Building Code Requirements and Specification for Masonry Structures

Containing

Building Code Requirements for Masonry Structures
(TMS 402-13/ACI 530-13/ASCE 5-13)

Specification for Masonry Structures
(TMS 602-13/ACI 530.1-13/ASCE 6-13)

and Companion Commentaries

Developed by the Masonry Standards Joint Committee (MSJC)

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The Masonry Society
105 South Sunset Street, Suite Q
Longmont, CO 80501
www.masonrysociety.org

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P.O. Box 9094
Farmington Hills, MI 48333
www.concrete.org

SEI ASCE STRUCTURAL ENGINEERING INSTITUTE

Structural Engineering Institute of the American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191
www.seinstitute.org

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ABSTRACT

Building Code Requirements and Specification for Masonry Structures contains two standards and their commentaries: Building Code Requirements for Masonry Structures (TMS 402-13/ACI 530-13/ASCE 5-13) and Specification for Masonry Structures (TMS 602-13/ACI 530.1-13/ASCE 6-13). These standards are produced through the joint efforts of The Masonry Society (TMS), the American Concrete Institute (ACI), and the Structural Engineering Institute of the American Society of Civil Engineers (SEI/ASCE) through the Masonry Standards Joint Committee (MSJC). The Code covers the design and construction of masonry structures while the Specification is concerned with minimum construction requirements for masonry in structures. Some of the topics covered in the Code are: definitions, contract documents; quality assurance; materials; placement of embedded items; analysis and design; strength and serviceability; flexural and axial loads; shear; details and development of reinforcement; walls; columns; pilasters; beams and lintels; seismic design requirements; glass unit masonry; veneers; and autoclaved aerated concrete masonry. An empirical design method and a prescriptive method applicable to buildings meeting specific location and construction criteria are also included. The Specification covers subjects such as quality assurance requirements for materials; the placing, bonding and anchoring of masonry; and the placement of grout and of reinforcement. This Specification is meant to be modified and referenced in the Project Manual. The Code is written as a legal document and the Specification as a master specification required by the Code. The commentaries present background details, committee considerations, and research data used to develop the Code and Specification. The Commentaries are not mandatory and are for information of the user only.

The Masonry Standards Joint Committee, which is sponsored by The Masonry Society, the American Concrete Institute, and the Structural Engineering Institute of the American Society of Civil Engineers, is responsible for these standards and strives to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of these documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of these documents are requested to contact TMS.

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About the MSJC and its Sponsors

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The Masonry Standards Joint Committee (MSJC) is, as its name suggests, a joint committee sponsored by The Masonry Society (TMS), the American Concrete Institute (ACI), and the Structural Engineering Institute of the American Society of Civil Engineers (SEI/ASCE). Its mission is to develop and maintain design and construction standards for masonry for reference by or incorporation into model building codes regulating masonry construction. In practice, the MSJC is responsible for the maintenance of the *Building Code Requirements for Masonry Structures* (TMS 402/ACI 530/ASCE 5), *Specification for Masonry Structures* (TMS 602/ACI 530.1/ASCE 6) and their companion *Commentaries*. Committee membership is open to all qualified individuals, within the constraints of balance requirements, balloting schedules and particular needs for technical expertise. Committee meetings are open to the public.

Committee Activities include:

1. Evaluate and ballot proposed changes to existing standards of the committee.
2. Develop and ballot new standards for masonry.
3. Resolve Negative votes from ballot items.
4. Provide interpretation of existing standards of the Committee.
5. Identify areas of needed research.
6. Sponsor educational seminars and symposia.
7. Monitor international standards.

Additional details of the Committee, its work, and its meeting schedule are posted at www.masonrysociety.org and can be obtained from The Masonry Society. A roster of the Committee Members during the 2013 Revision Cycle is shown on the following page.

THE MASONRY SOCIETY

Advancing the knowledge of masonry

The Masonry Society (TMS) was founded in 1977 as a not-for-profit professional, technical, and educational association dedicated to the advancement of knowledge on masonry. Today TMS is an international gathering of people interested in the art and science of masonry, and its members include design engineers, architects, builders, researchers, educators, building officials, material suppliers, manufacturers, and others who want to contribute to and benefit from the global pool of knowledge on masonry.

TMS gathers and disseminates technical information through its committees, publications, codes and standards, newsletter, refereed journal, educational programs, workshops, scholarships, disaster investigation team, and conferences. The work of TMS is conducted by individual TMS members and through the volunteer committees composed of both members and non-members. The Masonry Society serves as the lead Society for the support of the MSJC, and as such, meetings of the committee are held at TMS meetings and activities of the Committee are managed by TMS.

For more information about TMS, contact The Masonry Society, 105 South Sunset Street, Suite Q, Longmont, Colorado, 80501-6172 U.S.A; Phone: 303-939-9700; Fax:303-541-9215; E-mail: info@masonrysociety.org; Website: www.masonrysociety.org

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ACI was founded in 1904 as a nonprofit membership organization dedicated to public service and representing the user interest in the field of concrete. ACI gathers and distributes information on the improvement of design, construction, and maintenance of concrete products and structures. The work of ACI is conducted by individual ACI members and through volunteer committees composed of both members and non-members.

The committees, as well as ACI as a whole, operate under a consensus format, which assures all participants the right to have their views considered. Committee activities include the development of building codes requirements and specifications, analysis of research and development results, presentation of construction and repair techniques, and education.

Individuals interested in the activities of ACI are encouraged to become members. There are no educational or employment requirements. ACI's membership is composed of engineers, architects, scientists, contractors, educators, and representatives from a variety of companies and organizations. Members are encouraged to participate in committee activities that relate to their specific areas of interest.

For more information about ACI, contact the American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331 U.S.A; Phone: 248-848-3700; Fax: 248-848-3701; Website: www.concrete.org

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The Structural Engineering Institute (SEI) is a 22,000 plus member organization within the American Society of Civil Engineers (ASCE). SEI is organized into four Divisions. The Business and Professional Activities Division (BPAD), promotes needed change in business and professional development issues unique to the structural engineering profession. The Codes and Standards Activities Division (CSAD) develops and maintains leading design standards that are used worldwide. The Local Activities Division (LAD) provides technical, educational, and professional program support to the local structural technical groups within ASCE's sections and branches. The Technical Activities Division (TAD) advances the profession with the dedicated work of its 70 plus technical committees that produce technical papers and publications and produce the *Journal of Structural Engineers,* the *Journal of Bridge Engineers*, and the *Practice Periodical on Structural Design and Construction*.

Through its four divisions, SEI advances the profession in many ways including developing standards such as ASCE 7, encouraging discussion about licensure issues, enriching local Structural Technical Group programs, leading coordination efforts with other standards organizations, conducting an annual Structures Congress, offering cutting edge presentations, offering specialty conferences on topics of interest to the Structural Engineering community, coordinating efforts with other structural engineering organizations, responding to the community's need for help in crisis, and providing low-cost seminars and webinars to the Structural Engineering community

For more information about SEI, contact the Structural Engineering Institute, 1801 Alexander Bell Drive, Reston, VA 20191; Phone: 703-295-6196; E-mail: jrossberg@asce.org; Website: www.seinstitute.org

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3 Corresponding and Consulting Members during the 2013 Revision Cycle. They could participate in Subcommittee activities but did not have voting privileges.
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In addition to the Masonry Standards Joint Committee, a number of individuals assisted in the development, review, and layout of the provisions. Their contributions are greatly appreciated.

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Balloting Assistance

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WDP Manassas VA office
Susan Scheurer,
Committee Liaison,
The Masonry Society
Leyla Scott,
Office Manager
WDP Manassas, VA office

Cover Design

Thomas Escobar, Design Director, Masonry Institute of America

Final Editing & Proofing

Luis Dominguez, Production Manager,
Masonry Institute of Americas
Susan Scheurer, Committee Liaison,
The Masonry Society

Indexing

Christen Snydal

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Layout of this Publication

This publication is broken into several major parts.

- The first major section contains the standard *Building Code Requirements for Masonry Structures*, designated as TMS 402-13/ACE 530-13/ASCE 5-13 and the commentary on the Code provisions. These pages are designated by a "C" in the page number. Following this portion are references for the Code Commentary. These references are also designated with "C" page numbers, although these pages have their own "bleed tabs" on the page edges to make them easier to locate when trying to identify the references cited in the Code Commentary.

- The second major section of this publication contains the standard *Specification for Masonry Structures*, designated as TMS 602-13/ACE 530.1-13/ASCE 6-13 and commentary on the Specification provisions. These pages are designated by an "S" in the page number. Following this portion are references for the Specification Commentary. These references are also designated with "S" page numbers, although these pages have their own "bleed tabs" on the page edges to make them easier to locate when trying to identify the references cited in the Specification Commentary.

