.76 mm) diameter is normally supplied. Cross wires shall not project beyond the outside longitudinal wires by more than $^1/_8$ in. (3.2 mm).

The width of joint reinforcement is the out-to-out distance between outside longitudinal wires. Variation in the width must not exceed $^1/_8$ inch (3.2 mm).

The length of pieces of joint reinforcement may vary up to $^1/_2$ inch (13 mm) or 1.0 percent of the specified length, whichever is less.

Materials

2.7.4 Material Requirements

Additionally, the material requirements are described in ASTM A951.

Wire of the finished product shall meet the following requirements:

•Tensile strength, min, ksi (MPa)	80 (550)
•Yield strength, min, ksi (MPa)	70 (485)
•Reduction of area, min, %	30

Wire shall not break or crack along the outside diameter of the bend when tested.

The least weld shear strength in pounds must be at least 25,000 multiplied by the specified area of the larger wire in square inches.

Materials

2.7.5 Fabrication

The fabrication of joint reinforcement is described in ASTM A951.

The wires are to be assembled by automatic machines or by other suitable mechanical means which will assure accurate spacing and alignment of all members of the finished product.

Longitudinal and cross wires are securely connected at every intersection by a process of electric-resistance welding.

Materials

Longitudinal wires shall be deformed. One set of two deformations are required around the perimeter of the wire at a maximum spacing of 0.7 times the diameter of the wire but not less than eight sets per inch (25 mm) of length.

Materials

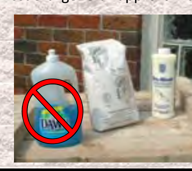
2.8 WATER

Water used in masonry construction should be potable, (suitable for drinking) and free of harmful substances such as oil, acids, alkalis, and any other impurities that would classify the water as unfit for human consumption.

Materials

2.9 ADDITIVES AND ADMIXTURES

Sometimes certain properties, such as delayed setting, super plasticity, water reduction, water penetration resistance or accelerated strength gain, are desirable in mortar or grout. These properties can be obtained by using special additives or admixtures. When using additives or admixtures, follow recommendations of the manufacturer to obtain satisfactory results after first obtaining approval of the local building official. Often, the building official will issue a general approval for additive use on all projects.



Materials

ASTM C270 Standard Specification for Mortar for Unit Masonry and ASTM C476 Standard Specification for Grout for Masonry provide general requirements.

Do not use additives and admixtures in mortar or grout unless specified and/or approved.

Materials

Antifreeze liquids, chloride salts or other substances should not be used in mortar or grout.

Air-entrainment substances must not be used in mortar or grout unless tests are conducted to determine compliance with the code requirements.

Materials

2.10 MORTAR

2.10.1 General

Mortar is a basic component of reinforced and unreinforced masonry. Some claim that mortar holds the units apart, others claim it holds the masonry units together. It actually does both.

Mortar has been made from many different materials. Some ancient mortar mixtures were plain mud or clay, earth with ashes, ox blood and earth, and sand with lime.

Materials

Mortar is a mixture of cementitious material and aggregate to which sufficient water and approved additives, if any, have been added to achieve a workable, plastic consistency.

Modern mortar consists of cementitious materials and well graded sand with sufficient fine aggregates. Mortar is used for the following purposes:

a. It is a bedding or seating material for the masonry unit.
b. It allows the unit to be leveled and properly placed.

Materials

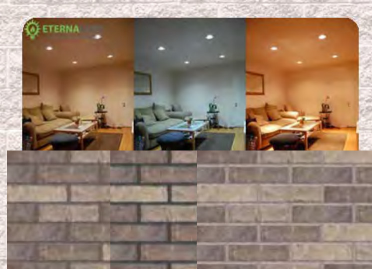
c. It bonds the units together.

Materials

d. It provides compressive strength.
e. It provides shear strength, particularly parallel to the wall.
f. It allows some movement and elasticity between units.
g. It seals irregularities of the masonry unit and provides a weather-tight wall, prevents penetration of wind and water into and through the wall.

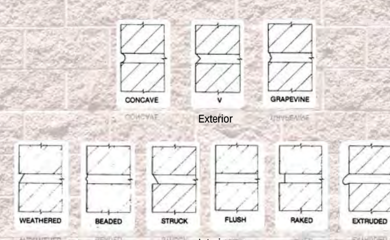
Materials

h. It can provide color to the wall by using mineral color additive.



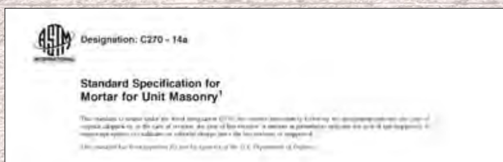
Materials

i. It can provide an architectural appearance by using various types of joints, as shown in Figures 4.7 and 4.8.



Materials

IBC Section 2103.9 and MSJC Specification Article 2.1 require that mortar complies with ASTM C270 *Standard Specification for Mortar for Unit Masonry.*
Special mortars, or bonding systems, may be used, subject to satisfactory evidence of their capabilities when specified and/or approved.


Designation: C270 − 14a

Standard Specification for
Mortar for Unit Masonry[1]

Materials

Materials used as ingredients in mortar need to conform to the applicable requirements. Cementitious materials for mortar include one or more of the following: lime, masonry cement, portland cement and mortar cement. Cementitious materials or additives should not contain epoxy resins and derivatives, phenols, asbestos fiber or fireclays.

Materials

2.10.2 Proportions of Mortar

Proportions of mortar may be based on proportions listed in ASTM C270 or based on laboratory testing based on prisms, cube strength, or cylinder strengths. Field experience based on history of performance with the mortar ingredients and masonry units for the project may be used as a basis for proportions.

Abundant research and experience has proved that mortar proportions contained in ASTM C270, Table 1, *Proportions Specification Requirements*, result in satisfactory performance.

Mortar with specified proportions of ingredients that differ from the mortar proportions of ASTM C270, Table 1, may be approved for use when it is demonstrated that the mortar will conform to the property specifications. Water content is adjusted to provide proper workability under existing field conditions. When the proportion of ingredients are not specified, the proportions by mortar type in ASTM C270, Table 1, are used.

Materials

ASTM C270 TABLE 1 MORTAR PROPORTIONS

MORTAR	TYPE	PROPORTIONS BY VOLUME (cementitious materials)								AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
		Portland cement or blended Cement	Masonry cement			Mortar cement			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 1 ¼	
	O	1	-	-	-	-	-	-	Over 1 ¼ or 2 ½	
Mortar cement	M	1	-	-	-	-	-	1	-	
	M	-	-	-	-	1	-	-	-	
	S	½	-	-	-	-	-	1	-	
	S	-	-	-	-	-	1	-	-	
	N	-	-	-	-	-	-	1	-	
	O	-	-	-	-	-	-	1	-	
Masonry cement	M	1	-	-	-	-	-	-	-	
	M	-	1	-	-	-	-	-	-	
	S	½	-	-	-	-	-	-	-	
	S	-	-	1	-	-	-	-	-	
	N	-	-	-	-	-	-	-	-	
	O	-	-	-	-	-	-	-	-	

Materials

ASTM C270 TABLE 2 MORTAR PROPERTIES[A]

MORTAR	TYPE	AVERAGE COMPRESSIVE STRENGTH AT 28 DAYS, MIN. psi (MPa)	WATER RETENTION, MIN. %	AIR CONTENT, MAX. %[B]	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
Cement-Lime	M	2,500 (17.2)	75	12	Not less than 2¼ and not more than 3½ times the sum of the separate volumes of cementitious materials
	S	1,800 (12.4)	75	12	
	N	750 (5.2)	75	14[C]	
	O	350 (2.4)	75	14[C]	
Mortar cement	M	2,500 (17.2)	75	12	
	S	1,800 (12.4)	75	12	
	N	750 (5.2)	75	14[C]	
	O	350 (2.4)	75	14[C]	
Masonry cement	M	2,500 (17.2)	75	18	
	S	1,800 (12.4)	75	18	
	N	750 (5.2)	75	20[D]	
	O	350 (2.4)	75	20[D]	

[A] **Laboratory prepared mortar only** (see Note 4).
[B] See Note 5.
[C] When structural reinforcement is incorporated in cement-lime or mortar cement mortar, the maximum air content shall be 12%.
[D] When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall be 18%.

Materials

In Seismic Design Categories D, E and F, either Type M or Type S Mortar must be used for the seismic force resisting system. In Seismic Design Categories A, B and C, Types M, S or N can be used for any masonry application, but softer (Type N) mortars are recommended for most applications.

The MSJC Code does not recognize the use of plastic cement in masonry construction. It also does not permit the use of masonry cement in the seismic force-resisting system in Seismic Categories D, E and F.

Materials

Field practice is to use the range of proportions for each type of mortar that will result is a workable, smooth mortar that spreads easily and is plastic enough to be able to push the masonry unit into the mortar when the unit is laid. It must also be stiff enough to support the masonry unit without deforming under the additional weight of masonry units.

Materials

For example, Type S mortar, made with portland cement and hydrated lime can be proportioned with one part portland cement, one-quarter to one-half part hydrated lime and 2.8 to 4.5 parts sand, depending on the amount of lime added. The variation in sand proportions allows an adjustment due to particle shape, size, and grading, all of which affect workability and spreadability.

Materials

2.10.3 Mortar Aggregate—Sand

The aggregate used for mortar should be well graded with sufficient fine material passing the No. 100 sieve to impart smoothness to the mortar. Washed sand is ideal for mortar for it should have no particle larger than $^1/_8$ in. (3.2 mm) and it has sufficient fines for workability and smoothness. Particle shape influences the workability of mortar. Round, spherical particles, well graded, are best for mortar while sharp, cubical or flat particles produce harsh mortar.

Materials

ASTM C 144, *Standard Specification for Aggregate for Masonry Mortar*, gives the grading requirements for sand.

Designation: C144 – 11

Standard Specification for Aggregate for Masonry Mortar[1]

Materials

ASTM C144, Section 4 Grading

Aggregate for use in masonry mortar shall be graded within the following limits, depending upon whether natural sand or manufactured sand is to be used.

Sieve Designation	Percent Passing	
	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

Materials

The aggregate must not be graded so that more than 50% of the material is retained between any two consecutive sieves with not more than 25% retained between No. 50 (300-mm) and the No. 100 (150-mm) sieve.

If the fineness modulus varies by more than 0.20 from the value assumed in selecting proportions for the mortar, the aggregate shall be rejected unless suitable adjustments are made in proportions to compensate for the change in grading.

Materials

When an aggregate fails the gradation limits specified above, it may be used provided the mortar can be prepared to comply with the aggregate ratio, water retention, and compressive strength requirements of the property specifications of ASTM C270.

Concrete sand should not be used in mortar since the maximum grain sizes may be $^{3}/_{16}$ inch (5 mm) to $^{1}/_{4}$ inch (6 mm) and needed fines washed out resulting in a sand too harsh, coarse and unsuitable for mortar.

Stored aggregate should be in a level, dry, clean place from which it can be measured into the mixer with minimum handling and kept free from contamination by harmful substances.

Materials

2.10.4 Mixing

Mortar mixing is best accomplished in a paddle type mixer. About one-half of the water and one quarter of the sand are placed in the operating mixer first, then the cement, lime, color (if any) and the remaining water and sand are added. All materials should then mix for not less than 3 minutes and not more than 5 minutes (MSJC Specification Article 2.6 A) in a mechanical mixer with the amount of water required to provide the desired workability. Small amounts of mortar can be hand mixed when approved for the project.

Figure 2.10 Plaster or paddle mortar mixer.

Materials

In a paddle mixer, shown in Figure 2.10, the drum is stationary and the blades rotate through the mortar materials for thorough mixing.

A drum or barrel mixer, shown in Figure 2.11, rotates the drum in which the materials are placed. The material is carried to the top of the rotation and drops down to achieve mixing.

Figure 2.11 Drum or barrel mixer.

Materials

2.10.5 Pre-Blended Mortar

Mortar can also be factory pre-blended and stored at the jobsite in silos. Some systems introduce water to the dry mortar mix in an auger screw at the base of the silo, while other systems discharge the dry mortar mix directly into a conventional mixer.

Materials

Pre-blended dry mortar is also available in sacks, which may be beneficial in keeping project debris at a minimum.

Dry mixes, pre-blended by the manufacturer should be mixed at the jobwsite in a mechanical batch mixer in accordance with MSJC Specification Article 2.6 A and ASTM C270, Section 7.3.

When factory blended mortar is used, manufacturers certification of the type of mortar satisfies submittal requirements.

Materials

2.10.6 Retempering

Mortar may be retempered with water when needed to maintain workability. This should be done on mortar boards by forming a basin or hollow in the mortar, adding water and then reworking the mortar into the water. Splashing water over the top of the mortar is not permissible. Harsh mortar, mortar that has begun to stiffen or harden due to hydration, should be discarded. Mortar must be used within two-and-one-half hours after the initial water has been added to the dry ingredients at the jobsite. Under certain hot weather conditions (ambient air over 100°F (37.8°C) or over 90°F (32.2°C) with wind velocity greater than 8 mph), the maximum time for mortar use is 2 hours.

Materials

2.10.7 Color

Mortar colors are generally mineral oxides or carbon black. Iron oxide is used for red, yellow and brown colors; chromium oxide is for green and cobalt oxide is for blue colors.

Materials

The amount of color additive depends on the color and intensity and typically ranges from 0.5% to 7.0% for the mineral oxides and a maximum of 2% for carbon black, when using a portland cement-lime mortar. When using masonry cement or mortar cement mortars the maximum amount of carbon black permitted is 1%. The percent is based on weight of cement content. These maximum percentages are far greater than the normal amounts of color added, and specific code limitations are listed below, based on cement type. The maximum amount of color pigments allowed in mortar, based on the weight of cement, is given in MSJC Specification Article 2.6 A.2.

Materials

MSJC Specification Article 2.6 A.2

2.6 A. *Mortar*

2. Limit the weight of mineral oxide or carbon black pigments added to project-site prepared mortar to the following maximum percentages by weight of cement:

a. Pigmented portland cement-lime mortar
   1) Mineral oxide pigment 10 percent
   2) Carbon black pigment 2 percent

b. Pigmented mortar cement mortar
   1) Mineral oxide pigment 5 percent
   2) Carbon black pigment 1 percent

c. Pigmented masonry cement mortar
   1) Mineral oxide pigment 5 percent
   2) Carbon black pigment 1 percent

Do not add mineral oxide or carbon black pigment to preblended colored mortar or colored cement without the approval of the Architect/Engineer.

Materials

There are commercially prepared colors for mortars that offer a wide variety of colors and shades.

Maximum percentage of mortar color, based on weight of cement

Pigment Type	Mortar Type		
	Portland Cement	Masonry Cement	Mortar Cement
Mineral Oxide	10%	5%	5%
Carbon Black	2%	1%	1%

Materials

Mixing time should be long enough for a uniform, even color to be obtained in the mortar and should be the approximately the same length of time for every batch.

Mixing sequence should be the same for each batch and as specified in Section 2.10.4 "Mixing."

Retempering must be kept to a minimum when coloring is used, and for best results should be avoided.

The source of materials, manufacturer and amount of each ingredient should remain the same for all colored mortar on the project in order to obtain uniform color throughout. Prepackaged mineral color additives that can be added to the mix based on full sacks of portland cement provide a consistent batching for quality control of mortar color. Preblended colored mortars as described in Section 2.10.5 yield controlled measurements for materials which helps in color consistency.

Materials

2.10.8 Proprietary Mortars

Proprietary mortars such as delayed set mortars and ready mix mortars must be approved by the engineer or architect and accepted by the building official, where applicable. Handling and use of these materials should be in strict compliance with the manufacturer's recommendations.

Materials

2.10.9 Mortar Admixtures

There are retarding admixtures that delay the set and stiffening of mortar. Retardation can be obtained for 36 hours or more.

There are also admixtures used to replace lime. These admixtures usually add air to the mortar mix to provide workability.

Integral water repellents can be added to mortar for improved resistance of water penetration to the mortar joints.

Admixtures must be approved by the architect or engineer and be acceptable to the building official, as applicable.

Materials

2.11 GROUT

2.11.1 General

Grout is a fluid mixture of cement, sand, and frequently coarse aggregate known as pea gravel. The required slump of conventional grout is 8 to 11 in. (203 to 279 mm). There is also a self-consolidating grout with a required slump flow of 24 to 30 in. (600 to 750 mm). This high slump or slump flow is necessary for the grout to flow into all the grout spaces and joints and completely surround the reinforcing steel.

Materials

The excess water is immediately absorbed into the masonry units, thereby reducing the initial water/cement ratio of the grout. The absorbed water in the concrete masonry units aids in curing the grout and increasing the strength gain.

Materials

Grout consist of a mixture of cementitious materials and aggregate to which water has been added such that the mixture will flow without segregation of the constituents.

Materials

Grout is designed for a minimum compressive strength f'_g of 2,000 pounds per square inch (14.0 MPa) at 28 days, or mixed in accordance with ASTM C476, Table 1, which also yields a 2,000 psi grout mix. Higher grout strength may be required by the designer and must be clearly specified in the project documents.

Materials

2.11.2 Type of Grout

Grout may be conventional grout, requiring consolidation by puddling or mechanical consolidation, or self-consolidating grout. There are also two main types of grout identified by ASTM C476:

Fine Grout: Fine grout, or sand grout, may be used in grout spaces in multiwythe masonry as small as $^3/_4$ in. (19 mm) or larger in least clear horizontal dimension and in grout spaces in hollow unit construction $1^1/_2$ in. by 2 in. (38 mm x 51 mm) or more in least clear horizontal dimensions.

Coarse Grout: Coarse grout which uses aggregate (pea gravel) may be used in grout spaces in multiwythe masonry $1^1/_2$ in. (38 mm) or larger in least clear horizontal dimension and in grout spaces in hollow unit construction $1^1/_2$ in. by 3 in. (38 mm x 76 mm) or more in least clear horizontal dimensions. Adding the coarse aggregate typically reduces the cost of the grout while also reducing shrinkage.

Materials

2.11.3 Proportions

Conventional grout may be proportioned by laboratory design mix based on testing or field experience (property requirements) or in accordance with the proportions of ASTM C476, Table 1.

ASTM C476, Table 1—(Conventional) Grout Proportions by Volume

Type	Portland or Blended Cement	Hydrated Lime or Lime Putty	Aggregate measured ion a damp, loose condition	
			Fine (Sand)	Coarse (3/8 in.
Fine	1	0 to 1/10	2 ¼ to 3 times cementitious materials	---
Coarse	1	0 to 1/10	2 ¼ to 3 times cementitious materials	1 to 2 times cementitious materials

Materials

The testing values are based on masonry prism tests or grout specimen tests made in accordance with field experience based on a history of performance with the same masonry units and grout materials and mix proportions used for the project. The use of 70% sand and 30% pea gravel requires six sacks of portland cement per cubic yard and results in a pumpable grout that will provide the strength required. Because of the influence of grout on the strength of the masonry and the need to properly embed and bond reinforcement and anchor bolts, grout must have adequate strength and be properly consolidated.

Extensive research and experience verifies that grout proportions based on the proportion table listed above are successful for typical load-bearing concrete masonry.

The water content of conventional grout may be adjusted to provide proper workability and to enable proper placement under existing field conditions, without segregation.

Materials

2.11.4 Aggregate for Grout

Aggregate for grout is required to conform to the grading requirements of ASTM C404, Table 1.

Materials

C404 – 11

TABLE 1 Grading Requirements

Sieve Designation	Amounts Finer than Each Laboratory Sieve Designation, weight %				
	Fine Aggregate			Coarse Aggregate	
	Size No. 1	Size No. 2		Size No. 8	Size No. 89
		Natural	Manufactured		
12.5-mm (½-in.)	...	...	...	100	100
9.5-mm (⅜-in.)	100	...	...	85 to 100	90 to 100
4.75-mm (No. 4)	95 to 100	100	100	10 to 30	20 to 55
2.36-mm (No. 8)	80 to 100	95 to 100	95 to 100	0 to 10	5 to 30
1.18-mm (No. 16)	50 to 85	70 to 100	70 to 100	0 to 5	0 to 10
600-μm (No. 30)	25 to 60	40 to 75	40 to 75	...	0 to 5
300-μm (No. 50)	5 to 30	10 to 35	20 to 40	...	...
150-μm (No. 100)	0 to 10	2 to 15	10 to 25	...	...
75-μm (No. 200)	...	0 to 5	0 to 10	...	...

Materials

2.11.5 Mixing

Grout prepared at the jobsite should be mechanically mixed for at least 5 minutes in accordance with ASTM C476.

Materials

Enough water must be used in the conventional grout mixing process to achieve a high slump of 8 to 11 in. (203 to 279 mm). This high slump is necessary for the grout to flow into relatively small cells of the concrete masonry. Excess water is immediately absorbed into the masonry, thereby aiding the curing process. Self-consolidating grout is typically ready (transit) mixed under strict quality control guidelines.

Materials

2.11.6 Grout Admixtures

Admixtures may be used in grout to enhance desired properties. When admixtures are used, they should be approved by the architect or the engineer and be acceptable to the building official, if applicable. Three types of admixtures used in masonry grout are:

Materials

a. Shrinkage compensating admixtures which counteract the loss of water and the shrinkage of portland cement by creating an expansive gas in the grout.

b. Super plasticizer admixtures to obtain high slump with reduced water in the grout. Grout with a 4 in. (102 mm) slump can go to a 10 in. (254 mm) slump with the use of a super plasticizer. Use of plasticizer admixture should be used with extreme caution since they may reduce water content of grout to an insufficient level for curing after the units have absorbed water.

c. Cement replacement such as fly ash can be used in grout. The maximum amount is dependent on the fly ash, portland cement, strength gain characteristics, available research and applicable code provisions.

Materials

Fly ash is a pozzolanic material obtained from combustion of coal which is collected in electrostatic precipitators or bag houses. It is classified by precise particle size and by chemical composition as Class N, F or C.

Class N fly ash consists of raw or calcined natural pozzolans such as diatomaceous earths; opaline cherts and shales; tuffs and volcanic ashes or pumicities. It is not typically used in masonry grout.

Class F fly ash is obtained from the combustion of anthracite, bituminous or sub-bituminous coal. It is low in lime, less than 7%, and contains greater than 70% silica, alumina and iron.

Class C fly ash comes from burning lignite of sub-bituminous coal and has more than 15% lime.

Materials

Class N, F and C ash are siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Fly ash, because of its fine, spherical particles, increases workability and cohesiveness. It reduces water demand and improves pumpability of grout.

When fly ash is used as a cement replacement, it is necessary to have assurance that the required strength will be obtained in the stated period of time.

Materials

2.11.7 Anti-Freeze Compounds

Most anti-freeze admixtures are actually accelerators that increase the temperature by speeding up the hydration process.

Some anti-freeze admixtures use alcohol to lower the freezing point; however, to be effective, a significant amount is required and this will reduce both the compressive strength and bond strength of mortar.

ASTM C270 and ASTM C476 state that the use of antifreeze liquids, chloride salts or other such substances are severely restricted in mortar or grout.

Materials

2.11.8 Ready Mixed Grout

On large commercial projects, grout is often batched at a concrete plant and shipped to the jobsite in transit mix trucks. This process introduces water to the cement and aggregates at the plant and mixes the grout while in transit. At the jobsite, slump may be adjusted as necessary (ASTM C476, Section 5.2.2.1) and the grout should be re-mixed at mixing speed for at least 1 minute before discharging. Grout is normally pumped in the wall by means of a grout pump.

Materials

Common practice is to batch this grout to the predetermined quantities of a mix design. The mix design may be a standard mix design which is known to yield a certain specified strength or a special mix design meeting the criteria for a specific project.

The requirements for ready mixed grout such as an 8 inch to 11 inch (203 mm to 279 mm) slump, are the same for field-mixed grout.

Grout should be placed within $1^{1}/_{2}$ hours after the initial water is introduced to the dry ingredients. For transit mixed grout, MSJC Specification Article 3.5 A.2.b states that the time limit is waived providing the grout maintains the specified slump range.

Materials

2.11.9 Grout Demonstration Panel

The concept of a grout demonstration panel is to show that alternate means and methods of grouting can effectively accomplish the process. For example, higher grout lifts without cleanouts may be effective and MSJC Specification Article 3.5 G now provides specific direction for establishing alternate grouting methods.

Materials

2.11.10 Self-Consolidating Grout (SCG)

The MSJC Specification contains explicit provisions for SCG. Self consolidating grout provisions have also been incorporated into ASTM C476-10, *Standard Specification for Grout for Masonry*. Self-consolidating grout is required to meet the property specification requirements of ASTM C476 and is developed based on specific requirements from the manufacturer.

SCG is similar to conventional grout with two types of self-consolidating grout, coarse and fine, the latter containing only fine aggregate. Coarse self-consolidating grout is more common, although fine SCG is predominant in several specific regions of the U.S. SCG has seen significant use all across the country for several years under the grout demonstration panel provisions of the code.

Materials

Self-consolidating grout does not attain its high flow from adding more water, but from a careful mix design to create a flowable yet highly cohesive grout that will not segregate and can pass freely through congested reinforcement and narrow openings without "blocking" or "bridging." SCG must maintain its fluidity without segregation and maintain consistent properties throughout placement of the grout lift. SCG is composed of aggregates, cementitious materials, water and special admixtures which provide the fluidity and stability to meet performance requirements. SCG is readily available in most major metropolitan markets as ready mix and it is also available for dry, prepackaged commercial on-site batching systems. Proportioning of SCG is not permitted in the field, however, final adjustment of the mix, in accordance with the SCG manufacturer's recommendations, utilizing water or the same admixture used in the mix may be permitted.

Materials

Self-Consolidating Grout Placement - Self-consolidating grout is pumped or placed into spaces to be grouted using the same procedures as for conventional grout. Since SCG is so fluid, it will flow through relatively narrow gaps, therefore, the masonry unit cross webs of cells containing grout in partially grouted construction must be mortared. Mortaring of the webs can be particularly difficult when using stretcher units (units with ¾ in. ears on the ends of the block) in running bond because of the nearly 2 in. wide space between end webs of adjacent units. These types of units in running bond are not recommended for use with SCG unless the mortar is slushed into the space between the units.

In bond beams, conventional grout-stop materials, such as wire or plastic mesh can adequately contain SCG. When filling intermediate bond beams using the high-lift grouting process, place the grout-stop material in the bed joints both above and below the bond beam to prevent the SCG from rising above the bond beam location.

Materials

Self-Consolidating Grout Inspection - When placing SCG, the following checks should be performed on each load of SCG before it is placed:

Slump Flow Test - The slump flow test method defined in ASTM C1611/C1611M, *Standard Test Method for Slump Flow of Self-Consolidating Concrete* is used to monitor the consistency of fresh, unhardened SCG and its unconfined flow potential. Measurement of batch-to-batch consistency of SCG supplied over time should be recorded.

Because of the fluid nature of SCG, traditional measures of consistency, such as the ASTM C143 slump test, are not applicable to SCG. The SCG slump flow test uses the same slump cone as the ASTM C143 test, but in an inverted position and the SCG is loaded in a single lift without consolidation. The cone is then removed (Figure 2.13) and the diameter of the grout slump flow is measured. MSJC Specification Article 2.2 A.2 requires the slump flow (spread) to be 24 to 30 in. (610 to 762 mm).

Materials

Figure 2.13 Slump flow testing of self-consolidating grout.

Materials

Visual Stability Index (VSI) - VSI measurement, defined in ASTM C1611, is performed after the slump flow test to provide a qualitative assessment of the SCG's stability. The SCG specimen (Figure 2.14) resulting from the slump flow test is examined for aggregate segregation, bleeding and evidence of a mortar halo (a cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of the SCG specimen). The SCG mix is then assigned a VSI, from 0 (highly stable) to 3 (highly unstable) by comparing to the pictures and descriptions of the various indexes found in ASTM C1611. MSJC Specification Article 2.2 A.2 requires that the VSI be 1 or less.

TABLE 2.3—VISUAL STABILITY INDEX RATNG

VSI Value	Criteria
0 = Highly Stable	No evidence of segregation or bleeding
1 = Stable	No evidence of segregation and slight bleeding observed as a sheen on the concrete mass
2 = Unstable	A slight mortar halo $\leq$ 0.5 in. ($\leq$ 10 mm) and/or aggregate pile in the center of the grout mass
3 = Highly Unstable	Clearly segregated by evidence of a large mortar halo > 0.5 in. (> 10 mm) and/or a large aggregate pile in the center of the grout mass

Materials

Figure 2.14 Self-consolidating grout specimen.

Materials

Self-Healing Ability 'S' Test - The 'S' test (Figure 2.15) can be used to help determine the stability of an SCG mix. While this is not a standardized test method, it is adapted from a simple test that is done by some practitioners in the field. There is a common version and a modified version, which gives an indication of the relative segregation resistance of the SCG when subjected to local vibration.

The common self-healing (non-disturbed) test is performed after the slump flow, and the VSI has been recorded. A 10 to 12 in. 'S' is drawn in the SCG specimen with a finger, making sure to scrape off the SCG all the way down to the board. The specimen is observed to see if the 'S' will self-heal. In cases where the self-healing is excellent, the SCG flows back together and there is little or no evidence of the 'S' remaining. In cases where the self-healing is poor, the SCG does not flow back together and the 'S' remains very visible with severe aggregate, paste or water segregation.

Compressive Strength Testing of SCG mixes – ASTM C1019, *Standard Test Method for Sampling and Testing Grout*, addresses SCG. The procedure for testing SCG is the same as that for conventional grout, except that SCG is placed in the mold in one lift instead of two and SCG is not rodded.

Materials

Figure 2.15 Self-consolidating grout specimen – "S" Test.

CHAPTER 3
Quality Control, Sampling and Testing

3.1 QUALITY CONTROL

To assure that materials are in accordance with the International Building Code, the MSJC Code, MSJC Specification and the particular project specifications, tests may be required on the mortar, grout, masonry units, and prisms. The following code excerpts mandate the implementation of a quality assurance program.

QUALITY CONTROL, SAMPLING AND TESTING

IBC Section 2105 Quality Assurance

2105.1 General. A quality assurance program shall be used to ensure that the constructed masonry is in compliance with the construction documents.

The quality assurance program shall comply with the inspection and testing requirements of Chapter 17.

QUALITY CONTROL, SAMPLING AND TESTING

The scope of the quality assurance program should include verification of f'_m by the Prism Test Method or the Unit Strength Method. Tests may also include units, mortar or grout, however these tests are unnecessary and redundant when testing masonry assemblages.

3.2 SAMPLING AND TESTING

Testing should be done in compliance with specifications and verified prior to the start of work. Jobsite tests, when required, should then be made to confirm the continuing acceptable quality of materials used.

QUALITY CONTROL, SAMPLING AND TESTING

3.2 SAMPLING AND TESTING

Testing should be done in compliance with specifications and verified prior to the start of work. Jobsite tests, when required, should then be made to confirm the continuing acceptable quality of materials used.

QUALITY CONTROL, SAMPLING AND TESTING

3.2.1 Cone Penetration Test for Consistency of Mortar

The cone penetration test as outlined in ASTM C780 *Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry* provides a technique for determining the consistency or plasticity of mortar.

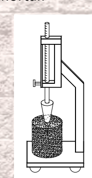


Figure 3.1 Cone penetrometer.

QUALITY CONTROL, SAMPLING AND TESTING

Consistency determinations by cone penetration allow controlling baselines for all mortars included in the pre-construction test series. Although mortar consistency as measured at the construction site may be a higher penetration value than the pre-construction tests, the cone penetration test serves to standardize water additions for mortar mixes being considered before construction. A cone penetrometer is illustrated in Figure 3.1.

Consistency retention by cone penetration using mortar samples provides a means of establishing the early age setting and stiffening characteristics of the mortar.

The cone penetration test method determines the consistency by measuring the penetration of a conical plunger into a mortar sample (see Figure 3.2). A cylindrical measure, having an inside diameter of 3 in. (76 mm) and a depth of $3^{15}/_{32}$ in. $\pm$ $^{1}/_{16}$ in. (88 mm $\pm$ 1.6 mm), is filled with mortar in three equal layers.

QUALITY CONTROL, SAMPLING AND TESTING

Each layer is tamped 20 times with a metal spatula. The top is leveled and a cone $1^5/_8$ in. (41 mm) in diameter and $3^5/_8$ in. (92 mm) long is released into the mortar. The depth of penetration is measured in millimeters.

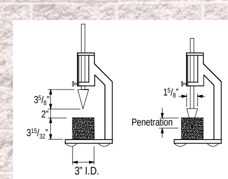


Figure 3.2 Cone penetration to test consistency of mortar.

Quality Control, Sampling and Testing

Consistency or plasticity of mortar for hollow unit concrete masonry is generally stiffer with a lower cone penetration value than mortar for brick, which generally will be a softer, more plastic mortar. This is because hollow concrete units are heavy and stiff mortar must hold the unit in position without squeezing down. Brick units are light and can be easily moved into position in the plastic mortar.

