Architecture 324
Structures II

Masonry

- Clay Masonry
- Concrete Masonry
- Autoclaved Aerated Concrete (AAC)

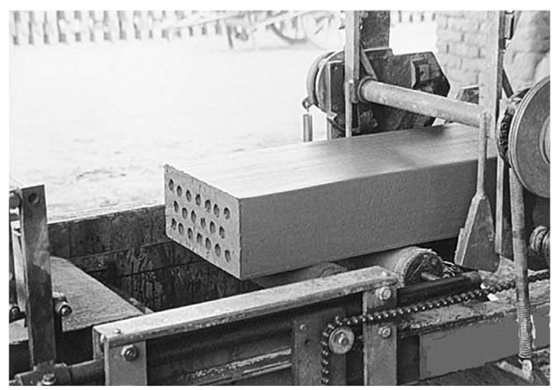
Höchst Entrance Hall, Frankfurt
Arch: Peter Behrens, 1920-24
Photo: Eva Kröcher

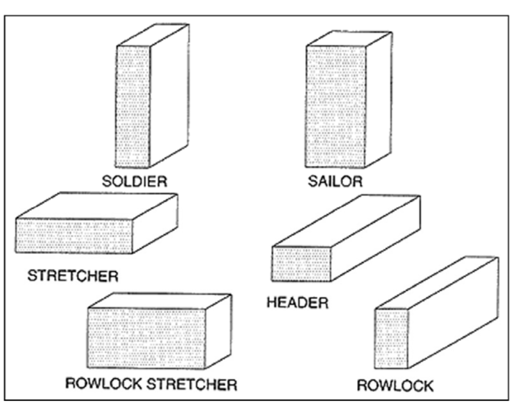
Clay Brick

- Molded
  or
- Extruded
- Cored – adds stability, strength
  cored < 25% > hollow
- Fired (2000° F)

- Sizes – use 3/8” mortar bed

- Six ways to position in wall:





3/8" Mortar Joint Between Bricks (Most Common)

BRICK TYPE	SPECIFIED SIZE D X H X L (INCHES)	NOMINAL SIZE D X H X L	VERTICAL COURSE
Standard	3 5/8 x 2 1/4 x 8	Not modular	3 courses = 8"
Modular	3 5/8 x 2 1/4 x 7 5/8	4 x 2 2/3 x 8	3 courses = 8"
Norman	3 5/8 x 2 1/4 x 11 5/8	4 x 2 2/3 x 12	3 courses = 8"
Roman	3 5/8 x 1 5/8 x 11 5/8	4 x 2 x 12	1 course = 2"
Jumbo	3 5/8 x 2 3/4 x 8	4 x 3 x 8	1 course = 3"
Economy	3 5/8 x 3 5/8 x 7 5/8	4 x 4 x 8	1 course = 4"
Engineer	3 5/8 x 2 13/16 x 7 5/8	4 x 3 1/5 x 8	5 courses = 16"
King	2 3/4 x 2 5/8 x 9 5/8	Not modular	5 courses = 16"
Queen	2 3/4 x 2 3/4 x 7 5/8	Not modular	5 courses = 16"
Utility	3 5/8 x 3 5/8 x 11 5/8	4 x 4 x 12	1 course = 4"

Clay Brick

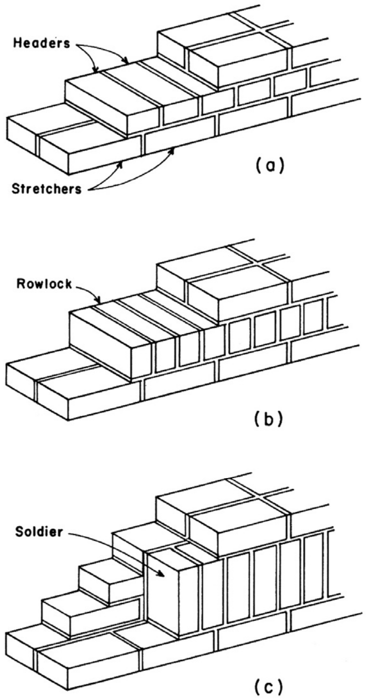
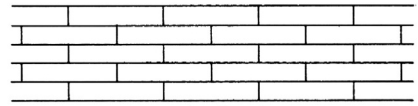
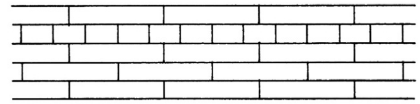
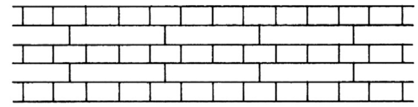
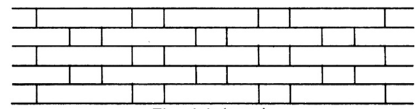