- At the end of this publication is an Index with major terms used in these standards. These pages are designated by an "I" in the page number

Additional information on the "Code" and the "Specification" is provided in the Synopsis for each.

Revision Formatting for the 2013 Building Code Requirements and Specification for Masonry Structures

As with the 2011 Edition of these standards, Commentary has been shown adjacent to Code and Specification requirements so that users can quickly and easily obtain background on the required provisions. Commentary is shown throughout these standards with light gray shading. Additional background on the purpose of the Commentary, and what is generally included in the Commentary is shown at the beginning of the Commentary Sections on pages C-1 and S-1. However, recognize that the Commentaries are for information only and are not mandatory.

While the 2011 Edition of these standards included revision bars and deletion arrows to designate places where major changes occurred since the 2008 edition of these standards, they have not been included in the 2013 Edition because of the major reformatting of the provisions. Had they been included, users would likely have been confused since so many provisions moved from the earlier edition, while some sections also were substantively revised. To assist users, a summary of major changes is included at http://www.masonrysociety.org/2013MSJC/index.htm. In addition, a cross reference index is also posted on that website to show where things moved from the 2011 edition. The use of revision bars and deletion arrows will be considered for future editions of the standards.

Other Formatting Conventions

To aide users of these standards, "bleed tabs" are provided on the outside edges of most pages so that the user can quickly to determine which portion (Code, Specification, References, or Index) they are reviewing.

Also be advised that a number of pages are intentionally left blank so that the beginning of each Chapter starts on a right hand page.

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Building Code Requirements for Masonry Structures (TMS 402-13/ACI 530-13/ASCE 5-13)

SYNOPSIS

This Code covers the design and construction of masonry structures. It is written in such form that it may be adopted by reference in a legally adopted building code.

Among the subjects covered are: definitions; contract documents; quality assurance; materials; placement of embedded items; analysis and design; strength and serviceability; flexural and axial loads; shear; details and development of reinforcement; walls; columns; pilasters; beams and lintels; seismic design requirements; glass unit masonry; and veneers. An empirical design method applicable to buildings meeting specific location and construction criteria are also included.

The quality, inspection, testing, and placement of materials used in construction are covered by reference to TMS 602-13/ACI 530.1-13/ASCE 6-13 Specification for Masonry Structures and other standards.

Keywords: AAC, masonry, allowable stress design, anchors (fasteners); anchorage (structural); autoclaved aerated concrete masonry, beams; building codes; cements; clay brick; clay tile; columns; compressive strength; concrete block; concrete brick; construction; detailing; empirical design; flexural strength; glass units; grout; grouting; infills; joints; loads (forces); limit design; masonry; masonry cements; masonry load bearing walls; masonry mortars; masonry walls; modulus of elasticity; mortars; pilasters; prestressed masonry, quality assurance; reinforced masonry; reinforcing steel; seismic requirements; shear strength; specifications; splicing; stresses; strength design, structural analysis; structural design; ties; unreinforced masonry; veneers; walls.

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PART 1: GENERAL

CHAPTER 1
GENERAL REQUIREMENTS

CODE

1.1 — Scope

1.1.1 *Minimum requirements*

This Code provides minimum requirements for the structural design and construction of masonry elements consisting of masonry units bedded in mortar.

1.1.2 *Governing building code*

This Code supplements the legally adopted building code and shall govern in matters pertaining to structural design and construction of masonry elements. In areas without a legally adopted building code, this Code defines the minimum acceptable standards of design and construction practice.

1.1.3 *SI information*

SI values shown in parentheses are not part of this Code. The equations in this document are for use with the specified inch-pound units only.

COMMENTARY

1.1 — Scope

1.1.1 *Minimum requirements*

This code governs structural design of both structural and non-structural masonry elements. Examples of non-structural elements are masonry veneer, glass unit masonry, and masonry partitions. Structural design aspects of non-structural masonry elements include, but are not limited to, gravity and lateral support, and load transfer to supporting elements.

Masonry structures may be required to have enhanced structural integrity as part of a comprehensive design against progressive collapse due to accident, misuse, sabotage or other causes. General design guidance addressing this issue is available in Commentary Section 1.4 of ASCE 7. Suggestions from that Commentary, of specific application to many masonry structures, include but are not limited to: consideration of plan layout to incorporate returns on walls, both interior and exterior; use of load-bearing interior walls; adequate continuity of walls, ties, and joint rigidity; providing walls capable of beam action; ductile detailing and the use of compartmentalized construction.

1.1.3 *SI information*

The equivalent equations for use with SI units are provided in the Equation Conversions table in Part 5.

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1.2 — Contract documents and calculations

1.2.1 Show all Code-required drawing items on the project drawings, including:

(a) Name and date of issue of Code and supplement to which the design conforms.

(b) Loads used for the design of masonry structures.

(c) Specified compressive strength of masonry at stated ages or stages of construction for which masonry is designed, for each part of the structure, except for masonry designed in accordance with Part 4 or Appendix A.

(d) Size and location of structural elements.

(e) Details of anchorage of masonry to structural members, frames, and other construction, including the type, size, and location of connectors.

(f) Details of reinforcement, including the size, grade, type, lap splice length, and location of reinforcement.

(g) Reinforcing bars to be welded and welding requirements.

(h) Provision for dimensional changes resulting from elastic deformation, creep, shrinkage, temperature, and moisture.

(i) Size and permitted location of conduits, pipes, and sleeves.

1.2.2 Each portion of the structure shall be designed based on the specified compressive strength of masonry for that part of the structure, except for portions designed in accordance with Part 4 or Appendix A.

COMMENTARY

1.2 — Contract documents and calculations

The provisions for preparation of project drawings, project specifications, and issuance of permits are, in general, consistent with those of most legally adopted building codes and are intended as supplements to those codes.

This Code is not intended to be made a part of the contract documents. The contractor should not be required through contract documents to assume responsibility for design (Code) requirements, unless the construction entity is acting in a design-build capacity. A Commentary on TMS 602/ACI 530.1/ASCE 6 accompanies the Specification.

1.2.1 This Code lists some of the more important items of information that must be included in the project drawings or project specifications. This is not an all-inclusive list, and additional items may be required by the building official.

Masonry does not always behave in the same manner as its structural supports or adjacent construction. The designer should consider differential movements and the forces resulting from their restraint. The type of connection chosen should transfer only the loads planned. While some connections transfer loads perpendicular to the wall, other devices transfer loads within the plane of the wall. Figure CC-1.2-1 shows representative wall anchorage details that allow movement within the plane of the wall. While load transfer usually involves masonry attached to structural elements, such as beams or columns, the connection of nonstructural elements, such as door and window frames, should also be addressed.

Connectors are of a variety of sizes, shapes, and uses. In order to perform properly they should be identified on the project drawings.

1.2.2 Masonry design performed in accordance with engineered methods is based on the specified compressive strength of the masonry. For engineered masonry, structural adequacy of masonry construction requires that the compressive strength of masonry equals or exceeds the specified strength. Masonry design by prescriptive approaches relies on rules and masonry compressive strength need not be verified.

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CODE

1.2.3 The contract documents shall be consistent with design assumptions.

1.2.4 Contract documents shall specify the minimum level of quality assurance as defined in Section 3.1, or shall include an itemized quality assurance program that equals or exceeds the requirements of Section 3.1.

COMMENTARY

1.2.3 The contract documents must accurately reflect design requirements. For example, joint and opening locations assumed in the design should be coordinated with locations shown on the drawings.

1.2.4 Verification that masonry construction conforms to the contract documents is required by this Code. A program of quality assurance must be included in the contract documents to satisfy this Code requirement.