Quality Control, Sampling and Testing

3.2.2 Field Test for Mortar Strength

It may be necessary to know the properties of mortar used on the project. Therefore, specimens can be made in the field, using jobsite materials. ASTM C780 is not intended to evaluate compressive strength properties of masonry mortar. When mortar compressive strength evaluation is required, a reflection on prior code requirements is appropriate. ASTM C780-11, Appendix A6 gives a procedure for testing mortar with a qualification that the results will not correlate to mortar specified in ASTM C270.

Further, ASTM C780, Section 5.2.6 states, "Cylinders and cubes exhibit different strengths even when made from the same mortar mix. Both of these specimen configurations yield lower strengths than what would be attained if a specimen having the same size and configuration of a typical mortar joint could be reliably tested." This reality is due to a number of differences, including geometry, water content and curing conditions.

Quality Control, Sampling and Testing

When there is a concern about the mortar strength in a wall, a much more reliable approach is to test masonry prisms which represent units, mortar and grout (if applicable) combined as an assemblage.

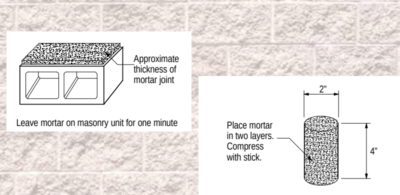


Figure 3.3 Preparing and making field test mortar specimens.

Quality Control, Sampling and Testing

3.2.3 Field Tests for Grout

Grout significantly contributes to the strength of the masonry wall and bonds reinforcing steel into the structural system. Specimens are made in such a way as to duplicate the condition of grout in the wall.

Quality Control, Sampling and Testing

3.2.3.1 Field Compressive Test Specimens for Grout

ASTM C1019 outlines the method of making a grout specimen to achieve similarity to grout in the wall. An absorptive paper towel prevents bond of grout to the unit and allows the excess moisture to be absorbed into the unit. Refer to Figure 3.3

Quality Control, Sampling and Testing

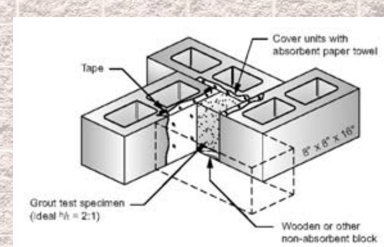


Figure 3.3 Arrangement of masonry units for making a grout test specimen.

Quality Control, Sampling and Testing

Requirements of ASTM C1019 are to:

Select a level location where the molds can remain undisturbed for 48 hours.

Construct the mold space to replicate the grout location in the wall. If the grout is placed between two different types of masonry units, both types should be used to construct the mold.

Quality Control, Sampling and Testing

Form a square prism space, nominally 3 in. (76 mm) or larger on each side, twice as high as its width, by stacking masonry units of the same type and moisture condition as those being used in the construction. Place wooden blocks, cut to proper size and of the proper thickness or quantity, at the bottom of the space to achieve the necessary height of specimen. Tolerance on space and specimen dimensions are required to be within 5 percent of the specimen width.

Line the masonry surfaces that will be in contact with the grout specimen with a permeable material, such as a paper towel, to prevent bond to the masonry units.

Quality Control, Sampling and Testing

Measure and record the slump of the grout.

Fill the mold with grout in two layers. Rod each layer 15 times with the tamping rod penetrating $^1/_2$ in. (13 mm) into the lower layer. Distribute the strokes uniformly over the cross section of the mold.

Level the top surface of the specimen with a straightedge and cover immediately with a damp absorbent material such as cloth or paper towel. Keep the top surface of the sample damp by wetting the absorbent material.

Quality Control, Sampling and Testing

Protect the sample from freezing and variations in temperature. Store a maximum-minimum indicating thermometer with the sample and record the maximum and minimum temperatures experienced prior to the time the specimens are placed in the moist laboratory room.

Remove the masonry units between 24 and 48 hours after casting specimens. Transport field specimens to the laboratory, keeping the specimens damp and in a protective container.

Quality Control, Sampling and Testing

Alternate Methods: Some laboratories and inspectors prepare grout specimens by pouring the grout into the concrete block cells, as shown in Figure 3.4. After the grout has set for a few days, the masonry shells and webs are broken off. The grout specimens are:

a. tested as is and an adjustment made for height and area,
b. sawed into $3^3/_4$ in. x $3^3/_4$ in. x $7^5/_8$ in. (95 mm x 95 mm x 194 mm) prismatic specimens and tested, or
c. cored into a 3 in. or 4 in. (76 mm or 102 mm) diameter specimen drilled from the grout cell and then tested.

Quality Control, Sampling and Testing

The alternate methods are not recommended since the breaking, sawing and coring will negatively impact the strength of the sample, thereby yielding distorted test results.

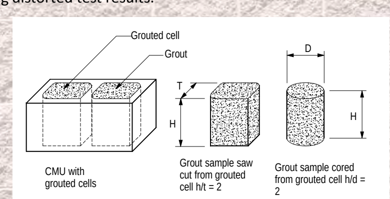


Figure 3.4 Alternate grout test specimens.

QUALITY CONTROL, SAMPLING AND TESTING

Another method that could be used is to pour grout into a special concrete block that has three 4 in. (102 mm) diameter cells, as shown in Figure 3.5. After the grout has set for several days, the block is broken away and three 4 in. x 8 in. (102 mm x 203 mm) grout specimens are obtained.

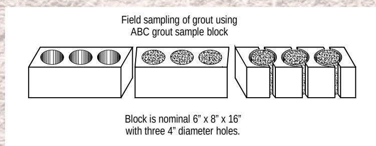
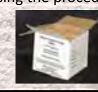


Figure 3.5 Proprietary grout sample block.

QUALITY CONTROL, SAMPLING AND TESTING

The alternate methods of making a grout specimen closely relate to actual field conditions. Comparison specimens can be made for both the alternate method and standard method to establish the relationship between the strength of the grout of specimens made by each method. This relationship, once established for the job, can then be used throughout the project.

Use of an alternate method of making grout specimens may be subject to question should the test results not comply with specification requirements and comparison tests are not made. Alternate methods, including cardboard from boxes for grout specimens, do not follow the testing procedures set forth in ASTM C1019, unless such methods are calibrated for the project and compared to the results using the procedure shown in Figure 3.3 (ASTM C1019, Note 7).



QUALITY CONTROL, SAMPLING AND TESTING

3.2.3.2 Grout Strength Requirements

The minimum design mix compressive strength of 2000 psi (13.8 MPa) or proportion mix by ASTM C476, Table 1, is to:

a. insure compatibility with the concrete masonry units.
b. provide adequate bond strength of the grout to the reinforcing bars.
c. provide compressive strength capacity to the wall assemblage.

The minimum value is satisfactory for masonry construction in which the design strength f'_m = 1500 psi (10.3 MPa) and the masonry unit has a compressive strength of 1900 psi (13.1 MPa).

ASTM C476 requires grout to be specified by the required compressive strength for a particular project (minimum 2,000 psi (13.8 MPa)) based on a mix design or by the proportions stated in ASTM C476, Table 1 (see Section 2.11).

QUALITY CONTROL, SAMPLING AND TESTING

IBC section 2105.2.2.1.2.3.2 requires grout strength to equal or exceed f'_m, however, the contractor should consider the recommendation that the compressive strength of grout in concrete masonry construction be at least equal to 1.25 to 1.33 times the design strength of the masonry assemblage, f'_m.

An example of this is that 2000 psi (13.8 MPa) grout is required for a masonry assemblage strength f'_m of 1500 psi (10.3 MPa).

If grout tests are required, the following schedule is suggested.

At the start of grouting operations, take one test per day for the first three days. The tests shall consist of three specimens which are made in accordance with ASTM C1019 Section 5, Test Specimens.

QUALITY CONTROL, SAMPLING AND TESTING

After the first three tests, take specimens for continuing quality control once a week or for every 30 cubic yards (23 m^3) of grout or for every 5000 square feet (465 m^2) of wall, whichever comes first.

For minimum grout strength as required by ASTM C476, historical laboratory test data may justify that a seven day compressive strength of 1,200 psi (6.9 MPa) will extrapolate to 2,000 psi (13.8 MPa) at 28 days. For higher strength grout, it is appropriate to rely on actual 28 day strength test results instead of seven day extrapolated results.

QUALITY CONTROL, SAMPLING AND TESTING

3.3 CONCRETE MASONRY UNITS

While most of the tests on concrete masonry units are performed prior to start of work, some random sampling at the jobsite may be required of concrete masonry units by project specifications or by request of the building official, architect or other authorized person. Selected units should be truly random, representative, and average samples.

Quality Control, Sampling and Testing

The tests that should be conducted are based on the requirements of ASTM C90 *Standard Specification for Loadbearing Concrete Masonry Units* and should meet the requirements for compressive strength, water absorption and thickness for face shells and webs. In addition, the linear shrinkage of the unit must not exceed 0.065% at time of delivery.

Designation: C90 – 14

Standard Specification for Loadbearing Concrete Masonry Units[1]

Quality Control, Sampling and Testing

The test procedures for compressive strength, absorption, weight, moisture content and dimensions are given in ASTM C140 *Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units*.

See Chapter 13, Masonry Units, for some of the numerous sizes and types of hollow concrete masonry units.

Designation: C140/C140M – 14b

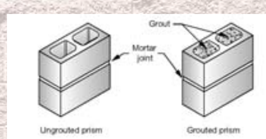
Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units[1]

Quality Control, Sampling and Testing

3.4 PRISM TESTING

3.4.1 General

Prism testing is primarily used when strengths are required higher than the conventional assumed design values allow. Unusual conditions are frequently involved, therefore, it is important that adequate time be allowed for preparing these prisms since retesting could be required. The test is to determine how well different materials work together. The full strength developed depends on many factors, including workmanship and materials.



Quality Control, Sampling and Testing

The procedure for making samples, curing and testing is specified in ASTM C1314, *Standard Test Method for Compressive Strength of Masonry Prisms*. The method consists essentially of making sample assemblies of the materials to be used in the construction and then testing the assemblages to see what capacities that combination of materials will develop. Typically, three samples (one set) are made and tested prior to starting the work. Subsequent sets of three are taken at 5,000 sq ft (465 m^2) intervals during construction using the same masonry units, mortar, grout and masons used in the construction of the wall.

For field control as the project is being constructed three specimens are required for one test.

Quality Control, Sampling and Testing

Care must be exercised in handling the prisms in order to prevent damage before testing. The prisms should be left undisturbed and under moist cover for two days after grouting before being moved to the laboratory. They are then cured moist, as specified, and tested at 28 days. Grouted prisms are tested 28 days after grouting of the prism.

Quality Control, Sampling and Testing

Construct the prisms on a flat, level base. Use masonry units representative of the units used in the corresponding construction. Build each prism in an opened moisture-tight bag which is large enough to enclose and seal the completed prism. The orientation of the units, where top and bottom cross sections vary due to taper of the cells, or where the architectural surface of either side of the unit varies, shall be the same orientation as used in the corresponding construction. Construct prism a single wythe in thickness and lay up in stack bond (see Figure 3.6).

QUALITY CONTROL, SAMPLING AND TESTING

If architectural features, such as flutes or ribs, are part of the unit and project more than $^1/_2$ in. (13 mm) from the surface of the unit, cut the projections off to give the unit an even face.

The length of masonry prisms may be reduced by saw cutting; however, prisms composed of regular shaped hollow units require at least one complete cell with one full-width cross web on either end. Prisms composed of irregular-shaped units need to be cut to obtain a cross section as symmetrical as possible. The minimum length of saw-cut prisms shall be 4 in. (102 mm).

Masonry prisms are laid in full mortar bed (mortar bed on both webs and face shells). Mortar shall be representative of that used in the corresponding construction. Mortar joint thickness and the method of positioning and aligning units must be representative of the corresponding construction. ASTM C1314 requires mortar joints to be flush cut.

QUALITY CONTROL, SAMPLING AND TESTING

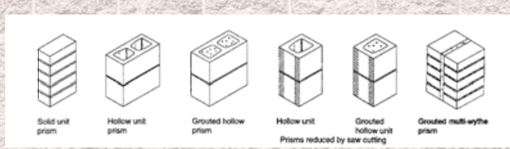
Prisms are constructed with a minimum of two units in height, with the total height at least 1.3 times the least actual thickness and not more than 5.0 times the least actual thickness. Immediately following the construction of the prism, the moisture-tight bag is drawn around the prism and sealed.

Where the corresponding construction is solid grouted, prisms are solid grouted. Grout must be representative of grout used in the corresponding construction. Place grout not less than 24 hours nor more than 48 hours following the construction of the prism. Grout consolidation must be representative of that used in the construction. Place additional grout in the prism after reconsolidation and settlement due to water loss, but prior to the grout setting. Screed off excess grout and level with the top of the prism. When open-end units are used, additional masonry units should be used as forms to confine the grout during placement. Masonry unit forms shall be sufficiently braced to prevent displacement during grouting. Immediately following the grouting operation, the moisture-tight bag is drawn around the prism and resealed.

QUALITY CONTROL, SAMPLING AND TESTING

Where the corresponding construction is partially grouted, construct two sets of prisms; one set is grouted solid and the other set is not grouted.

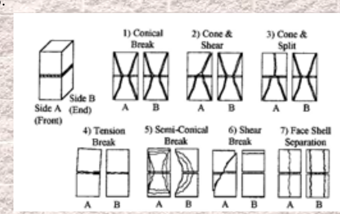
Leave prisms undisturbed for at least two days after construction.



QUALITY CONTROL, SAMPLING AND TESTING

3.4.2 Standard Prism Tests

The Test Method for Compressive Strength of Masonry Prisms is based on ASTM C1314. A typical masonry prism will be twice as tall as the lesser of thickness or length (h/t = 2), however ASTM C1314, Table 1 allows for a h/t ratio between 1.3 and 5.



QUALITY CONTROL, SAMPLING AND TESTING

3.4.3 Tests of Masonry Prisms

When masonry prisms are required in accordance with IBC Section 2105.2.2.2 or MSJC Specification Article 1.4 B.3, test prisms in accordance with ASTM C1314. Refer to Figure 3.7.

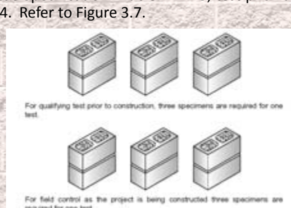


Figure 3.7 Number of specimens for a prism test (ASTM C1314).

QUALITY CONTROL, SAMPLING AND TESTING

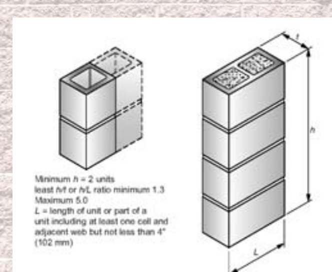


Figure 3.8 Size of prism specimen.

Quality Control, Sampling and Testing

3.4.4 Specified Compressive Strength, f'_m

The value of the specified compressive strength (f'_m) must be verified based upon either the provisions of IBC Section 2105.2.2.1, Unit Strength Method or 2105.2.2.2, Prism Test Method. The Unit Strength Method uses IBC Tables 2105.2.2.1.1 and 2105.2.2.1.2 to determine compressive strength values of clay and concrete masonry respectively. These are similar to Tables 1 and 2 of the MSJC Specification.

Quality Control, Sampling and Testing

IBC Section 2105.2

2105.2 Acceptance relative to strength requirements. Where required by Chapter 17, verification of the strength of masonry shall be in accordance with Sections 2105.2.1 and 2105.2.2.

2105.2.1 Compliance with f'_m and f'_{AAC}. Compressive strength of masonry shall be considered satisfactory if the compressive strength of each masonry wythe and grouted collar joint equals or exceeds the value of f'_m for clay and concrete masonry and f'_{AAC} for AAC masonry. For partially grouted clay and concrete masonry, the compressive strength of both the grouted and ungrouted masonry shall equal or exceed the applicable f'_m. At the time of prestress, the compressive strength of the masonry shall equal or exceed f'_{mi}, which shall be less than or equal to f'_m.

2105.2.2 Determination of compressive strength. The compressive strength for each wythe shall be determined by the unit strength method or by the prism test method as specified herein.

Quality Control, Sampling and Testing

2105.2.2.1 Unit strength method. The determination of compressive strength by the unit strength method shall be in accordance with Section 2105.2.2.1.1 for clay masonry, Section 2105.2.2.1.2 for concrete masonry and Section 2105.2.2.1.3 for AAC masonry.

2105.2.2.1.1 Clay masonry. The compressive strength of masonry shall be determined based on the strength of the units and the type of mortar specified using Table 2105.2.2.1.1, provided:

1. Units are sampled and tested to verify compliance with ASTM C62, ASTM C216, or ASTM C652.
2. Thickness of bed joints does not exceed $^5/_8$ inch (15.9 mm).
3. For grouted masonry, the grout meets one of the following requirements:
   - 3.1. Grout conforms to Article 2.2 of TMS 602/ACI 530.1/ ASCE 6.
   - 3.2. Minimum grout compressive strength equals or exceed f'_m but not less than 2,000 psi (13.79 MPa). The compressive strength of grout shall be determined in accordance with ASTM C1019.

Quality Control, Sampling and Testing

TABLE 2105.2.2.1.1
COMPRESSIVE STRENGTH OF CLAY MASONRY

NET AREA COMPRESSIVE STRENGTH OF CLAY MASONRY UNITS (psi)		NET AREA COMPRESSIVE STRENGTH OF MASONRY (psi)
Type M or S mortar	Type N mortar	
1,700	2,100	1,000
3,350	4,150	1,500
4,950	6,200	2,000
6,600	8,250	2,500
8,250	10,300	3,000
9,900	---	3,500
11,500	---	4,000

For SI: 1 pound per square inch = 0.00689 MPa.

Quality Control, Sampling and Testing

2105.2.2.1.2 Concrete masonry. The compressive strength of masonry shall be determined based on the strength of the unit and type of mortar specified using Table 2105.2.2.1.2, provided:

1. Units are sampled and tested to verify compliance with ASTM C55 or ASTM C90.
2. Thickness of bed joints does not exceed $^5/_8$ inch (15.9 mm).
3. For grouted masonry, the grout meets one of the following requirements:
   - 3.1. Grout conforms to Article 2.2 of TMS 602/ACI 530.1/ASCE 6.
   - 3.2. Minimum grout compressive strength equals or exceeds f'_m but not less than 2,000 psi (13.79 MPa). The compressive strength of grout shall be determined in accordance with ASTM C1019.

Quality Control, Sampling and Testing

TABLE 2105.2.2.1.2
COMPRESSIVE STRENGTH OF CONCRETE MASONRY

NET AREA COMPRESSIVE STRENGTH OF CONCRETE MASONRY UNITS (psi)		NET AREA COMPRESSIVE STRENGTH OF MASONRY (psi)[a]
Type M or S mortar	Type N mortar	
1,250	1,900	1,350
1,900	2,150	1,500
2,800	3,050	2,000
3,750	4,050	2,500
4,800	5,250	3,000

For SI: 1 inch = 25.4 mm, 1 pound per square inch = 0.00689 MPa.
[a] For units less than 4 inches in height, 85 percent of the values listed.

QUALITY CONTROL, SAMPLING AND TESTING

2105.2.2.1.3 AAC masonry. The compressive strength of AAC masonry shall be based on the strength of the AAC masonry unit only and the following shall be met:

1. Units conform to ASTM C1386.
2. Thickness of bed joints does not exceed $^1/_8$ inch (3.2 mm).
   For grouted masonry, the grout meets one of the following requirements:
   - 3.1. Grout conforms to Article 2.2 of TMS 602/ACI 530.1/ASCE 6.
   - 3.2. Minimum grout compressive strength equals or exceeds f'_{AAC} but not less than 2,000 psi (13.79 MPa). The compressive strength of grout shall be determined in accordance with ASTM C1019.

QUALITY CONTROL, SAMPLING AND TESTING

2105.2.2.2 Prism test method. The determination of compressive strength by the prism test method shall be in accordance with Sections 2105.2.2.2.1 and 2105.2.2.2.2.

2105.2.2.2.1 General. The compressive strength of clay and concrete masonry shall be determined by the prism test method:

1. Where specified in the construction documents.
2. Where masonry does not meet the requirements for application of the unit strength method in Section 2105.2.2.1.

2105.2.2.2.2 Number of prisms per test. A prism test shall consist of three prisms constructed and tested in accordance with ASTM C1314.

QUALITY CONTROL, SAMPLING AND TESTING

In the event that verification of f'_m is not confirmed, the IBC provides for testing prisms from constructed masonry. Inadequate test results can be a result of improper casting, handling, or testing of the original masonry prisms, therefore, this is a logical step in lieu of rejecting the masonry.

QUALITY CONTROL, SAMPLING AND TESTING

IBC Section 2105.3

2105.3 Testing prisms from constructed masonry. When approved by the building official, acceptance of masonry that does not meet the requirements of Sections 2105.2.2.1 or 2105.2.2.2 shall be permitted to be based on tests of prisms cut from the masonry construction in accordance with Sections 2105.3.1, 2105.3.2 and 2105.3.3.

2105.3.1 Prism sampling and removal. A set of three masonry prisms that are at least 28 days old shall be saw cut from the masonry for each 5,000 square feet (465 m^2) of the wall area that is in question but not less than one set of three masonry prisms for the project. The length, width and height dimensions of the prisms shall comply with the requirements of ASTM C1314. Transporting, preparation and testing of prisms shall be in accordance with ASTM C1314.

QUALITY CONTROL, SAMPLING AND TESTING

2105.3.2 Compressive strength calculations. The compressive strength of prisms shall be the value calculated in accordance ASTM C1314, except that the net cross-sectional area of the prism shall be based on the net mortar bedded area.

2105.3.3 Compliance. Compliance with the requirements for the specified compressive strength of masonry, f'_m, shall be considered satisfied provided the modified compressive strength equals or exceeds the specified f'_m. Additional testing of specimens cut from locations in question shall be permitted.

QUALITY CONTROL, SAMPLING AND TESTING

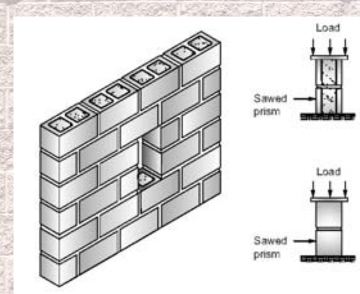


Figure 3.9 Test prism sawed from wall.

QUALITY CONTROL, SAMPLING AND TESTING

QUALITY CONTROL, SAMPLING AND TESTING

The MSJC Specification contains requirements for the verification of compressive strength of masonry.

MSJC Specification Article 1.4 B

1.4 B. *Compressive strength determination*

1. *Alternatives for determination of compressive strength* – Determine the compressive strength for each wythe by the unit strength method or by the prism test method as specified here.

QUALITY CONTROL, SAMPLING AND TESTING

2. *Unit strength method*

a. *Clay masonry* – Use Table 1 to determine the compressive strength of clay masonry based on the strength of the units and the type of mortar specified. The following requirements apply to masonry:

1) Units are sampled and tested to verify conformance with ASTM C62, ASTM C216, or ASTM C652.
2) Thickness of bed joints does not exceed $^5/_8$ in. (15.9 mm).
3) For grouted masonry, the grout meets one of the following requirements:
   a) Grout conforms to Article 2.2.
   b) Grout compressive strength equals or exceeds f'_m but compressive strength is not less than 2,000 psi (13.79 MPa). Determine compressive strength of grout in accordance with ASTM C1019.

QUALITY CONTROL, SAMPLING AND TESTING

MSJC Specification 1.4 B
Table 1 – Compressive strength of masonry based on the compressive strength of clay masonry units and type of mortar used in construction

NET AREA COMPRESSIVE STRENGTH OF CLAY MASONRY UNITS (psi)		NET AREA COMPRESSIVE STRENGTH OF MASONRY (psi)
Type M or S mortar	Type N mortar	
1,700	2,100	1,000
3,350	4,150	1,500
4,950	6,200	2,000
6,600	8,250	2,500
8,250	10,300	3,000
9,900	---	3,500
11,500	---	4,000

For SI: 1 pound per square inch = 0.00689 MPa.

QUALITY CONTROL, SAMPLING AND TESTING

b. *Concrete masonry* – Use Table 2 to determine the compressive strength of concrete masonry based on the strength of the unit and the type of mortar specified. The following Articles must be met:

1) Units are sampled and tested to verify conformance with ASTM C55 or ASTM C90.
2) Thickness of bed joints does not exceed $^5/_8$ in. (15.9 mm).
3) For grouted masonry, the grout meets one of the following requirements:
   a) Grout conforms to Article 2.2.
   b) Grout compressive strength equals or exceeds f'_m but compressive strength is not less than 2,000 psi (13.79 MPa). Determine compressive strength of grout in accordance with ASTM C1019.

QUALITY CONTROL, SAMPLING AND TESTING

MSJC Specification 1.4 B
Table 2 – Compressive strength of masonry based on the compressive strength of concrete masonry units & type of mortar used in construction

NET AREA COMPRESSIVE STRENGTH OF CONCRETE MASONRY UNITS (psi)		NET AREA COMPRESSIVE STRENGTH OF MASONRY (psi)[a]
Type M or S mortar	Type N mortar	
---	1,900	1,350
1,900	2,150	1,500
2,800	3,050	2,000
3,750	4,050	2,500
4,800	5,250	3,000

For SI: 1 inch = 25.4 mm, 1 pound per square inch = 0.00689 MPa.
[a] For units less than 4 inches in height, 85 percent of the values listed.

QUALITY CONTROL, SAMPLING AND TESTING

c. *AAC masonry* – Determine the compressive strength of masonry based on the strength of the AAC masonry unit only. The following requirements apply to the masonry.

1) Units conform to Article 2.3 E.
2) Thickness of bed joints does not exceed $^1/_8$ in. (3.2 mm).
3) For Grouted masonry, the grout meets one of the following requirements.
   a) Grout conforms to Article 2.2.
   b) Grout compressive strength equals or exceeds f'_{AAC} but compressive strength is not less than 2,000 psi (13.79 MPa). Determine compressive strength of grout in accordance with ASTM C1019.

QUALITY CONTROL, SAMPLING AND TESTING

3. *Prism test method* - Determine the compressive strength of clay masonry and concrete masonry by the prism test method in accordance with ASTM C1314.

QUALITY CONTROL, SAMPLING AND TESTING

4. *Testing prisms from constructed masonry.* When approved by the building official, acceptance of masonry that does not meet the requirements of Article 1.4 B.2 or 1.4 B.3 is permitted to be based on tests of prisms cut from the masonry construction.

a. *Prism sampling and removal*— For each 5,000 square feet (465 m2) of wall area in question, saw-cut three prisms from masonry that is at least 28 days old. Obtain a minimum of three prisms from the project. Select, remove and transport prisms in accordance with ASTM C1532. Determine the length, width and height dimensions of the prism and test in accordance with ASTM C1314.

QUALITY CONTROL, SAMPLING AND TESTING

b. *Compressive strength calculations* — Calculate the compressive strength of prisms in accordance with ASTM C1314.

c. *Compliance* — Strengths determined from saw-cut prisms shall equal or exceed the specified compressive strength of masonry. Additional testing of specimens cut from construction in question is permitted.

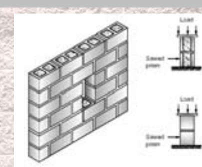


Figure 3.9 Test prism sawed from wall.

QUALITY CONTROL, SAMPLING AND TESTING

3.5 LEVEL OF INSPECTION

The amount of material certification and construction inspection varies from job to job. This section summarizes those requirements. Note that the designer may increase the minimum listed testing or inspection requirements, but any additional testing or inspection requirements must be clearly indicated on the project documents.

QUALITY CONTROL, SAMPLING AND TESTING

TMS 402/602 Quality Assurance Levels

Design Method	Risk Category I, II, III	Risk Category IV
• Veneer • Glass Masonry • Partition Walls • Empirical Masonry (App)	Level 1 / Level A	Level 2 / Level B
• Allowable Stress Design • Strength Design • Prestressed Masonry • AAC Masonry • Masonry Infill (App) • Limit States Design (App)	Level 2 / Level B Small Commercial	Level 3 / Level C Disaster Shelters

Quality Control, Sampling and Testing

3.5.1 Quality Assurance Level A

Projects that are Empirically Designed, or veneer, or glass unit masonry and fall within Risk Category I, II or III (Non-Essential Facilities) require a minimum of Quality Assurance verification. These requirements are contained in MSJC Code Table 1.19.1 and MSJC Specification Table 3. IBC does not specifically list these requirements.

Level A Quality Assurance (MSJC Code Table 1.19.1 and MSJC Specification Table 3)

MINIMUM TESTS
None
MINIMUM INSPECTION
Verify compliance with the approved submittals

Quality Control, Sampling and Testing

3.5.2 Quality Assurance Level B

When projects of the type listed in Section 3.5.1 fall in Risk Category IV (Essential Facilities) the next level of Quality Assurance must be implemented. This QA level also applies to Engineered Masonry (Allowable Stress Design, Strength Design, Prestressed Masonry) falling within Risk Categories I, II or III (Non-Essential Facilities).

These requirements are contained in MSJC Code Table 1.19.2 and MSJC Specification Table 4.

Quality Control, Sampling and Testing

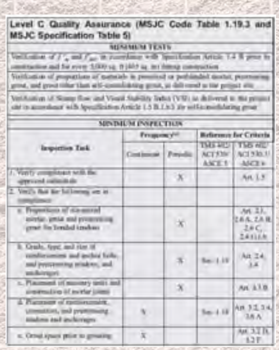

Level B Quality Assurance (MSJC Code Table 1.19.2 and MSJC Specification Table 4)

Quality Control, Sampling and Testing

3.5.3 Quality Assurance Level C

Minimum testing and inspection requirements for Engineered projects that fall in Risk Category IV (Essential Facilities) are listed in MSJC Code Table 1.19.3 and MSJC Specification Table 5. Examples of Risk Category IV Facilities include: hospitals, fire and police stations, emergency shelters, 911 facilities, power generating facilities, water storage and pumping facilities, aviation control towers, and structures containing highly toxic materials.

Quality Control, Sampling and Testing


Level C Quality Assurance (MSJC Code Table 1.19.3 and MSJC Specification Table 5)

MINIMUM TESTS

MINIMUM INSPECTION

Quality Control, Sampling and Testing

NEW!

MINIMUM SPECIAL INSPECTION *[2016 TMS 602]*			
Inspection Task	Frequency		
	Level 1 (Level A)	Level 2 (Level B)	Level 3 (Level C)
1. As masonry construction begins, verify that the following are in compliance:			
a. Proportions of site-prepared mortar	NR	P	P
b. Grade and size of prestressing tendons and anchorages	NR	P	P
c. Grade, type and size of reinforcement, connectors, anchor bolts and prestressing tendons and anchorages	NR	P	P
d. Prestressing technique	NR	P	P
e. Properties of thin-bed mortar for AAC masonry	NR	C(b)/P(c)	C
f. Sample panel construction	NR	P	C

QUALITY CONTROL, SAMPLING AND TESTING

MINIMUM SPECIAL INSPECTION *[2016 TMS 602]*			
Inspection Task	Frequency		
	Level 1 (Level A)	Level 2 (Level B)	Level 3 (Level C)
2. Prior to grouting, verify that the following are in compliance:			
a. Grout space	NR	P	C
b. Placement of prestressing tendons and anchorages	NR	P	P
c. Placement of reinforcement, connectors, and anchor bolts	NR	P	C
d. Proportions of site-prepared grout and prestressing grout for bonded tendons	NR	P	P

QUALITY CONTROL, SAMPLING AND TESTING

MINIMUM SPECIAL INSPECTION *[2016 TMS 602]*			
Inspection Task	Frequency		
	Level 1 (Level A)	Level 2 (Level B)	Level 3 (Level C)
3. Verify compliance of the following during construction:			
a. Materials and procedures with the approved submittals	NR	P	P
b. Placement of masonry units and mortar joint construction	NR	P	P
c. Size and location of structural elements	NR	P	P
d. Type, size, and location of anchors, including other details of anchorage of masonry to structural members, frames, or other construction	NR	P	C
e. Welding of reinforcement	NR	C	C

QUALITY CONTROL, SAMPLING AND TESTING

MINIMUM SPECIAL INSPECTION *[2016 TMS 602]*			
Inspection Task	Frequency		
	Level 1 (Level A)	Level 2 (Level B)	Level 3 (Level C)
3. Verify compliance of the following during construction:			
f. Preparation, construction, and protection of masonry during cold weather (temperature below 40°F (4.4°C)) or hot weather (temperature above 90°F (32.2°C))	NR	P	P
g. Application and measurement of prestressing force	NR	C	C
h. Placement of grout and prestressing grout for bonded tendons is in compliance	NR	C	C
i. Placement of AAC masonry units and construction of thin-bed mortar joints	NR	C[(b)]/P[(c)]	C
4. Observe preparation of grout specimens, mortar specimens, and/or prisms	NR	P	C

QUALITY CONTROL, SAMPLING AND TESTING

3.6 CORE TESTING

The California Division of the State Architect recognizes core testing as an acceptable method to determine compressive strength. Cores are drilled from the face of the wall to the opposite site, avoiding the reinforcing steel.