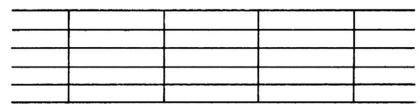
FIGURE 4.2. Ordinary positions for bricks.


running bond

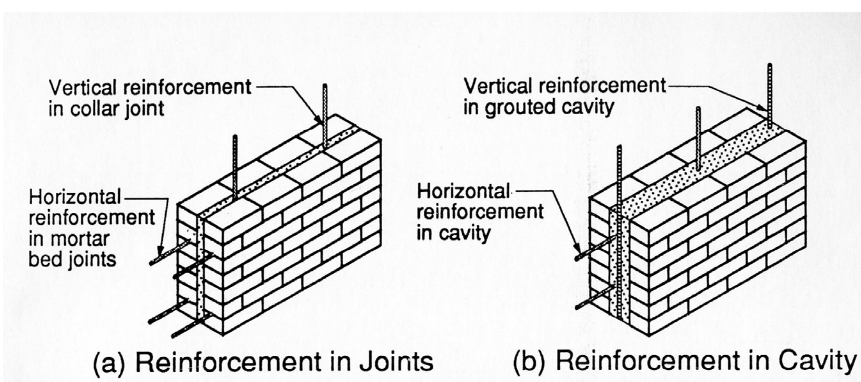

common bond

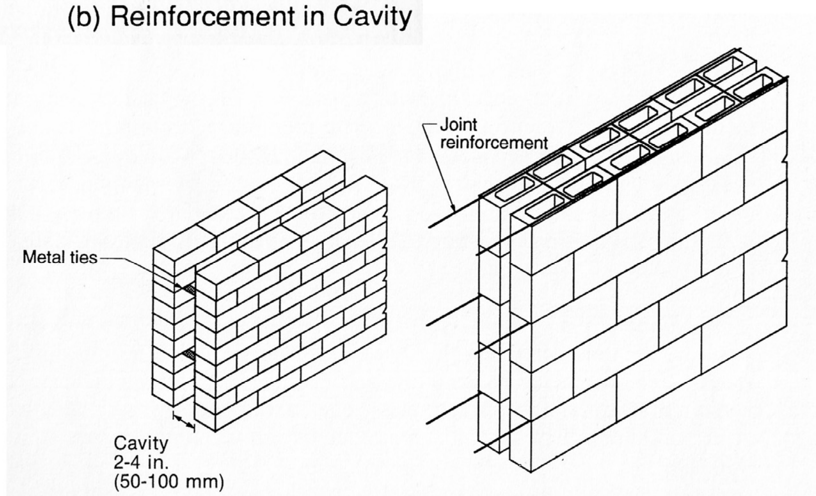

English bond


Flemish bond


stack bond

Cavity Walls

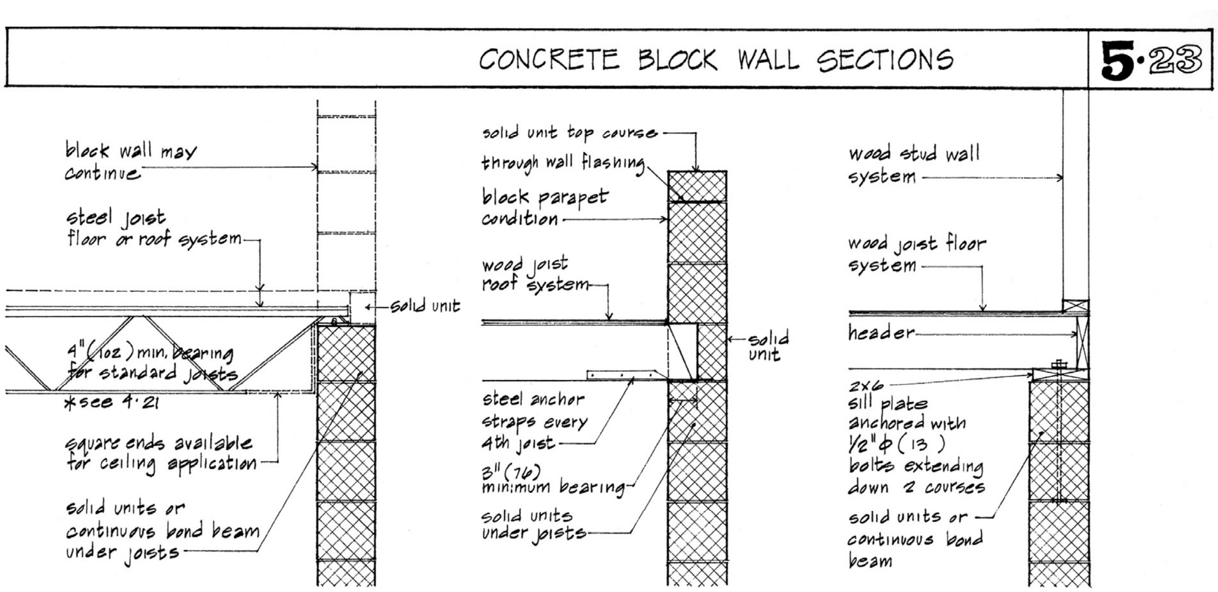




Concrete Masonry Units (CMU) wall construction

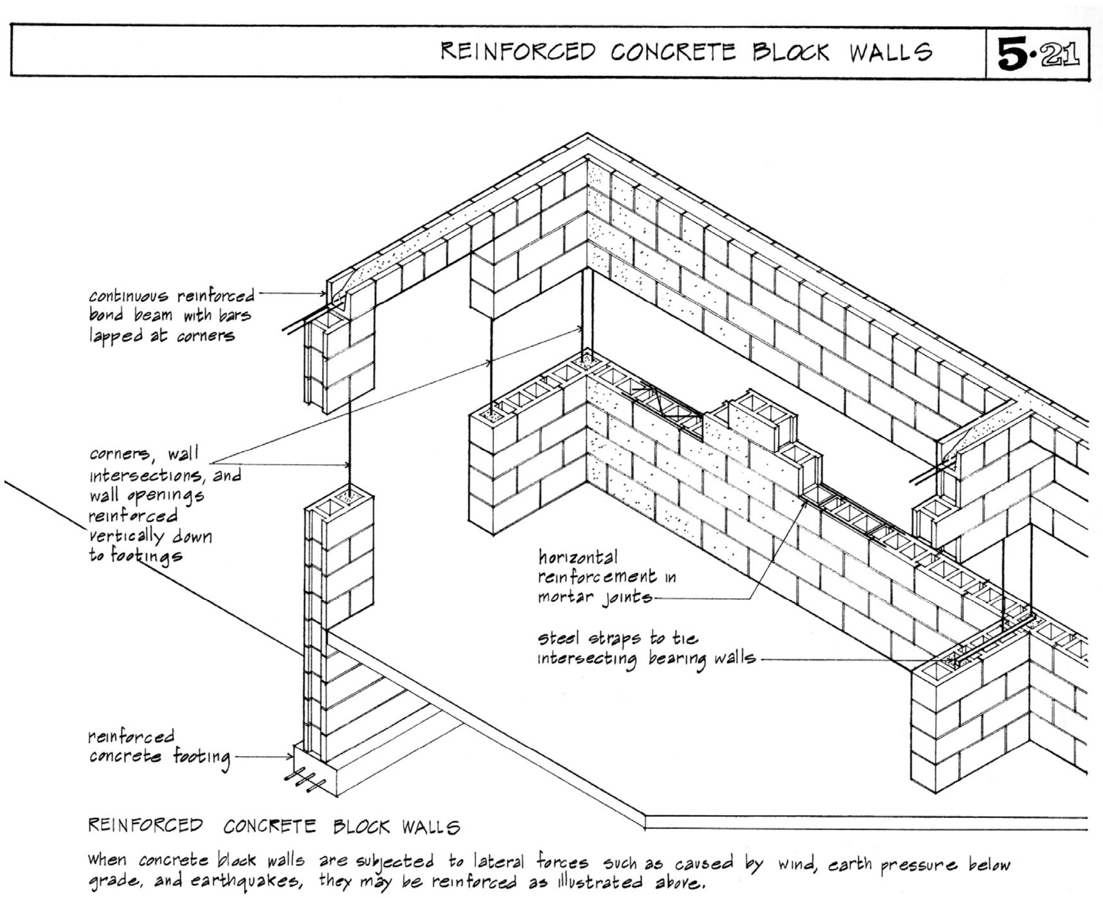
Concrete Masonry Units (CMU)

- wall sections



These wall sections are not intended to be complete. They exclude floor, wall, and ceiling finishes, trim, etc. They attempt to illustrate how various floor and roof systems are supported by a concrete block bearing wall. The above-grade wall is literally an extension of the concrete block foundation wall system. Note that the edges of floor and roof planes are not visible from the exterior except at the top of the concrete block wall. All vertical dimensions should be modular, especially is the block is left exposed as the wall finish

Concrete Masonry Units (CMU)



Concrete Masonry Units
(CMU)