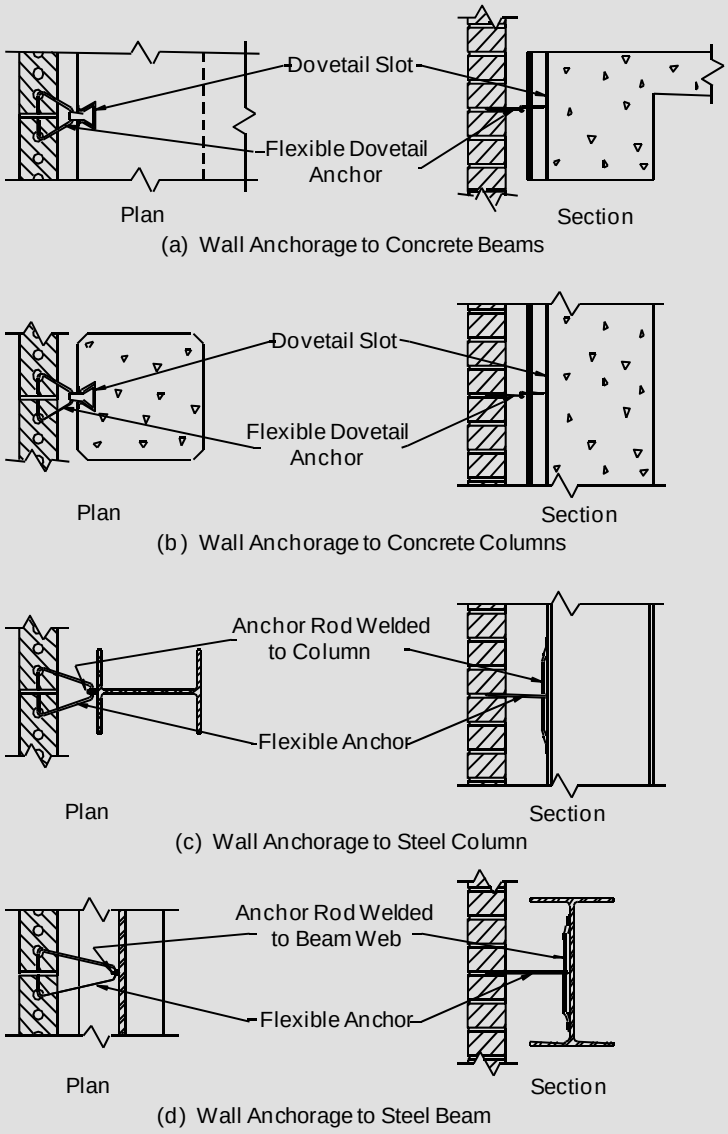


Figure CC-1.2-1 — Wall anchorage details

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CODE

1.3 — Approval of special systems of design or construction

Sponsors of any system of design or construction within the scope of this Code, the adequacy of which has been shown by successful use or by analysis or test, but that does not conform to or is not addressed by this Code, shall have the right to present the data on which their design is based to a board of examiners appointed by the building official. The board shall be composed of licensed design professionals and shall have authority to investigate the submitted data, require tests, and formulate rules governing design and construction of such systems to meet the intent of this Code. The rules, when approved and promulgated by the building official, shall be of the same force and effect as the provisions of this Code.

1.4 — Standards cited in this Code

Standards of the American Concrete Institute, the American Society of Civil Engineers, ASTM International, the American Welding Society, and The Masonry Society cited in this Code are listed below with their serial designations, including year of adoption or revision, and are declared to be part of this Code as if fully set forth in this document.

TMS 602-13/ACI 530.1-13/ASCE 6-13 — Specification for Masonry Structures

ASCE 7-10 — Minimum Design Loads for Buildings and Other Structures

ASTM A416/A416M-12 — Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete

ASTM A421/A421M-10 — Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete

ASTM A706/A706M-09b — Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

ASTM A722/A722M-12 — Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete

ASTM C34-12 — Standard Specification for Structural Clay Load-Bearing Wall Tile

ASTM C140-12a — Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units

ASTM C426-10 — Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units

COMMENTARY

1.3 — Approval of special systems of design or construction

New methods of design, new materials, and new uses of materials must undergo a period of development before being specifically addressed by a code. Hence, valid systems or components might be excluded from use by implication if means were not available to obtain acceptance. This section permits proponents to submit data substantiating the adequacy of their system or component to a board of examiners.

1.4 — Standards cited in this Code

These standards are referenced in this Code. Specific dates are listed here because changes to the standard may result in changes of properties or procedures.

Contact information for these organizations is given below:

American Concrete Institute (ACI)
38800 Country Club Drive
Farmington Hills, MI 48331
www.aci-int.org

American Society of Civil Engineers (ASCE)
1801 Alexander Bell Drive
Reston, VA 20191
www.asce.org

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
www.astm.org

American Welding Society (AWS)
8669 NW 36th Street, Suite 130
Miami, Florida 33166-6672
www.aws.org

The Masonry Society (TMS)
105 South Sunset Street, Suite Q
Longmont, Colorado 80501-6172
www.masonrysociety.org

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ASTM C476-10 — Standard Specification for Grout for Masonry

ASTM C482-02 (2009) — Standard Test Method for Bond Strength of Ceramic Tile to Portland Cement Paste

ASTM C1006-07 — Standard Test Method for Splitting Tensile Strength of Masonry Units

ASTM C1611/C1611M-09be1 — Standard Test Method for Slump Flow of Self-Consolidating Concrete

ASTM C1693-11 — Standard Specification for Autoclaved Aerated Concrete (AAC)

ASTM E111-04 (2010) — Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

ASTM E488-96 (2003) — Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements

AWS D 1.4/D1.4M: 2011 — Structural Welding Code — Reinforcing Steel

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CHAPTER 2
NOTATION AND DEFINITIONS

CODE

2.1 — Notation

A_b = cross-sectional area of an anchor bolt, in.^{2} (mm^2)

A_{br} = bearing area, in.^{2} (mm^2)

A_g = gross cross-sectional area of a member, in.^{2} (mm^2)

A_n = net cross-sectional area of a member, in.^{2} (mm^2)

A_{nv} = net shear area, in.^{2} (mm^2)

A_{ps} = area of prestressing steel, in.^{2} (mm^2)

A_{pt} = projected tension area on masonry surface of a right circular cone, in.^{2} (mm^2)

A_{pv} = projected shear area on masonry surface of one-half of a right circular cone, in.^{2} (mm^2)

A_s = area of nonprestressed longitudinal tension reinforcement, in.^{2} (mm^2)

A_{sc} = area of reinforcement placed within the lap, near each end of the lapped reinforcing bars and transverse to them, in.^{2} (mm^2)

A_{st} = total area of laterally tied longitudinal reinforcing steel, in.^{2} (mm^2)

A_v = cross-sectional area of shear reinforcement, in.^{2} (mm^2)

A_1 = loaded area, in.^{2} (mm^2)

A_2 = supporting bearing area, in.^{2} (mm^2)

a = depth of an equivalent compression stress block at nominal strength, in. (mm)

B_a = allowable axial load on an anchor bolt, lb (N)

B_{ab} = allowable axial tensile load on an anchor bolt when governed by masonry breakout, lb (N)

B_{an} = nominal axial strength of an anchor bolt, lb (N)

B_{anb} = nominal axial tensile strength of an anchor bolt when governed by masonry breakout, lb (N)

B_{anp} = nominal axial tensile strength of an anchor bolt when governed by anchor pullout, lb (N)

B_{ans} = nominal axial tensile strength of an anchor bolt when governed by steel yielding, lb (N)

B_{ap} = allowable axial tensile load on an anchor bolt when governed by anchor pullout, lb (N)

B_{as} = allowable axial tensile load on an anchor bolt when governed by steel yielding, lb (N)

COMMENTARY

2.1 — Notation

Notations used in this Code are summarized here.

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B_v = allowable shear load on an anchor bolt, lb (N)

B_{vb} = allowable shear load on an anchor bolt when governed by masonry breakout, lb (N)

B_{vc} = allowable shear load on an anchor bolt when governed by masonry crushing, lb (N)

B_{vn} = nominal shear strength of an anchor bolt, lb (N)

B_{vnb} = nominal shear strength of an anchor bolt when governed by masonry breakout, lb (N)

B_{vnc} = nominal shear strength of an anchor bolt when governed by masonry crushing, lb (N)

B_{vnpry} = nominal shear strength of an anchor bolt when governed by anchor pryout, lb (N)

B_{vns} = nominal shear strength of an anchor bolt when governed by steel yielding, lb (N)

B_{vpry} = allowable shear load on an anchor bolt when governed by anchor pryout, lb (N)

B_{vs} = allowable shear load on an anchor bolt when governed by steel yielding, lb (N)

b = width of section, in. (mm)

b_a = total applied design axial force on an anchor bolt, lb (N)

b_{af} = factored axial force in an anchor bolt, lb (N)

b_v = total applied design shear force on an anchor bolt, lb (N)

b_{vf} = factored shear force in an anchor bolt, lb (N)

b_w = width of wall beam, in. (mm)

C_d = deflection amplification factor

c = distance from the fiber of maximum compressive strain to the neutral axis, in. (mm)

D = dead load or related internal moments and forces

d = distance from extreme compression fiber to centroid of tension reinforcement, in. (mm)

d_b = nominal diameter of reinforcement or anchor bolt, in. (mm)

d_v = actual depth of a member in direction of shear considered, in. (mm)

E = load effects of earthquake or related internal moments and forces

E_{AAC} = modulus of elasticity of AAC masonry in compression, psi (MPa)

E_{bb} = modulus of elasticity of bounding beams, psi (MPa)