California Building Code, Section 2105A.4
2105A.4 Masonry core testing*. Not less than two cores shall be taken from each building for each 5,000 square feet (465 m^2) of the greater of the masonry wall area or the floor area or fraction thereof. The architect or structural engineer in responsible charge of the project or his or her representative (inspector) shall select the areas for sampling. Cores shall be a minimum of $3^3/_4$ inches (76 mm) in diameter and shall be taken in such a manner as to exclude masonry unit webs and reinforcing steel. The inspector of record or testing agency shall inspect the coring of the masonry walls.*

QUALITY CONTROL, SAMPLING AND TESTING

Visual examination of all cores shall be made and the condition of the cores reported. One half of the number of cores taken shall be tested in shear. The shear test shall test both joints between the grout core and the outside wythes or face shells of the masonry. Shear testing apparatus shall be of a design approved by the enforcement agency. Core samples shall not be soaked before testing. The unit shear on the cross section of the core shall not be less than $2.5\sqrt{f'_m}$ psi.

All cores shall be submitted to the laboratory for examination regardless of whether the core specimens failed during cutting operation. The laboratory shall report the location where each core was taken, the findings of their visual examination of each core, identify which cores were selected for shear testing and the results of the shear tests.

QUALITY CONTROL, SAMPLING AND TESTING

Quite often, the opposite face shell or wythe of the wall separates from the grout during the coring process. This is usually caused by the excessive vibration, torque of the coring process, and force from the drilling process or alignment that is not perfectly perpendicular to the face of the wall. Cores containing separated wall elements should not be tested.

This section of the California Building Code (CBC) has been applied to all masonry walls, however, when one looks closely at the code language and considers the construction of different masonry elements, the application appears to be intended for double wythe wall systems.

The first paragraph of CBC Section 2105A.4 correctly refers to testing shear wall loadings between the grout and the outside wythes of the masonry. By definition, a wythe is one masonry unit of thickness, therefore, it is clear that this section does apply to double wythe walls where the brick faces on each side of the wall are not homogeneous units. In this application, the bond is a significant issue.

QUALITY CONTROL, SAMPLING AND TESTING

Reinforced hollow unit masonry, however, has the face shells connected by cross webs and are an integral unit. In addition to any bond afforded by the grout, the homogeneous makeup of the unit virtually eliminates the possibility the face shell could separate from the wall even under the most extreme loading conditions. Naturally, this assumes that the design and construction of the masonry is code compliant.

The method of core testing to verify the compressive strength of masonry, f'_m, is an option of minimal destructive testing that may be desirable when other non-destructive test methods have not produced satisfactory results.

QUALITY CONTROL, SAMPLING AND TESTING

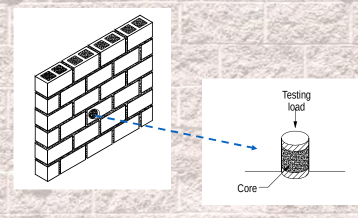


Figure 3.10 Compressive test of core from wall.

QUALITY CONTROL, SAMPLING AND TESTING

QUALITY CONTROL, SAMPLING AND TESTING

3.7 SUMMARY

Specifications and verification requirements for the State of California, Title 24, the International Building Code, and MSJC Specification are summarized in Table 3-1. As detailed in this chapter, the required level of material certification and construction inspection will vary depending on the type of project.

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 Specification and Verification Requirements[1] for Masonry/Masonry Materials[2]

Material Category	Material Type & Property	Specification Requirements ASTM	Additional Verification Requirements[3]		
			CAC T24	2012 IBC	TMS 602-11
Building, Facing Hollow Brick	Burned Clay Brick	ASTM C62 C216 C652	Test Prior to Use Grade NW Not Permitted	N/A	N/A
Sand-Lime Brick	Sand-Lime Brick	ASTM C73	Material Not Permitted	N/A	N/A
Clay Load Bearing Tile	Burned Hollow Clay Tile	ASTM C34 C212	Material Not Permitted	N/A	N/A
Structural Clay, Non Load Bearing Tile	Burned Hollow Clay Tile	ASTM C56	Material Not Permitted	N/A	N/A
Cast Stone	Portland Concrete Trim & Facing	ASTM C744	Test Prior to Use	N/A	N/A

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 Specification and Verification Requirements[1] for Masonry/Masonry Materials[2]

Material Category	Material Type & Property	Specification Requirements ASTM	Additional Verification Requirements[3]		
			CAC T24	2012 IBC	TMS 602-11
Unburned Clay Units	Adobe Block		Material Not Permitted	N/A	N/A
Wire	Steel Wire	ASTM A82, A185, A496, A497, A641	Test Prior to Use	N/A	N/A
Quicklime	Unslaked Lime	ASTM* C270 ► C5	Test as Required	N/A	N/A
Hydrated Lime	Slaked Lime	ASTM* C270 ► C207	Test as Required	N/A	N/A

* Footnote ► Arrow means sub-reference

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 Specification and Verification Requirements[1] for Masonry/Masonry Materials[2] (Cont'd)

Material Category	Material Type & Property	Specification Requirements ASTM	Additional Verification Requirements[3]		
			CAC T24	2012 IBC	TMS 602-11
Grout[4]	Portland Cement Grout	ASTM C476, C1019	Proportioned per Code Field Test for Compressive Strength Required	N/A	N/A
Masonry Cement	Cement (Any Binder)	ASTM* C270 ► C91	Material Not Permitted	Material Not Permitted in Seismic Design Categories D, E, and F	Material Not Permitted in Seismic Design Categories D, E, and F
Cores	Sample of Masonry	Not Noted	Compression & Shear Tests per Section 2105A.4[5]	Not Required	Not Required

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 Specification and Verification Requirements[1] for Masonry/Masonry Materials[2] (Cont'd)

Material Category	Material Type & Property	Specification Requirements ASTM	Additional Verification Requirements[3]		
			CAC T24	2012 IBC	TMS 602-11
Admixtures		TMS 602/ Art. 2.2; 2.6 ASTM C270/ Sec. 4.1.4 TMS 602/4.2.1 ASTM C476	See Footnotes 7 & 8	Refer to TMS 402-11	See Footnote 9
Portland Cement	Portland Cement	ASTM C270 ► C150 C476 ► C150	Test as Required	N/A	N/A
Metal Ties & Anchors	Steel Connectors	ASTM A123, A153, A167, A653, A1008	N/A	N/A	N/A
Water	Water	ASTM C670/4.1.3 C476/3.1.4	N/A	N/A	N/A

* Footnote ► Arrow means sub-reference

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 Specification and Verification Requirements[1] for Masonry/Masonry Materials[2] (Cont'd)

Material Category	Material Type & Property	Specification Requirements ASTM	Additional Verification Requirements[3]		
			CAC T24	2012 IBC	TMS 602-11
Aggregate for Grout	Aggregate for Grout	ASTM C404	Test Prior to Use	N/A	N/A
Aggregate for Mortar	Aggregate for Mortar	ASTM C144	Test Prior to Use	N/A	N/A
Mortar	Proportion Spec. or Property Spec.	ASTM C270	Proportioned per Code Field Test for Compressive Strength Required[10]	N/A	As Noted by Quality Assurance Level B or C
Mortar	Ready Mix	ASTM C270	Subject to Prior Approval of Agency	N/A	As Noted by Quality Assurance Level B or C

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 Specification and Verification Requirements[1] for Masonry/Masonry Materials[2] (Cont'd)

Material Category	Material Type & Property	Specification Requirements ASTM	Additional Verification Requirements[3]		
			CAC T24	2012 IBC	TMS 602-11
Mortar	Field Test		Per Section 2103A.8[11]		Method Not Noted
Concrete Masonry Unit	Hollow Load Bearing	ASTM C90	Complete Test Prior to Use	N/A	N/A
Concrete Masonry Unit	Non Load Bearing	ASTM C129	Complete Test Prior to Use	N/A	N/A
Masonry Prisms	Qualification Testing	ASTM C1314	Prism Tests if Spec. f'_m is greater than 1500 psi with Approved Quality Control Methods	N/A	Frequency as Required Noted by QA Level B or C

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 Specification and Verification Requirements[1] for Masonry/Masonry Materials[2] (Cont'd)

Material Category	Material Type & Property	Specification Requirements ASTM	Additional Verification Requirements[3]		
			CAC T24	2012 IBC	TMS 602-11
Cement	Plastic	Not Noted	Not Permitted	Not Recognized	Not Recognized
Concrete Brick	Concrete Building Brick	ASTM C55	Complete Test Prior to Use	N/A	N/A
Ceramic Structural Facing Tile	Load Bearing Tiles	ASTM C126	Complete Test Prior to Use	N/A	N/A
Brick	Sampling and Testing	ASTM C67	Not Required	N/A	N/A
Gypsum Concrete	Gypsum Concrete	Not Covered	Complete Test Prior to Use	Not Recognized	

QUALITY CONTROL, SAMPLING AND TESTING

TABLE 3.1 - Footnotes

[1] The specification listed fall into one classification. The ASTM Standards and the ACI Standards are industry standards used to inform the buyer of the conditions under which materials are furnished.

[2] Based on Sub-Committee Testing Guidelines for Construction Materials by Nezih Gunal, P.E., Chairman Report No. 2, Masonry and Masonry Materials, 1986, Structural Engineers Association of Southern California, Los Angeles, California.

[3] Additional verification requirements are specific tests and/or analysis required by the building code enforcement agency in addition to the ASTM specification requirements. These tests and/or analysis are generally based on the ASTM specification indicated, and are generally conducted by independent agents such as testing laboratories.

[4] Tensile and bend tests per each 10 tons or fraction thereof of each size of reinforcement in each lot. Where manufacturer's name, or heat identification number, or manufacturer's chemical analysis is unknown, testing frequency must be increased to each 2½ tons or fraction thereof.

Quality Control, Sampling and Testing

(Table 3-1 - Footnotes Continued)

[5] Field tests for compressive strength may be required, by jurisdiction or specifications.

[6] Two cores minimum, with at least one core taken from every 5,000 sq ft of floor area, or fraction thereof.

[7] Admixtures require prior approval by the building official before addition to grout or mortar.

[8] For color, only pure mineral oxides, carbon black limited to 3%, or synthetic colors are permitted.

[9] For portland cement-lime mortar, color is limited to 10% for mineral oxide pigment and 2% for carbon black pigment. For masonry cement mortar, color is limited to 5% for mineral oxide pigment and 1% for carbon black pigment.

[10] Test sampling consists of at least one sample taken on each of three consecutive working days at beginning of masonry work, and at least one at weekly intervals thereafter.

CHAPTER 4
General Construction Practice and Layout

4.1 GENERAL

Inspection is most important during actual construction. The inspector's job is to verify that all work performed is done according with the applicable building code and the approved plans and specifications, and the materials are as specified and used correctly.

General Construction Practice and Layout

4.2 MATERIALS, HANDLING, STORAGE AND PREPARATION

Figures 4.1 through 4.6 illustrate the requirements contained in MSJC Specification Article 1.7 for delivery, storage and handling of material.

MSJC Specification Article 1.7

1.7 – Delivery, storage, and handling

1.7 A. Do not use damaged masonry units, damaged components of structure, or damaged packaged material.

1.7 B. Protect cementitious materials for mortar and grout from precipitation and ground water.

1.7 C. Do not use masonry materials that are contaminated.

1.7 D. Store different aggregates separately.

1.7 E. Protect reinforcement, ties, and metal accessories from permanent distortions and store them off the ground.

General Construction Practice and Layout

Figure 4.1 Proper storage of masonry units.

General Construction Practice and Layout

Figure 4.2 Reinforcing steel.

General Construction Practice and Layout

Figure 4.3 Concrete masonry units should normally not be wetted.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

Figure 4.4 Properly stored sacked material.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

Figure 4.5 Mortar (plaster) mixer.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

Figure 4.6 Pre-blended mortar silo setup.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

4.3 MORTAR JOINTS

Mortar is used in the joints between masonry units. The horizontal joint is the bed joint and the vertical joint is the head joint. Mortar is the bedding material that allows the units to be placed level, plumb and in proper position. Mortar is also the sealing material between masonry units. The exposed surface of the mortar can be finished in a number of ways, as illustrated in Figures 4.7 and 4.8.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

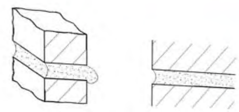
Concave, V-joints and weathered joints are recommended for exterior masonry. Tooling the joints requires pressure, which compresses the mortar, creating a tight bond between the mortar and the unit thus providing a dense surface for weatherproofing and sealing the interface between mortar and masonry unit.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

Mortar joints for interiors may be the same as exterior joints or they may be raked, extruded or weeping, struck or flush cut. These types of joints increase the chance for water leakage in weather exposed masonry since the small ledges allow water to collect and migrate into the wall at the mortar-unit interface and they are usually not compressed by tooling. These joints require special attention and tooling to improve water tightness and are not recommended for exterior work.

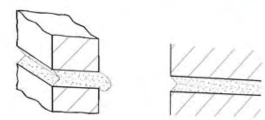
Flush cut joints should be used where the finished surface is to be plastered or texture covered.

Special effect joints that are sometimes used are beaded and grapevine. These are for simulating old style masonry.



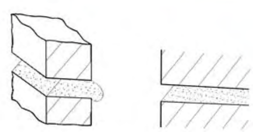
a) Concave joint
Most common joint used, tooling works the mortar tight into the joint to produce a good weather joint. Pattern is emphasized and small irregularities in laying are concealed.

Figure 4.7 Types of recommended mortar joints.



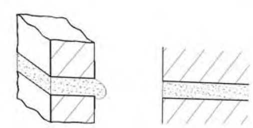
b) "V" joint
Tooling works the mortar tight and provides a good weather joint. Used to emphasize joints and conceal small irregularities in laying and provide a line in center of mortar joint.

Figure 4.7 Types of recommended mortar joints.



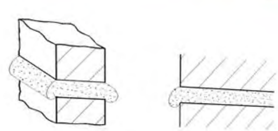
c) Weather joint
Use to emphasize horizontal joints. Acceptable weather joint with proper tooling.

Figure 4.7 Types of recommended mortar joints.



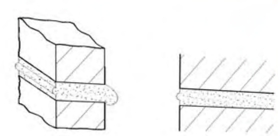
d) Flush joint
Use where wall is to be plastered or where it is desired to hide joints under paint. Special care is required to make joint weatherproof.

Figure 4.7 Types of recommended mortar joints.



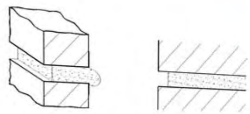
e) Squeeze joint (Extruded or Weeping)
Provide a rustic, high texture look. Satisfactory indoors and exterior fences. Not recommended for exterior building walls.

Figure 4.8 Types of non-weather mortar joints, for special effects only.



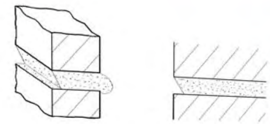
f) Beaded joint
Special effect, poor exterior weather joint because of exposed ledge – Not recommended for exterior use.

Figure 4.8 Types of non-weather mortar joints, for special effects only.



g) Raked joint
Strongly emphasizes joints. Poor weather joint – Not recommended if exposed to weather unless tooled at bottom of mortar joint.

Figure 4.8 Types of non-weather mortar joints, for special effects only.



h) Struck joint
Use to emphasize horizontal joints. Poor weather joint. Not recommended as water will penetrate on lower ledge.

Figure 4.8 Types of non-weather mortar joints, for special effects only.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

4.4 PREPARATION OF FOUNDATION AND SITE

Prior to laying the first course of concrete masonry, clean the concrete surfaces, removing laitance, loose aggregate, dirt, mud, grease or anything that will prevent the mortar from bonding properly. The concrete surface of the foundation must be rough to provide a good bond between the foundation concrete and the mortar and grout.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

Surfaces should be level and at a correct grade so that the initial bed joint is not less than $^1/_4$ in. (6 mm) nor more than $^3/_4$ in. (19 mm) in height.

UPDATE: 2013 TMS 602 allows initial bed joint up to 1¼ inch when first course is solidly grouted and masonry is supported by concrete foundation.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

MSJC Specification Article 3.3 B

3.3 B. *Placing mortar and units*

1. *Bed and head joints* – Unless otherwise required, construct $^3/_8$ in. (9.5 mm) thick bed and head joints, except at foundation or with glass unit masonry. Construct bed joint of the starting course of foundation with a thickness not less than $^1/_4$ in. (6.4 mm) and not more than $^3/_4$ in. (19.1 mm).

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

Foundation tolerances are contained in MSJC Specification Article 3.1 A

MSJC Specification Article 3.1 A

3.1 A. Prior to the start of masonry construction, the Contractor shall verify:

1. That foundations are constructed within a level alignment tolerance of ±½ in. (12.7 mm).

General Construction Practice and Layout

When foundations are poured to the extreme tolerances, the initial mortar bed joint would range between $^1/_4$ in. (6.4 mm) and $1^1/_4$ in. (31.8 mm) which exceeds the maximum initial mortar bed joint limit of $^3/_4$ in. (19.1 mm). The 2010 California Building Code, Chapter 21*A* harmonizes the foundation tolerance and initial mortar bed joint thickness with the following provision:

California Building Code Section 2104A.1.1

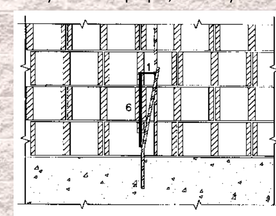
2104A.1.1 Tolerances. Masonry, except masonry veneer, shall be constructed within the tolerances specified in TMS 602/ACI 530.1/ASCE 6

Exception: *The maximum thickness of the initial bed joint in fully grouted masonry walls shall not exceed $1^1/_4$ in. (31.7 mm).*

General Construction Practice and Layout

Properly place reinforcing steel dowels. Check the specified size and length and if they need to be bent, they may be bent at a slope of no more than 1 in. (25.4 mm) horizontally per 6 in. (152 mm) of vertical height, in accordance with MSJC Specification Article 3.4 B.11.d.

If any of the site conditions or layout are improper, masonry work should not begin until corrected.



General Construction Practice and Layout

The first course on the foundation should have all webs and face shells set in mortar for full bearing. Face shell bedding for solid-grouted masonry walls is acceptable. The mortar, however, must not project more than $^1/_2$ in. (13 mm) into the cells that are to contain grout, as shown in Figure 4.9. Inverted bond beam units may be used on initial course to maximize grout contact with foundation. The grout must have direct contact and bearing on the foundation or slab.

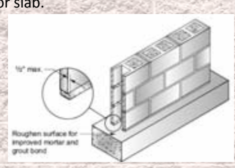


Figure 4.9 First course mortar joint.

General Construction Practice and Layout

4.5 PLACEMENT AND LAYOUT

4.5.1 General

All dimensions, locations of all wall openings, positions of vertical reinforcing steel, methods of grouting, mortar mixes, patterns of bond, and the general sequence of operation should be determined prior to laying the first course of masonry.

Where no bond pattern is shown, the wall should be laid in straight uniform courses with alternate vertical joints aligning (called running bond, shown in Figure 4.10). Proper alignment of the vertical cells gives maximum size openings for pouring grout in vertically reinforced cells and reduces ledges or projections that may impede the flow of grout.

General Construction Practice and Layout

Figure 4.10 Running bond masonry.

General Construction Practice and Layout

In bearing and nonbearing walls, except veneer walls, if the units in any transverse vertical plane lap the ends of the units above and below a distance less than one fourth the length of the unit, the wall is considered to be laid in stack bond.

If units are laid in stack bond, shown in Figure 4.11, give particular attention to proper type and placement of reinforcing steel or metal ties and joint reinforcement used to provide the mechanical bond.

General Construction Practice and Layout

Unless specified otherwise, horizontal mortar joints (bed joints) for precision units should be $^3/_8$ in. (10 mm) $\pm\ ^1/_8$ in. (3 mm). The vertical (head) joints are typically $^3/_8$ in. (10 mm) with a tolerance of $+^3/_8$ in. (10 mm) or $-^1/_4$ in. (6 mm). Slumped or adobe-textured units have a typical $^1/_2$ in. (13 mm) mortar joint and may require a tolerance of $\pm\ ^1/_4$ in. (6 mm).

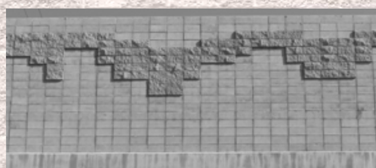


Figure 4.11 Masonry laid up in stack bond.

General Construction Practice and Layout

General Construction Practice and Layout

4.5.2 Installation

4.5.2.1 Placing Masonry Units

The IBC, through MSJC Specifications, contains language on construction tolerances for masonry installation.

IBC Section 2104

SECTION 2104
CONSTRUCTION

2104.1 Masonry construction. Masonry construction shall comply with the requirements of Sections 2104.1.1 through 2104.4 and with TMS 602/ACI 530.1/ASCE 6.

General Construction Practice and Layout

2104.1.1 Tolerances. Masonry, except masonry veneer, shall be constructed within the tolerances specified in TMS 602/ACI 530.1/ASCE 6

2104.1.2 Placing mortar and units. Placement of mortar, grout, and clay, concrete, glass, and AAC masonry units shall comply with TMS 602/ACI 530.1/ASCE 6.

General Construction Practice and Layout

MSJC Specification Article 3.3 B

3.3 B. ***Placing mortar and units***

1. *Bed and head joints* – Unless otherwise required, construct $^3/_8$-in. (9.5-mm) thick bed and head joints, except at foundation or with glass unit masonry. Construct bed joint of the starting course of foundation with a thickness not less than ¼ in. (6.4 mm) and not more than ¾ in. (19.1 mm). Provide glass unit masonry bed and head joint thicknesses in accordance with Article 3.3 B.6.c. Construct joints that also conform to the following:
   a. Fill holes not specified in exposed and below grade masonry with mortar.
   b. Unless otherwise required, tool joint with a round jointer when the mortar is thumbprint hard.
   c. Remove masonry protrusions extending ½ in. (12.7 mm) or more into cells or cavities to be grouted.
2. *Collar joints* – Unless otherwise required, solidly fill collar joints less than ¾ in. (19.1 mm) wide with mortar as the project progresses.

General Construction Practice and Layout

3. *Hollow units* – Place hollow units so:
   a. Face shells of bed joints are fully mortared.
   b. Webs are fully mortared in:
      1) all courses of piers, columns and pilasters;
      2) when necessary to confine grout or insulation.
   c. Head joints are mortared, a minimum distance from each face equal to the face shell thickness of the unit.
   d. Vertical cells to be grouted are aligned and unobstructed openings for grout are provided in accordance with the Project Drawings.
4. *Solid units* – Unless otherwise required, solidly fill bed and head joints with mortar and:
   a. Do not fill head joints by slushing with mortar.
   b. Construct head joints by shoving mortar tight against the adjoining unit.
   c. Do not deeply furrow bed joints.

General Construction Practice and Layout

5. *Open-end units with beveled ends* – Fully grout open-end units with beveled ends. Head joints of open-end units with beveled ends need not be mortared. At the beveled ends, form a grout key that permits grout with $^5/_8$ inch (15.9 mm) of the face of the unit. Tightly butt the units to prevent leakage of grout.
6. *Glass units*
   a. Apply a complete coat of asphalt emulsion, not exceeding $^1/_8$ in. (3.2 mm) in thickness, to panel bases.
   b. Lay units so head and bed joints are filled solidly. Do not furrow mortar.
   c. Unless otherwise required, construct head and bed joints of glass unit masonry ¼ in. (6.4 mm) thick, except that vertical joint thickness of radial panels shall not be less than $^1/_8$ in. (3.2 mm). The bed-joint thickness tolerance shall be minus $^1/_{16}$ in. (1.6 mm) and plus $^1/_8$ in. (3.2 mm). The head-joint thickness tolerance shall be plus or minus $^1/_8$ in. (3.2 mm).
   d. Do not cut class units.

General Construction Practice and Layout

7. *All units*
   a. Place clean units while the mortar is soft and plastic. Remove and re-lay in fresh mortar any unit disturbed to the extent that initial bond is broken after initial positioning.
   b. Except for glass units, cut exposed edges or faces of masonry units smooth, or position so that exposed faces or edges are unaltered manufactured surfaces.
   c. When the bearing of a masonry wythe on its support is less than two-thirds of the wythe thickness, notify the Architect/Engineer.

General Construction Practice and Layout

8. *AAC masonry*
   a. Place mortar for leveling bed joint in accordance with the requirements of Article 3.3 B.1.
   b. Lay subsequent courses using thin-bed mortar. Use special notched trowels manufactured for use with thin-bed mortar to spread thin-bed mortar so that it completely fills the bed joints. Unless otherwise specified in the Contract Documents, similarly fill the head joints. Spread mortar and place the next unit before the mortar dries. Place each AAC unit as close to head joint as possible before lowering the block onto the bed joint. Avoid excessive movement along bed joint. Make adjustments while thin-bed mortar is still soft and plastic by tapping to plumb and bring units into alignment. Set units into final position, in mortar joints approximately $^1/_{16}$ in. (1.5 mm) thick, by striking on the end and top with a rubber mallet.
   c. Lay units in alignment with the plane of the wall. Align vertically and plumb using the first course for reference. Make minor adjustments by sanding the exposed faces of the units and the bed joint surface with a sanding board manufactured for use with AAC masonry.

General Construction Practice and Layout

In order to install concrete masonry units in a professional manner, many project specifications require units to be cut with a masonry saw using a diamond blade. This is normally a wet-cut process and the slight amount of water used in cutting does not appreciably affect the absorption requirements. MSJC Specification Article 3.2 C.1 clarifies the requirement of not wetting concrete masonry units prior to laying:

MSJC Specification Article 3.2 C.1

3.2 C. *Wetting masonry units*

1. *Concrete masonry* – Unless otherwise required, do not wet concrete masonry or AAC masonry units before laying. Wet cutting is permitted.

General Construction Practice and Layout

Water used in the cutting process does not saturate the concrete masonry unit and typically dissipates by the time the unit is given to the bricklayer for installation in the wall.

Figure 4.12 Cutting masonry units.

General Construction Practice and Layout

4.5.2.2 Tolerances

Tolerances contained in the MSJC Specification are based on structural requirements (eccentricities) for performance, not aesthetics. It is, however, reasonable to use these tolerance values for aesthetic acceptance of the project. Consideration must also be given to the ASTM distance viewing requirements for aesthetic acceptance.

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

1. Dimension of elements
   a. In cross section or elevation
   ……………………………….......-$^1/_4$ in. (6.4 mm), +$^1/_2$ in. (12.7 mm)

General Construction Practice and Layout

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

Dimension of elements

Mortar Joint Thickness

bed...$\pm$ $^1/_8$ in. (3.2 mm)

head...- $^1/_4$ in. (6.4 mm), +$^3/_8$ in. (9.5 mm)

collar..- $^1/_4$ in. (6.4 mm), +$^3/_8$ in. (9.5 mm)

General Construction Practice and Layout

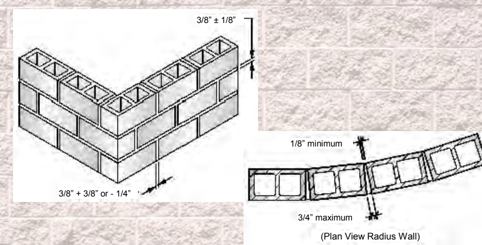


Figure 4.13 Permissible variations in mortar joint thickness.

General Construction Practice and Layout

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

1. Dimension of elements

c. Grout space or cavity width, except for masonry walls passing framed construction

....- $^1/_4$ in. (6.4 mm), + $^3/_8$ in. (9.5 mm)

General Construction Practice and Layout

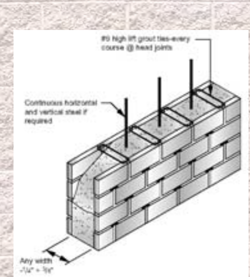


Figure 4.14 Permissible variation of grout space.

General Construction Practice and Layout

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

2. Elements

a. Variation from level:

bed joints

....$\pm$ $^1/_4$ in. (6.4 mm) in 10 ft. (3.05 m)

....$\pm$ $^1/_2$ in (12.7 mm) maximum

top surface of bearing walls

....$\pm$ $^1/_4$ in. (6.4 mm) in 10 ft. (3.05 m)

....$\pm$ $^1/_2$ in (12.7 mm) maximum

General Construction Practice and Layout

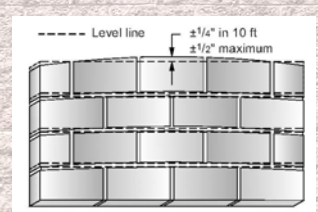


Figure 4.15 Permissible variations from level for bed joints.

General Construction Practice and Layout

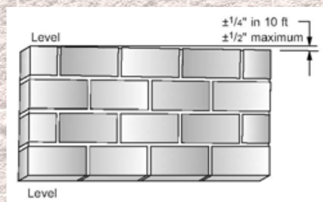


Figure 4.16 Permissible variation from level, top surface of bearing walls.

General Construction Practice and Layout

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

2. Elements
   b. Variation from plumb
      .... $\pm\,{}^{1}/_{4}$ in. (6.4 mm) in 10 ft. (3.05 m)
      .... $\pm\,{}^{3}/_{8}$ in. (9.5 mm) in 20 ft. (6.10 m)
      .... $\pm\,{}^{1}/_{2}$ in (12.7 mm) maximum

General Construction Practice and Layout

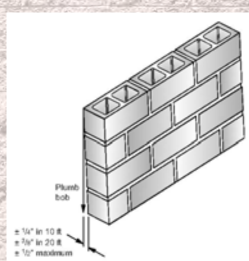


Figure 4.17 Permissible variation from plumb.

General Construction Practice and Layout

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

2. Elements
   c. True to a line
      .... $\pm\,{}^{1}/_{4}$ in. (6.4 mm) in 10 ft. (3.05 m)
      .... $\pm\,{}^{3}/_{8}$ in. (9.5 mm) in 20 ft. (6.10 m)
      .... $\pm\,{}^{1}/_{2}$ in (12.7 mm) maximum

General Construction Practice and Layout

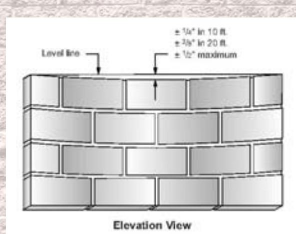


Figure 4.18 Permissible variation from true to line.

General Construction Practice and Layout

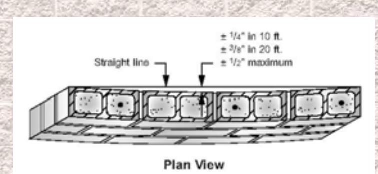


Figure 4.18 Permissible variation from true to line.

General Construction Practice and Layout

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

2. Elements
   d. Alignment of columns and walls (bottom versus top)
   …..............….........$\pm ^1/_2$ in. (12.7 mm) for bearing walls and columns
   …..............………...............$\pm ^3/_4$ in. (19.7 mm) for nonbearing walls

3. Location of elements
   a. Indicated in plan
   ....……...………....................$\pm ^1/_2$ in. (12.7 mm) in 20 ft. (6.10 m)
   ....………................................$\pm ^3/_4$ in (19.1 mm) maximum

General Construction Practice and Layout

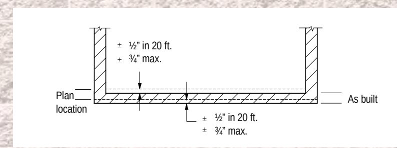


Figure 4.19 Permissible variation of element indicated in the plan.

General Construction Practice and Layout

MSJC Specification Article 3.3 F

3.3 F. *Site tolerances* – Erect masonry within the following tolerances from the specified dimensions.

3. Location of elements
   b. Indicated in elevation
   ....………........................$\pm ^1/_4$ in. (6.4 mm) in story height
   ....……………...................$\pm ^3/_4$ in (19.1 mm) maximum

General Construction Practice and Layout

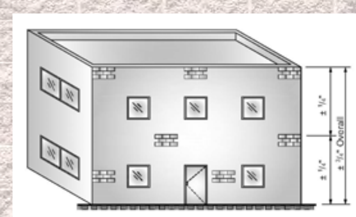


Figure 4.20 Permissible variation of element indicated in elevation.

General Construction Practice and Layout

4.5.2.3 Unit Installation Requirements

In solid grouted masonry, any minor voids in mortar joints within the wall cavity will be filled with grout. This will satisfy the requirement that mortar joints be filled the face shell depth for hollow-unit masonry and solid mortar fill for solid masonry units.

General Construction Practice and Layout

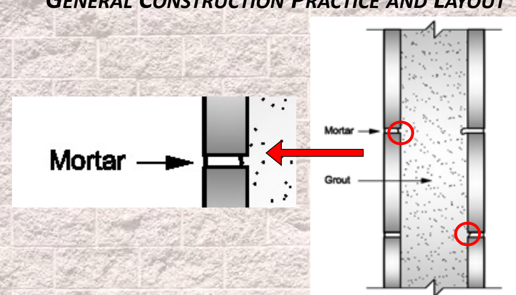


Figure 4.21 Grout flows into head joint and bed joint for full joints in concrete bricks.