- Cast (molds)
- Dried
- Autoclaved

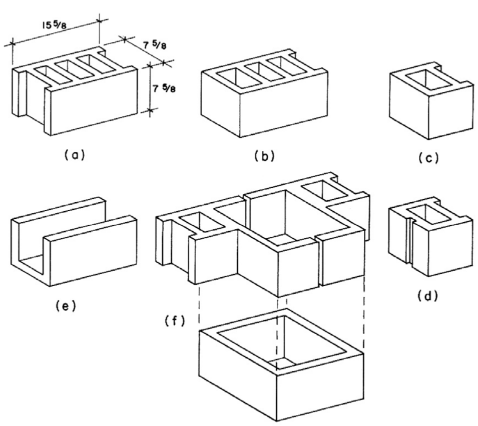
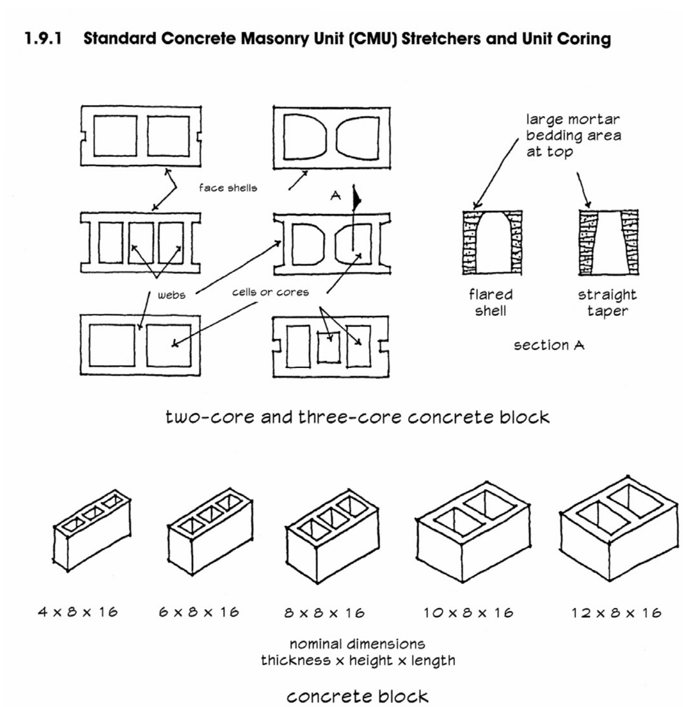
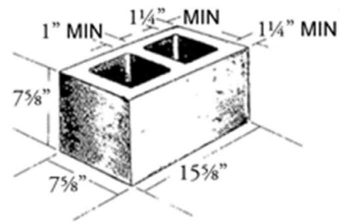


FIGURE 5.1. Forms of CMUs for unreinforced construction.



Concrete Masonry Units
(CMU)

- Geometric Properties
- NCMA TEK 14-1B
- Radius of gyration, r = $\sqrt{\frac{I}{A}}$



8-inch (203-mm) Single Wythe Walls, 1¼ in. (32 mm) Face Shells (standard)

Horizontal Section Properties (Masonry Spanning Vertically)

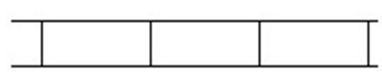
Unit	Grout spacing (in.)	Mortar bedding	Net cross-sectional properties[A] A_n (in.^{2}/ft)	I_n (in.^{4}/ft)	S_n (in.^{3}/ft)
Hollow	No grout	Face shell	30.0	308.7	81.0
Hollow	No grout	Full	41.5	334.0	87.6
100% solid/solidly grouted		Full	91.5	443.3	116.3
Hollow	16	Face shell	62.0	378.6	99.3
Hollow	24	Face shell	51.3	355.3	93.2
Hollow	32	Face shell	46.0	343.7	90.1
Hollow	40	Face shell	42.8	336.7	88.3
Hollow	48	Face shell	40.7	332.0	87.1
Hollow	72	Face shell	37.1	324.3	85.0
Hollow	96	Face shell	35.3	320.4	84.0
Hollow	120	Face shell	34.3	318.0	83.4

Concrete Masonry Units
(CMU)

- Reinforcing

Joint Reinforcing

Truss Type



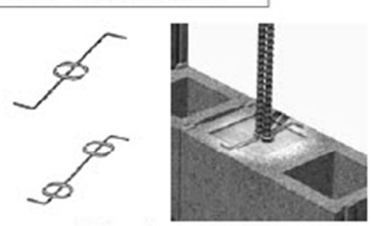
Ladder Type

4.5 Horizontal reinforcement required for masonry not laid in running bond of $0.00028A_g$, placed at a maximum spacing of 48 in. o.c. in horizontal mortar joints or in bond beams.