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E_{bc} = modulus of elasticity of bounding columns, psi (MPa)

E_m = modulus of elasticity of masonry in compression, psi (MPa)

E_{ps} = modulus of elasticity of prestressing steel, psi (MPa)

E_s = modulus of elasticity of steel, psi (MPa)

E_v = modulus of rigidity (shear modulus) of masonry, psi (MPa)

e = eccentricity of axial load, in. (mm)

e_b = projected leg extension of bent-bar anchor, measured from inside edge of anchor at bend to farthest point of anchor in the plane of the hook, in. (mm)

e_u = eccentricity of P_{uf}, in. (mm)

F_a = allowable compressive stress available to resist axial load only, psi (MPa)

F_b = allowable compressive stress available to resist flexure only, psi (MPa)

F_s = allowable tensile or compressive stress in reinforcement, psi (MPa)

F_v = allowable shear stress, psi (MPa)

F_{vm} = allowable shear stress resisted by the masonry, psi (MPa)

F_{vs} = allowable shear stress resisted by the shear reinforcement, psi (MPa)

f_a = calculated compressive stress in masonry due to axial load only, psi (MPa)

f_b = calculated compressive stress in masonry due to flexure only, psi (MPa)

f'_{AAC} = specified compressive strength of AAC masonry, psi (MPa)

f'_g = specified compressive strength of grout, psi (MPa)

f'_m = specified compressive strength of clay masonry or concrete masonry, psi (MPa)

f'_{mi} = specified compressive strength of clay masonry or concrete masonry at the time of prestress transfer, psi (MPa)

f_{ps} = stress in prestressing tendon at nominal strength, psi (MPa)

f_{pu} = specified tensile strength of prestressing tendon, psi (MPa)

f_{py} = specified yield strength of prestressing tendon, psi (MPa)

f_r = modulus of rupture, psi (MPa)

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f_{rAAC} = modulus of rupture of AAC, psi (MPa)

f_s = calculated tensile or compressive stress in reinforcement, psi (MPa)

f_{se} = effective stress in prestressing tendon after all prestress losses have occurred, psi (MPa)

$f_{t\,AAC}$ = splitting tensile strength of AAC as determined in accordance with ASTM C1006, psi (MPa)

f_v = calculated shear stress in masonry, psi (MPa)

f_y = specified yield strength of steel for reinforcement and anchors, psi (MPa)

h = effective height of column, wall, or pilaster, in. (mm)

h_{inf} = vertical dimension of infill, in. (mm)

h_w = height of entire wall or of the segment of wall considered, in. (mm)

I_{bb} = moment of inertia of bounding beam for bending in the plane of the infill, in.^{4} (mm^4)

I_{bc} = moment of inertia of bounding column for bending in the plane of the infill, in.^{4} (mm^4)

I_{cr} = moment of inertia of cracked cross-sectional area of a member, in.^{4} (mm^4)

I_{eff} = effective moment of inertia, in.^{4} (mm^4)

I_g = moment of inertia of gross cross-sectional area of a member, in.^{4} (mm^4)

I_n = moment of inertia of net cross-sectional area of a member, in.^{4} (mm^4)

j = ratio of distance between centroid of flexural compressive forces and centroid of tensile forces to depth, d

K = dimension used to calculate reinforcement development, in. (mm)

K_{AAC} = dimension used to calculate reinforcement development for AAC masonry, in. (mm)

k_c = coefficient of creep of masonry, per psi (per MPa)

k_e = coefficient of irreversible moisture expansion of clay masonry

k_m = coefficient of shrinkage of concrete masonry

k_t = coefficient of thermal expansion of masonry per degree Fahrenheit (degree Celsius)

L = live load or related internal moments and forces

l = clear span between supports, in. (mm)

l_b = effective embedment length of headed or bent anchor bolts, in. (mm)

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l_{be} = anchor bolt edge distance, in. (mm)

l_d = development length or lap length of straight reinforcement, in. (mm)

l_e = equivalent embedment length provided by standard hooks measured from the start of the hook (point of tangency), in. (mm)

l_{eff} = effective span length for a deep beam, in. (mm)

l_{inf} = plan length of infill, in. (mm)

l_p = clear span of the prestressed member in the direction of the prestressing tendon, in. (mm)

l_w = length of entire wall or of the segment of wall considered in direction of shear force, in. (mm)

M = maximum moment at the section under consideration, in.-lb (N-mm)

M_a = maximum moment in member due to the applied unfactored loading for which deflection is calculated, in.-lb (N-mm)

M_{cr} = nominal cracking moment strength, in.-lb (N-mm)

M_n = nominal moment strength, in.-lb (N-mm)

M_{ser} = service moment at midheight of a member, including P-delta effects, in.-lb (N-mm)

M_u = factored moment, magnified by second-order effects where required by the code, in.-lb (N-mm)

$M_{u,0}$ = factored moment from first-order analysis, in.-lb (N-mm)

n = modular ratio, E_s/E_m

N_u = factored compressive force acting normal to shear surface that is associated with the V_u loading combination case under consideration, lb (N)

N_v = compressive force acting normal to shear surface, lb (N)

P = axial load, lb (N)

P_a = allowable axial compressive force in a reinforced member, lb (N)

P_e = Euler buckling load, lb (N)

P_n = nominal axial strength, lb (N)

P_{ps} = prestressing tendon force at time and location relevant for design, lb (N)

P_u = factored axial load, lb (N)

P_{uf} = factored load from tributary floor or roof areas, lb (N)

COMMENTARY

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CODE

P_{uw} = factored weight of wall area tributary to wall section under consideration, lb (N)

Q = first moment about the neutral axis of an area between the extreme fiber and the plane at which the shear stress is being calculated, in.^{3} (mm^3)

Q_E = the effect of horizontal seismic (earthquake-induced) forces

$q_{n\,inf}$ = nominal out-of-plane flexural capacity of infill per unit area, psf (Pa)

q_z = velocity pressure determined in accordance with ASCE 7, psf (kPa)

R = response modification coefficient

r = radius of gyration, in. (mm)

S = snow load or related internal moments and forces

S_n = section modulus of the net cross-sectional area of a member, in.^{3} (mm^3)

s = spacing of reinforcement, in. (mm)

s_l = total linear drying shrinkage of concrete masonry units determined in accordance with ASTM C426

t = nominal thickness of member, in. (mm)

t_{inf} = specified thickness of infill, in. (mm)

$t_{net\,inf}$ = net thickness of infill, in. (mm)

t_{sp} = specified thickness of member, in. (mm)

v = shear stress, psi (MPa)

V = shear force, lb (N)

V_{lim} = limiting base-shear strength, lb (N)

V_{nAAC} = nominal shear strength provided by AAC masonry, lb (N)

V_n = nominal shear strength, lb (N)

$V_{n\,inf}$ = nominal horizontal in-plane shear strength of infill, lb (N)

V_{nm} = nominal shear strength provided by masonry, lb (N)

V_{ns} = nominal shear strength provided by shear reinforcement, lb (N)

V_u = factored shear force, lb (N)

V_{ub} = base-shear demand, lb (N)

W = wind load or related internal moments and forces

W_S = dimension of the structural wall strip defined in Sections 14.3.2 and A.5.1 and shown in Figures 14.3.1-1 and A.5.1-1.

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W_T = dimension of the tributary length of wall, defined in Sections 14.3.2 and A.5.1 and shown in Figures 14.3.1-1 and A.5.1-1.

w_{inf} = width of equivalent strut, in. (mm)

w_{strut} = horizontal projection of the width of the diagonal strut, in. (mm)

w_u = out-of-plane factored uniformly distributed load, lb/in. (N/mm)

z = internal lever arm between compressive and tensile forces in a deep beam, in. (mm)

α_{arch} = horizontal arching parameter for infill, $lb^{0.25}$ ($N^{0.25}$)

β_{arch} = vertical arching parameter for infill, $lb^{0.25}$ ($N^{0.25}$)

β_b = ratio of area of reinforcement cut off to total area of tension reinforcement at a section

γ = reinforcement size factor

γ_g = grouted shear wall factor

Δ = calculated story drift, in. (mm)

Δ_a = allowable story drift, in. (mm)

δ = moment magnification factor

δ_{ne} = displacements calculated using code-prescribed seismic forces and assuming elastic behavior, in. (mm)

δ_s = horizontal deflection at midheight under allowable stress design load combinations, in. (mm)

δ_u = deflection due to factored loads, in. (mm)

ε_{cs} = drying shrinkage of AAC

ε_{mu} = maximum usable compressive strain of masonry

ξ = lap splice confinement reinforcement factor

θ_{strut} = angle of infill diagonal with respect to the horizontal, degrees

λ_{strut} = characteristic stiffness parameter for infill, $in.^{-1}$ (mm^{-1})

μ_{AAC} = coefficient of friction of AAC

ρ = reinforcement ratio

ρ_{max} = maximum flexural tension reinforcement ratio

ϕ = strength-reduction factor

ψ = magnification factor for second-order effects

COMMENTARY

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2.2 — Definitions

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

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.