General Construction Practice and Layout

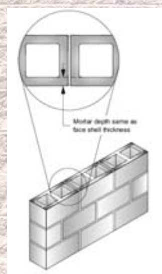


Figure 4.22 Hollow masonry unit head joints.

General Construction Practice and Layout

Open-end units with beveled ends are fully grouted. Head joints of open-end units with beveled ends need not be mortared. The beveled ends form a grout key that permits grouts within $^5/_8$ in. (15.9 mm) of the face of the unit. The units are tightly butted to prevent leakage of the grout.

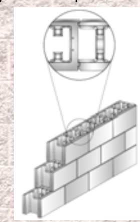


Figure 4.23 Speed block mortarless head joints.

General Construction Practice and Layout

Pilasters (in the wall columns) should be laid up at the same time as the wall, taking care to place the pilaster ties as required.

No unit should be moved after setting as this breaks the mortar bond. Should moving of a unit be necessary, the mortar should be removed and the unit set in fresh mortar.

General Construction Practice and Layout

4.5.3 Typical Layout of CMU Walls

4.5.3.1 Corner Details

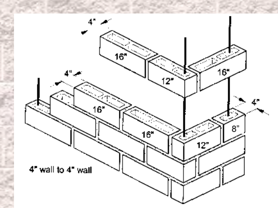


Figure 4.24 Arrangement of masonry units for corners.

General Construction Practice and Layout

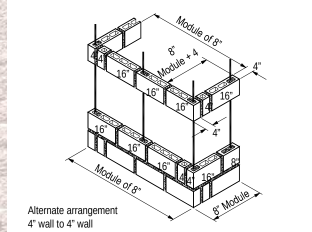


Figure 4.24 Arrangement of masonry units for corners.

General Construction Practice and Layout

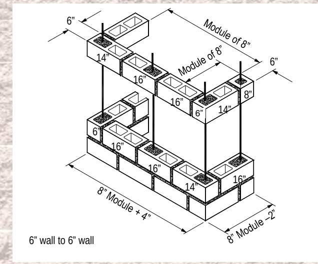


Figure 4.24 Arrangement of masonry units for corners.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

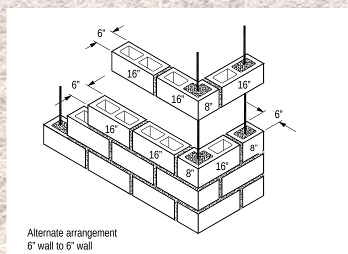


Figure 4.24 Arrangement of masonry units for corners.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

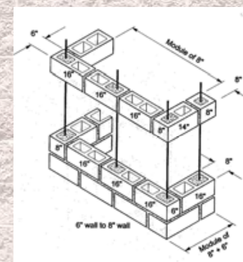


Figure 4.25 Arrangement of masonry units for corners.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

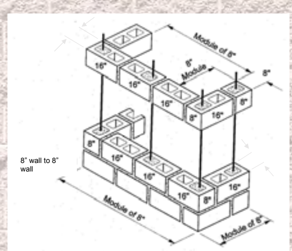


Figure 4.25 Arrangement of masonry units for corners.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

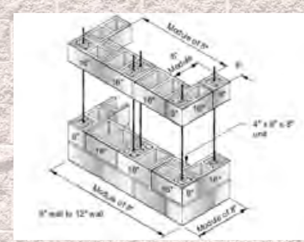


Figure 4.25 Arrangement of masonry units for corners.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

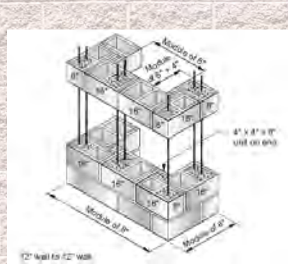


Figure 4.25 Arrangement of masonry units for corners.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

4.5.3.2 Typical Layout of Pilasters

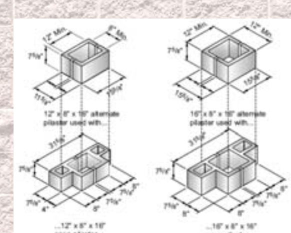


Figure 4.26 Arrangement of units for pilaster.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

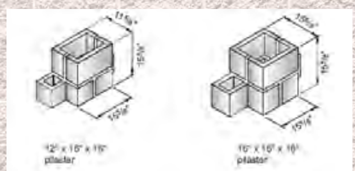


Figure 4.26 Arrangement of units for pilaster.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

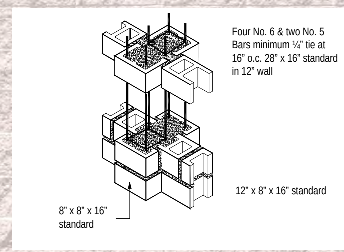


Figure 4.27 Pilaster details.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

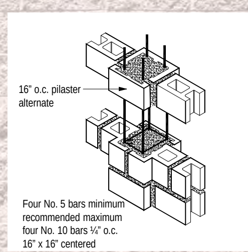


Figure 4.27 Pilaster details.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

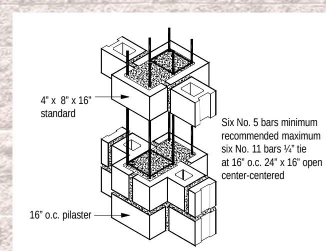


Figure 4.27 Pilaster details.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

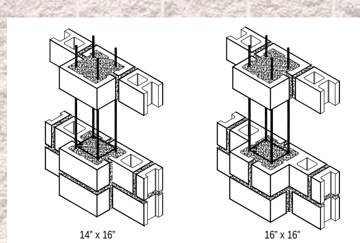


Figure 4.28 Pilaster details.

GENERAL CONSTRUCTION PRACTICE AND LAYOUT

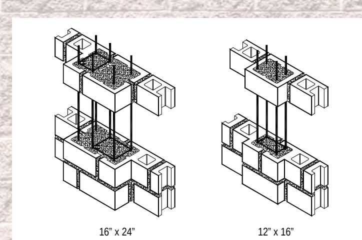


Figure 4.28 Pilaster details.

General Construction Practice and Layout

4.5.3.3 Typical Connections of Intersecting Walls and Embedded Columns

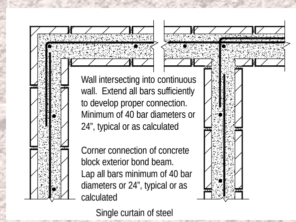


Figure 4.29 Typical intersection wall connections.

General Construction Practice and Layout

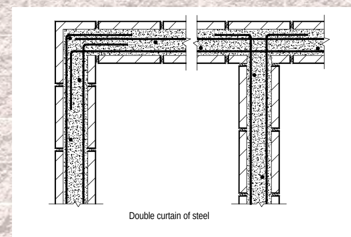


Figure 4.29 Typical intersection wall connections.

General Construction Practice and Layout

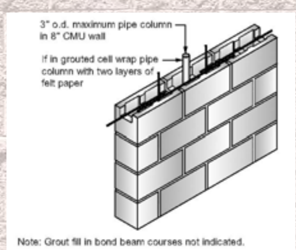


Figure 4.30 Embedded steel columns in masonry wall.

General Construction Practice and Layout

4.5.3.4 Lintel and Bond Beam.

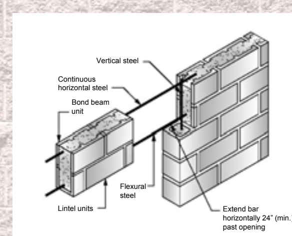


Figure 4.31 Lintel and bond beam detail.

General Construction Practice and Layout

General Construction Practice and Layout

4.5.3.5 Arrangement of Open End Units

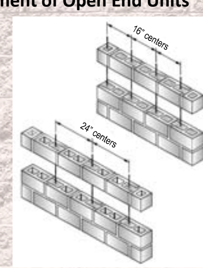


Figure 4.32 Typical arrangement of steel and open-end units – 16 in. (406 mm) and 24 in. (610 mm) spacing.

General Construction Practice and Layout

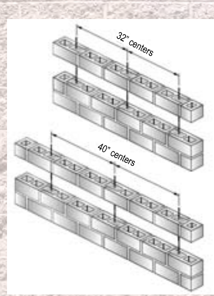


Figure 4.33 Typical arrangement of steel and open-end units — 32 in. (813 mm) and 40 in. (1016 mm) spacing.

General Construction Practice and Layout

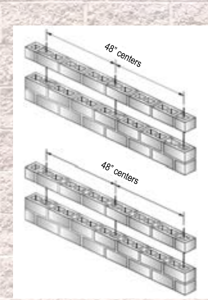


Figure 4.33 (Cont'd) Typical arrangement of steel and open-end units — 48 in. (1219 mm) spacing.

General Construction Practice and Layout

4.5.3.6 Typical Wall Assembly

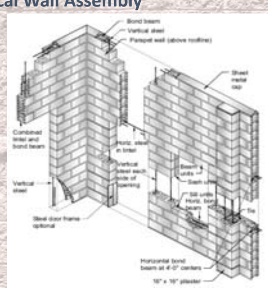


Figure 4.34 Wall assembly and terminology.

General Construction Practice and Layout

4.6 RACKING and TOOTHING

Occasionally, a section of wall cannot be sequentially constructed due to project conditions. An example would be constructing a wall next to a door frame, but the door frame has not been installed, causing an interruption in the masonry construction.

Given this condition, it may be necessary to "rack back" the wall. This method is shown in Figure 4.35. When the condition causing the interruption has been eliminated, then the mason can return and continue to construct the masonry wall. The racking method is preferred over the toothing method.

General Construction Practice and Layout

Figure 4.35 Racked masonry.

General Construction Practice and Layout

There are times when racking is not practical. An example would be the adjoining of new construction to old with a design that integrates the masonry units. Another example would be filling in a pre-existing door or window opening. Under these conditions, the method of construction would be toothing the block, as shown in Figure 4.36. Consent from the Architect or Engineer should be obtained before toothing is performed.

When toothing, careful consideration must be given to the mortar joints. While placing units into the existing "tooth", the mason must properly compact the mortar to ensure a full and tightly compressed joint. Inserting steel and grouting the toothed cells must also be done with care to assure full contact between the reinforcement and the grout.

General Construction Practice and Layout

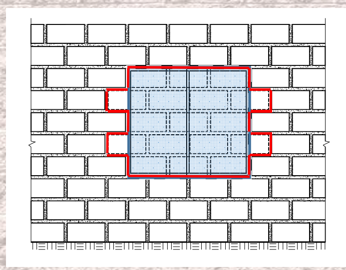


Figure 4.33 Toothed masonry – window infill.

Chapter 5
Reinforcing Steel

5.1 GENERAL

Reinforcing steel is the material that imparts ductility, added strength and toughness to masonry structures. It is one of the primary components for lateral force-resistant design and construction.

Reinforcing Steel

5.2 MAXIMUM SIZE/AMOUNT OF REINFORCING STEEL

Building codes impose the maximum size and amount of reinforcing steel that can be placed in a masonry wall depending on the applicable code and the design method. Tables 5-1 and 5-2 summarize the requirements.

Reinforcing Steel

Table 5.1 – Maximum Size of Reinforcement

	Allowable Stress Design	Strength Design
IBC (2012)	Lesser of: $^1/_8$ of nominal wall thickness, or $^1/_4$ of least cell dimension	See MSJC Code
MSJC Code (2011)	#11	Lesser of: #9 bar, or $^1/_8$ of nominal wall thickness, or $^1/_4$ of least cell dimension

Table 5.2 – Maximum Amount of Reinforcement

	Allowable Stress Design	Strength Design
MSJC Code (2011)	6% of area of grout space per Table 1.20.1, Footnote 4	4% of cell area except at splices

Reinforcing Steel

5.2.1 Maximum Size/Amount of Reinforcing Steel —Allowable Stress Design

IBC sets forth maximum reinforcement size based on cell dimension, whereas, the MSJC Code bases maximum reinforcement size based on a specific bar size.

The maximum size and amount of reinforcing steel reduces the congestion and facilitates grouting of the cells. Splices increase the congestion and should therefore be staggered whenever possible.

Reinforcing Steel

IBC Section 2107.4

2107.4 TMS 402/ACI 530/ASCE 5, Section 2.3.7, maximum bar size. Add the following to Chapter 2:

2.3.7 Maximum bar size. The bar diameter shall not exceed one-eighth of the nominal wall thickness and shall not exceed one-quarter of the least dimension of the cell, course or collar joint in which it is placed.

REINFORCING STEEL

MSJC Code Section 1.16.2

1.16.2 *Size of reinforcement*

1.16.2.1 The maximum size of reinforcement used in masonry shall be No. 11 (M #36).

1.16.2.2 The diameter of reinforcement shall not exceed one-half the least clear dimension of the cell, bond beam, or collar joint in which it is placed.

1.16.2.3 Longitudinal and cross wires of joint reinforcement shall have a minimum wire size of W1.1 (MW7) and a maximum wire size of one-half the joint thickness.

REINFORCING STEEL

5.2.2 Maximum Size/Amount of Reinforcing Steel — Strength Design

The Strength Design provisions of the 2012 International Building Code defers to the MSJC Code for reinforcement size and amount limitations. The MSJC Code limits the size of reinforcement to a No. 9 (M#29) bar or $^1/_4$ of the least clear cell dimension or $^1/_8$ of the nominal member thickness, whichever is most restrictive. The amount of reinforcement, excluding splices, is limited to 4% of the area of grout space. The area is not a volume measurement, but a two dimensional cross section, typically perpendicular to the vertical reinforcement to evaluate the area of the vertical reinforcement.

MSJC Code Section 3.3.3.1

3.3.3.1 *Reinforcing bar size limitations* – Reinforcing bars used in masonry shall not be larger than No. 9 (M#29). The nominal bar diameter shall not exceed one-eighth of the nominal member thickness and shall not exceed one-quarter of the least clear dimension of the cell, course, or collar joint in which the bar is placed. The area of reinforcing bars placed in a cell or in a course of hollow unit construction shall not exceed 4 percent of the cell area.

REINFORCING STEEL

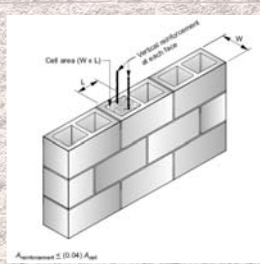


Figure 5.1 Reinforcement limit (Strength Design).

REINFORCING STEEL

5.3 SPACING OF STEEL IN WALLS

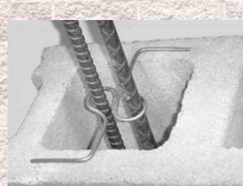
Placing steel reinforcement in the proper location is critical. For a masonry structure to resist wind, seismic and other loads, the steel reinforcement must be positioned where it can function properly. The Codes provide specific language addressing this important issue.

REINFORCING STEEL

MSJC Specification Article 3.4 B

3.4 B *Reinforcement*

1. Support reinforcement to prevent displacement caused by construction loads or by placement of grout or mortar, beyond the allowable tolerances.



REINFORCING STEEL

MSJC Specification Article 3.4 B

3.4 B *Reinforcement*

2. Completely embed reinforcing bars in grout in accordance with Article 3.5.
3. Maintain clear distance between reinforcing bars and the interior of masonry unit or formed surface of at least ¼ in. (6.4 mm) for fine grout and ½ in. (12.7 mm) for coarse grout, except where cross webs of hollow units are used as supports for horizontal reinforcement.
4. Place reinforcing bars maintaining the following minimum cover:
   a. Masonry face exposed to earth or weather: 2 in. (50.8 mm) for bars larger than No. 5 (M #16); 1½ in. (38.1 mm) for No. 5 (M #16) bars or smaller
   b. Masonry not exposed to earth or weather: 1½ in. (38.1 mm).

Reinforcing Steel

MSJC Specification Article 3.4 B

3.4 B *Reinforcement*

5. Maintain minimum clear distance between parallel bars of the nominal bar size or 1 in. (25.4 mm), whichever is greater.
6. In columns and pilasters, maintain minimum clear distance between vertical bars of one and one-half times the nominal bar size or 1½ in. (38.1 mm), whichever is greater.
7. Splice only where indicated on the Project Drawings, unless otherwise acceptable. When splicing by welding, provide welds in conformance with the provisions of AWS D 1.4.
8. Unless accepted by the Architect/Engineer, do not bend reinforcement after it is embedded in grout or mortar.

Reinforcing Steel

MSJC Specification Article 3.4 B

3.4 B *Reinforcement*

9. *Noncontact lap splices* – Position bars spliced by noncontact lap splice no farther apart transversely than one-fifth the specified length of lap nor more than 8 in. (203 mm).
10. *Joint reinforcement*
    a. Place joint reinforcement so that longitudinal wires are embedded in mortar with a minimum cover of ½ in. (12.7 mm) when not exposed to weather or earth and $^5/_8$ in. (15.9 mm) when exposed to weather or earth.
    b. Provide minimum 6 in. (152 mm) lap splices for joint reinforcement.
    c. Ensure that all ends of longitudinal wires of joint reinforcement are embedded in mortar at laps.

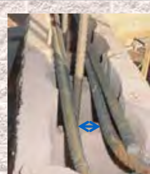
Reinforcing Steel

The codes also provide language for clear distances between bars. This language in graphically presented in Figures 5.2 and 5.3.

MSJC Section 1.16.3

1.16.3 *Placement of reinforcement*

1.16.3.1 The clear distance between parallel bars shall not be less than the nominal diameter of the bars, nor less than 1 in. (25.4 mm).



Reinforcing Steel

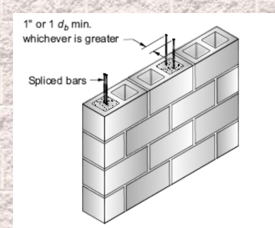


Figure 5.2 Spacing of vertical reinforcement in cells.

Reinforcing Steel

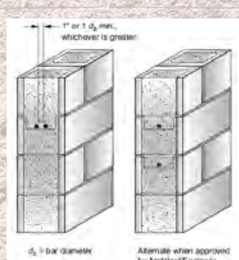


Figure 5.3 Spacing of horizontal reinforcement in masonry wall.

Reinforcing Steel

5.4 CLEARANCES OF STEEL IN MASONRY

For a reinforced masonry wall to function properly, reinforcing steel must be completely surrounded by grout. This requires a minimum clearance between the bars and masonry to allow grout to flow around the steel and bond the concrete block and steel together.

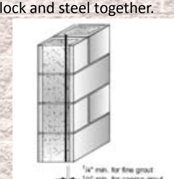


Figure 5.4 Clearance of reinforcing steel.

REINFORCING STEEL

MSJC Code Section 1.16.3.5

1.16.3.5 Reinforcement embedded in grout shall have a thickness of grout between the reinforcement and masonry units not less than ¼ in. (6.4 mm) for fine grout and ½ in. (12.7 mm) for coarse grout.

MSJC Specification Article 3.4 B

3.4 B.3 *Reinforcement*

3. Maintain clear distance between reinforcing bars and the interior of masonry unit or formed surface of at least ¼ in. (6.4 mm) for fine grout and ½ in. (12.7 mm) for coarse grout, except where cross webs of hollow units are used as supports for horizontal reinforcement.

REINFORCING STEEL

Horizontal reinforcement in bond beam courses may be supported by webs of concrete masonry units.

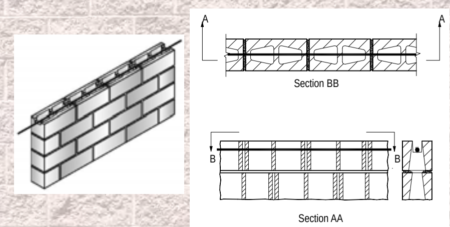


Figure 5.5 Support of reinforcing steel.

REINFORCING STEEL

MSJC Code Section 1.16.4 and MSJC Spec Article 3.4 B.4

1.16.4 *Protection of reinforcement and metal accessories*

1.16.4.1 Reinforcing bars shall have a masonry cover not less than the following:

(a) Masonry face exposed to earth or weather: 2 in. (50.8 mm) for bars larger than No. 5 (M #16); 1½ in. (38.1 mm) for No. 5 (M #16) bars or smaller.

(b) Masonry not exposed to earth or weather: 1½ in. (38.1 mm).

TABLE 5.3-Minimum Reinforcement Protective Cover, in (mm)

Condition	Bar Size	
	#3 to #5	#6 to #11
Masonry exposed to earth or weather	1½ (38)	2 (51)
Masonry not exposed to earth or weather	1½ (38)	1½ (38)

REINFORCING STEEL

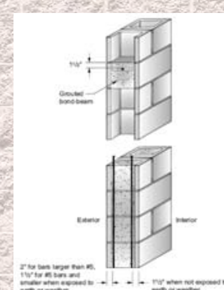


Figure 5.6 Minimum cover over reinforcing steel.

REINFORCING STEEL

Lapping vertical steel to dowels projecting from the foundation is satisfactory if the dowels are in the prescribed location. If they are not, the dowels can be bent to properly position them, as shown in Figure 5.7. However, the vertical steel can lap the dowels without the bars being immediately adjacent. In fact, they can be separated by several inches and transmit force between them.

MSJC Specification Article 3.4 B.9

3.4 B.9 *Reinforcement*

9. *Noncontact lap splices* – Position bars spliced by noncontact lap splice no farther apart transversely than one-fifth the specified length of lap nor more than 8 in. (203 mm).

MSJC Specification Article 3.4 B.11

3.4 B.11 *Placement tolerances*

d. Foundation dowels that interfere with unit webs are permitted to be bent to a maximum of 1 in. (25.4 mm) horizontally for every 6 in. (152 mm) of vertical height.

REINFORCING STEEL

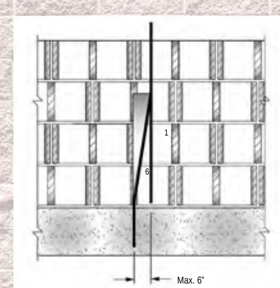


Figure 5.7 Slope for bending reinforcing steel into position.

Reinforcing Steel

If necessary, due to improper location or failure to install dowels, new dowels may be required. These can be installed by several methods, such as drilling, then epoxying around a reinforcing bar; or drilling, then installing anchored dowels, using cinch anchors, anchor shields or similar method.

Vertical steel may be held in place by reinforcing bar positioners. These wire positioners will locate the bar in the proper position (e.g. center, to one side, or one bar on each side) and will also secure reinforcement within tolerances during grouting of the wall (see Figure 5.8 and Figure 5.9).

Reinforcing Steel

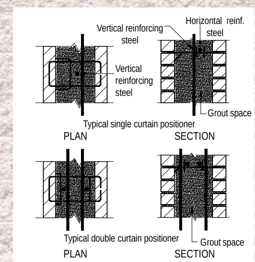


Figure 5.8 Reinforcement positioners used to locate and hold vertical and horizontal steel.

Reinforcing Steel

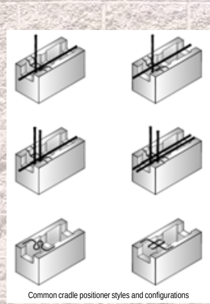


Figure 5.9 Reinforcing bar positioners for concrete masonry.

Reinforcing Steel

5.5 SECURING REINFORCING STEEL

All reinforcing steel must be accurately placed and properly braced by mechanical devices to maintain correct positions shown on the plans. Building codes do not require horizontal steel to be tied to vertical steel.
IBC Section 2104.1 defers to MSJC Specification for securing steel reinforcement in masonry.

MSJC Specification Article 3.4 B.1
3.4. B *Reinforcement*
1. Support reinforcement to prevent displacement caused by construction loads or by placement of grout or mortar, beyond the allowable tolerances.

Historically, codes required securing reinforcement at 112 to 200 bar diameters, depending on seismic exposure. MSJC Specification Article 3.4 B.1 requires that reinforcement be secured against displacement, particularly during grouting operations without specific requirements of the device or distance between devices, if applicable.

Reinforcing Steel

Table 5.4 Maximum Intervals for Securing Reinforcing Bars Based on 112 Bar Diameters

Bar Size	Maximum Secured Intervals	Bar Size	Maximum Secured Intervals
#3	3'-6" (1.1 m)	#8	9'-4" (2.8 m)
#4	4'-8" (1.4 m)	#9	10'-6" (3.2 m)
#5	5'-10" (1.8 m)	#10*	11'-8" (3.6 m)
#6	7'-0" (2.1 m)	#11*	12'-10" (3.9 m)
#7	8'-2" (2.5 m)		

*Not permitted for Strength Design

Reinforcing Steel

Table 5.5 Maximum Intervals for Securing Reinforcing Bars Based on 200 Bar Diameters

Bar Size	Maximum Secured Intervals	Bar Size	Maximum Secured Intervals
#3	6'-3" (1.9 m)	#8	16'-8" (5.1 m)
#4	8'-4" (2.5 m)	#9	18'-9" (5.7 m)
#5	10'-5" (3.2 m)	#10*	20'-10" (6.3 m)
#6	12'-6" (3.8 m)	#11*	22'-11" (7.0 m)
#7	14'-7" (4.4 m)		

*Not permitted for Strength Design

REINFORCING STEEL

5.6 LOCATION TOLERANCES OF BARS

Proper location of structural reinforcing steel is important for safe and adequate performance. To assure proper location, the MSJC Specification provides p permitted tolerances for placement of bars.

REINFORCING STEEL

MSJC Specification Article 3.4 B.11

3.4 B *Reinforcement*

11. *Placement tolerances*

a. Place reinforcing bars in walls and flexural elements within a tolerance of ± ½ in. (12.7 mm) when the distance from the centerline of reinforcing bars to the opposite face of masonry, *d*, is equal to 8 in. (203 mm) or less, ± 1 in. (25.4 mm) for *d* equal to 24 in. (610 mm) or less but greater than 8 in. (203 mm), and ± 1¼ in. (31.8 mm) for *d* greater than 24 in. (610 mm).

b. Place vertical bars within:

1) 2 in. (50.8 mm) of the required location along the length of the wall when the wall segment length exceeds 24 in. (610 mm).

REINFORCING STEEL

MSJC Specification Section 3.4 B.11

11. *Placement tolerances*

b. Place vertical bars within:

1 in. (25.4 mm) of the required location along the length of the wall when the wall segment length does not exceed 24 in. (610 mm).

c. If it is necessary to move bars more than one bar diameter or a distance exceeding the tolerance stated above to avoid interference with other reinforcing steel, conduits, or embedded items, notify the Architect/ Engineer for acceptance of the resulting arrangement of bars.

d. Foundation dowels that interfere with unit webs are permitted to be bent to a maximum of 1 in. (25.4 mm) horizontally for every 6 in. (152 mm) of vertical height.

(Note: For clarification see Table 5.6 and Figure 5.10.)

REINFORCING STEEL

Application of the '*d*' distance to determine allowable tolerances is the distance from the center of reinforcement to the farthest face of masonry as shown in Figure 5.10 for a typical wall, Figure 5.11 for masonry columns, and Figure 5.12 for a lintel support above an opening.

Table 5.6 Tolerances for Placing Reinforcement

Distance (d) from face of CMU to enter of reinforcement	Tolerance
d $\leq$ 8 in.	$\pm$ ½ in.
8 in < d $\leq$ 24 in.	$\pm$ 1in.
24 in. < d	$\pm$ 1¼ in.

REINFORCING STEEL

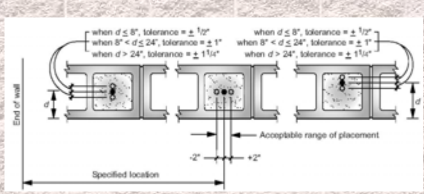


Figure 5.10 Typical tolerances for placement of reinforcing bars in a cell for CMU.

REINFORCING STEEL

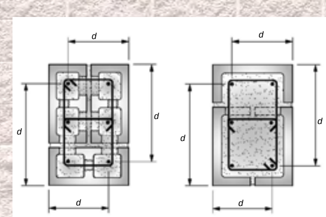
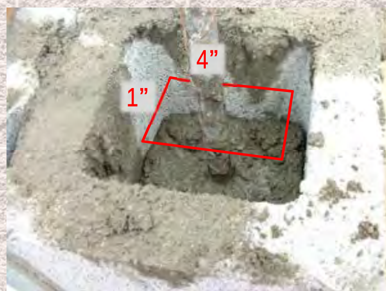


Figure 5.11 Typical tolerances for placement of reinforcing bars in a column ('d' distance dependent on individual location and direction of potentially applied force).

Reinforcing Steel



Reinforcing Steel

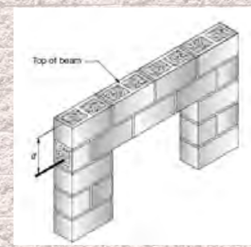


Figure 5.12 Typical tolerances for placement of lintel reinforcing bars above an opening.

Reinforcing Steel

5.7 LAP SPLICES, REINFORCING BARS

Reinforcing bars and joint reinforcing steel are typically delivered to construction jobsites in uniform lengths which can be easily handled by one person. When reinforcing bars meet in a wall they must be connected in some fashion so that all of the stresses can be transferred from one bar to the other. This is usually accomplished by lapping or splicing the bars. Physical tying, or contact, is not a requirement for transferring stresses, however, a designer may require tying of reinforcing bars in project specifications.

Reinforcing Steel

Splices may be made only at such points and in such a manner that the structural strength of the member will not be reduced. Lapped splices must provide sufficient lap to transfer the working stress of the reinforcement by bond and shear.

Bars that are not spliced need to be in the same cell as if the bar were spliced and not in an adjacent cell.

Reinforcing Steel

MSJC Code Section 2.1.7.7 (Allowable Stress Design)

2.1.7.7 *Splices of reinforcement* – Lap splices, welded splices, or mechanical splices are permitted in accordance with the provisions of this section. Welding shall conform to AWS D1.4

2.1.7.7.1 *Lap Splices*

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

The deletion of MSJC Code Section 2.1.7.7.1.1 is a result of IBC Section 2107.2.1.

Reinforcing Steel

IBC Equation 21-1 translates into 40 bar diameters for Grade 40 reinforcement and 48 bar diameters for Grade 60 reinforcement.

Ongoing research has revealed that horizontal reinforcement has a positive impact on lap splices. The results of this research was the basis for the following code provisions:

MSJC Code Section 2.1.7.7.1.2 (Allowable Stress Design)

2.1.7.7.1.2 Where reinforcement consisting of No. 3 (M #10) or larger bars is placed transversely within the lap, with at least one bar 8 inches (203 mm) or less from each end of the lap, the minimum length of lap for bars in tension or compression determined by Equation 2-12 shall be permitted to be reduced by multiplying by the confinement factor, ξ. The clear space between the transverse bars and the lapped bars shall not exceed 1.5 in. (38 mm) and the transverse bars shall be fully developed in grouted masonry. The reduced lap splice length shall not be less than $36d_b$.

REINFORCING STEEL

MSJC Code Section 2.1.7.7.1.2 (Continued)

$$\xi = 1.0 - \frac{2.3A_{sc}}{d_b^{2.5}} \quad \text{(Equation 2-13)}$$

$$\text{Where } \frac{2.3A_{sc}}{d_b^{2.5}} \leq 1.0$$

A_{sc} is the area of the transverse bars at each end of the lap splice and shall not be taken greater than 0.35 in.^{2} (226 mm^2)

When considering the MSJC Code (the lap splice requirement in IBC Allowable Stress Design is 0.002 $d_b f_s$) the lap splice could be 36 bar diameters and would follow the configuration of Figure 5.13.

See NCMA TEK 12-6A (2013) for more information

REINFORCING STEEL

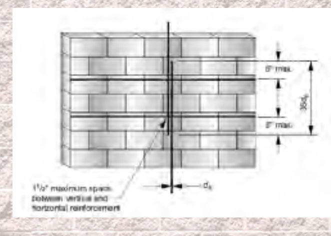


Figure 5.13 Lap splice requirement.

REINFORCING STEEL

MSJC Code Section 2.1.7.7 (Allowable Stress Design)

2.1.7.7.1.3 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).

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

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

REINFORCING STEEL

MSJC Code Section 2.1.7

2.1.7 *Development of reinforcement embedded in grout*

2.1.7.1 *General* – The calculated tension or compression in the reinforcement at each section shall be developed on each side of the section by development length, hook or mechanical device, or combination thereof. Hooks shall not be used to develop bars in compression.

2.1.7.2 *Development of wires in tension* – The development length of wire shall be determined by Equation 2-11, but shall not be less than 6 in. (152 mm).

$$l_d = 0.0015\, d_b F_s \quad \text{(Equation 2-11)}$$

Development length of epoxy-coated wire shall be taken as 150 percent of the length determined by Equation 2-11.