W1.7 wire
dia. = 0.147 in
area = 0.017 in^2
2x wire = 0.034 in^2

$0.00028(7.625)(16) = 0.034\text{in}^2$ Use 9 gage (W1.7) at 16 in. o.c.

Rebar Positioners

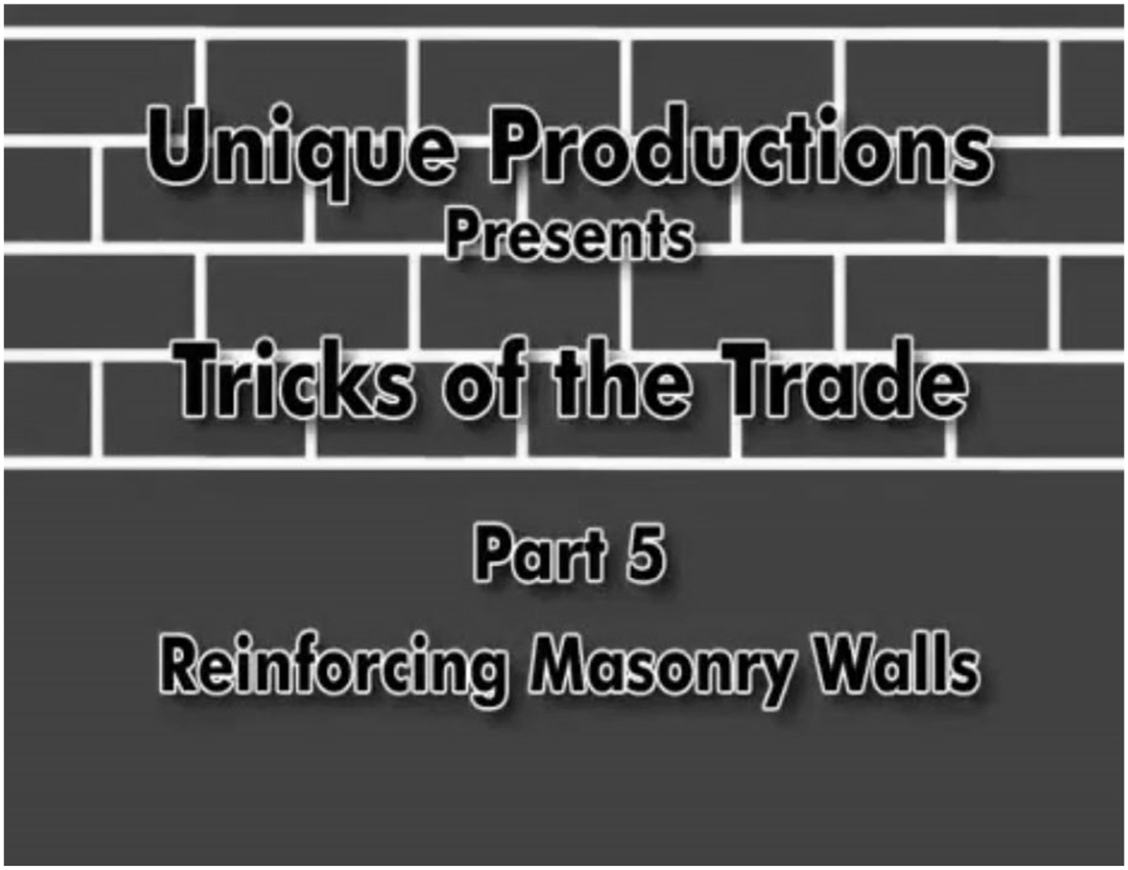


Placed in mortar joints

Placed in cells

Concrete Masonry Units 8

Concrete Masonry Construction



Mortar Types

Types M, S, N, O

The following mortar designations took effect in the mid–1950's:

M a **S** o **N** w **O** r **K**

strongest ... weakest

Table 2-3. Guide to the Selection of Mortar Type*

Location	Building segment	Mortar type: Recommended	Mortar type: Alternative
Exterior, above grade	Load-bearing walls Non-load-bearing walls Parapet walls	N O** N	S or M N or S S
Exterior, at or below grade	Foundation walls, retaining walls, manholes, sewers, pavements, walks, and patios	S†	M or N†
Interior	Load-bearing walls Non-load-bearing partitions	N O	S or M N

*Adapted from ASTM C270. This table does not provide for specialized mortar uses, such as chimney, reinforced masonry, and acid-resistant mortars.

**Type O mortar is recommended for use where the masonry is unlikely to be frozen when saturated or unlikely to be subjected to high winds or other significant lateral loads. Type N or S mortar should be used in other cases.

†Masonry exposed to weather in a nominally horizontal surface is extremely vulnerable to weathering. Mortar for such masonry should be selected with due caution.