Area, gross cross-sectional — The area delineated by the out-to-out dimensions of masonry in the plane under consideration.

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

Area, net shear — The net area of the web of a shear element.

Autoclaved aerated concrete — Low-density cementitious product of calcium silicate hydrates, whose material specifications are defined in ASTM C1693.

Autoclaved aerated concrete (AAC) masonry — Autoclaved aerated concrete units manufactured without reinforcement, set on a mortar leveling bed, bonded with thin-bed mortar, placed with or without grout, and placed with or without reinforcement.

Backing — Wall or surface to which veneer is attached.

Bed joint — The horizontal layer of mortar on which a masonry unit is laid.

COMMENTARY

2.2 — Definitions

For consistent application of this Code, terms are defined that have particular meanings in this Code. The definitions given are for use in application of this Code only and do not always correspond to ordinary usage. Other terms are defined in referenced documents and those definitions are applicable. If any term is defined in both this Code and in a referenced document, the definition in this Code applies. Referenced documents are listed in Section 1.4 and include ASTM standards. Terminology standards include ASTM C1232 Standard Terminology of Masonry and ASTM C1180 Standard Terminology of Mortar and Grout for Unit Masonry. Glossaries of masonry terminology are available from several sources within the industry (BIA TN 2, 1999; NCMA TEK 1-4, 2004; and IMI, 1981).

Area, net shear — The net shear area for a partially grouted flanged shear wall is shown in Figure CC-2.2-1.

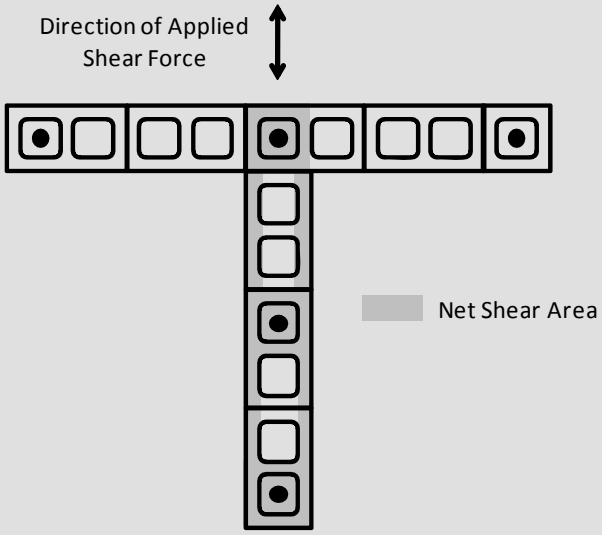


Figure CC-2.2-1 — Net shear area

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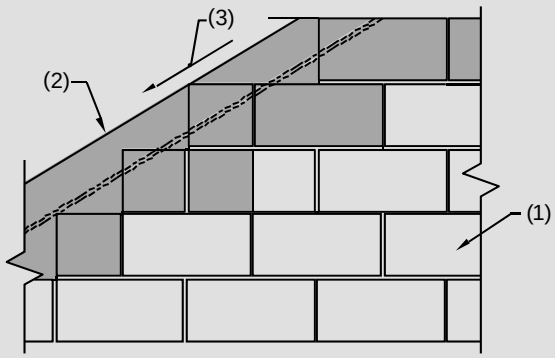
Bond beam — A horizontal, sloped, or stepped element that is fully grouted, has longitudinal bar reinforcement, and is constructed within a masonry wall.

COMMENTARY

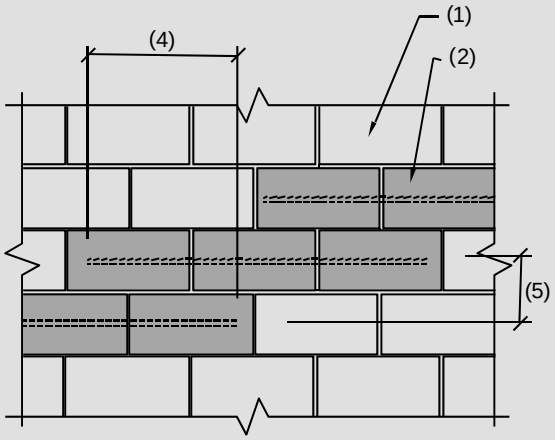
Bond beam – This reinforced member is usually constructed horizontally, but may be sloped or stepped to match an adjacent roof, for example, as shown in Figure CC-2.2-2.

Notes:

(1) Masonry wall
(2) Fully grouted bond beam with reinforcement
(3) Sloped top of wall
(4) Length of noncontact lap splice
(5) Spacing between bars in noncontact lap splice



(a) Sloped Bond Beam
(not to scale)



(b) Stepped Bond Beam
(not to scale)

Figure CC-2.2-2 — Sloped and stepped bond beams

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Bonded prestressing tendon — Prestressing tendon encapsulated by prestressing grout in a corrugated duct that is bonded to the surrounding masonry through grouting.

Bounding frame — The columns and upper and lower beams or slabs that surround masonry infill and provide structural support.

Building official — The officer or other designated authority charged with the administration and enforcement of this Code, or the building official's duly authorized representative.

Cavity wall — A masonry wall consisting of two or more wythes, at least two of which are separated by a continuous air space; air space(s) between wythes may contain insulation; and separated wythes must be connected by wall ties.

Collar joint — Vertical longitudinal space between wythes of masonry or between masonry wythe and back-up construction, which is permitted to be filled with mortar or grout.

Column — A structural member, not built integrally into a wall, designed primarily to resist compressive loads parallel to its longitudinal axis and subject to dimensional limitations.

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.

Composite masonry — Multiwythe masonry members with wythes bonded to produce composite action.

Compressive strength of masonry — Maximum compressive force resisted per unit of net cross-sectional area of masonry, determined by testing masonry prisms or a function of individual masonry units, mortar, and grout, in accordance with the provisions of TMS 602/ACI 530.1/ ASCE 6.

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

Contract documents — Documents establishing the required work, and including in particular, the project drawings and project specifications.

Corbel — A projection of successive courses from the face of masonry.

Cover, grout — thickness of grout surrounding the outer surface of embedded reinforcement, anchor, or tie.

Cover, masonry — thickness of masonry units, mortar, and grout surrounding the outer surface of embedded reinforcement, anchor, or tie.

COMMENTARY

Column — Generally, a column spans vertically, though it may have another orientation in space.

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Cover, mortar — thickness of mortar surrounding the outer surface of embedded reinforcement, anchor, or tie.

Deep beam — A beam that has an effective span-to-depth ratio, l_{eff}/d_v, less than 3 for a continuous span and less than 2 for a simple span.

Depth — The dimension of a member measured in the plane of a cross section perpendicular to the neutral axis.

Design story drift — The difference of deflections at the top and bottom of the story under consideration, taking into account the possibility of inelastic deformations as defined in ASCE 7. In the equivalent lateral force method, the story drift is calculated by multiplying the deflections determined from an elastic analysis by the appropriate deflection amplification factor, C_d, from ASCE 7.

Design strength — The nominal strength of an element multiplied by the appropriate strength-reduction factor.

Diaphragm — A roof or floor system designed to transmit lateral forces to shear walls or other lateral-force-resisting elements.

Dimension, 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 nearest to the specified dimensions.

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

Effective height — Clear height of a member between lines of support or points of support and used for calculating the slenderness ratio of a member. Effective height for unbraced members shall be calculated.

Effective prestress — Stress remaining in prestressing tendons after all losses have occurred.

Foundation pier — A vertical foundation member, not built integrally into a foundation wall, empirically designed to support gravity loads and subject to dimensional limitations.

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

Grout — (1) A plastic mixture of cementitious materials, aggregates, and water, with or without admixtures, initially produced to pouring consistency without segregation of the constituents during placement. (2) The hardened equivalent of such mixtures.

COMMENTARY

Dimension, nominal — Nominal dimensions are usually used to identify the size of a masonry unit. The thickness or width is given first, followed by height and length. The permitted tolerances for units are given in the appropriate material standards. Permitted tolerances for joints and masonry construction are given in the Specification.

Dimensions, specified — Specified dimensions are most often used for design calculations.

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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.

Head joint — Vertical mortar joint placed between masonry units within the wythe at the time the masonry units are laid.

Header (bonder) — A masonry unit that connects two or more adjacent wythes of masonry.

Infill — Masonry constructed within the plane of, and bounded by, a structural frame.