REINFORCING STEEL

5.8 JOINT REINFORCEMENT

5.8.1 Lap Splices, Joint Reinforcement

Joint reinforcement may be used for reinforcing masonry without the need for grouting horizontal bond beams. Since the steel wire is placed in horizontal mortar joints, the cross-section area of steel is less than deformed reinforcement. In areas of high seismic exposure, joint reinforcement may not satisfy the reinforcement required for design.

REINFORCING STEEL

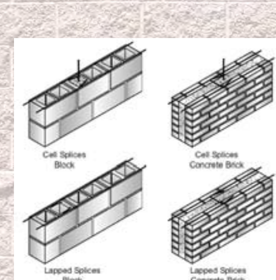


Figure 5.14 Typical splice arrangement for ladder type joint reinforcement.

REINFORCING STEEL

MSJC Specification Article 3.4 B.10

3.4 B.10 *Joint reinforcement*

b. Provide minimum 6 in. (152 mm) lap splices for joint reinforcement.

c. Ensure that all ends of longitudinal wires of joint reinforcement are embedded in mortar at laps.

REINFORCING STEEL

5.8.2 Coverage and Layout of Joint Reinforcing Steel

All longitudinal wires need to be completely embedded in mortar or grout. Joint reinforcement embedded in horizontal mortar joints require at least $^5/_8$ in. (16 mm) mortar coverage protection. Refer to Figure 5.15.

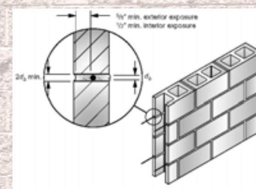


Figure 5.15 Cover over joint reinforcement.

REINFORCING STEEL

MSJC Code, Section 1.16.4.2

1.16.4.2 Longitudinal wires of joint reinforcement shall be fully embedded in mortar or grout with a minimum cover of $^5/_8$ in. (15.9 mm) when exposed to earth or weather and $^1/_2$ in. (12.7 mm) when not exposed to earth or weather. Joint reinforcement shall be stainless steel or protected from corrosion by hot-dipped galvanized coating or epoxy coating when used in masonry exposed to earth or weather and in interior walls exposed to a mean relative humidity exceeding 75 percent. All other joint reinforcement shall be mill galvanized, hot-dip galvanized, or stainless steel.

MSJC Code Section 1.16.2.3

1.16.2.3 Longitudinal and cross wires of joint reinforcement shall have a minimum wire size of W1.1 (MW7) and a maximum wire size of one-half the joint thickness.

MSJC Specification Article 3.4 B.10

3.4 B.10 *Joint reinforcement*

a. Place joint reinforcement so that longitudinal wires are embedded in mortar with a minimum cover of $^1/_2$ in. (12.7 mm) when not exposed to weather or earth and $^5/_8$ in. (15.9 mm) when exposed to weather or earth.

REINFORCING STEEL

Figure 5.16 illustrates a plan for joint reinforcement showing intersecting walls and reinforcement lapping. Figure 5.17 shows typical joint reinforcement.

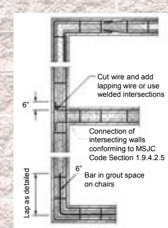


Figure 5.16 Plan of joint reinforcement showing intersection and corner.

REINFORCING STEEL

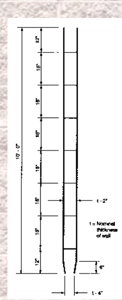


Figure 5.17 Typical joint reinforcement.

REINFORCING STEEL

5.9 HOOKS AND BENDS IN REINFORCING BARS

The general requirements for hooks and bends in reinforcing bars are stated in the MSJC Code.

MSJC Code Section 1.16.5

1.16.5 ***Standard hooks***

Standard hooks shall consist of the following:

(a) 180-degree bend plus a minimum $4d_b$ extension, but not less than $2^1/_2$ in. (64 mm) at free end of bar.

(b) 90-degree bend plus a minimum $12d_b$ extension at free end of bar; or

(c) For stirrup and tie hooks for a No. 5 bar and smaller, either a 90-degree or 135-degree bend plus a minimum $6d_b$ extension, but not less than $2^1/_2$ in. (64 mm) at free end of bar.

1.16.6 ***Minimum bend diameter for reinforcing bars***

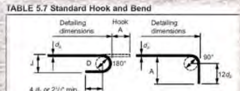
The diameter of bend measured on the inside of reinforcing bars, other than for stirrups and ties, shall not be less than values specified in Table 1.16.6.

REINFORCING STEEL

REINFORCING STEEL

MSJC Code Table 1.16.6 Minimum diameters of bend	
Bar Size and type	**Minimum diameter**
No. 3 through No. 7 (M #10 through #22) Grade 40 (Grade 300)	5 bar diameters
No. 3 through No. 8 (M #10 through #25) Grade 50 or 60 (Grade 350 or 420)	6 bar diameters
No. 9, No. 10, and No. 11 (M #29, #32, and #36) Grade 50 or 60 (Grade 350 or 420)	8 bar diameters

TABLE 5.7 Standard Hook and Bend



d_b = bar diameter
D = Finished inside bend diameter

D = $5d_b$ for #3 through #7, Grade 40
D = $6d_b$ for #3 through #8, Grade 50/60
D = $8d_b$ for #9 through #11, Grade 50/60

			180º Hook	90º Hook
Bar Size	Grade	D	J	A
#3	40	1⅞"	2⅝"	5.5"
#4	40	2½"	3½"	7.3"
#5	40	3⅛"	4⅜"	9.1"
#6	40	3¾"	5¼"	10.9"
#7	40	4⅜"	6⅛"	12.7"
#3	50/60	2¼"	3"	5.7"
#4	50/60	3"	4"	7.5"
#5	50/60	3¾"	5"	9.4"
#6	50/60	4½"	6"	11.3"
#7	50/60	5¼"	7"	13.2"
#8	50/60	6"	8"	15.0"
#9	50/60	9"	11¼"	18.0"
#10	50/60	10"	12½"	20.0"
#11	50/60	11"	13¾"	22.0"

REINFORCING STEEL

5.10 ANCHORAGE OF SHEAR REINFORCING STEEL

Reinforcing steel to resist shear loads must be anchored according to the MSJC Code. Refer to Figure 5.18.

MSJC Code Section 1.18.4.4.2 (Seismic Category D)

1.18.4.4.2 *Design of participating elements* – Masonry shear walls shall be designed to comply with the requirements of Section 1.18.3.2.6, 1.18.3.2.9, or 1.18.3.2.12.

REINFORCING STEEL

MSJC Code Section 1.18.3.2.6

1.18.3.2.6 *Special reinforced masonry shear walls* – Design of special reinforced masonry shear walls shall comply with the requirements of Section 2.3 or Section 3.3. Reinforcement detailing shall also comply with the requirements of Section 1.18.3.2.3.1 and the following:

(a) The maximum spacing of vertical reinforcement shall be the smallest of one-third the length of the shear wall, one-third the height of the shear wall, and 48 in. (1219 mm) for masonry laid in running bond and 24 in. (610 mm) for masonry not laid in running bond.

(b) The maximum spacing of horizontal reinforcement required to resist in-plane shear shall be uniformly distributed, shall be the smaller of one-third the length of the shear wall and one-third the height of the shear wall, and shall be embedded in grout. The maximum spacing of horizontal reinforcement shall not exceed 48 in. (1219 mm) for masonry laid in running bond and 24 in. (610 mm) for masonry not laid in running bond.

REINFORCING STEEL

MSJC Code Section 1.18.3.2.6

(c) The minimum cross-sectional area of vertical reinforcement shall be one-third of the required shear reinforcement. The sum of the cross-sectional area of horizontal and vertical reinforcement shall be at least 0.002 multiplied by the gross cross-sectional area of the wall using specified dimensions.

1. For masonry laid in running bond, the minimum cross-sectional area of reinforcement in each direction shall be not less than 0.0007 multiplied by the gross cross-sectional area of the wall, using specified dimensions.
2. For masonry not laid in running bond, the minimum cross-sectional area of vertical reinforcement shall be not less than 0.0007 multiplied by the gross cross-sectional area of the wall, using specified dimensions. The minimum cross-sectional area of horizontal reinforcement shall be not less than 0.0015 multiplied by the gross cross-sectional area of the wall, using specified dimensions.

REINFORCING STEEL

MSJC Code Section 1.18.3.2.6

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

(e) Masonry not laid in running bond shall be fully grouted and shall be constructed of hollow open-end units or two wythes of solid units.

REINFORCING STEEL

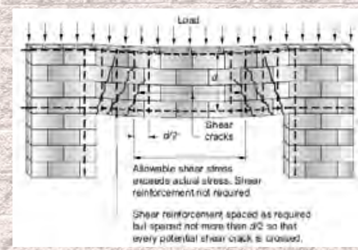


Figure 5.18 Shear reinforcement in beams, and possible crack patterns from excessive loads.

REINFORCING STEEL

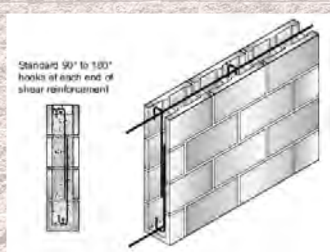


Figure 5.19 Shear steel for beams.

REINFORCING STEEL

MSJC Code Section 3.3.4.2.3 (Strength Design)

3.3.4.2.3 *Transverse reinforcement* – Transverse reinforcement shall be provided where V_u exceed ϕV_{nm}. The factored shear, V_u, shall include the effects of lateral load. When transverse reinforcement is required, the following provisions shall apply:

(a) Transverse reinforcement shall be a single bar with a 180-degree hook at each end.

(b) Transverse reinforcement shall be hooked around the longitudinal reinforcement.

(c) The minimum area of transverse reinforcement shall be $0.0007bd_v$.

(d) The first transverse bar shall not be located more than one-fourth of the beam depth, d_v, from the end of the beam.

(e) The maximum spacing shall not exceed one-half the depth of the beam nor 48 in. (1219 mm).

REINFORCING STEEL

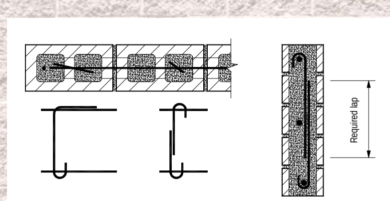


Figure 5.20 Details of beam shear reinforcement.

REINFORCING STEEL

MSJC Code Section 3.3.4.2.2

3.3.4.2.2 *Longitudinal reinforcement.*

3.3.4.2.2.1 The variation in longitudinal reinforcing bars in a beam shall not be greater than one bar size. Not more than two bar sizes shall be used in a beam.

REINFORCING STEEL

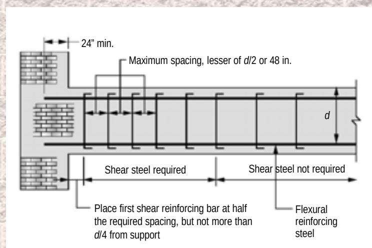


Figure 5.21 Vertical web or shear reinforcing steel arrangement for beams.

REINFORCING STEEL

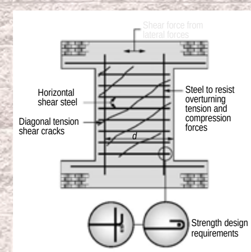


Figure 5.22 Shear wall reinforced with horizontal steel to resist lateral shear forces induced by wind or seismic forces.

REINFORCING STEEL

5.11 COLUMN REINFORCEMENT

5.11.1 Vertical Reinforcement

Steel reinforcement for concrete masonry columns must conform to the same clearances and tolerances as other masonry, with some additional requirements.

MSJC Code Section 1.16.3

1.16.3 *Placement of reinforcement.*

1.16.3.2 In columns and pilasters, the clear distance between vertical bars shall not be less than one and one-half multiplied by the nominal bar diameter, nor less than $1^1/_2$ in. (38.1 mm).

MSJC Code Section 1.14.1.3

1.14.1.3 *Vertical reinforcement* – Vertical reinforcement in columns shall not be less than $0.0025A_n$ nor exceed $0.04A_n$. The minimum number of bars shall be four.

REINFORCING STEEL

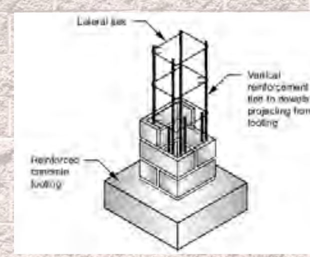


Figure 5.23 Construction of reinforced concrete masonry column.

REINFORCING STEEL

REINFORCING STEEL

5.11.2 Lightly Loaded Columns

Small masonry columns supporting light loads, such as carport roofs may be constructed using the following restrictions:

- The minimum column dimension is 8 inches
- The column height is limited to 12 feet
- At least 0.2 in.^{2} (129 mm^2) vertical reinforcement is present and centered in the middle of the column
- The columns are grouted solid
- The dead load does not exceed 2,000 psi
- The structure is located in SDC C or below

Reinforcing Steel

MSJC Code Section 1.14.2

1.14.2 *Lightly loaded columns*

Masonry columns used only to support light frame roofs of carports, porches, sheds or similar structures assigned to Seismic Design Category A, B, or C, which are subject to unfactored gravity loads not exceeding 2,000 lbs (8,900 N) acting within the cross-sectional dimensions of the column are permitted to be constructed as follows:

(a) Minimum side dimension shall be 8 in. (203 mm) nominal.

(b) Height shall not exceed 12 ft (3.66 m).

(c) Cross-sectional area of longitudinal reinforcement shall not be less than 0.2 in.^{2} (129 mm^2) centered in the column.

(d) Columns shall be fully grouted.

Reinforcing Steel

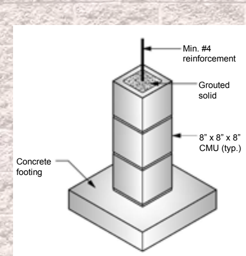


Figure 5.24 Lightly loaded column.

Reinforcing Steel

5.11.3 Reinforcing Tie Details

Lateral tie details are shown in Figure 5.25.

Lateral ties may be placed within the grouted column against the vertical bars or placed in the horizontal bed joints. Although not required by the code, alternating the ends of ties, as shown in Figure 5.23, is good a construction practice.

When ties are placed in horizontal bed joints, hooks with a 90-degree bend having a minimum radius is recommended. The radius is four tie diameters with a recommended extension of 6 tie diameters, but not less than 1^1/2 in. (64 mm) continuing beyond the radius.

Reinforcing Steel

5.11.3 Reinforcing Tie Details

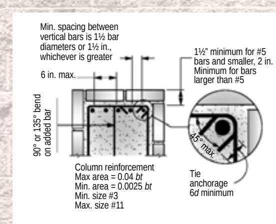


Figure 5.25 Tie details.

Reinforcing Steel

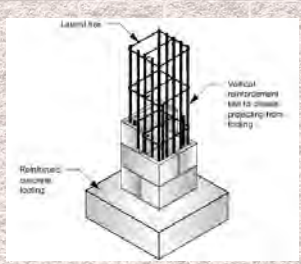


Figure 5.25 Tie details.

Reinforcing Steel

MSJC Code Section 1.14.1.4

1.14.1.4 *Lateral ties* - Lateral ties shall conform to the following:

(a) Vertical 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 least cross-sectional dimension of the member.

(c) Lateral ties shall be arranged so that every corner and alternate longitudinal bar shall have lateral support provided by the corner of the 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 in grout. Where longitudinal bars are located around the perimeter of a circle, a complete circular lateral tie is permitted. Lap length for circular ties shall be 48 tie diameters.

REINFORCING STEEL

MSJC Code Section 1.14.1.4

1.14.1.4 *Lateral ties* - Lateral ties shall conform to the following:

(d) Lateral ties shall be located vertically not more than one-half lateral tie spacing above the top of footing or slab in any story, and shall be spaced not more than one-half a lateral tie spacing below the lowest horizontal reinforcement in beam, girder, slab, or drop panel above.

(e) Where beams or brackets frame into a column from four directions, lateral ties shall be permitted to be terminated not more than 3 in. (76.2 mm) below the lowest reinforcement in the shallowest of such beams or brackets.

REINFORCING STEEL

MSJC Code and Specification provide some guidance on grouting of columns.

MSJC Code Section 1.14.1.2

1.14.1.2 *Construction.* Columns shall be fully grouted.

MSJC Specification Article 3.4 B.2

2. Completely embed reinforcing bars in grout in accordance with Article 3.5.

Although it is conceivable that partially grouted columns could be designed, it is generally not practical. Unless the project drawings indicate otherwise, all columns should be grouted solid.

REINFORCING STEEL

5.11.3.1 LATERAL TIE SPACING, SDC A, B AND C

Lateral column ties around vertical bars for columns in Seismic Design Categories A, B, and C are illustrated in Figure 5.26.

MSJC Code Section 1.14.1.4 (b)

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

REINFORCING STEEL

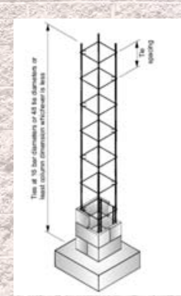


Figure 5.26 Tie spacing for columns in Seismic Design Categories A, B, and C.

REINFORCING STEEL

REINFORCING STEEL

Table 5-8 Tie Spacing – 16 Bar Diameters[1]

Longitudinal Steel Bar No.	Maximum Tie Spacing
#3	6" (152 mm)
#4	8" (203 mm)
#5	10" (254 mm)
#6	12" (305 mm)
#7	14" (356 mm)
#8	16" (406 mm)
#9	18" (457 mm)
#10	20" (508 mm)
#11	22" (559 mm)

[1]Maximum tie spacing may not exceed 16 bar diameters, 48 tie diameters nor the least dimension column.

REINFORCING STEEL

Table 5-9 Tie Spacing – 48 Tie Diameters[1]	
Tie Steel Bar Size	Maximum Tie Spacing
#3	18" (457 mm)
#4	24" (610 mm)
#5	30" (762 mm)

[1]Maximum tie spacing may not exceed 16 longitudinal bar diameters, 48 tie diameters, or the least column dimensions.

REINFORCING STEEL

5.11.3.2 Lateral Tie Spacing, SDC D, E and F

In addition to the column tie spacing requirements set forth above, there are more stringent spacing requirements for columns in moderate to high seismic exposure.

MSJC Code Section 1.18.4.4.2.3 (Seismic Category D)

1.18.4.4.2.3 *Lateral tie anchorage* – Standard hooks for lateral tie anchorage shall be either a 135-degree standard hook or a 180-degree standard hook.

REINFORCING STEEL

The MSJC Code requires additional column ties for moderate to high seismic exposure as shown in Figure 5.27.

MSJC Code Section 1.18.4.4.2.1 (Seismic Category D)

1.18.4.4.2.1 *Minimum reinforcement for masonry columns* – Lateral ties in masonry columns shall be spaced not more than 8 in. (203 mm) on center and shall be at least $^3/_8$ in. (9.5 mm) diameter. Lateral ties shall be embedded in grout.

REINFORCING STEEL

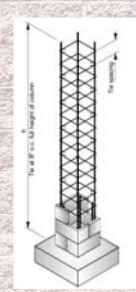


Figure 5.27 Tie spacing in columns with moderate to high seismic exposure.

REINFORCING STEEL

Layout of ties in concrete masonry columns is shown in Figure 5.28. Unexposed webs and face shells should be removed for additional grout continuity.

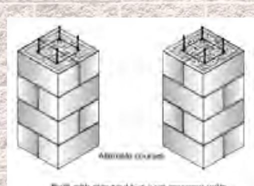


Figure 5.28 Layout of concrete masonry units for column with tie details.

REINFORCING STEEL

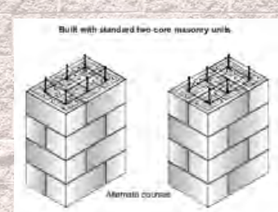


Figure 5.28 Layout of concrete masonry units for column with tie details (Continued).

REINFORCING STEEL

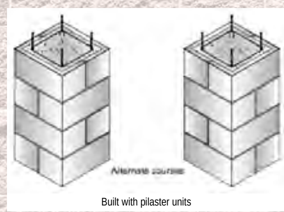


Figure 5.28 Layout of concrete masonry units for column with tie details (Continued).

REINFORCING STEEL

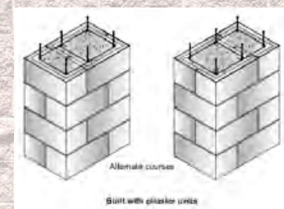


Figure 5.28 Layout of concrete masonry units for column with tie details (Continued).

REINFORCING STEEL

5.11.4 Projecting Wall Columns or Pilasters

Heavily loaded girders framing into a wall may require substantial base plates and columns to carry the load. Columns may be built projecting out from the wall to provide a convenient seat or surface to support the girders.

Projecting pilasters also serve to stiffen the wall and are supported at the top and bottom. The wall between the pilasters can be designed to span horizontally. By this technique, very high walls can be built using nominal thicknesses. See Figure 5.29 and 5.30.

REINFORCING STEEL

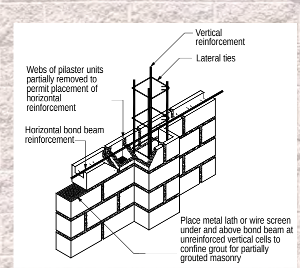


Figure 5.29 Construction of reinforced concrete masonry pilaster with continuous bond beam.

REINFORCING STEEL

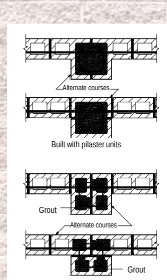


Figure 5.30 Projecting wall column masonry unit details.

REINFORCING STEEL

5.11.5 Flush Wall Columns, Pilasters and Compression Steel at End of Walls

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 the wall and are flush with the wall. The wall contained columns permit faster construction, cause no projections from the wall, and do not require special units. The reinforcing steel must be tied in accordance with the code requirements (refer to Figure 5.31).

REINFORCING STEEL

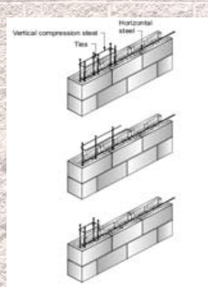


Figure 5.31 Ties around column bars and compression bars at end of wall.

REINFORCING STEEL

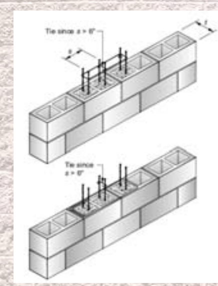


Figure 5.32 Flush wall columns in concrete masonry.

REINFORCING STEEL

5.11.6 Ties on Compression Steel in Beams

See Figure 5.33 for an illustration of ties for compression steel in beams.

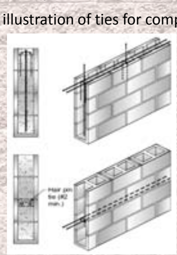


Figure 5.33 Ties for compression steel in beams.

REINFORCING STEEL

5.11.7 Anchor Bolts

5.11.7.1 Anchor Bolt Clearance.

Clearance around anchor bolts is necessary so that the grout can fully surround the bolt. Certain Code provisions require $^{1}/_{2}$ in. (12.7 mm) of grout between anchor bolts and the masonry. This requirement ensures adequate grout around the bolt and the exposed face shell of the masonry unit and was not intended to be applied behind the bolt head. This clearance may be reduced to $^{1}/_{4}$ in. (6 mm) when using fine grout. See Figure 5.36.

MSJC Code Section 1.17

1.17 – Anchor bolts

Headed and bent-bar anchor bolts shall conform to the provisions of Sections 1.17.1 through 1.17.7.

REINFORCING STEEL

1.17.1 *Placement*

Headed and bent-bar anchor bolts shall be embedded in grout. Anchor bolts of $^{1}/_{4}$ in. (6.4 mm) diameter are permitted to be placed in mortar bed joints that are at least $^{1}/_{2}$ in. (12.7 mm) in thickness and, for purposes of application of the provisions of Sections 1.17, 2.1.4 and 3.1.6, are permitted to be considered as if they are embedded in grout.

Anchor bolts placed in the top of grouted cells and bond beams shall be positioned to maintain a minimum of $^{1}/_{4}$ in. (6.4 mm) of fine grout between bolts and masonry unit or $^{1}/_{2}$ in. (12.7 mm) of course grout between bolts and masonry unit. Anchor bolts placed in drilled holes in the face shells of hollow masonry units shall be permitted to contact the masonry unit where the bolt passes through the face shell, but the portion of the bolt that is within the grouted cell shall be positioned to maintain a minimum of $^{1}/_{4}$ in. (6.4 mm) of fine grout between the head or bent leg of each bolt and the masonry unit or $^{1}/_{2}$ in. (12.7 mm) of course grout between the head or bent leg of each bolt and the masonry unit.

The clear distance between parallel anchor bolts shall not be less than the nominal diameter of the anchor bolt, nor less than 1 in. (25.4 mm).

REINFORCING STEEL

MSJC Specification Article 3.4 D

3.4 D. *Anchor bolts*

1. Embed headed and bent-bar anchor bolts larger than $^{1}/_{4}$ in. (6.4 mm) diameter in grout that is placed in accordance with Article 3.5 A and Article 3.5 B. Anchor bolts of $^{1}/_{4}$ in. (6.4 mm) diameter or less are permitted to be placed in grout or mortar bed joints that have a specified thickness of at least $^{1}/_{2}$ in. (12.7 mm) thickness.

2. For anchor bolts placed in the top of grouted cells and bond beams, maintain a clear distance between the anchor bolt and the face of masonry unit of at least $^{1}/_{4}$ in. (6.4 mm) when using fine grout and at least $^{1}/_{2}$ in. (12.7 mm) when using coarse grout.

Reinforcing Steel

MSJC Specification Article 3.4 D
3.4 D. *Anchor bolts*

3. For anchor bolts placed through the face shell of a hollow masonry unit, drill a hole that is tight-fitting to the bolt or provide minimum clear distance that conforms to Article 3.4 D.2 around the bolt and through the face shell. For the portion of the bolt that is within the grouted cell, maintain a clear distance between the bolt and the face of masonry unit and between the head or bent leg of the bolt and the formed surface of grout of at least $^1/_4$ in. (6.4 mm) when using fine grout and at least $^1/_2$ in. (12.7 mm) when using coarse grout.

4. Place anchor bolts with a clear distance between parallel anchor bolts not less than the nominal diameter of the anchor bolt, nor less than 1 in. (25.4 mm).

Reinforcing Steel

5.11.7.2 Anchor Bolt Ties.

In order for lateral forces on anchor bolts to be transferred to vertical steel, ties may be required around the anchor bolts and steel.

MSJC Code Section 1.18.4.3.2.1 (Seismic Category C)
1.18.4.3.2.1 *Connections to masonry columns* – Connections shall be designed to transfer forces between masonry columns and horizontal elements in accordance with the requirements of Section 1.7.4. Where anchor bolts are used to connect horizontal elements to the tops of columns, anchor bolts shall be placed within lateral ties. Lateral ties shall enclose both the vertical bars in the column and the anchor bolts. There shall be a minimum of two No. 4 (M #13) lateral ties provided in the top 5 in. (127 mm) of the column.

Reinforcing Steel

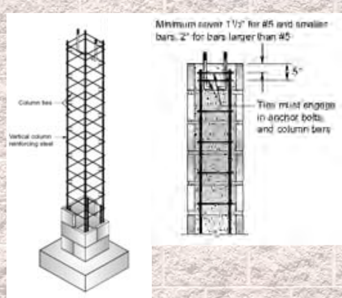


Figure 5.34 Ties of anchor bars on top of columns.

Reinforcing Steel

5.11.7.3 Anchor Bolts in Walls.

Anchor bolts must be placed with adequate edge distance and spacing to ensure adequate performance.

MSJC Code Section 1.17.1 provides for a 1 in. (25 mm) minimum spacing between anchor bolts as shown in Figure 5.35. Note that anchor bolts also require adequate grout coverage, $^1/_2$ in. (13 mm) surround for coarse grout and $^1/_4$ in. (6 mm) for fine grout

Reinforcing Steel

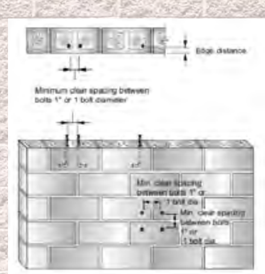


Figure 5.35 Anchor bolt spacing and edge distance.

Reinforcing Steel

5.11.7.4 Embedment of Anchor Bolts.

MSJC Specification Article 3.2 E

3.2 E. *Reinforcement* - Place reinforcement and ties in grout spaces prior to grouting.

MSJC Code Section 1.16.4

1.17.4 *Effective embedment length for headed anchor bolts* The effective embedment length for a headed anchor bolt, l_b, shall be the length of the embedment measured perpendicular from the masonry surface to the compression bearing surface of the anchor head.

Reinforcing Steel

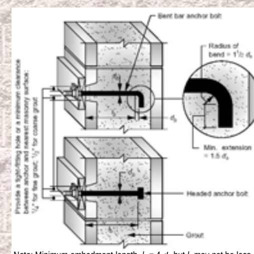
1.17.5 *Effective embedment length of bent-bar anchor bolts* The effective embedment for a bent-bar anchor bolt, l_b, shall be the length of embedment measured perpendicular from the masonry surface to the compression bearing surface of the bent end, minus one anchor bolt diameter.

1.17.6 *Minimum permissible effective embedment length*

The minimum permissible effective embedment length for headed and bent-bar anchor bolts shall be the greater of 4 bolt diameters or 2 in. (50.8 mm).

The minimum effective embedment depth for headed and bent-bar anchor bolts is the greater of 4 bolt diameters or 2 in. (51 mm). Bolts should be accurately set with templates including bolts in tops of walls. Vertical bolts should not be forced in place into previously poured grout.

Reinforcing Steel



Note: Minimum embedment length, $l_b = 4\ d_b$ but l_b may not be less than 2" (51 mm).

Figure 5.36 Embedment of plate or headed anchor bolts and bent bar anchor bolts.

CHAPTER 6
Grouting of Concrete Masonry Walls

6.1 GENERAL

The most important function of masonry grout is to tie the system together to act as a single structural element. In order for grout to tie the system components into a single structural element, certain provisions must be followed. This Chapter thoroughly discusses those requirements.

Grouting of Concrete Masonry Walls

6.2 MORTAR PROTRUSIONS

Mortar projections should not obstruct the placement and consolidation of grout. Take reasonable care either to prevent excessive mortar projections as the masonry units are placed or excessive projections must be removed while the mortar is plastic or broken off when hard and removed through the cleanout openings.

Grouting of Concrete Masonry Walls

MSJC Specification Article 3.3 B.1.c

3.3 B. *Placing mortar and units*

c. Remove masonry protrusions extending $^{1}/_{2}$ in. (12.7 mm) or more into cells or cavities to be grouted.

Clean means reasonably clean, not surgically clean. A 1999 demonstration for the California Division of the State Architect showed that a small amount of mortar droppings had virtually no detrimental structural impact on the masonry system.

Grouting of Concrete Masonry Walls

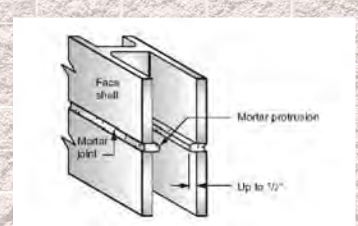


Figure 6.1 Mortar projections into grout space.

GROUTING OF CONCRETE MASONRY WALLS

6.3 GROUT SLUMP

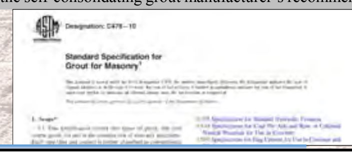
Grout (other than self-consolidating grout) must be plastic with a slump fluidity of 8 in. (203 mm) to 11 in. (279 mm) when tested in accordance with ASTM C143 and be cohesive to avoid segregation of materials, particularly pea gravel. See Figure 6.2.

GROUTING OF CONCRETE MASONRY WALLS

MSJC Specification Article 2.6 B.

2.6 B. *Grout*

1. Except for self-consolidating grout, mix grout in accordance with the requirements of ASTM C476.
2. Unless otherwise required, mix grout other than self-consolidating grout to a consistency that has a slump between 8 and 11 in. (203 and 279 mm).
3. Proportioning of self-consolidating grout at the project site is not permitted. Do not add water at the project site except in accordance with the self-consolidating grout manufacturer's recommendations.



Designation: C476 – 10

Standard Specification for Grout for Masonry

GROUTING OF CONCRETE MASONRY WALLS

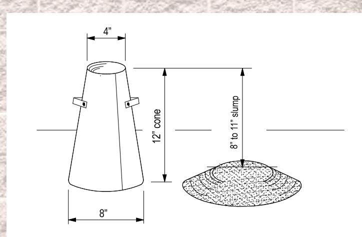


Figure 6.2 Slump of grout 8 in. to 11 in. (203 mm to 279 mm).

GROUTING OF CONCRETE MASONRY WALLS

6.4 GROUTING LIMITATIONS

MSJC Specification Article 3.5 contains requirements for placement of grout, including placement time and placement height limitations. Grout contains excess water enabling flow into the small voids within the cell or cavity. After placement, the excess water is absorbed by the units enabling hydration in a normal manner.