Note: For tuckpointing mortar, see "Tuckpointing," Chapter 9.

Relative Parts by Volume

mortar type	Portland cement	lime	sand
M	1	$\frac{1}{4}$	$3\frac{1}{2}$
S	1	$\frac{1}{2}$	$4\frac{1}{2}$
N	1	1	6
O	1	2	9

sum should equal 1/3 of sand volume
(assuming that sand has void ratio of 1 in 3)

Mortar Types

Type M, S, N, O

Slump is higher than cast concrete based on workability

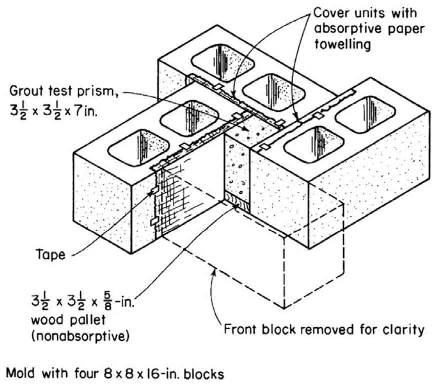


Fig. 2-29. ASTM C1019 method of using masonry units to form a prism for compression-testing of masonry grout.

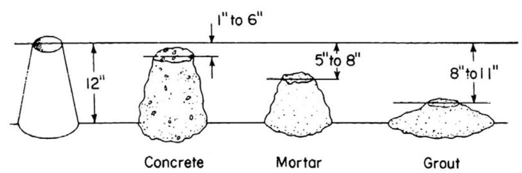
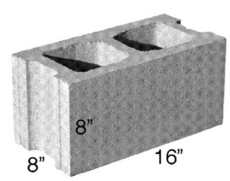


Fig. 2-27. Slump test comparison of concrete, mortar, and masonry grout.

Masonry Strength

Masonry strength, f'm, based on unit strength, fu, and mortar type

Clay Masonry



Concrete Masonry

Required Net Area Compressive Strength of Clay Masonry Units (psi) fu		f'm For Net Area Compressive Strength of Masonry (psi)
When Used With Type M or S Mortar	When Used With 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

(*From Masonry Standards Joint Committee* Specifications for Masonry Structures, *ACI 530.1/ASCE 6/TMS 602-99*)

Required Net Area Compressive Strength of Concrete Masonry Units (psi) fu		f'm For Net Area Compressive Strength of Masonry (psi)
When Used With Type M or S Mortar	When Used With Type N Mortar	
1,250	1,300	1,000
1,900	2,150	1,500
2,800	3,050	2,000
3,750	4,050	2,500
4,800	5,250	3,000

(*From* International Building Code 2000 *and Masonry Standards Joint Committee* Specifications for Masonry Structures, *ACI 530.1/ASCE 6/TMS 602-99*)

Constructive Properties

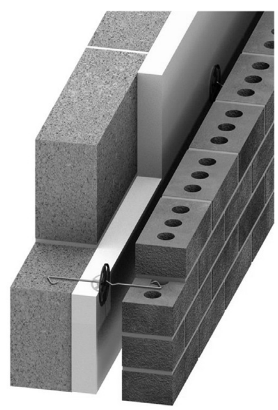
Typical Values

Property		Clay Masonry	Concrete Masonry
Unit strength		$8000\ psi$	$2000\ psi$
Type N mortar	f'_m	$2440\ psi$	$1750\ psi$
	E_m	$1.70x10^6\ psi$	$1.58x10^6\ psi$
Type M or S mortar	f'_m	$2920\ psi$	$2000\ psi$
	E_m	$2.05x10^6\ psi$	$1.80x10^6\ psi$

Property	Clay Masonry	Concrete Masonry
Modulus of Elasticity, E_m	$700f'_m$	$900f'_m$
Shear Modulus, G	$0.4E_m$	$0.4E_m$
Coefficient of Creep	$\frac{0.7\ x10^{-7}}{psi}$	$\frac{2.5x10^{-7}}{psi}$

Analysis and Design

Empirical approach
based on experience
limits on lateral loading
limits on height
limits on eccentricity
(basically no flexure)
non-reinforced



Rational approach
based on Strength Design (LRFD)
either reinforced or non-reinforced
limited by strength

Reinforced Masonry Analysis

for axial compression using TMS 402 (2016)
Strength Design (LRFD) – **non-reinforced**

Rational Approach

Given: geometry, material
Find: axial compressive load capacity, Pn

1. Determine the masonry strength, f'm, based on unit strength, fu, and mortar type
2. Find the net area, A_n, and Moment of Inertia, I_n (see NCMA TEK 14-1B)
3. Calculate r = $\sqrt{I/A}$
4. Calculate h/r
5. Choose the axial strength equation, Pn:
   If h/r < 99 use TMS 402 eq.9-11
   If h/r > 99 use TMS 402 eq.9-12
6. Calculate øPn where ø for axial force = 0.90
7. Check that øPn is greater than Pu.