Infill, net thickness — Minimum total thickness of the net cross-sectional area of an infill.

Infill, non-participating — Infill designed so that in-plane loads are not imparted to it from the bounding frame.

Infill, participating — Infill designed to resist in-plane loads imparted to it by the bounding frame.

Inspection, continuous — The Inspection Agency's full-time observation of work by being present in the area where the work is being performed.

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.

Laterally restrained prestressing tendon — Prestressing tendon that is not free to move laterally within the cross section of the member.

Laterally unrestrained prestressing tendon — Prestressing tendon that is free to move laterally within the cross section of the member.

COMMENTARY

Infill, net thickness – The net thickness is shown in Figure CC-2.2-3

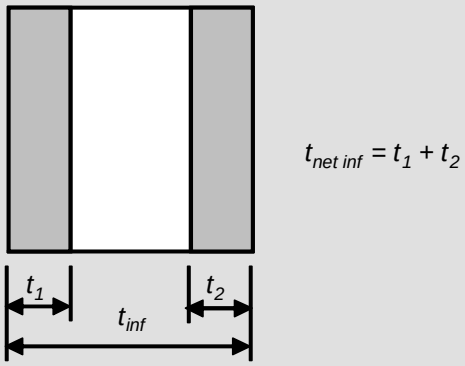


Figure CC-2.2-3 — Thickness and net thickness of an infill

Inspection, continuous — The Inspection Agency is required to be on the project site whenever masonry tasks requiring continuous inspection are in progress.

Inspection, periodic — During construction requiring periodic inspection, the Inspection Agency is only required to be on the project site intermittently, and is required to observe completed work. The frequency of periodic inspections should be defined by the Architect/Engineer as part of the quality assurance plan, and should be consistent with the complexity and size of the project.

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Licensed design professional — An individual who is licensed to practice design as defined by the statutory requirements of the professional licensing laws of the state or jurisdiction in which the project is to be constructed and who is in responsible charge of the design; in other documents, also referred to as *registered design professional*.

Load, dead — Dead weight supported by a member, as defined by the legally adopted building code.

Load, live — Live load specified by the legally adopted building code.

Load, service — Load specified by the legally adopted building code.

Longitudinal reinforcement — Reinforcement placed parallel to the longitudinal axis of the member.

Masonry breakout — Anchor failure defined by the separation of a volume of masonry, approximately conical in shape, from the member.

Masonry, partially grouted — Construction in which designated cells or spaces are filled with grout, while other cells or spaces are ungrouted.

Masonry unit, hollow — A masonry unit with net cross-sectional area of less than 75 percent of its gross cross-sectional area when measured in any plane parallel to the surface containing voids.

Masonry unit, solid — A masonry unit with net cross-sectional area of 75 percent or more of its gross cross-sectional area when measured in every plane parallel to the surface containing voids.

Modulus of elasticity — Ratio of normal stress to corresponding strain for tensile or compressive stresses below proportional limit of material.

Modulus of rigidity — Ratio of unit shear stress to unit shear strain for unit shear stress below the proportional limit of the material.

Nominal strength — The strength of an element or cross section calculated in accordance with the requirements and assumptions of the strength design methods of these provisions before application of strength-reduction factors.

Partition wall — An interior wall without structural function.

Pier —A reinforced, vertically spanning portion of a wall next to an opening, designed using strength design, and subject to dimensional limitations.

COMMENTARY

Licensed design professional — For convenience, the Commentary uses the term "designer" when referring to the licensed design professional.

Pier — The term "Pier" is used for convenience to define a portion of a wall, and only has meaning for certain reinforced members designed using strength design. The reinforcement requirements for piers are less severe than for columns because piers are part of a wall, have less slender geometry and more restrictive loading limits. A strength-designed member, not meeting the dimensional limits and requirements for a pier, should be designed as a wall or, if not built integrally with a wall, as a column.

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Post-tensioning — Method of prestressing in which a prestressing tendon is tensioned after the masonry has been placed.

Prestressed masonry — Masonry in which internal compressive stresses have been introduced by prestressed tendons to counteract potential tensile stresses resulting from applied loads.

Prestressing grout — A cementitious mixture used to encapsulate bonded prestressing tendons.

Prestressing tendon — Steel elements such as wire, bar, or strand, used to impart prestress to masonry.

Pretensioning — Method of prestressing in which a prestressing tendon is tensioned before the transfer of stress into the masonry.

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

Project drawings — The drawings that, along with the project specifications, complete the descriptive information for constructing the work required by the contract documents.

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.

Quality assurance — The administrative and procedural requirements established by the contract documents to assure that constructed masonry is in compliance with the contract documents.

Reinforcement — Nonprestressed steel reinforcement.

Required strength — The strength needed to resist factored loads.

Running bond — The placement of masonry units so that head joints in successive courses are horizontally offset at least one-quarter the unit length.

COMMENTARY

Running bond — This Code concerns itself only with the structural effect of the masonry bond pattern. Therefore, the only distinction made by this Code is between masonry laid in running bond and masonry that is not laid in running bond. For purposes of this Code, architectural bond patterns that do not satisfy the Code definition of running bond are classified as not running bond. Masonry laid in other bond patterns must be reinforced to provide continuity across the heads joints. Stack bond, which is commonly interpreted as a pattern with aligned heads joints, is one bond pattern that is required to be reinforced horizontally.

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Shear wall — A wall, load-bearing or non-load-bearing, designed to resist lateral forces acting in the plane of the wall (sometimes referred to as a vertical diaphragm).

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 connections.

Shear wall, 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.

Shear wall, 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.

Shear wall, 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.

Shear wall, ordinary plain (unreinforced) AAC masonry — An AAC masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, if present.

Shear wall, ordinary plain (unreinforced) masonry — A masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, if present.

Shear wall, ordinary plain (unreinforced) prestressed masonry — A prestressed masonry shear wall designed to resist lateral forces while neglecting stresses in reinforcement, if present.

Shear wall, 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.

Shear wall, ordinary reinforced masonry — A masonry shear wall designed to resist lateral forces while considering stresses in reinforcement and satisfying prescriptive reinforcement and connection requirements.

Shear wall, 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.

Shear wall, 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.

COMMENTARY

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Slump flow — The circular spread of plastic self-consolidating grout, which is evaluated in accordance with ASTM C1611/C1611M.

Special boundary elements — In walls that are designed to resist in-plane load, end regions that are strengthened by reinforcement and are detailed to meet specific requirements, and may or may not be thicker than the wall.

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).

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 contract 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 psi (MPa).

Stirrup — Reinforcement used to resist shear in a flexural member.

Stone masonry — Masonry composed of field, quarried, or cast stone units bonded by mortar.

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

Stone masonry, rubble — Stone masonry composed of irregular-shaped units bonded by mortar.

Strength-reduction factor, ϕ — The factor by which the nominal strength is multiplied to obtain the design strength.

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.

Tendon coupler — A device for connecting two tendon ends, thereby transferring the prestressing force from end to end.

Tendon jacking force — Temporary force exerted by a device that introduces tension into prestressing tendons.

COMMENTARY

Special boundary elements — Requirements for longitudinal and transverse reinforcement have not been established in general and must be verified by testing. Research in this area is ongoing.

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Thin-bed mortar — Mortar for use in construction of AAC unit masonry whose joints shall not be less than 1/16 in. (1.5 mm).

Tie, lateral — Loop of reinforcing bar or wire enclosing longitudinal reinforcement.

Tie, wall — Metal connector that connects wythes of masonry walls together.

Transfer — Act of applying to the masonry member the force in the prestressing tendons.

Transverse reinforcement — Reinforcement placed perpendicular to the longitudinal axis of the member.

Unbonded prestressing tendon — Prestressing tendon that is not bonded to masonry.

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

Veneer, adhered — Masonry veneer secured to and supported by the backing through adhesion.

Veneer, anchored — Masonry veneer secured to and supported laterally by the backing through anchors and supported vertically by the foundation or other structural elements.

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.

Visual stability index (VSI) — An index, defined in ASTM C1611/C1611M, that qualitatively indicates the stability of self-consolidating grout

Wall — A vertical element with a horizontal length to thickness ratio greater than 3, used to enclose space.

Wall, load-bearing — Wall supporting vertical loads greater than 200 lb/linear ft (2919 N/m) in addition to its own weight.

Wall, masonry bonded hollow — A multiwythe wall built with masonry units arranged to provide an air space between the wythes and with the wythes bonded together with masonry units.

Width — The dimension of a member measured in the plane of a cross section parallel to the neutral axis.