Grout can easily exceed the $1^1/2$ hour placement time limitation with the excess water, therefore, MSJC Specification Article 3.5 A.2.b allows for a longer placement duration providing the grout meets the specified slump.

GROUTING OF CONCRETE MASONRY WALLS

6.4 GROUTING LIMITATIONS

MSJC Specification Article 3.5

3.5 – Grout placement

3.5 A. *Placing time* – Place grout within $1^1/_2$ hr from introducing water in the mixture and prior to initial set.

1. Discard site-mixed grout that does not meet the specified slump without adding water after initial mixing.
2. For ready-mixed grout:
   a. Addition of water is permitted at the time of discharge to adjust slump.
   b. Discard ready-mixed grout that does not meet the specified slump without adding water, other than the water that was added at the time of discharge.

   The time limitation is waived as long as the ready-mixed grout meets the specified slump.

GROUTING OF CONCRETE MASONRY WALLS

3.5 B. *Confinement* – Confine grout to the areas indicated on the Project Drawings. Use material to confine grout that permits bond between masonry units and mortar.

3.5 C. *Grout pour height* – Do not exceed the maximum grout pour height given in Table 7.

3.5 D. *Grout lift height*

1. For grout conforming to Article 2.2 A.1:
   a. Where the following conditions are met, place grout in lifts not exceeding 12 ft 8 in. (3.86 m).
      i. The masonry has cured for at least 4 hours.
      ii. The grout slump is maintained between 10 and 11 in. (254 and 279 mm).
      iii. No intermediate reinforced bond beams are placed between the top and the bottom of the pour height.

Grouting of Concrete Masonry Walls

b. When the conditions of Articles 3.5 D.1.a.i and 3.5 D.1.a.ii are met but there are intermediate bond beams within the grout pour, limit the grout lift height to the bottom of the lowest bond beam that is more than 5 ft 4 in. (1.63 m) above the bottom of the lift, but do not exceed a grout lift height of 12 ft 8 in. (3.86 m).

c. When the conditions of Article 3.5 D.1.a.i or Article 3.5 D.1.a.ii are not met, place grout in lifts not exceeding 5 ft 4 in. (1.63 m).

2. For self-consolidating grout conforming to Article 2.2:

a. When placed in masonry that has cured for at least 4 hours, place in lifts not exceeding the grout pour height.

b. When placed in masonry that has not cured for at least 4 hours, place in lifts not exceeding 5 ft 4 in. (1.63 m).

Grouting of Concrete Masonry Walls

TABLE 6-1 – Grout Space Requirements[6]

Grout Type[1]	Maximum grout pour height, ft. (m)	Minimum width of grout space,[2,3] in. (mm)	Minimum grout space dimensions for grouting cells of hollow units,[3,4,5] in. x in. (mm x mm)
Fine	1 (0.30)	¾ (19.1)	1½ x 2 (38.1 x 50.8)
Fine	5 (1.52)	2 (50.8)	2 x 3 (50.8 x 76.2)
Fine	12 (3.66)	2½ (63.5)	2½ x 3 (63.5 x 76.2)
Fine	24 (7.32)	3 (76.2)	3 x 3 (76.2 x 76.2)
Coarse	1 (0.30)	1½ (38.1)	1½ x 3 (38.1 x 76.2)
Coarse	5 (1.52)	2 (50.8)	2½ x 3 (63.5 x 76.2)
Coarse	12 (3.66)	2½ (63.5)	3 x 3 (76.2 x 76.2)
Coarse	24 (7.32)	3 (76.2)	3 x 4 (76.2 x 102)

1 Fine and coarse grout are defined in ASTM C476.
2 For grouting between masonry wythes.
3 Minimum clear width of grout space and minimum clear grout space dimension are the net dimensions of the space, determined by subtracting masonry protrusions and the diameters of horizontal bars from the as-built cross-section of the grout space. Select the grout type and maximum grout pour height based on the minimum clear space.
4. Area of vertical reinforcement shall not exceed 6 percent of the area of the grout space.
5. Minimum grout space dimension for AAC masonry units shall be 3-in. x 3-in. or a 3-in. diameter cell.
6. MSJC Code Table 1.19.1, MSJC Specification Table 7.

Grouting of Concrete Masonry Walls

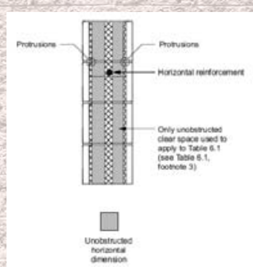


Figure 6.3 Grouting space requirements.

Grouting of Concrete Masonry Walls

6.5 LOW LIFT GROUTING

The grouting method commonly known as low lift grouting is performed in grout pours of 5 ft 4 in. (1.6 m) or less in height.

The wall is constructed in increments of 5 ft 4 in. (1.6 m) to match bond of 8 in. (203 mm) high units. Prior to grouting, horizontal and vertical reinforcement, bolts and other embedded items are positioned. Sufficient curing time is required so that mortar joints can set and are able to withstand the grout pressure. For hollow-unit concrete masonry it is common and successful practice to lay the masonry units and grout the wall shortly thereafter, such as laying the units one day and grouting the following morning.

Grouting of Concrete Masonry Walls

Grouting of Concrete Masonry Walls

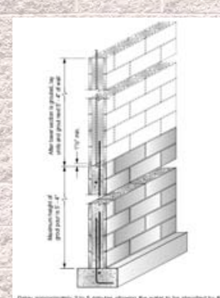


Figure 6.4 Grouting without cleanouts, commonly called low-lift grouting

GROUTING OF CONCRETE MASONRY WALLS

Grout is poured into all reinforced cells and other designated cells, if required, to a height slightly below the wall (top of wall increment). The water loss and consolidation will allow the grout to settle approximately $1^1/_2$ in.(38 mm) below the mortar joint forming a key between the grout and masonry units. The top lift is poured so that the settled grout will be even with the top of the wall.

GROUTING OF CONCRETE MASONRY WALLS

MSJC Specification Article 3.5 **F**

3.5 F. *Grout key* — When grouting, form grout keys between grout pours. Form grout keys between grout lifts when the first lift is permitted to set prior to placement of the subsequent lift.

1. Form a grout key by terminating the grout a minimum of $1^1/_2$ in. (38.1 mm) below a mortar joint.
2. Do not form grout keys within beams.
3. At beams or lintels laid with closed bottom units, terminate the grout pour at the bottom of the beam or lintel without forming a grout key.

GROUTING OF CONCRETE MASONRY WALLS

Vertical cells to be filled must align vertically to maintain a continuous unobstructed cell area not less than $1^1/_2$ in. x 2 in. (38 mm x 51 mm), or as dimensionally required by Table 6.1. In partially grouted masonry, horizontal beams to be grouted should be isolated horizontally with metal lath or special concrete block units to prevent the grout from flowing into cells that should be void. Paper should not be used for this purpose.

GROUTING OF CONCRETE MASONRY WALLS

The principal advantage of the low-lift grouting method is that cleanouts or inspection openings are not required. The inspector can visually check the cells for proper alignment, check that the bottom of the cells are reasonably clean and free of excessive mortar protrusions and verify the reinforcing steel location, all before grouting the wall.

GROUTING OF CONCRETE MASONRY WALLS

If the grout pours are 12 in. (305 mm) or less in height, the grout may be consolidated by puddling.

GROUTING OF CONCRETE MASONRY WALLS

For grout pours greater than 12 in. (305 mm) in height, the grout must be consolidated by mechanical vibration and reconsolidated by mechanical vibration prior to the grout losing its plasticity.

Grouting of Concrete Masonry Walls

6.6 HIGH LIFT GROUTING

High-lift grouting procedures are used when walls and grout pours exceed 5 ft 4 in. (1.6 m). In high lift grouting the walls are built to their full height before grouting, up to a maximum of 24 ft (7.3 m). Cleanout holes are required at the bottom of all cells containing vertical reinforcing steel, but not more than 32 in. (813 mm) apart (on center) for solid grouted masonry. Partially grouted masonry should have cleanouts so that cells to be grouted can be adequately cleaned. One recommendation for walls that are to be solid grouted, is to invert a bond beam unit to allow for cleaning mortar droppings or debris from the foundation and between cleanouts, which may be as much as 32 in. (813 mm) on center. This also improves the flow of grout at the foundation and provides maximum shear interface between the grout and the foundation.

Grouting of Concrete Masonry Walls

Figure 6.5 Bond beam used on first course for cleanouts.

Grouting of Concrete Masonry Walls

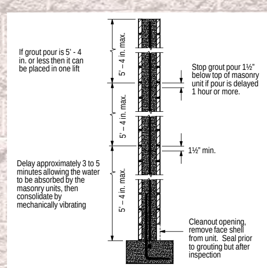


Figure 6.6 High-lift method of grouting block.

Grouting of Concrete Masonry Walls

Mortar projections exceeding $^1/_2$ in. (13 mm) and excessive mortar droppings must be removed from the grout cells prior to grouting. "Clean" does not mean "surgically clean," but merely no loose deleterious material in the areas to be grouted that would be detrimental to the structural integrity of the masonry.

There are various methods of cleaning mortar droppings and mortar fins which include using compressed air, a rod, a stick, or a high-pressure jet stream of water to dislodge the material.

Mortar fins, within permitted tolerances, are beneficial in providing a mechanical interlock between the grout and the mortar/masonry unit. Parging mortar fins smooth within the cell will not provide such a mechanical interlock.

Grouting of Concrete Masonry Walls

Grout should not be poured until the mortar has set a sufficient time to adequately withstand the pressure of the grout. Typically, hollow masonry is laid one day and grouted the next morning. Under moderate to ideal weather conditions, units could be laid in the morning and be grouted in the afternoon of the same day.

All reinforcing steel, bolts, and other embedded items, and cleanout closures are required to be properly secured in place within tolerances, and should be inspected prior to grouting.

Grouting of Concrete Masonry Walls

When high-lift grouting, the grout is placed in lifts not exceeding 5 ft 4 in. (1.6 m) and consolidated at the time of placement by a mechanical vibrator. After each lift is placed, wait for absorption of water into the block, approximately 3 to 5 minutes, and then reconsolidate the grout before it loses its plasticity. The next lift should be placed immediately, or as soon as reasonable. The full height of any section of wall should be completed in one day, with no interruption between lifts greater than one hour. After the last lift at the top of the wall is consolidated, the grout space is filled to the top.

There is also a provision in the MSJC Specification that allows for single grout lifts as high as 12 ft 8 in. (3.86 m) provided certain conditions are satisfied:

Grouting of Concrete Masonry Walls

MSJC Specification Article 3.5 D

3.5 D. *Grout lift height*

1. For grout conforming to Article 2.2 A.1:

a. Where the following conditions are met, place grout in lifts not exceeding 12 ft 8 in. (3.86 m).

i. The masonry has cured for at least 4 hours.

ii. The grout slump is maintained between 10 and 11 in. (254 and 279 mm).

iii. No intermediate reinforced bond beams are placed between the top and the bottom of the pour height.

b. When the conditions of Articles 3.5 D.1.a.i and 3.5 D.1.a.ii are met but there are intermediate bond beams within the grout pour, limit the grout lift height to the bottom of the lowest bond beam that is more than 5 ft 4 in. (1.63 m) above the bottom of the lift, but do not exceed a grout lift height of 12 ft 8 in. (3.86 m).

Grouting of Concrete Masonry Walls

3.5 D. *Grout lift height*

1. For grout conforming to Article 2.2 A.1:

c. When the conditions of Article 3.5 D.1.a.i or Article 3.5 D.1.a.ii are not met, place grout in lifts not exceeding 5 ft 4 in. (1.63 m).

2. For self-consolidating grout conforming to Article 2.2:

a. When placed in masonry that has cured for at least 4 hours, place in lifts not exceeding the grout pour height.

b. When placed in masonry that has not cured for at least 4 hours, place in lifts not exceeding 5 ft 4 in. (1.63 m).

This provision cannot be applied where horizontal deformed reinforcement is used in the bond beams within the wall. Additionally, the time provisions (minimum 4 hour curing) and grout slump requirements (10 in. to 11 in. [254 mm to 279 mm]) must be met. The 4 hour minimum time requirement may not be adequate in certain conditions, such as cold or inclement weather.

Grouting of Concrete Masonry Walls

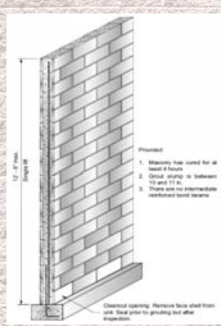


Figure 6.7 Special grout lift height

Grouting of Concrete Masonry Walls

6.7 CLEANOUTS

A cleanout is an opening or hole of sufficient size defined as 3 in. (76 mm) minimum dimension either direction through the face of the block used to successfully clean out all mortar droppings and other debris from the bottom of the cell that is to be grouted. Removing (cutting off) the entire face shell is an excellent way of providing cleanouts. When the face shell is replaced (prior to grouting) there are no cut marks in the wall. Cleanouts are illustrated in Figure 6.8.

Historically, cleanouts were placed so that every reinforced cell was accessible, but in no event were cleanouts spaced more than 48 in. (1.2 m) apart. Current codes do not impose a maximum spacing for partially grouted masonry walls, but do require that the space to be grouted is clean.

Grouting of Concrete Masonry Walls

Grouting of Concrete Masonry Walls

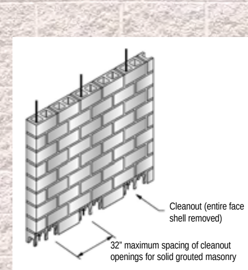


Figure 6.4 Cleanouts for grout pour height greater than 5 ft 4 in. (1.6 m).

Grouting of Concrete Masonry Walls

MSJC Specification Article 3.2 F

3.2 F. *Cleanouts* – Provide cleanouts in the bottom course of masonry for each grout pour, when the grout pour height exceeds 5 ft 4 in. (1.63 m).

1. Construct cleanouts so that the space to be grouted can be cleaned and inspected. In solid grouted masonry, space cleanouts horizontally a maximum of 32 in. (813 mm) on center.
2. Construct cleanouts with an opening of sufficient size to permit removal of debris. The minimum opening dimension shall be 3 in. (76.2 mm).
3. After cleaning, close cleanouts with closures braced to resist grout pressure.

Grouting of Concrete Masonry Walls

6.8 CONSOLIDATION OF GROUT

Conventional grout is required to be consolidated by means of a mechanical vibrator if the lift is more than 12 in. (305 mm) in height. The vibrator, shown in Figure 6.9, is usually on a flexible cable with the head from $^3/_4$ in. to $1^1/_2$ in. (19 mm to 38 mm) in width. While the vibrator is on, it need only be lowered into the grout and slowly removed. Excessive vibration can cause segregation of grout. If cells are congested with steel and adequate open-end and bond beam units are used, adjacent grouted cells can be consolidated by vibration.

Grouting of Concrete Masonry Walls

6.8 CONSOLIDATION OF GROUT

Figure 6.9 Grout vibrator.

Grouting of Concrete Masonry Walls

MSJC Specification Article 3.5 E

3.5 E. *Consolidation*

1. Consolidate grout at the time of placement.
   a. Consolidate grout pours 12 in. (305 mm) or less in height by mechanical vibration or by puddling.
   b. Consolidate pours exceeding 12 in. (305 mm) in height by mechanical vibration, and reconsolidate by mechanical vibration after initial water loss and settlement has occurred.
2. Consolidation or reconsolidation is not required for self-consolidating grout.

Grouting of Concrete Masonry Walls

Reconsolidation of grout is necessary after excess water is absorbed into the masonry. A film of water between the masonry shell and the grout can form and consolidating the grout closes up this space causing the grout to have intimate contact with the shell and thus achieve bond.

Grouting of Concrete Masonry Walls

6.9 GROUT BARRIERS

Although not a code requirement in multiwythe grouted masonry, vertical barriers of masonry should be built across the grout space the entire height of the grout pour and spaced not more than 30 ft (9.1 m) horizontally to prevent grout segregation. The grouting of any section of wall between barriers should be completed in one day with no interruption longer than one hour. Grout barriers are shown in Figure 6.10.

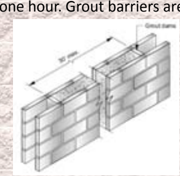


Figure 6.10 Grout flow barriers in multiwythe masonry.

Grouting of Concrete Masonry Walls

6.10 USE OF ALUMINUM EQUIPMENT

Grout pumped through aluminum pipes can cause abrasion of the interior of the pipe. This abrasion can cause aluminum particles to be mixed with the grout and may reduce strength and the particles can react with the cement and create hydrogen gas, causing expansion of the grout.

Grouting of Concrete Masonry Walls

6.11 PUMPING GROUT

Grout is commonly placed into masonry walls using a grout pump. The grout is loaded into a grout pump directly from a transit mix truck and then pumped into the masonry cells through a long hose. Figure 6.11 shows a typical masonry grout pump.

Grouting of Concrete Masonry Walls

Lime or fly ash can be used to aid pumping. The use of fly ash can save on cement.

Grout pumps are specifically made to pump high slump pea gravel grout and are not intended to pump concrete, which is stiffer with larger aggregate.

Figure 6.11 Typical masonry grout pump.

Grouting of Concrete Masonry Walls

Grouting of a concrete masonry wall.

Grouting of Concrete Masonry Walls

6.12 GROUT DEMONSTRATION PANEL

Originally, grouting masonry in a manner not prescribed by the code may be more efficient than traditional means. One example would be grouting a 2 ft (610 mm) long wall section between two doors. Forming a cold grout joint at a 5 ft 4 in. (1.6 m) height would be less advantageous than a continuous lift. The code provides for exceptions using a grout demonstration panel.

MSJC Specification Article 3.5 G

3.5 G. Alternate grout placement — Place masonry units and grout using construction procedures employed in the accepted grout demonstration panel.

Chapter 7 - Special Provisions for Seismic Design and Construction

7.1 GENERAL

Earthquakes are a recognized threat to life, safety and buildings. To help prevent loss of life and reduce damage to structures, special detailing requirements are imposed by the Building Codes. These requirements are based on the seismic exposure in which the building is located.

SEISMIC DESIGN AND CONSTRUCTION

SEISMIC DESIGN AND CONSTRUCTION

WEST COAST EARTHQUAKES		
Date	Location	Magnitude
1994	Northridge, California	6.7
1989	Loma Prieta, California	7.1
1987	Whittier Narrows, California	6.1
1971	San Fernando, California	6.4
1965	Seattle, Washington	6.5
1954	Dixie Valley, Nevada	7.3
1954	Fallon, Nevada	6.3 & 6.8
1949	Olympia, Washington	7.1
1946	Tacoma, Washington	6.3
1932	Cedar Mountain, Nevada	7.3
1906	San Francisco, California	8.3

SEISMIC DESIGN AND CONSTRUCTION

MOUNTAIN STATES EARTHQUAKES		
Date	Location	Magnitude
1983	Lost River Mountains, Idaho	7.3
1975	Yellowstone National Park	6.4
1975	Pocatello Valley, Idaho	6.1
1962	Salt Lake City, Utah	5.2
1959	Yellowstone National Park	7.1
1935	Helena, Montana	6.0
1935	Helena, Montana	6.2
1934	Helena, Montana	6.7
1934	Hansel Valley, Utah	6.0
1934	Hansel Valley, Utah	6.6

SEISMIC DESIGN AND CONSTRUCTION

CENTRAL STATES EARTHQUAKES		
Date	Location	Magnitude
1980	Sharpsburg, Kentucky	5.1
1968	Southern Illinois	5.5
1906	Manhattan, Kansas	5.5
1867	Manhattan, Kansas	5.3
1812	New Madrid, Missouri	8.4
1812	New Madrid, Missouri	8.7
1811	New Madrid, Missouri	8.6

SEISMIC DESIGN AND CONSTRUCTION

EAST COAST EARTHQUAKES		
Date	Location	Magnitude
1944	St. Lawrence Valley	6.0
1929	Atica, New York	5.5
1925	St. Lawrence Valley	7.0
1913	Union County, South Carolina	6.0
1897	Giles County, Georgia	6.3
1886	Charleston, South Carolina	7.7
1755	Cape Ann, Massachusetts	6.5
1663	St. Lawrence Valley	7.0
1638	St. Lawrence Valley	7.0

SEISMIC DESIGN AND CONSTRUCTION

The International Building Code uses Seismic Design Categories instead of Seismic Zones. The Seismic Design Category is defined as a classification assigned to a structure based on the Risk Category and the severity of the design earthquake ground motion at the site. In other words, the importance factor is considered before the Seismic Design Category (SDC). Another important item in establishing the Seismic Design Category is the site soil condition. It is therefore conceivable that one project would be assigned SDC D and a nearby project would be assigned SDC C due solely to soil conditions.

Seismic Design and Construction

NCMA TEK 14-18A

Seismic Design and Construction

NCMA TEK 14-18A

Seismic Design and Construction

7.2 IBC SEISMIC DESIGN CATEGORIES

IBC Section 2106 defers entirely to MSJC Code Section 1.18 for special seimic provisions relating to masonry.

IBC Section 2106.1

2106.1 Seismic design requirements for masonry. Masonry structures and components shall comply with the requirements in Section 1.18 of TMS 402/ACI 530/ASCE 5 depending on the structure's *seismic design category*.

Seismic Design and Construction

There are also some significant provisions in Chapter 16 of the IBC that relate to masonry.

IBC Section 1613.2

1613.2 Definitions. The following term is defined in Chapter 2, Section 202 Definitions:

SEISMIC DESIGN CATEGORY. A classification assigned to a structure based on its risk category and the severity of the design earthquake ground motion at the site.

Seismic Design and Construction

IBC Section 1604.8.2

1604.8.2 Structural walls. Walls that provide vertical load-bearing resistance or lateral shear resistance for a portion of the structure shall be anchored to the roof and to all floors and members that provide lateral support for the wall or that are supported by the wall. The connections shall be capable of resisting the horizontal forces specified in Section 1.4.4 of ASCE 7 for walls of structures assigned to Seismic Design Category A and to Section 12.11 of ASCE 7 for walls of structures assigned to all other seismic design categories. Required anchors in masonry walls of hollow units or cavity walls shall be embedded in a reinforced grouted structural element of the wall. See Sections 1609 for wind design requirements and 1613 for earthquake design requirements.

Seismic Design and Construction

MSJC Code Section 1.18 contains seismic provisions relating to all masonry except glass unit masonry and masonry veneers. Although many of the provision are not something the inspector typically observes, it is helpful for the masonry inspector to understand the implications of the quality of construction.

Seismic Design and Construction

7.2.1 Seismic Design Category A

The MSJC Code requires that masonry structures meet minimum requirements for anchorage:

IBC Section 1.18.2.3

1.18.2.3 *Anchorage design* — Load path connections and minimum anchorage forces shall comply with the requirements of the legally adopted building code. When the legally adopted building code does not provide minimum load path connection requirements and anchorage design forces, the requirements of ASCE 7 shall be used.

Seismic Design and Construction

Notwithstanding the absence of seismic requirements, horizontal reinforcement should be placed in the top of footings, on all sides of wall openings, at roof and floor levels and at the top of parapet walls. Horizontal reinforcement in a wall is generally for temperature volume changes and natural shrinkage, and the exact positioning is not critical. Steel must be in place or laid on top of the cross webs in concrete masonry prior to grouting. The horizontal steel should be placed with enough clearance between bars to allow the grout to flow through and completely surround the bar. This will help ensurethe development of good bond.

Seismic Design and Construction

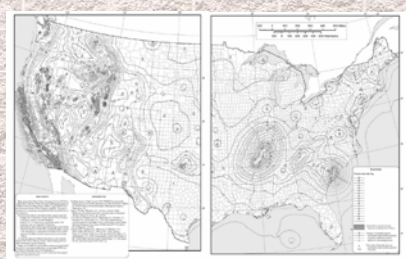


Figure 7.1 IBC Figure 1613.3.1.(1), Seismic Map of the United States, 02-Second Spectral Response Acceleration.

Seismic Design and Construction

7.2.2 Seismic Design Category B

The designer must consider lateral seismic forces in accordance with Code requirements. These requirements are in addition to those contained in SDC A.

MSJC Code Section 1.18.4.2

1.18.4.2 *Seismic Design Category B requirements* – Masonry elements in structures assigned to Seismic Design Category B shall comply with the requirements of Section 1.18.4.1 and with the additional requirements of Section 1.18.4.2.

1.18.4.2.1 *Design of participating elements* – Participating masonry elements shall be designed to comply with the requirements of Chapter 2, 3, or 4 or 8. Masonry shear walls shall be designed to comply with the requirements of Section 1.18.3.2.2, 1.18.3.2.3, 1.18.3.2.4, 1.18.3.2.5, 1.18.3.2.6, 1.18.3.2.7, 1.18.3.2.8, 1.18.3.2.9, 1.18.3.2.10, 1.18.3.2.11, or 1.18.3.2.12.

Seismic Design and Construction

The method of design for participating elements will be determined by the designer and may range from no reinforcement to full reinforcement where code provisions require vertical and horizontal reinforcement at maximum intervals of 4 ft (1.2 m) on center.

Seismic Design and Construction

7.2.3 Seismic Design Category C

As seismic exposure increases due to factors such as site soil conditions and proximity to known earthquake faults, so do the requirements affecting masonry construction.

The MSJC Code incorporates the requirements from SDC A and SDC B into SDC C.

MSJC Code Section 1.18.4.3

1.18.4.3 *Seismic Design Category C requirements* – Masonry elements in structures assigned to Seismic Design Category C shall comply with the requirements of Section 1.18.4.2 and with the additional requirements of Section 1.18.4.3.1 and 1.18.4.3.2.

SEISMIC DESIGN AND CONSTRUCTION

A nonparticipating element is not designed to resist external lateral seismic forces (forces other than it's own load). MSJC Code Section 1.18.4.3.1 contains specific prescriptive detailing requirements for this type of element in Seismic Design Category C.

MSJC Code Section 1.18.4.3.1

1.18.4.3.1 *Design of nonparticipating elements* – Nonparticipating masonry elements shall comply with the requirements of Section 1.18.3.1 and Chapter 2, 3, 4, 5, or 8. Nonparticipating masonry elements, except those constructed of AAC masonry, shall be reinforced in either the horizontal or vertical direction in accordance with the following:

SEISMIC DESIGN AND CONSTRUCTION

MSJC Code Section 1.18.4.3.1

(a) *Horizontal reinforcement* – Horizontal reinforcement shall consist of at least two longitudinal wires of W1.7 (MW11) bed joint reinforcement spaced not more than 16 in. (406 mm) on center 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) on center 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) on center. Where two longitudinal wires of joint reinforcement are used, the space 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 120 in. (3048 mm). Vertical reinforcement shall be located within 16 in. (406 mm) of the ends of masonry walls.

SEISMIC DESIGN AND CONSTRUCTION

SEISMIC DESIGN AND CONSTRUCTION

Masonry walls that resist seismic forces, or elements that are part of the lateral-force-resisting system, are commonly known as shear walls or participating elements. The MSJC Code makes special provisions for these types of walls.

MSJC Code Section 1.18.4.3.2

1.18.4.3.2 *Design of participating elements* — Participating masonry elements shall be designed to comply with the requirements of Section 2.3, 3.3, or 8.3. Masonry shear walls shall be designed to comply with the requirements of Section 1.18.3.2.4, 1.18.3.2.5, 1.18.3.2.6, 1.18.3.2.9, 1.18.3.2.11, or 1.18.3.2.12.

SEISMIC DESIGN AND CONSTRUCTION

MSJC Code Section 1.18.4.3.2.1

1.18.4.3.2.1 *Connections to masonry columns* — Connections shall be designed to transfer forces between masonry columns and horizontal elements in accordance with the requirements of Section 1.7.4. Where anchor bolts are used to connect horizontal elements to the tops of columns, anchor bolts shall be placed within lateral ties. Lateral ties shall enclose both the vertical bars in the column and the anchor bolts. There shall be a minimum of two No. 4 (M #13) lateral ties provided in the top 5 in. (127 mm) of the column.

SEISMIC DESIGN AND CONSTRUCTION

MSJC Code Section 1.18.3.2.4

1.18.3.2.4 *Ordinary reinforced masonry shear walls* — Design of ordinary reinforced masonry shear walls shall comply with the requirements of Section 2.3 or Section 3.3, and shall comply with the requirements of Section 1.18.3.2.3.1.

1.18.3.2.5 *Intermediate reinforced masonry shear walls* – Design of intermediate reinforced masonry shear walls shall comply with the requirements of Section 2.3 or Section 3.3. Reinforcement detailing shall also comply with the requirements of Section 1.18.3.2.3.1, except that the spacing of vertical reinforcement shall not exceed 48 in. (1219 mm).

1.18.3.2.6 *Special reinforced masonry shear walls* – Design of special reinforced masonry shear walls shall comply with the requirements of Section 2.3 or Section 3.3. Reinforcement detailing shall also comply with the requirements of Sections 1.18.3.2.3.1 and the following:

(a) The maximum spacing of vertical reinforcement shall be the smallest of one-third the length of the shear wall, one-third the height of the shear wall, and 48 in. (1219 mm) for masonry laid in running bond and 24 in. (610 mm) for masonry not laid in running bond.

SEISMIC DESIGN AND CONSTRUCTION

(b) The maximum spacing of horizontal reinforcement required to resist in-plane shear shall be uniformly distributed, shall be the smaller of one-third the length of the shear wall and one-third the height of the shear wall, and shall be embedded in grout. The maximum spacing of horizontal reinforcement shall not exceed 48 in. (1219 mm) for masonry laid in running bond and 24 in. (610 mm) for masonry not laid in running bond.

(c) The minimum cross-sectional area of vertical reinforcement shall be one-third of the required shear reinforcement. The sum of the cross-sectional area of horizontal and vertical reinforcement shall be at least 0.002 multiplied by the gross cross-sectional area of the wall, using specified dimensions.

1. For masonry laid in running bond, the minimum cross-sectional area of reinforcement in each direction shall be not less than 0.0007 multiplied by the gross cross-sectional area of the wall, using specified dimensions.

SEISMIC DESIGN AND CONSTRUCTION

2. For masonry not laid in running bond, the minimum cross-sectional area of vertical reinforcement shall be not less than 0.0007 multiplied by the gross cross-sectional area of the wall, using specified dimensions. The minimum cross-sectional area of horizontal reinforcement shall be not less than 0.0015 multiplied by the gross cross-sectional area of the wall, using specified dimensions.

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

(e) Masonry not laid in running bond shall be fully grouted and shall be constructed of hollow open-end units or two wythes of solid units.

SEISMIC DESIGN AND CONSTRUCTION

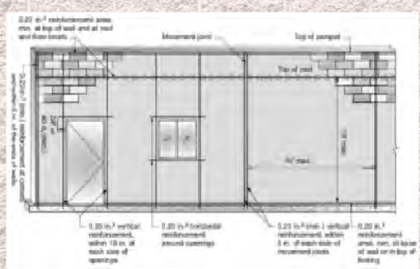


Figure 7.3 Minimum reinforcement spacing for ordinary reinforced lateral load resisting systems, Seismic Design Category C.

SEISMIC DESIGN AND CONSTRUCTION

7.2.4 Seismic Design Category D

Seismic exposure increases design and construction requirements. As one would expect, the requirements for Seismic Design Categories A, B and C also apply to Seismic Category D.

MSJC Code Section 1.18.4.4

1.18.4.4 *Seismic Design Category D requirements* — Masonry elements in structures assigned to Seismic Design Category D shall comply with the requirements of Section 1.18.4.3 and with the additional requirements of Sections 1.18.4.4.1 and 1.18.4.4.2.

Exception: Design of participating elements of AAC masonry shall comply with the requirements of 1.18.4.3.

SEISMIC DESIGN AND CONSTRUCTION

There are general design requirements for masonry structures in Seismic Design Category D.

MSJC Code Section 1.18.4.4.1

1.18.4.4.1 *Design of nonparticipating elements* — Nonparticipating masonry elements shall comply with the requirements of Chapters 2, 3, 4, or 8. Nonparticipating masonry elements, except those constructed of AAC masonry, shall be reinforced in either the horizontal or vertical direction in accordance with the following:

(a) *Horizontal reinforcement* – Horizontal reinforcement shall comply with Section 1.18.4.3.1(a).

(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.

SEISMIC DESIGN AND CONSTRUCTION

1.18.4.4.2.1 *Minimum reinforcement for masonry columns* – Lateral ties in masonry columns shall be spaced not more than 8 in. (203 mm) on center and shall be at least $^{3}/_{8}$ in. (9.5 mm) diameter. Lateral ties shall be embedded in grout.

Stack bond masonry walls in SDC D require minimum horizontal reinforcement as shown in Figure 7.4 or joint reinforcement as required in MSJC Code Section 1.18.4.3.1(a). Participating (shear wall) stack bond masonry, however, must contain minimum horizontal reinforcement based on a calculation of 0.0015 times the gross sectional wall area. For an 8 in. (203 mm) wide wall, this would calculate to about 1 #4 bar spaced at 16 in. (406 mm) on centers.