(Equation 9-11) for h/r < 99

$$P_n = 0.80\left\{0.80A_n f'_m\left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

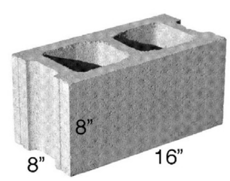
(Equation 9-12) for h/r > 99

$$P_n = 0.80\left[0.80A_n f'_m\left(\frac{70r}{h}\right)^2\right]$$

Masonry Strength

Masonry strength, f'm, based on unit strength, fu, and mortar type

Clay Masonry



Concrete Masonry

Required Net Area Compressive Strength of Clay Masonry Units (psi) fu		f'm For Net Area Compressive Strength of Masonry (psi)
When Used With Type M or S Mortar	When Used With Type N Mortar	
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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

(*From Masonry Standards Joint Committee* Specifications for Masonry Structures, *ACI 530.1/ASCE 6/TMS 602-99*)

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When Used With Type M or S Mortar	When Used With Type N Mortar	
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1,900	2,150	1,500
2,800	3,050	2,000
3,750	4,050	2,500
4,800	5,250	3,000

(*From* International Building Code 2000 *and Masonry Standards Joint Committee* Specifications for Masonry Structures, *ACI 530.1/ASCE 6/TMS 602-99*)

Reinforced Masonry Analysis

Rational Approach

for axial compression using TMS 402 (2016)
Strength Design – **non-reinforced**

Section Properties of Concrete Masonry Walls NCMA TEK 14 – 1B

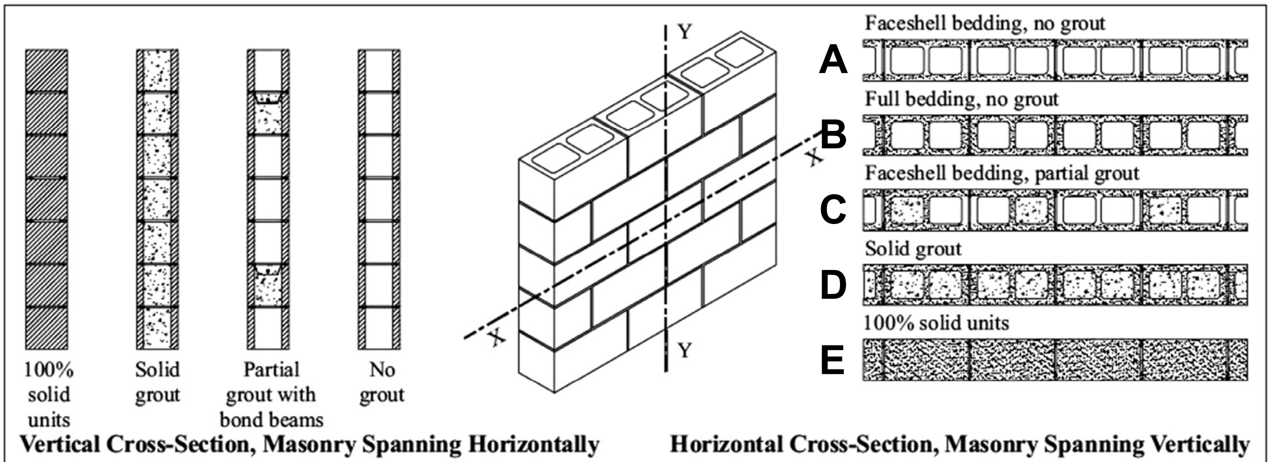


Figure 3—Horizontal and Vertical Cross-Sections

Reinforced Masonry Analysis

Rational Approach

for axial compression using TMS 402 (2016)
Strength Design – **non-reinforced**

Section Properties of Concrete Masonry Walls NCMA TEK 14 – 1B

Table 3—8-inch (203-mm) Single Wythe Walls, 1¼ in. (32 mm) Face Shells (standard)

3a: Horizontal Section Properties (Masonry Spanning Vertically)