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

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CHAPTER 3
QUALITY AND CONSTRUCTION

CODE

3.1 — Quality Assurance program

The quality assurance program shall comply with the requirements of this section, depending on the Risk Category, as defined in ASCE 7 or the legally adopted building code. The quality assurance program shall itemize the requirements for verifying conformance of material composition, quality, storage, handling, preparation, and placement with the requirements of TMS 602/ACI 530.1/ASCE 6.

3.1.1 *Level A Quality Assurance*

The minimum quality assurance program for masonry in Risk Category I, II, or III structures and designed in accordance with Part 4 or Appendix A shall comply with Table 3.1.1.

COMMENTARY

3.1 — Quality Assurance program

Masonry design provisions in this Code are valid when the quality of masonry construction meets or exceeds that described in the Specification. Therefore, in order to design masonry by this Code, verification of good quality construction is required. The means by which the quality of construction is monitored is the quality assurance program.

A quality assurance program must be defined in the contract documents, to answer questions such as “how to”, “what method”, “how often”, and “who determines acceptance”. This information is part of the administrative and procedural requirements. Typical requirements of a quality assurance program include review of material certifications, field inspection, and testing. The acts of providing submittals, inspecting, and testing are part of the quality assurance program.

Because the design and the complexity of masonry construction vary from project to project, so must the extent of the quality assurance program. The contract documents must indicate the testing, Special Inspection, and other measures that are required to assure that the Work is in conformance with the project requirements.

Section 3.1 establishes the minimum criteria required to assure that the quality of masonry construction conforms to the quality upon which the Code-permissible values are based. The scope of the quality assurance program depends on whether the structure is a Risk Category IV structure or not, as defined by ASCE 7 or the legally adopted building code. Because of their importance, Risk Category IV structures are subjected to more extensive quality assurance measures.

The level of required quality assurance depends on whether the masonry was designed in accordance with Part 3, Appendix B, or Appendix C (engineered) or in accordance with Part 4 or Appendix A (empirical or prescriptive).

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CODE

3.1.2 *Level B Quality Assurance*

3.1.2.1 The minimum quality assurance program for masonry in Risk Category IV structures and designed in accordance with Chapter 12 or 13 shall comply with Table 3.1.2.

3.1.2.2 The minimum quality assurance program for masonry in Risk Category I, II, or III structures and designed in accordance with chapters other than those in Part 4 or Appendix A shall comply with Table 3.1.2.

3.1.3 *Level C Quality Assurance*

The minimum quality assurance program for masonry in Risk Category IV structures and designed in accordance with chapters other than those in Part 4 or Appendix A shall comply with Table 3.1.3.

3.1.4 *Procedures*

The quality assurance program shall set forth the procedures for reporting and review. The quality assurance program shall also include procedures for resolution of noncompliances.

COMMENTARY

3.1.2 *Level B Quality Assurance*

Implementation of testing and inspection requirements contained in Table 3.1.2 requires detailed knowledge of the appropriate procedures. Comprehensive testing and inspection procedures are available from recognized industry sources (Chrysler, 2010; NCMA, 2008; BIA, 2001; BIA 1988), which may be referenced for assistance in developing and implementing a Quality Assurance program. Certain applications, such as Masonry Veneer (Chapter 12), Masonry Partition Walls (Chapter 14) and Empirical Design of Masonry (Appendix A), do not require compressive strength verification of masonry as indicated in Table 3.1.2.

Installation techniques for AAC masonry and thin-bed mortar differ from concrete and clay masonry. Once it has been demonstrated in the field that compliance is attained for the installation of AAC masonry and thin-bed mortar, the frequency of Special Inspection may be revised from continuous to periodic. However, the frequency of Special Inspection should revert to continuous for the prescribed period whenever new AAC masonry installers work on the project.

3.1.3 *Level C Quality Assurance*

Premixed mortars and grouts are delivered to the project site as “trowel ready” or “pourable” materials, respectively. Preblended mortars and grouts are dry combined materials that are mixed with water at the project site. Verification of proportions of premixed or preblended mortars and grouts can be accomplished by review of manufacture’s batch tickets (if applicable), a combination of preconstruction and construction testing, or other acceptable documentation.

3.1.4 *Procedures*

In addition to specifying testing and Special Inspection requirements, the quality assurance program must define the procedures for submitting the testing and inspection reports (that is, how many copies and to whom) and define the process by which those reports are to be reviewed.

Testing and evaluation should be addressed in the quality assurance program. The program should allow for the selection and approval of a testing agency, which agency should be provided with prequalification test information and the rights for sampling and testing of specific masonry construction materials in accordance with referenced standards. The evaluation of test results by the testing agency should indicate compliance or noncompliance with a referenced standard.

Further quality assurance evaluation should allow an appraisal of the testing program and the handling of nonconformance. Acceptable values for all test methods should be given in the contract documents.

Identification and resolution of noncomplying

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CODE

3.1.5 *Qualifications*

The quality assurance program shall define the qualifications for testing laboratories and for inspection agencies.

COMMENTARY

conditions should be addressed in the contract documents. A responsible person should be identified to allow resolution of nonconformances. In agreement with others in the design/construct team, the resolutions should be repaired, reworked, accepted as is, or rejected. Repaired and reworked conditions should initiate a reinspection.

Records control should be addressed in the contract documents. The distribution of documents during and after construction should be delineated. The review of documents should persist throughout the construction period so that each party is informed and that records for documenting construction occurrences are available and correct after construction has been completed.

3.1.5 *Qualifications*

The entities verifying compliance must be competent and knowledgeable of masonry construction and the requirements of this Code. Therefore, minimum qualifications for those individuals must also be established by the quality assurance program in the contract documents.

The responsible party performing the quality control measures should document the organizational representatives who will be a part of the quality control segment, their qualifications, and their precise conduct during the performance of the quality assurance phase.

Laboratories that comply with the requirements of ASTM C1093 are more likely to be familiar with masonry materials and testing. Specifying that the testing agencies comply with the requirements of ASTM C1093 should improve the quality of the resulting masonry.

Table 3.1.1 — Level A Quality Assurance

MINIMUM VERIFICATION
Prior to construction, verify certificates of compliance used in masonry construction

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Table 3.1.2 — Level B Quality Assurance

MINIMUM TESTS				
Verification of Slump flow and Visual Stability Index (VSI) as delivered to the project site in accordance with Specification Article 1.5 B.1.b.3 for self-consolidating grout				
Verification of f'_m and f'_{AAC} in accordance with Specification Article 1.4 B prior to construction, except where specifically exempted by this Code				
MINIMUM SPECIAL INSPECTION				
Inspection Task	**Frequency [a]**		**Reference for Criteria**	
	Continuous	Periodic	TMS 402/ ACI 530/ ASCE 5	TMS 602/ ACI 530.1/ ASCE 6
1. Verify compliance with the approved submittals		X		Art. 1.5
2. As masonry construction begins, verify that the following are in compliance:				
a. Proportions of site-prepared mortar		X		Art. 2.1, 2.6 A
b. Construction of mortar joints		X		Art. 3.3 B
c. Grade and size of prestressing tendons and anchorages		X		Art. 2.4 B, 2.4 H
d. Location of reinforcement, connectors, and prestressing tendons and anchorages		X		Art. 3.4, 3.6 A
e. Prestressing technique		X		Art. 3.6 B
f. Properties of thin-bed mortar for AAC masonry	X[b]	X[c]		Art. 2.1 C
3. Prior to grouting, verify that the following are in compliance:				
a. Grout space		X		Art. 3.2 D, 3.2 F
b. Grade, type, and size of reinforcement and anchor bolts, and prestressing tendons and anchorages		X	Sec. 6.1	Art. 2.4, 3.4
c. Placement of reinforcement, connectors, and prestressing tendons and anchorages		X	Sec. 6.1, 6.2.1, 6.2.6, 6.2.7	Art. 3.2 E, 3.4, 3.6 A
d. Proportions of site-prepared grout and prestressing grout for bonded tendons		X		Art. 2.6 B, 2.4 G.1.b
e. Construction of mortar joints		X		Art. 3.3 B

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Table 3.1.2 — Level B Quality Assurance (Continued)

MINIMUM SPECIAL INSPECTION				
Inspection Task	**Frequency [a]**		**Reference for Criteria**	
	Continuous	Periodic	TMS 402/ ACI 530/ ASCE 5	TMS 602/ ACI 530.1/ ASCE 6
4. Verify during construction:				
a. Size and location of structural elements		X		Art. 3.3 F
b. Type, size, and location of anchors, including other details of anchorage of masonry to structural members, frames, or other construction		X	Sec. 1.2.1(e), 6.1.4.3, 6.2.1	
c. Welding of reinforcement	X		Sec. 8.1.6.7.2, 9.3.3.4 (c), 11.3.3.4(b)	
d. 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))		X		Art. 1.8 C, 1.8 D
e. Application and measurement of prestressing force	X			Art. 3.6 B
f. Placement of grout and prestressing grout for bonded tendons is in compliance	X			Art. 3.5, 3.6 C
g. Placement of AAC masonry units and construction of thin-bed mortar joints	X[b]	X[c]		Art. 3.3 B.9, 3.3 F.1.b
5. Observe preparation of grout specimens, mortar specimens, and/or prisms		X		Art. 1.4 B.2.a.3, 1.4 B.2.b.3, 1.4 B.2.c.3, 1.4 B.3, 1.4 B.4

(a) Frequency refers to the frequency of Special Inspection, which may be continuous during the task listed or periodic during the listed task, as defined in the table.
(b) Required for the first 5000 square feet (465 square meters) of AAC masonry.
(c) Required after the first 5000 square feet (465 square meters) of AAC masonry.