1.18.4.4.2.3 *Lateral tie anchorage* – Standard hooks for lateral tie anchorage shall be either a 135-degree standard hook or a 180-degree standard hook.

Seismic Design and Construction

7.2.4.1 Shear Walls
Shear walls are defined as participating elements for seismic resistance. Shear walls in SDC D are designed as special reinforced masonry shear walls conforming to the prescriptive requirements contained in MSJC Code Section 1.18.3.2.6.

7.2.4.2 Material Restrictions
Seismic Design Category D imposes restrictions on use of certain materials for the lateral-load-resisting system. Instead of prohibiting certain mortar types, the 2011 MSJC Code requires portland cement-lime or mortar cement, Type M or S, mortar. Plastic cement, a product used primarily in stucco application is not recognized in the masonry section of the IBC and MSJC Code, and should not be used in masonry construction.

MSJC Section 1.18.4.4.2.2
1.18.4.4.2.2 *Material requirements* — Participating elements shall be designed and specified with Type S or Type M cement-lime mortar or mortar cement mortar.

Seismic Design and Construction

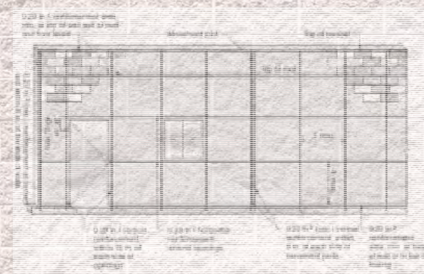


Figure 7.4 Minimum reinforcement spacing for lateral load resisting systems Seismic Design Category D.

Seismic Design and Construction

7.2.5 Seismic Design Categories E and F

For masonry constructed in the highest seismic exposure, the most stringent requirements apply. The greatest concern is structural performance of stack bond masonry (masonry not laid in running bond), hence, the additional reinforcement. As with other Seismic Categories, the requirements accumulate.

MSJC Code Section 1.18.4.5
1.18.4.5 *Seismic Design Categories E and F requirements* – Masonry elements in structures assigned to Seismic Design Category E or F shall comply with the requirements of Section 1.18.4.4 and with the additional requirements of Section 1.18.4.5.1.

Seismic Design and Construction

For stack bond masonry, elements not part of the lateral load resisting system, the requirements are stated in MSJC Code Section 1.18.4.5.1.

MSJC Code Section 1.18.4.5.1
1.18.4.5.1 *Minimum reinforcement for nonparticipating masonry elements not laid in running bond* — Masonry not laid in running bond in nonparticipating elements shall have a cross-sectional area of horizontal reinforcement of at least 0.0015 multiplied by the gross cross-sectional area of masonry, using specified dimensions. The maximum spacing of horizontal reinforcement shall be 24 in. (610 mm). These elements shall be fully grouted and shall be constructed of hollow open-end units or two wythes of solid units.

Seismic Design and Construction

For stack bond masonry walls that are part of the lateral-load-resisting system, the requirements are contained in MSJC Code Section 1.18.3.2.6 and are based on the same calculation as contained in MSJC Code Section 1.18.4.5.1

CHAPTER 8
Prestressed Masonry

8.1 GENERAL

Post-tensioned, prestressed masonry is used in Europe and is gaining in popularity in the United States. This type of masonry offers an alternative to conventional construction that can be advantageous to the owner, designer and contractor.

In order to understand prestressed masonry, it is helpful to review the definitions contained in the MSJC Specification.

PRESTRESSED MASONRY

MSJC Specification Article 1.2

1.2 – Definitions

H. *Bonded prestressing tendon* — Prestressing tendon that is encapsulated by prestressing grout in a corrugated duct that is bonded to the surrounding masonry through grouting.

AH. *Post-tensioning* — Method of prestressing in which prestressing tendons are tensioned after the masonry has been placed.

AI. *Prestressed masonry* — Masonry in which internal compressive stresses have been introduced by prestressed tendons to counteract potential tensile stresses resulting from applied loads.

AJ. *Prestressing grout* — A cementitious mixture used to encapsulate bonding prestressing tendons.

PRESTRESSED MASONRY

PRESTRESSED MASONRY

AK. *Prestressing tendon* — Steel element such as wire, bar, or strand, or a bundle of such elements, used to impart prestress to masonry.

AL. *Pretensioning* — Method of prestressing in which prestressing tendons are tensioned before the transfer of stress into the masonry.

AW. *Tendon anchorage* — In post-tensioning, a device used to anchor the prestressing tendon to the masonry or concrete member; in pretensioning, a device used to anchor the prestressing tendon during hardening of masonry mortar, grout, prestressing grout, or concrete.

AX. *Tendon coupler* — A device for connecting two tendon ends, thereby transferring the prestressing force from end to end.

PRESTRESSED MASONRY

AY. *Tendon jacking force* — Temporary force exerted by device that introduces tension into prestressing tendons.

AZ. *Unbonded prestressing tendon* — Prestressing tendon that is not bonded to masonry.

This type of masonry is constructed, then tensioned (post-tensioned) to a state where internal stresses are introduced prior to the service life of the masonry wall (prestressed).

Although MSJC Code Section 4.3.4 is directed toward the designer, the inspector should be aware of the important issues affecting prestressed masonry.

PRESTRESSED MASONRY

MSJC Code Section 4.3.4

4.3.4 *Effective prestress*

The computed effective stress in the prestressing tendons under service loads, f_{se}, shall include the effects of the following:

(a) anchorage seating losses,

(b) elastic shortening of masonry,

(c) creep of masonry,

(d) shrinkage of concrete masonry,

(e) relaxation of prestressing tendon stress,

(f) friction losses

(g) irreversible moisture expansion of clay masonry, and

(h) thermal effects.

PRESTRESSED MASONRY

The inspector plays an important role in the quality control of the post-tensioned masonry system. Specifically, the inspector should be observant of the following:

a. Visual inspection of the layout, bond pattern and workmanship.
b. Verify placement and conformance of anchorage in footing.
c. Check that the tension rods are in compliance with the design criteria.
d. Verify threading of rods in accordance with manufacturers' requirements.
e. Verify proper rod tensions.

Prestressed Masonry

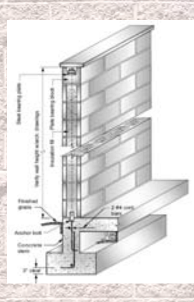
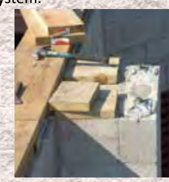


Figure 8.1 Prestressed masonry system.

Prestressed Masonry

8.2 MATERIALS

The inspector must be aware of the required materials for a prestressed masonry application. Manufacturers publish adequate information related to their particular prestressed masonry products and the designer must be clear in the project requirements. The information contained in the MSJC Specification relates to the minimum material requirements for the application of a prestressed masonry system.



Prestressed Masonry

MSJC Specification Article 2.4 B

2.4 B. *Prestressing tendons*

1. Provide prestressing tendons that conform to one of the following standards, except for those permitted in Articles 2.4 B.2 and 2.4 B.3:

   a. Wire..........…....….............................ASTM A421/A421M

   b. Low-relaxation wire..….....……….......ASTM A421/A421M

   c. Strand...............……………..….........ASTM A416/A416M

   d. Low-relaxationstrand…..……………..ASTM A416/A 416M

   e. Bar......................…….……………......ASTM A722/A722M

Prestressed Masonry

2. Wire, strands and bars not specifically listed in ASTM A416/A416M, A421/A421M, or A722/A722M are permitted, provided they conform to the minimum requirements in ASTM A416/A416M, A421/A421M or A722/A722M and are approved by the Architect/ Engineer.
3. Bars and wires of less than 150 ksi (1034 MPa) tensile strength and conforming to ASTM A82/A82M, A510/A510M, A615/A615M, A996/A996M, or A706/A706M are permitted to be used as prestressed tendons, provided that the stress relaxation properties have been assessed by tests according to ASTM E328 for the maximum permissible stress in the tendon.

Prestressed Masonry

Prior to installation, the inspector must verify that the materials meet the applicable ASTM requirements.

Additionally, the tendon materials must be protected to avoid any degradation of the tensile members. The masonry inspector should be aware of guidance provided to the designer.

Prestressed Masonry

MSJC Code Section 4.9.2

4.9.2 Corrosion protection of prestressing tendon shall not rely solely on masonry cover.

The masonry inspector also needs to be aware of the direction given to the contractor.

PRESTRESSED MASONRY

MSJC Specification Article 2.4 G

2.4 G. *Corrosion protection for tendons* — Protect tendons from corrosion when they are in exterior walls exposed to earth or weather or walls exposed to a mean relative humidity exceeding 75 percent (corrosive environment). Select corrosion protection methods for bonded and unbonded tendons from one of the following:

1. *Bonded tendons* — Encapsulate bonded tendons in corrosion resistant and watertight corrugated ducts complying with Article 2.4 G.1.a. Fill ducts with prestressing grout complying with Article 2.4 G.1.b.
   - a. Ducts — High-density polyethylene or polypropylene.
     - 1) Use ducts that are mortar-tight and non-reactive with masonry, tendons and grout.
     - 2) Provide ducts with an inside diameter at least ¼ in. (6.4 mm) larger than the tendon diameter.
     - 3) Maintain ducts free of water if members to be grouted are exposed to temperatures below freezing prior to grouting.
     - 4) Provide openings at both ends of ducts for grout injection.

PRESTRESSED MASONRY

b. Prestressing grout

- 1) Select proportions of materials for prestressing grout using either of the following methods as accepted by the Architect/ Engineer.
  - a) Results of tests on fresh and hardened prestressing grout —prior to beginning of grouting operations, or
  - b) Prior documented experience with similar materials and equipment and under comparable field conditions.
- 2) Use portland cement conforming to ASTM C150, Type I, II, or III, that corresponds to the type upon which selection of prestressing grout was based.
- 3) Use the minimum water content necessary for proper pumping of prestressing grout; however, limit the water-cement ratio to a maximum of 0.45 by weight.
- 4) Discard prestressing grout that has begun to set due to delayed use.
- 5) Do not use admixtures, unless acceptable to the Architect/ Engineer.
- 6) Use water that is potable and free of materials known to be harmful to masonry materials and reinforcement.

PRESTRESSED MASONRY

Many items in traditional masonry construction and prestressed masonry construction are similar: testing prestressed grout for acceptability or using historic documentation to verify the adequacy of prestressed grout, the use of portland cement in grout, discarding cementitious materials that have hardened, limitations on admixtures, and use of clean water.

One should be aware of significant differences that exist. The water content in prestressed grout is carefully limited whereas traditional masonry grout requires a very high water content.

When the designer elects to use a prestressed system with unbonded tendons, then it is essential the inspector be knowledgeable of the applicable requirements.

PRESTRESSED MASONRY

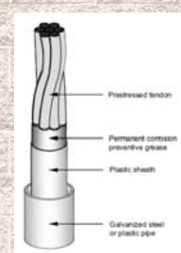


Figure 8.2 Corrosion protection system for an unbonded tendon.

PRESTRESSED MASONRY

MSJC Specification Article 2.4 G.2

2. *Unbonded tendons* — Coat unbonded tendons with a material complying with Article 2.4 G.2.b and covered with a sheathing complying with Article 2.4 G.2.a. Acceptable materials include a corrosion-inhibiting coating material with a tendon covering (sheathing).
   - a. Provide continuous tendon sheathing over the entire tendon length to prevent loss of coating materials during tendon installation and stressing procedures. Provide a sheathing of medium-density or high-density polyethylene or polypropylene with the following properties:
     - 1) Sufficient strength to withstand damage during fabrication, transport, installation, and tensioning.
     - 2) Water-tightness over the entire sheathing length.
     - 3) Chemical stability without embrittlement or softening over the anticipated exposure temperature range and service life of the structure.

PRESTRESSED MASONRY

- 4) Non-reactive with masonry and the tendon corrosion-inhibiting coating.
- 5) In normal (non-corrosive) environments, a sheathing thickness of not less than 0.025 in. (0.6 mm). In corrosive environments, a sheathing thickness of not less than 0.040 in. (1.0 mm).
- 6) An inside diameter at least 0.010 in. (0.3 mm) greater than the maximum diameter of the tendon.
- 7) For applications in corrosive environments, connect the sheathing to intermediate and fixed anchorages in a watertight fashion, thus providing a complete encapsulation of the tendon.

b. Provide a corrosion-inhibiting coating material with the following properties:

- 1) Lubrication between the tendon and the sheathing.
- 2) Resist flow from the sheathing within the anticipated temperature range of exposure.

PRESTRESSED MASONRY

3) A continuous non-brittle film at the lowest anticipated temperature of exposure.
4) Chemically stable and non-reactive with the tendon, sheathing material, and masonry.
5) An organic coating with appropriate polar-moisture displacing and corrosion-preventive additives.
6) A minimum weight not less than 2.5 lb of coating material per 100 ft (37.2 g of coating material per m) of 0.5 in. (12.7 mm) diameter tendon and 3.0 lb of coating material per 100 ft (44.6 g of coating material per m) of 0.6 in. (15.2 mm) diameter tendon. Use a sufficient amount of coating material to ensure filling of the annular space between tendon and sheathing.
7) Extend the coating over the entire tendon length.
8) Provide test results in accordance with Table 6 for the corrosion-inhibiting coating material.

PRESTRESSED MASONRY

One of the basic concepts of the Code is that alternate materials of equivalency are not restricted from use.

IBC Section 104.11

104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

PRESTRESSED MASONRY

The prestressed masonry section of the MSJC Specification goes one step further in clarifying alternatives for corrosion protection.

MSJC Specification Article 2.4 G.3

3. Alternative methods of corrosion protection that provide a protection level equivalent to Articles 2.4 G.1 and 2.4 G.2 are permitted. Stainless steel prestressing tendons or tendons galvanized according to ASTM A153/A153M, Class B, are acceptable alternative methods. If galvanized, further evidence must be provided that the coating will not produce hydrogen embrittlement of the steel.

PRESTRESSED MASONRY

Additionally, there are material requirements covering materials associated with anchoring the prestressed tendons.

MSJC Specification Article 2.4 H

2.4 H. *Prestressing anchorages, couplers, and end blocks*

1. Provide anchorages and couplers that develop at least 95 percent of the specified breaking strength of the tendons or prestressing steel when tested in an unbonded condition, without exceeding anticipated set.
2. Place couplers where accepted by Architect/Engineer. Enclose with housing that permits anticipated movements of the couplers during stressing.
3. Protect anchorages, couplers, and end fittings against corrosion.
4. Protect exposed anchorages, couplers, and end fittings to achieve the fire-resistance rating required for the element by the legally adopted building code.

PRESTRESSED MASONRY

8.3 CONSTRUCTION

Construction of prestressed masonry is somewhat more critical than with conventional masonry. This is apparent by the allowable tolerances contained in MSJC Specification Article 3.6 A. When the tendon is properly located, the stresses hold the masonry wall together, but if the tendon location is extreme to either face of the wall, the tendon could contribute in pulling the wall down.

In order to assure the quality of the prestressed masonry wall system, some manufacturers require certified installers, additional inspection and tensioning by specialized and recognized individuals.

Prior to construction, the inspector should be aware of certain design requirements affecting the layout of the tendons and tendon restraints.

PRESTRESSED MASONRY

MSJC Code Section 4.8.3

4.8.3 Reinforcement shall be provided in masonry members near anchorages if tensile stresses created by bursting, splitting, and spalling forces induced by the prestressing tendon exceed the capacity of the masonry.

PRESTRESSED MASONRY

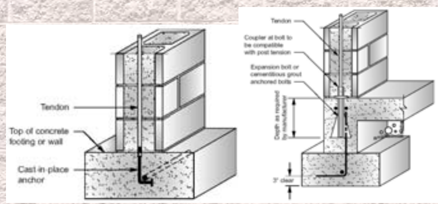


Figure 8.3 Typical bottom anchorage details.

PRESTRESSED MASONRY

PRESTRESSED MASONRY

MSJC Specification Article 3.6

3.6 — Prestressing tendon installation and stressing procedure

3.6 A. *Site tolerances*

1. Tolerance for prestressing tendon placement in the out-of-plane direction in walls shall be ± 1/4 in. (6.4 mm) for masonry cross-sectional dimensions less than nominal 8 in. (203 mm) and ± 3/8 in. (9.5 mm) for masonry cross-sectional dimensions equal to or greater than nominal 8 in. (203 mm).
2. Tolerance for prestressing tendon placement in the in-plane direction of walls shall be ± 1 in. (25.4 mm).
3. If prestressing tendons are moved more than one tendon diameter or a distance exceeding the tolerances stated in Articles 3.6 A.1 and 3.6 A.2 to avoid interference with other tendons, reinforcement, conduits, or embedded items, notify the Architect/Engineer for acceptance of the resulting arrangement of prestressing tendons.

PRESTRESSED MASONRY

3.6 B. *Application and measurement of prestressing force*

1. Determine the prestressing force by both of the following methods:
   a. Measure the prestressing tendon elongation and compare it with the required elongation based on average load-elongation curves for the prestressing tendons.
   b. Observe the jacking force on a calibrated gage or load cell or by use of a calibrated dynamometer. For prestressing tendons using bars of less than 150 ksi (1034 MPa) tensile strength, Direct Tension Indicator (DTI) washers complying with ASTM F959M are acceptable.
2. Ascertain the cause of the difference in force determined by the two methods described in Article 3.6 B.1, when the difference exceeds 5 percent for pretensioned elements or 7 percent for post-tensioned elements, and correct the cause of the difference.
3. When the total loss of prestress due to unreplaced broken prestressing tendons exceeds 2 percent of total prestress, notify the Architect/Engineer.

PRESTRESSED MASONRY

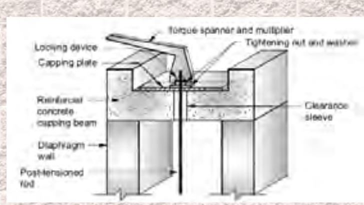


Figure 8.4 Torque anchorage.

PRESTRESSED MASONRY

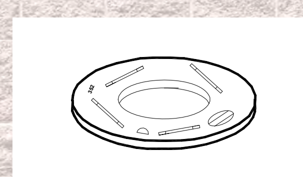


Figure 8.5 Direct tension indicator (DTI) washer.

PRESTRESSED MASONRY

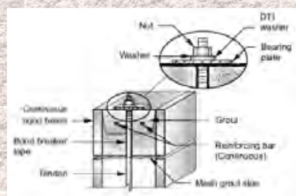


Figure 8.6 Top anchorage.

PRESTRESSED MASONRY

MSJC Specification Article 3.6 (Continued)

3.6 C. *Grouting bonded tendons*

1. Mix prestressing grout in equipment capable of continuous mechanical mixing and agitation so as to produce uniform distribution of materials, pass through screens, and pump in a manner that will completely fill tendon ducts.
2. Maintain temperature of masonry above 35°F (1.7°C) at time of grouting and until field-cured 2 in. (50.8 mm) cubes of prestressing grout reach a minimum compressive strength of 800 psi (5.52 MPa).
3. Keep prestressing grout temperatures below 90°F (32.2°C) during mixing and pumping.

PRESTRESSED MASONRY

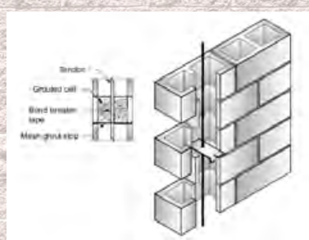


Figure 8.7 Typical lateral restraint.

PRESTRESSED MASONRY

When completing the prestressed masonry it is important to check for performance issues, such as fire protection of the members.

MSJC Code Section 4.9.3

4.9.3 Parts of prestressing tendons not embedded in masonry shall be provided with mechanical and fire protection equivalent to that of the embedded parts of the tendon.

PRESTRESSED MASONRY

Accordingly, when finishing or removing excess tendon, it is necessary to see that such operations do not have an adverse affect on the permanent components.

MSJC Specification Article 3.6 D

3.6 D. *Burning and welding operations* — Carefully perform burning and welding operations in the vicinity of prestressing tendons so that tendons and sheathings, if used, are not subjected to excessive temperatures, welding sparks, or grounding currents.

PRESTRESSED MASONRY

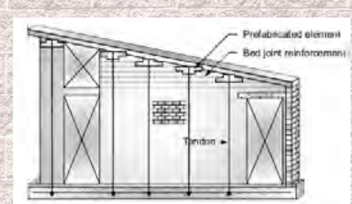


Figure 8.8 Typical prestressed masonry application.

CHAPTER 9
Special Topics or Conditions

9.1 BRACING OF WALLS

Part of the construction process includes protection of the installed masonry work during construction. One of the issues associated with protection of work is bracing of the work during the construction process. Historically, this is a means-and-methods issue, not a code issue. It is, however, a potential life-safety issue during the construction process, which is everyone's responsibility.

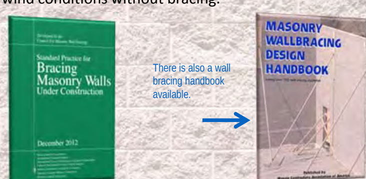
Special Topics

It is recommended, and some jurisdictions require, that walls be braced during construction to prevent damage or collapse by wind or other forces.

Special Topics

The masonry industry publishes *Standard Practice for Bracing Masonry Walls Under Construction* which provides the guidelines and recommendations associated with bracing of masonry walls. The Standard addresses bracing of masonry walls against wind loads. It does not address bracing of masonry for seismic applications.

The Standard is developed to allow work to continue on a project during low speed wind conditions without bracing.



Special Topics

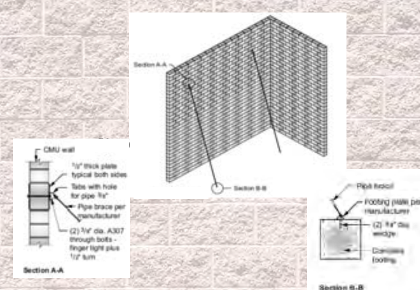


Figure 9.1 **Typical wall bracing.**

Special Topics

9.2 PIPES AND CONDUITS EMBEDDED IN MASONRY

Since masonry walls are solid, careful planning is necessary in coordinating with other trades that interface with masonry. For example, if a mechanical penetration, such as an air shaft, is required to pass through a masonry wall, the plans should clearly show the manner in which the opening is structurally detailed.

Special Topics

MSJC Specification Article 3.3 D

3.3 D. *Embedded items and accessories* — Install embedded items and accessories as follows:

1. Construct chases as masonry units are laid.
2. Install pipes and conduits passing horizontally through nonbearing masonry partitions.
3. Place pipes and conduits passing horizontally through piers, pilasters, or columns.
4. Place horizontal pipes and conduits in and parallel to plane of walls.

Special Topics

The inspector should be aware that a large embedment (pipe) located in the wall in a horizontal orientation will have a significant structural impact on the performance of the wall.

9.3 ADJACENT WORK

Bolts, anchors and other inserts which attach adjoining construction to the walls should be embedded in mortar at the face shell and solidly grouted for the entire remaining embedment in the walls. Where possible, they should be wired to the reinforcing bars to keep them from dislodging during consolidation of the grout.

Special Topics

MSJC Specification Article 3.3 D

5. Install and secure connectors, flashing, weep holes, weep vents, nailing blocks, and other accessories.
6. Install movement joints.
7. Aluminum – Do not embed aluminum conduits, pipes, and accessories in masonry, grout, or mortar, unless effectively coated or covered to prevent chemical reaction between aluminum and cement or electrolytic action between aluminum and steel.

Special Topics

Special Topics

Roof flashing should penetrate the mortar joints not more than 1 in. (25 mm). Metal door frames should be set and braced in-place before the masonry walls are erected. They should be anchored and solidly grouted in-place as the wall is constructed.

Special Topics

9.4 INTERSECTING STRUCTURAL ELEMENTS

9.4.1 Wall to Wall

It is often advantageous for a wall to be designed to work structurally with another intersecting wall or to a roof or floor. The intersecting structural elements must conform to the applicable code requirements.

Special Topics

MSJC Code Section 1.9.4

1.9.4 *Intersecting walls*

1.9.4.1 Wall intersections shall meet one of the following requirements:

(a) Design shall conform to the provisions of Section 1.9.4.2.

(b) Transfer of shear between walls shall be prevented.

1.9.4.2 *Design of wall intersection*

1.9.4.2.1 Masonry shall be in running bond.

1.9.4.2.2 Flanges shall be considered effective in resisting applied loads.

1.9.4.2.3 The width of flange considered effective on each side of the web shall be the smaller of the actual flange on either side of the web wall or the following:

SPECIAL TOPICS

(a) 6 multiplied by the nominal flange thickness for unreinforced and reinforced masonry, when the flange is in compression.

(b) 6 multiplied by the nominal flange thickness for unreinforced masonry, when the flange is in flexural tension.

0.75 multiplied by the floor-to-floor wall height for reinforced masonry, when the flange is in flexural tension.

1.9.4.2.4 Design for shear, including the transfer of shear at interfaces, shall conform to the requirements of Section 2.2.5 or 2.3.6; or Sections 3.1.3 and 3.3.4.1.2; or Sections 3.1.3 and 3.2.4; or Section 4.6; or Section 8.1.3 and 8.3.4.1.2.

1.9.4.2.5 The connection of intersecting walls shall conform to one of the following requirements:

SPECIAL TOPICS

(a) At least fifty percent of the masonry units at the interface shall interlock.

(b) Walls shall be anchored by steel connectors grouted into the wall and meeting the following requirements:

(1) Minimum size: $^1/_4$ in. x $1^1/_2$ in. x 28 in. (6.4 mm x 38.1 mm x 711 mm) including 2 in. (50.8 mm) long, 90 degree bend at each end to form a U or Z shape.

(2) Maximum spacing: 48 in. (1219 mm).

(c) Intersecting reinforced bond beams shall be provided at a maximum spacing of 48 in. (1219 mm) on centers. The area of reinforcement in each bond beam shall not be less than 0.1 in.^{2} per ft (211 mm^2/m) multiplied by the vertical spacing of the bond beams in feet (meters). Reinforcement shall be developed on each side of the intersection.

SPECIAL TOPICS

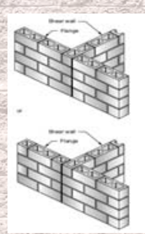


Figure 9.2 Running bond layout with interlocking intersecting wall.

SPECIAL TOPICS

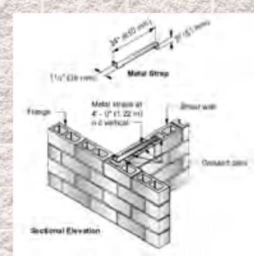


Figure 9.3 Metal strap anchorage at wall intersection.

SPECIAL TOPICS

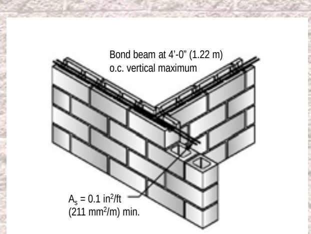


Figure 9.4 Grout and reinforcement bonding of intersecting walls.

SPECIAL TOPICS

Figure 9.5 shows a few traditional details that have been used to tie together corners or intersecting walls.

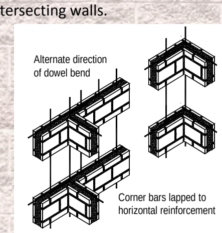


Figure 9.5 Concrete block intersecting wall and corner details. Stagger laps of bars in alternate courses. Suggest lapping all bars a minimum of 30 bar diameters or 24 in. (610 mm), whichever is greater.

Special Topics

9.4.2 Wall to Floor or Roof

In addition to the requirements of masonry construction, the masonry inspector must be aware of the interface of masonry with other building elements.

MSJC Code Section 1.2.2

1.2.2 Show all Code-required drawing items on the project drawings, including:

(e) Details of anchorage of masonry to structural members, frames, and other construction including the type, size, and location of connectors.

Special Topics

Precast floor planks can be used on an interior block wall. The planks change directions of span. A concrete topping is cast after the upper wall has been erected. Vertical reinforcing steel goes through the wall and is anchored in the topping concrete.

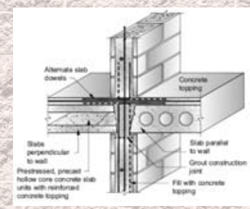


Figure 9.6 Floor to side wall connection details.

Special Topics

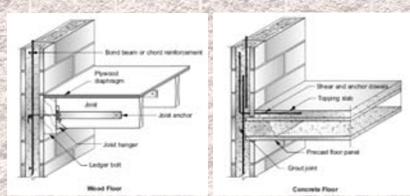


Figure 9.7 Through floor and wall connection details.

Special Topics

In addition to the connection requirements contained in the masonry section of the applicable code, the Structural Design Provisions of the code provide the designer with specific connection requirements. The International Building Code applies these provisions to Seismic Design Category B and above.

IBC Section 1604.8.2

1604.8.2 Structural walls. Walls that provide vertical load-bearing resistance or lateral shear resistance for a portion of the structure shall be anchored to the roof and to all floors and members that provide lateral support for the wall or that are supported by the wall.

Special Topics

The MSJC Code provides the designer minimum design levels that apply to Seismic Design Category C and above.

MSJC Code Section 1.18.4.3.2.1

1.18.4.3.2.1 *Connections to masonry columns* — Connections shall be designed to transfer forces between masonry columns and horizontal elements in accordance with the requirements of Section 1.7.4. Where anchor bolts are used to connect horizontal elements to the tops of columns, anchor bolts shall be placed within lateral ties. Lateral ties shall enclose both the vertical bars in the column and the anchor bolts. There shall be a minimum of two No. 4 (M #13) lateral ties provided in the top 5 in. (127 mm) of the column.

Special Topics

9.5 MULTIWYTHE WALLS

9.5.1 General

Masonry walls of two independent wythes (widths) must be tied together in some manner according to the applicable code. The MSJC Code provides the requirements for walls of composite and noncomposite action.

Special Topics

MSJC Code Section 2.1.5

2.1.5 *Multiwythe walls*

2.1.5.1 Design of walls composed of more than one wythe shall comply with the provisions of this section.

2.1.5.2 *Composite action*

2.1.5.2.1 Multiwythe walls designed for composite action shall have collar joints either:

(a) crossed by connecting headers, or

(b) filled with mortar or grout and connected by wall ties.

Special Topics

2.1.5.3.2 Wythes of walls designed for noncomposite action shall be connected by wall ties meeting the requirements of Section 2.1.5.2.4 or by adjustable ties. Where the cross wires of joint reinforcement are used as ties, the joint reinforcement shall be ladder-type or tab-type. Wall ties shall be without cavity drip.

Special Topics

CBC Section 2104.A.5.1.1.3 High-lift grouted construction

5. Vertical grout barriers or dams shall be built of solid masonry across the grout space the entire height of the wall to control the flow of the grout horizontally. Grout barriers shall not be more than 30 feet (9144 mm) apart.

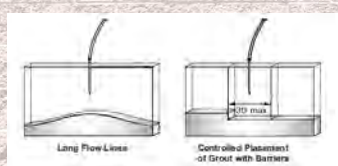


Figure 9.8 Use of grout barriers to control segregation in grout.

Special Topics

Special Topics

9.5.2 Metal Ties for Cavity Wall Construction

In order to assure the performance of ties connecting wythes, the code provides mandatory guidelines for the material and installation of wall ties.

IBC Section 2104.1.3

2104.1.3 Installation of wall ties. Wall ties shall be installed in accordance with TMS 602/ACI 530.1/ASCE 6.

Special Topics

MSJC Specification Article 3.4 C

3.4 C. *Wall ties*

1. Embed the ends of wall ties in mortar joints. Embed wall tie ends at least $^1/_2$ in. (12.7 mm) into the outer face shell of hollow units. Embed wire wall ties at least $1^1/_2$ in. (38.1 mm) into the mortar bed of solid masonry units or solid grouted hollow units.
2. Unless otherwise required, bond wythes not bonded by headers with wall ties as follows:

Wire size	*Minimum number of wall ties required*
W1.7 (MW 11)	One per 2.67 ft^2 (0.25 m^2)
W2.8 (MW 18)	One per 4.50 ft^2 (0.42 m^2)

The maximum spacing between ties is 36 in. (914 mm) horizontally and 24 in. (610 mm) vertically.

3. Unless accepted by the Architect/Engineer, do not bend wall ties after being embedded in grout or mortar.

Special Topics

4. Unless otherwise required, install adjustable ties in accordance with the following requirements:
   a. One tie for each 1.77 ft^2 (0.16 m^2) of wall area
   b. Do not exceed 16 in. (406 mm) horizontal or vertical spacing.
   c. The maximum misalignment of bed joints from one wythe to the other is 1 $^1/_4$ in. (31.8 mm).
   d. The maximum clearance between connecting parts of the ties is $^1/_{16}$ in. (1.6 mm).
   e. When pintle anchors are used, provide ties with one or more pintle legs made of wire size W2.8 (MW 18).
5. Install wire ties perpendicular to a vertical line on the face of the wythe from which they protrude. Where one-piece ties or joint reinforcement are used, the bed joints of adjacent wythes shall align.