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Table 3.1.3 — Level C Quality Assurance

MINIMUM TESTS				
Verification of f'_m and f'_{AAC} in accordance with Specification Article 1.4 B prior to construction and for every 5,000 sq. ft (465 sq. m) during construction				
Verification of proportions of materials in premixed or preblended mortar, prestressing grout, and grout other than self-consolidating grout, as delivered to the project site				
Verification of Slump flow and Visual Stability Index (VSI) as delivered to the project site in accordance with Specification Article 1.5 B.1.b.3 for self-consolidating grout				
MINIMUM SPECIAL INSPECTION				
Inspection Task	**Frequency [(a)]**		**Reference for Criteria**	
	Continuous	Periodic	TMS 402/ ACI 530/ ASCE 5	TMS 602/ ACI 530.1/ ASCE 6
1. Verify compliance with the approved submittals		X		Art. 1.5
2. Verify that the following are in compliance:				
a. Proportions of site-mixed mortar, grout and prestressing grout for bonded tendons		X		Art. 2.1, 2.6 A, 2.6 B, 2.6 C, 2.4 G 1.b
b. Grade, type, and size of reinforcement and anchor bolts, and prestressing tendons and anchorages		X	Sec. 6.1	Art. 2.4, 3.4
c. Placement of masonry units and construction of mortar joints		X		Art. 3.3 B
d. Placement of reinforcement, connectors, and prestressing tendons and anchorages	X		Sec. 6.1, 6.2.1, 6.2.6, 6.2.7	Art. 3.2 E, 3.4, 3.6 A
e. Grout space prior to grouting	X			Art. 3.2 D, 3.2 F
f. Placement of grout and prestressing grout for bonded tendons	X			Art. 3.5, 3.6 C
g. Size and location of structural elements		X		Art. 3.3 F
h. Type, size, and location of anchors including other details of anchorage of masonry to structural members, frames, or other construction	X		Sec. 1.2.1(e), 6.1.4.3, 6.2.1	
i. Welding of reinforcement	X		Sec. 8.1.6.7.2, 9.3.3.4 (c), 11.3.3.4(b)	
j. 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))		X		Art. 1.8 C, 1.8 D
k. Application and measurement of prestressing force	X			Art. 3.6 B
l. Placement of AAC masonry units and construction of thin-bed mortar joints	X			Art. 3.3 B.9, 3.3 F.1.b
m. Properties of thin-bed mortar for AAC masonry	X			Art. 2.1 C.1
3. Observe preparation of grout specimens, mortar specimens, and/or prisms	X			Art. 1.4 B.2.a.3, 1.4 B.2.b.3, 1.4 B.2.c.3, 1.4 B.3, 1.4 B.4

(a) Frequency refers to the frequency of Special Inspection, which may be continuous during the task listed or periodic during the listed task, as defined by the statute.

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CODE

3.1.6 *Acceptance relative to strength requirements*

3.1.6.1 *Compliance with f'_m* — 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.

3.1.6.2 Determination of compressive strength — Compressive strength of masonry shall be determined in accordance with the provisions of TMS 602/ACI 530.1/ASCE 6.

3.2 — Construction considerations

3.2.1 *Grouting, minimum spaces*

The minimum dimensions of spaces provided for the placement of grout shall be in accordance with Table 3.2.1. Grout pours with heights exceeding those shown in Table 3.2.1, cavity widths, or cell sizes smaller than those permitted in Table 3.2.1 or grout lift heights exceeding those permitted by Article 3.5 D of TMS 602/ACI 530.1/ASCE 6 are permitted if the results of a grout demonstration panel show that the grout spaces are filled and adequately consolidated. In that case, the procedures used in constructing the grout demonstration panel shall be the minimum acceptable standard for grouting, and the quality assurance program shall include inspection during construction to verify grout placement.

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3.1.6 *Acceptance relative to strength requirements*

Fundamental to the structural adequacy of masonry construction is the necessity that the compressive strength of masonry equals or exceeds the specified strength. Rather than mandating design based on different values of f'_m for each wythe of a multiwythe wall construction made of differing material, this Code requires the strength of each wythe and of grouted collar joints to equal or exceed f'_m for the portion of the structure considered. If a multiwythe wall is designed as a composite wall, the compressive strength of each wythe or grouted collar joint should equal or exceed f'_m.

3.2 — Construction considerations

The TMS 602/ACI 530.1/ASCE 6 Specification addresses material and construction requirements. It is an integral part of the Code in terms of minimum requirements relative to the composition, quality, storage, handling, and placement of materials for masonry structures. The Specification also includes provisions requiring verification that construction achieves the quality specified. The construction must conform to these requirements in order for the Code provisions to be valid.

3.2.1 *Grouting, minimum spaces*

Code Table 3.2.1 contains the least clear dimension for grouting between wythes and the minimum cell dimensions when grouting hollow units. Selection of units and bonding pattern should be coordinated to achieve these requirements. Vertical alignment of cells must also be considered. Projections or obstructions into the grout space and the diameter of horizontal reinforcement must be considered when calculating the minimum dimensions. See Figure CC-3.2-1.

Coarse grout and fine grout are differentiated by aggregate size in ASTM C476.

The grout space requirements of Code Table 3.2.1 are based on coarse and fine grouts as defined by ASTM C476, and cleaning practice to permit the complete filling of grout spaces and adequate consolidation using typical methods of construction. Grout spaces smaller than specified in Table 3.2.1 have been used successfully in some areas. When the designer is requested to accept a grouting procedure that does not comply with the limits in Table 3.2.1, construction of a grout demonstration panel is required. Destructive or non-destructive evaluation can confirm that filling and adequate consolidation have been achieved. The designer should establish criteria for the grout demonstration panel to assure that critical masonry elements included in the construction will be represented in the demonstration panel. Because a single grout demonstration panel erected prior to masonry construction cannot account for all conditions that may be encountered during construction, the designer should establish inspection

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3.2.2 *Embedded conduits, pipes, and sleeves*

Conduits, pipes, and sleeves of any material to be embedded in masonry shall be compatible with masonry and shall comply with the following requirements.

3.2.2.1 Conduits, pipes, and sleeves shall not be considered to be structural replacements for the displaced masonry. The masonry design shall consider the structural effects of this displaced masonry.

3.2.2.2 Conduits, pipes, and sleeves in masonry shall be no closer than 3 diameters on center. Minimum spacing of conduits, pipes or sleeves of different diameters shall be determined using the larger diameter.

3.2.2.3 Vertical conduits, pipes, or sleeves placed in masonry columns or pilasters shall not displace more than 2 percent of the net cross section.

3.2.2.4 Pipes shall not be embedded in masonry, unless properly isolated from the masonry, when:

(a) Containing liquid, gas, or vapors at temperature higher than 150º F (66ºC).

(b) Under pressure in excess of 55 psi (379 kPa).

(c) Containing water or other liquids subject to freezing.

COMMENTARY

procedures to verify grout placement during construction. These inspection procedures should include destructive or non-destructive evaluation to confirm that filling and adequate consolidation have been achieved.

3.2.2 *Embedded conduits, pipes, and sleeves*

3.2.2.1 Conduits, pipes, and sleeves not harmful to mortar and grout may be embedded within the masonry, but the masonry member strength should not be less than that required by design. Effects of reduction in section properties in the areas of conduit, pipe, or sleeve embedment should be considered.

For the integrity of the structure, conduit and pipe fittings within the masonry should be carefully positioned and assembled. The coupling size should be considered when determining sleeve size.

Aluminum should not be used in masonry unless it is effectively coated or otherwise isolated. Aluminum reacts with ions, and may also react electrolytically with steel, causing cracking, spalling of the masonry, or both. Aluminum electrical conduits present a special problem because stray electric current accelerates the adverse reaction.

Pipes and conduits placed in masonry, whether surrounded by mortar or grout or placed in unfilled spaces, need to allow unrestrained movement.

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