Special Topics

Special Topics

Special Topics

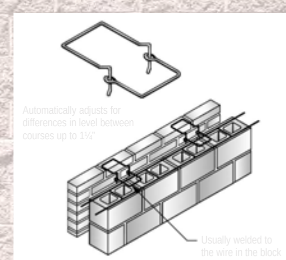


Figure 9.9 Adjustable wall tie (Pintel type).

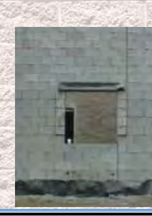
Special Topics

Figure 9.10 Metal ties for cavity wall construction.

Special Topics

MSJC Specification Article 3.4 C (continued)

6. Unless otherwise required, provide additional unit ties around openings larger than 16 in. (406 mm) in either dimension. Space ties around perimeter of opening at a maximum of 3 ft (0.91 m) on center. Place ties within 12 in. (305 mm) of opening.



Special Topics

7. Unless otherwise required, provide unit ties within 12 in. (305 mm) of unsupported edges at horizontal or vertical spacing given in Article 3.4 C.2.

9.5.3 Metal Ties for Grouted Multiwythe Construction

The following figure illustrates placement of a typical wall tie in a multiwythe wall.

Special Topics

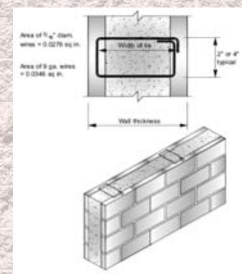


Figure 9.11 Typical positioning of grout tie.

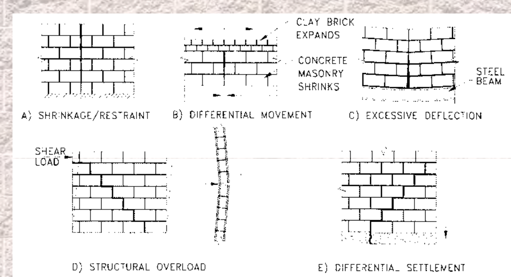
CHAPTER 10
Movement Joints and Crack Control

10.1 GENERAL

Cracking in concrete masonry can be caused by a number of factors and is usually aesthetic, not structural. It can, however, have structural implications. For example, if masonry cracks and moisture is allowed to freely migrate to the reinforcement, then the steel can degrade, which is not a desirable condition.

Historically, the building codes did not address the issue of control joints and expansion joints in walls, but the MSJC Code gives the designer some direction on considering the issue.

Movement Joints and Crack Control



Proper Design Can Avert Cracking of These Types

Movement Joints and Crack Control

Movement Joints and Crack Control

MSJC Code Section 1.7.5

1.7.5 *Other effects*

Consideration shall be given to effects of forces and deformations due to prestressing, vibrations, impact, shrinkage, expansion, temperature changes, creep, unequal settlement of supports, and differential movement.

The subsequent MSJC Code Section (Section 1.8) provides the designer coefficient values to use in considering the effects on masonry.

MOVEMENT JOINTS AND CRACK CONTROL

10.2 JOINTING; CONTROL JOINTS AND EXPANSION JOINTS

10.2.1 Sources of Movement

All structures are subject to movement. Movements can occur from a number of sources, such as:

a. Temperature changes
b. Material expansion and contraction
c. Changes in moisture content or conditions
d. Loading conditions
e. Foundation movement
f. Differential movement of various materials in the building
g. Lateral deflections from wind loads
h. Seismic activity

MOVEMENT JOINTS AND CRACK CONTROL

Masonry walls that move can develop cracks which may be due to the material properties, environmental factors and design or construction deficiencies.

10.2.2 Properties Affecting Concrete Masonry Units

a. Moisture content, e.g. green block at time of laying
b. Shrinkage characteristics of the block
c. Tensile strength
d. Carbonation shrinkage (an irreversible reaction between cementitious materials and carbon dioxide in the atmosphere)

10.2.3 Environmental Factors

a. Temperature increases and decreases causing thermal expansion and contraction
b. Moisture exposure, such as inclement weather

MOVEMENT JOINTS AND CRACK CONTROL

10.2.4 Design/Construction Deficiencies

The following may be a concern contributing to poor performance of masonry

a. Excessive spacing of horizontal steel or joint reinforcement
b. Control joints
   i. None or too few
   ii. Improperly spaced
   iii. Improperly constructed
c. Embedded structural steel not properly isolated

MOVEMENT JOINTS AND CRACK CONTROL

10.3 CRACK CONTROL

There are three recommendations that reduce the possibility of unsightly cracks in concrete masonry walls. These recommendations are:

a. Proper jointing
b. Proper reinforcement
c. Moisture control

MOVEMENT JOINTS AND CRACK CONTROL

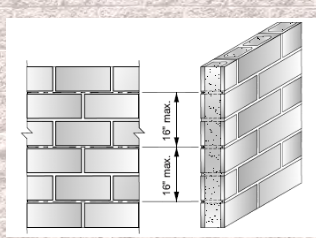
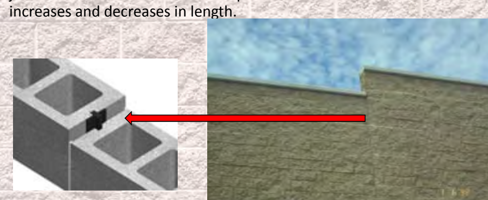


Figure 10.2 Joint reinforcement in alternate bed joints of CMU wall laid in running bond.

MOVEMENT JOINTS AND CRACK CONTROL

10.4 CONTROL JOINTS

Control joints are considered joints that will accommodate shortening, shrinkage and/or reduction in the length of the wall, while expansion joints will accommodate both expansion and contraction of the wall or increases and decreases in length.



MOVEMENT JOINTS AND CRACK CONTROL

Control joints are usually vertical and spaced at intervals so that when shortening occurs the resulting cracks will be at the location of the control joints. Locating a sufficient number of control joints is required so that relative movement occurs at the control joint rather than through the blocks and mortar joints between the control joints.

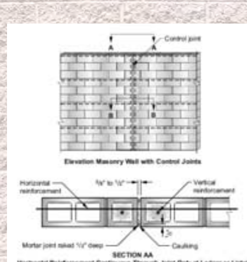
Joints in the wall, whether they are control joints or expansion joints, should match any joints that are built into the roof system, the floor system, the spandrel beams, or other elements that are intended to accommodate movement of the building.

MOVEMENT JOINTS AND CRACK CONTROL

When horizontal reinforcing steel is used in the wall, either in bond beams or in the mortar bed with joint reinforcement, the spacing of the control joints to accommodate the shortening of the wall can be adjusted accordingly.

Historically, spacing of control joints was largely dependent on spacing of horizontal reinforcement and a variable ratio of panel length to height. This gave spacing recommendations of up to 60 ft between control joints. Current recommendations from the National Concrete Masonry Association (NCMA) are given in NCMA TEK 10-2C, Table 1; as listed in Table 10.1, however based on engineering and aesthetic design, a reasonable maximum horizontal spacing of control joints is 25 to 30 feet.

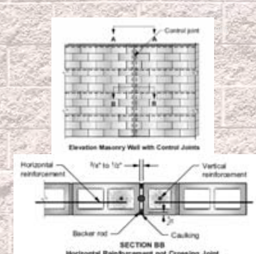
MOVEMENT JOINTS AND CRACK CONTROL



This detail as shown is intended to illustrate a general concept or method of construction. Not intended for use without review and approval of designer who shall be responsible for design and proper application.

Figure 10.2 Typical control joint layout.

MOVEMENT JOINTS AND CRACK CONTROL



This detail as shown is intended to illustrate a general concept or method of construction. Not intended for use without review and approval of designer who shall be responsible for design and proper application.

Figure 10.2 Typical control joint layout. *(Continued)*

MOVEMENT JOINTS AND CRACK CONTROL

Vertical control joints should be located in masonry walls at the following locations:

a. At determined intervals and spacing for the length of the wall
b. At major changes in the wall height
c. At changes in the wall thickness
d. At control joints in the foundation floor and roof
e. At wall openings
f. At wall intersections

MOVEMENT JOINTS AND CRACK CONTROL

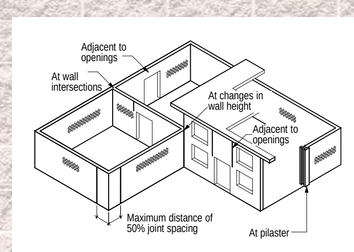


Figure 10.3 Typical control joint locations.

MOVEMENT JOINTS AND CRACK CONTROL

Table 10.1—Recommended Control Joint Spacing for Above Grade Exposed Concrete Masonry Walls*

Distance between joints should not exceed the lesser of:

Length to height ratio	or feet (m)
$1\frac{1}{2}:1$	25 (7.62)

*Notes:

1. Table values based on the use of horizontal reinforcement having an equivalent area of not less than 0.025 in^2/ft. (52.9 mm^2/m) of height to keep unplanned cracks closed.
2. Criteria applies to all concrete masonry units.
3. This criteria is based on experience over a wide geographical area. Control joint spacing should be adjusted up or down where local experience justifies. See NCMA TEK 10-3 for further information.
4. NCMA TEK 10-2C, Table 1.

MOVEMENT JOINTS AND CRACK CONTROL

Control joints should be constructed with a vertical head joint, raking back the mortar at least one inch and interrupting the horizontal steel at least at every other bar or joint reinforcement. Control joints may also be mortarless head joints with flange as in Figure 10.5. To prevent the wall from displacing perpendicular to the plane of the wall, dowels may be used across the joint provided one end is encased in a plastic sleeve or pipe. Solid grouted walls crack at the control joint and provide aggregate interlock which prevents displacement and slip, therefore, dowels may not be required. Primary structural reinforcing steel, such as reinforcement located in perimeter chord beams and lintels, must not be cut. Fill the raked vertical head joints with caulk or sealant to keep the system weatherproof.

MOVEMENT JOINTS AND CRACK CONTROL

Typical caulking and sealant compounds can stretch best when the width of the joint is greater than the depth of the sealant, similar to a rubber band. Manufacturer's recommendations should always be followed. The usual practice is to place the caulking or sealant so the depth of sealant is only half the width. Sealant depth is controlled by using a compatible backup rod. See Figure 10.4.

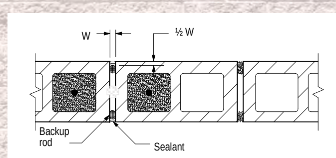


Figure 10.4 Control joint in a wall.

MOVEMENT JOINTS AND CRACK CONTROL

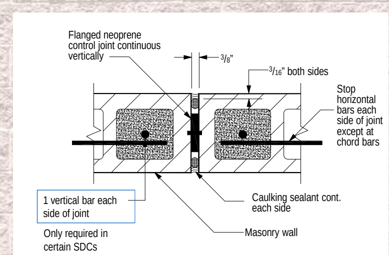


Figure 10.5 Wall control joint/flanged neoprene.

MOVEMENT JOINTS AND CRACK CONTROL

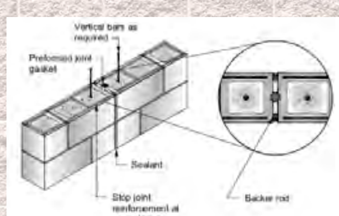
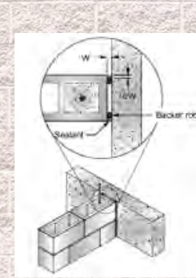


Figure 10.6 Preformed gasket.

MOVEMENT JOINTS AND CRACK CONTROL



Control joint must be coordinated with structural anchoring requirements of intersecting walls.

Figure 10.7 Control joints in walls.

MOVEMENT JOINTS AND CRACK CONTROL

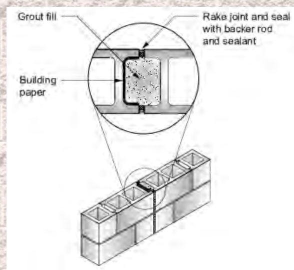
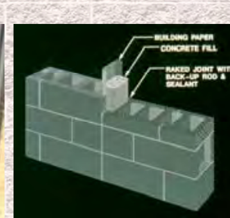


Figure 10.8 Formed paper joint. (4 Hour Fire Rated)

MOVEMENT JOINTS AND CRACK CONTROL



MOVEMENT JOINTS AND CRACK CONTROL

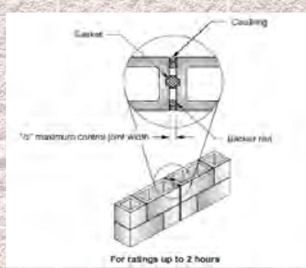


Figure 10.9 Fire rated masonry control joints.

MOVEMENT JOINTS AND CRACK CONTROL

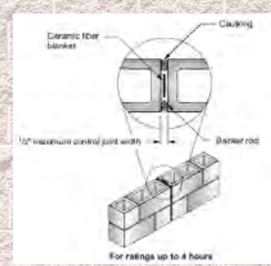


Figure 10.9 Fire rated masonry control joints.

MOVEMENT JOINTS AND CRACK CONTROL

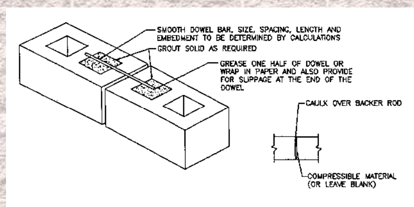
10.5 EXPANSION JOINTS

Expansion joints can be used to accommodate increases in length in long runs of walls and where there are large temperature swings. When used, spacing of expansion joints should be between 150 and 200 feet (45.7 m and 61.0 m) and located with consideration to the shape and plan of the structure. Concern must be given to the expansion of the wall and the possibility of pushing out the adjoining perpendicular walls at the ends of walls, thus, the expansion joints should be near the ends of the building. Many conditions allow expansion joints to be placed in the middle between ends of the walls, allowing movement of the walls both ways toward the center.

The expansion joint should be filled with a caulking or compressible sealant material that will both expand and compress and allow for total movement of the wall.

MOVEMENT JOINTS AND CRACK CONTROL

Movement Joints and Crack Control



Movement Joints and Crack Control

10.6 SUMMARY

Crack control measures for concrete masonry walls are summarized as follows:

1. Use units in climatic balance. This means that the moisture condition of the concrete masonry units is in a state of equilibrium with the relative humidity of the project site.

2. Use joint reinforcement. This is effective when locating joint reinforcement in the bed joint mortar on the face shells.

3. Put in adequate, properly spaced and properly-constructed control joints and expansion joints.

Movement Joints and Crack Control

2. Use joint reinforcement. This is effective when locating joint reinforcement in the bed joint mortar on the face shells.

3. Put in adequate, properly spaced and properly-constructed control joints and expansion joints.

The knowledge of the mason contractor and the masonry inspector can be used to alert the general contractor and the designer concerning potential problem areas for crack control. When potential problems are noted ahead of time, costly delays and disruptions are avoided.

Movement Joints and Crack Control

10.7 CRACK REPAIR

If a crack does occur, the repair depends on location, size of the crack, what kind of block is involved, and how important appearance is. Usually it is not possible to complete a repair with only paint or a clear sealer. Repeated movement will reopen cracks that have been bridged over. The crack must be opened up enough so that a bead of flexible caulking or sealant can be applied. The caulking or sealant should remain flexible even when dry. It can be painted with a compatible paint. Some caulks and sealants come in a range of colors and can be matched reasonably close to mortar colors when used on integral color block jobs.

CHAPTER 11
Construction in Severe Weather Conditions

11.1 COLD WEATHER MASONRY CONSTRUCTION

11.1.1 General

The following cold weather provisions were initially prepared by the International Masonry Industry All Weather Council and are based on *Recommended Practice Guide Specification for Cold Weather Masonry, 1970*, applicable to BOCA and SBC. The publication has been updated by the Masonry Industry Council's *Hot & Cold Weather Masonry Construction, 1999*, which also applies to more recent IBC and MSJC Specification.

Severe Weather Conditions

SEVERE WEATHER CONDITIONS

11.1.2 Construction

During adverse weather conditions the contractor should make the necessary arrangements for hot or cold weather construction and protection. There are specific provisions in the MSJC Specification for masonry installed in ambient temperatures below 40°F (4.4°C) and above 90°F (32.2°C) when certain wind conditions exists. Verification of the extreme weather construction and protection is a requirement in MSJC Quality Assurance Levels B and C.

IBC Section 2104.3

2104.3 Cold weather construction. The cold weather construction provisions of TMS 602/ACI 530.1/ASCE 6, Article 1.8 C, shall be implemented when the ambient temperature falls below 40°F (4°C).

SEVERE WEATHER CONDITIONS

SEVERE WEATHER CONDITIONS

SEVERE WEATHER CONDITIONS

SEVERE WEATHER CONDITIONS

SEVERE WEATHER CONDITIONS

MSJC Specification Article 1.8 C

1.8 C. *Cold weather construction* – When ambient air temperature is below 40°F (4.4°C), implement cold weather procedures and comply with the following:

1. Do not lay glass unit masonry.
2. *Preparation* – Comply with the following requirements prior to conducting masonry work:
   a. Do not lay masonry units having either a temperature below 20°F (-6.7°C) or containing frozen moisture, visible ice or snow on their surface.
   b. Remove visible ice and snow from the top surface of existing foundations and masonry to receive new construction. Heat these surfaces above freezing, using methods that do not result in damage.

Severe Weather Conditions

11.1.3 Placing Grout and Protection of Grouted Masonry

The MSJC Specification incorporates grout provisions in the cold weather construction requirements.

MSJC Specification Article 1.8 C

3. Construction – These requirements apply to work in progress and are based on ambient air temperature. Do not heat water or aggregates used in mortar or grout above 140°F (60°C). Comply with the following requirements when the following ambient air temperatures exist:
   a. 40°F to 32°F (4.4°C to 0°C):
   1) Heat sand or mixing water to produce mortar temperature between 40°F (4.4°C) and 120°F (48.9°C) at the time of mixing. Grout does not require heated materials, unless the temperature of materials is below 32°F (0°C).
   2) Heat grout materials when the temperature of the materials is below 32°F (0°C).

Severe Weather Conditions

11.1.3 Placing Grout and Protection of Grouted Masonry

The MSJC Specification incorporates grout provisions in the cold weather construction requirements.

b. Below 32°F to 25°F (0°C to -3.9°C):
1) Heat sand and mixing water to produce mortar temperature between 40°F (4.4°C) and 120°F (48.9°C) at the time of mixing. Maintain mortar temperature above freezing until used in masonry.
2) Heat grout aggregates and mixing water to produce grout temperature between 70°F (21.1°C) and 120°F (48.9°C) at the time of mixing. Maintain grout temperature above 70°F (21.1°C) at the time of grout placement.
3) Heat AAC units to a minimum temperature of 40°F (4.4°C) before installing thin-bed mortar.

Severe Weather Conditions

11.1.3 Placing Grout and Protection of Grouted Masonry

The MSJC Specification incorporates grout provisions in the cold weather construction requirements.

c. Below 25°F to 20°F (-3.9°C to -6.7°C): Comply with Article 1.8 C.3.b and the following:
1) Heat masonry surfaces under construction to 40°F (4.4°C) and use wind breaks or enclosures when the wind velocity exceeds 15 mph (24 km/h).
2) Heat masonry to a minimum of 40°F (4.4°C) prior to grouting.

d. Below 20°F (-6.7°C): Comply with Article 1.8 C.3.c and the following: Provide an enclosure and auxiliary heat to maintain air temperature above 32°F (0°C) within the enclosure.

Severe Weather Conditions

11.1.4 Protection

The MSJC Specification incorporates protection provisions in the cold weather construction requirements.

MSJC Specification Article 1.8.C

4. *Protection* – These requirements apply after masonry is placed and are based on anticipated minimum daily temperature for grouted masonry and anticipated mean daily temperature for ungrouted masonry. Protect completed masonry in the following manner:
   a. Maintain the temperature of glass unit masonry above 40°F (4.4°C) for the first 48 hr after construction.
   b. Maintain the temperature of AAC masonry above 32°F (0°C) for the first 4 hr after thin-bed mortar application.

Severe Weather Conditions

c. 40°F to 25°F (4.4°C to -3.9°C): Protect newly constructed masonry by covering with a weather-resistive membrane for 24 hr after being completed.

d. Below 25°F to 20°F (-3.9°C to -6.7°C): Cover newly constructed masonry completely with weather-resistive insulating blankets, or equal protection, for 24 hr after completion of work. Extend time period to 48 hr for grouted masonry, unless the only cement in the grout is Type III portland cement.

e. Below 20°F (-6.7°C): Maintain newly constructed masonry temperature above 32°F (0°C) for at least 24 hr after being completed by using heated enclosures, electric heating blankets, infrared lamps, or other acceptable methods. Extend time period to 48 hr for grouted masonry, unless the only cement in the grout is Type III portland cement.

Severe Weather Conditions

In order to apply the above provisions, the mean daily temperature must be established. MSJC Specification defines the mean daily temperature as the average daily temperature of temperature extremes predicted by a local weather bureau for the subsequent 24 hour period.

Severe Weather Conditions

11.1.5 Summary of Recommended Cold Weather Practices

The following points are important factors in laying masonry work in cold weather.

- Schedule the work beforehand if masonry work is to be built in cold temperatures.
- Take advantage of warm days by working on the outside of the structure, saving the inside work for the colder days.
- Store all masonry units close to the structure. Be sure units are covered and off the ground to prevent moisture or frost from penetrating.
- Provide a covered mortar mixing area. Keep the sand pile covered to protect from moisture, ice or snow.
- Preheat sand and water before mixing mortar.

Severe Weather Conditions

- If available, use Type III, high early strength portland cement or a non-chloride accelerator additive for a quicker set.
- Do not use antifreeze in the mortar. Calcium chloride is considered to be an accelerator not an antifreeze. Never use calcium chloride particularly if there is metal in the mortar joints.
- Build protective shelters such as windbreaks and enclosures to protect the mason and masonry work.
- Observe good safety practices when building shelters to prevent them from collapsing or blowing over, causing damage and injury.
- Take protective measures at the end of the workday to protect the work and to ensure that work is started on time the next day. Some protective measures are covering the work and piles of materials, draining the hoses and cleaning out the mortar pans. Place a block of wood in the water barrel so the water does not freeze which also keeps the barrel from deforming.

Severe Weather Conditions

The requirements for cold weather masonry construction are summarized in the following tables. These requirements are consistent with MSJC Specification Article 1.8 C.

Severe Weather Conditions

Laying the Units	***Temperature Range °F***			
	40° to 32°	32° to 25°	25° to 20°	20° & below
Temperature of the units to be at least 20°F	X	X	X	X
Do not lay glass units	X	X	X	X
Remove ice and snow from footings and installed masonry	X	X	X	X
Heat sand or mixing water for mortar 40°F to 120°F. Do not heat water or aggregates above 140°F	X			
Heat sand and mixing water for mortar 40°F to 120°F. Do not heat water or aggregates above 140°F		X	X	X
Maintain mortar above freezing		X	X	X
Heat masonry surfaces to 40°F			X	X
Windbreaks for excess of 15 mph			X	X
Provide enclosures & auxiliary heat to produce air temperature above 32°F				X

Severe Weather Conditions

Protecting the Units	***Temperature Range °F***			
	40° to 32°	32° to 25°	25° to 20°	20° & below
Protect for 24 hours with weather resistive membrane	X	X		
Protect for 24 hours with insulating blankets			X	
Provide enclosure & auxiliary heat or equal to keep temperature above freezing for 24 hours				X

Severe Weather Conditions

Grouting the Units	***Temperature Range °F***			
	40° to 32°	32° to 25°	25° to 20°	20° & below
Heat aggregates *and* mixing water for grout 70°F to 120°F. Grout to be at least 70°F at time of placement		X	X	X
Heat masonry surfaces to 40°F minimum			X	X
For grouted masonry, protect for 48 hours with insulating blankets*			X	X
For grouted masonry, provide enclosure & auxiliary heat or equal to keep temperature above freezing for 48 hours*				X
*May reduce to 24 hours if only Type III portland cement is used in grout.				

Severe Weather Conditions

11.2 HOT WEATHER MASONRY CONSTRUCTION

11.2.1 General

Building with masonry in hot weather of 90ºF (32ºC) and above can cause special problems. High temperatures can cause the materials to become very warm, affecting their performance. Rapid evaporation will also occur having an effect on hydration and curing. Special consideration must be given to the handling and selection of materials and to construction procedures during hot weather.

Severe Weather Conditions

11.2.2 Performance

The physical properties of masonry will change with an increase in temperature.

Bond strength can decrease as units become hotter and drier, causing an increase in suction rate.

2. The compressive strength of the mortar and grout can also decrease if water quickly evaporates, leaving little for hydration.
3. Workability is affected, as more water is required in the mortar for constant consistency and in grout to make filling of spaces possible.
4. Heat will affect the amount of air entraining used, since more is required in hot weather.
5. The initial and final set of mortar will occur faster.
6. Water will evaporate quickly on the exterior surface of a mortar joint, potentially causing a decrease in strength and durability.
7. The initial water content of mortar will be higher, but the placing of mortar will be difficult and the time period for placing the mortar will be shortened.

Severe Weather Conditions

11.2.3 Handling and Selection of Materials

When hot weather is expected, the materials should be stored in a shaded or cool place. Increasing the cement content will cause the mortar and grout to gain strength quickly but will also impose a demand on the available water in the mix. The amount of lime can be increased giving the mortar a higher water retentivity.

Covering the aggregate with a light color or clear plastic sheet will retard the evaporation of any moisture in the raw material. Adding extra water will help keep the aggregate cool since evaporation has a cooling effect.

The units used should be stored in the shade and covered. The use of cold water or ice water as mixing water will lower the temperature of the mortar or grout. Ice can be used to cool the water only and should not directly contact the cement or aggregates.

Severe Weather Conditions

11.2.4 Construction Procedure

When placing masonry units during hot weather, special consideration should be given to all equipment that comes in contact with the mortar. Flushing the mixers, tools and mortar board, occasionally with cool water helps keep temperature to a minimum.

Mortar should not be mixed too far ahead, and when mixed, should be stored in a cool, shady place. When laying the masonry units, avoid placing long mortar beds ahead of the units.

When extremely high temperatures are expected, consideration should be given to stopping placement of masonry during the hottest times of day.

Severe Weather Conditions

IBC Section 2104.4

2104.4 Hot weather construction. The hot weather provisions of TMS 602/ACI 530.1/ASCE 6, Article 1.8 D, shall be implemented when ambient air temperature exceeds 100°F (37.8°C), or 90°F (32.2°C) with a wind velocity greater than 8 mph (12.9 km/hr).

Severe Weather Conditions

MSJC Specification Article 1.8 D

1.8 D *Hot weather construction* — Implement approved hot weather procedures and comply with the following provisions:

1. *Preparation* — Prior to conducting masonry work:

   a. When the ambient air temperature exceeds 100ºF (37.8ºC), or exceeds 90ºF (32.2ºC) with a wind velocity greater than 8 mph (12.9 km/hr):

      1) Maintain sand piles in a damp, loose condition.

      2) Provide necessary conditions and equipment to produce mortar having a temperature below 120ºF (48.9ºC).

   b. When the ambient temperature exceeds 115ºF (46.1ºC), or exceeds 105ºF (40.6ºC) with a wind velocity greater than 8 mph (12.9 km/hr), implement the requirements of Article 1.8 D.1.a and shade materials and mixing equipment from direct sunlight.

SEVERE WEATHER CONDITIONS

2. *Construction* — While masonry work is in progress:
   a. When the ambient air temperature exceeds 100ºF (37.8ºC), or exceeds 90ºF (32.2ºC) with a wind velocity greater than 8 mph (12.9 km/hr):
      1) Maintain temperature of mortar and grout below 120ºF (48.9ºC).
      2) Flush mixer, mortar transport container, and mortar boards with cool water before they come into contact with mortar ingredients or mortar.
      3) Maintain mortar consistency by retempering with cool water.
      4) Use mortar within 2 hours of initial mixing
      5) Spread thin-bed mortar no more than four feet ahead of AAC masonry units.
      6) Set AAC masonry units within one minute after spreading thin-bed mortar.

SEVERE WEATHER CONDITIONS

b. When the ambient temperature exceeds 115ºF (46.1ºC), or exceeds 105ºF (40.6ºC) with a wind velocity greater than 8 mph (12.9 km/hr), implement the requirements of Article 1.8 D.2.a and use cool mixing water for mortar and grout. Ice is permitted in the mixing water prior to use. Do not permit ice in the mixing water when added to the other mortar or grout materials.

3. *Protection* — When the mean daily temperature exceeds 100ºF (37.8ºC), or exceeds 90ºF (32.2ºC) with a wind velocity greater than 8 mph (12.9 km/hr), fog spray newly constructed masonry until damp, at least three times a day until the masonry is three days old.

SEVERE WEATHER CONDITIONS

SEVERE WEATHER CONDITIONS

SEVERE WEATHER CONDITIONS

11.2.5 Summary of Recommended Hot Weather Practices

The following points are important factors in laying masonry work in hot weather.

- Schedule the work beforehand if masonry work is to be built in hot temperatures.
- Start and end workday earlier to avoid the hottest times of the day.
- Implement hot weather construction provisions consistent to those contained in the Code.
- Receive and store materials to minimize heat absorption and heat containment.
- Cover materials, both stock and installed, so that materials can maintain some moisture content.

SEVERE WEATHER CONDITIONS

The requirements for hot weather masonry construction are summarized in the following tables. These requirements are consistent with MSJC Specification Article 1.8 D.

Preparation/Hot Weather	*Temperature Range (°F)*	
	Above 100° or above 90° with 8 mph wind	Above 115° or above 105° with 8 mph wind
Produce mortar that is less than 120°F	X	X
Keep sand piles in a damp, loose condition	X	X
Shade materials from direct sunlight		X

SEVERE WEATHER CONDITIONS

Construction/Hot Weather	Temperature Range (°F)	
	Above 100° or above 90° with 8 mph wind	Above 115° or above 105° with 8 mph wind
Keep mortar and grout less than 120°F	X	X
Flush mixers and equipment with cool water before contacting mortar or mortar material	X	X
Retemper mortar with cool water	X	X
Use mortar within 2 hours after initial water is added	X	X
Use cool mixing water in mortar and grout		X

SEVERE WEATHER CONDITIONS

Protection/Hot Weather	Temperature Range (°F)	
	Above 100° or above 90° with 8 mph wind	Above 115° or above 105° with 8 mph wind
Fog spray 3 times a day for 3 days	X	X

CHAPTER 11

CONSTRUCTION IN SEVERE WEATHER CONDITIONS

11.3 WET WEATHER MASONRY CONSTRUCTION

11.3.1 General

Building with masonry in rainy weather is possible if some type of shelter or covering is provided.

11.3.2 Performance

Rain can cause excessive wetting of materials, affecting their performance. The change in unit moisture content can cause dimensional changes, and will vary with the type of material used. Moisture may also reduce the absorptive property of the units so that poor bond can occur between the units, the mortar and the grout. Water will evaporate more slowly so less mixing water is required.

If it rains on a building before the mortar is set, the cementitious material may be washed out. The mortar could also be washed over the faces of the units causing a staining effect.

SEVERE WEATHER CONDITIONS

11.3.3 Construction Procedures

Construction of a building can proceed in wet weather providing moderate to heavy rain does not fall on the masonry materials or on the freshly laid walls. The cement, units and sand should be covered to keep them dry. They should also be stored off the ground so there is no migration of moisture from the ground to the materials particularly for the cement and lime.

A masonry wall, built in rainy conditions, should be built under a shelter. This can be in the form of a roof or floor slab, or inside an enclosure similar to the type used in cold weather. Walls should be protected from rain for at least 24 to 48 hours, depending on the temperature, so that the mortar is fully set and bond has occurred.

SEVERE WEATHER CONDITIONS

11.3.4 Protection of Masonry

Partially completed masonry walls that are exposed to rain may become so saturated with water that they require some time to dry out.

While the masonry walls are being built, it may be the responsibility of the mason to be sure that the walls are covered at all times (when not being worked on). The covering can be of plastic, canvas, or some other suitable material that not only covers the top of the wall but hangs over at least 2 ft (610 mm) on the face. It should also be weighted down to prevent the wind from getting under it and damaging the wall. The common practice of laying a heavy board on

SEVERE WEATHER CONDITIONS

top of the wall at the end of the workday does not keep the work protected and can cause the masonry underneath to sag or bow out of position. Covering, or protecting the masonry walls can be difficult when vertical deformed reinforcement extends above the completed walls. Since the code offers no clear direction for this condition, the contractor should make a practical effort to cover the wall.

When work resumes after a period of rain, the question of how dry must the block units be in order to be laid is frequently asked. Although there is no guidance in the Code, water may be splashed on a concrete block and if a color shade difference does not occur (from the water) then the block units are too wet to be placed into the wall.

John Chrysler
jc@masonry.pro
(800) 221-4000
MIA www.masonryinstitute.org

MIH MASONRY INSTITUTE OF HAWAII www.masonryhawaii.com