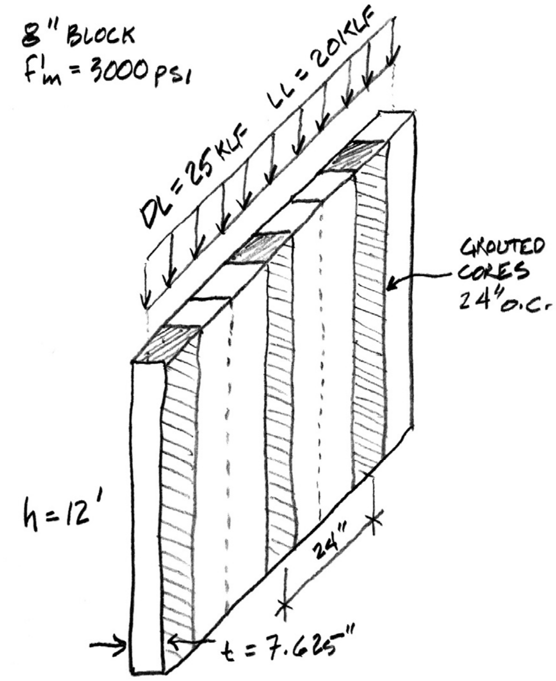
	Unit	Grout spacing (in.)	Mortar bedding	Net cross-sectional properties[A] A_n (in.^{2}/ft)	I_n (in.^{4}/ft)	S_n (in.^{3}/ft)
A	Hollow	No grout	Face shell	30.0	308.7	81.0
B	Hollow	No grout	Full	41.5	334.0	87.6
D/E	00% solid/solidly grouted		Full	91.5	443.3	116.3
C	Hollow	16	Face shell	62.0	378.6	99.3
↓	Hollow	24	Face shell	51.3	355.3	93.2
↓	Hollow	32	Face shell	46.0	343.7	90.1
↓	Hollow	40	Face shell	42.8	336.7	88.3
↓	Hollow	48	Face shell	40.7	332.0	87.1
↓	Hollow	72	Face shell	37.1	324.3	85.0
↓	Hollow	96	Face shell	35.3	320.4	84.0
↓	Hollow	120	Face shell	34.3	318.0	83.4

Reinforced Masonry Analysis

for axial compression using TMS 402 (2016)
Strength Design – **non-reinforced**

Rational Approach

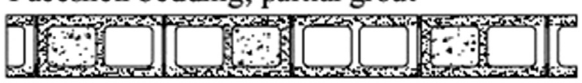
Example Problem



Given: geometry: 8" block, grouted 24" o.c.
material: f'm = 3000 psi
Find: check pass/fail for the given loading

1. Determine the masonry strength, f'm, based on unit strength, fu, and mortar type. (given f'm = 3000 psi)

Faceshell bedding, partial grout



Reinforced Masonry Analysis

for axial compression using TMS 402 (2016)
Strength Design – **non-reinforced**

Rational Approach

2. Find the net area, A_n, and Moment of Inertia, I_n (see NCMA TEK 14-1B)

Table 3—8-inch (203-mm) Single Wythe Walls, 1¹/₄ in. (32 mm) Face Shells (standard)

3a: Horizontal Section Properties (Masonry Spanning Vertically)

Unit	Grout spacing (in.)	Mortar bedding	Net cross-sectional properties[A] A_n (in.²/ft)	I_n (in.⁴/ft)	S_n (in.³/ft)
Hollow	No grout	Face shell	30.0	308.7	81.0
Hollow	No grout	Full	41.5	334.0	87.6
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Reinforced Masonry Analysis

for axial compression using TMS 402 (2016)
Strength Design – **non-reinforced**

Rational Approach

3. Calculate $r = \sqrt{I/A}$

TEK 14-1B 8" SINGLE WYTHE
HOLLOW BLOCK – GROUT @ 24" o.c. – FACE SHELL MORTAR
$A_n = 51.3 \text{ in}^2 \quad I_n = 355.3 \text{ in}^4$ (NET)

4. Calculate h/r

$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{355.3}{51.3}} = 1.952 \text{ in}$

$h/r = \frac{12'(12)}{1.952} = 73.75 < 99 \therefore$ EQ ①

5. Choose the axial strength equation, Pn:
   If h/r < 99 use TMS 402 eq.9-11
   If h/r > 99 use TMS 402 eq.9-12

(Equation 9-11) for h/r < 99

$$P_n = 0.80\left\{0.80 A_n f'_m\left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

Reinforced Masonry Analysis

for axial compression using TMS 402 (2016)
Strength Design – **non-reinforced**

Rational Approach

(Equation 9-11) for h/r < 99

$$P_n = 0.80\left\{0.80 A_n f'_m\left[1-\left(\frac{h}{140r}\right)^2\right]\right\}$$

6. Calculate øPn
   where ø for axial force = 0.90

$P_n = 0.8\left[0.8 \; A_n \, f'_m \left(1-\left(\frac{h}{140r}\right)^2\right)\right]$

$P_n = 0.8\left[0.8 \; (51.3)(3)\left(1-\left(\frac{144''}{140(1.952'')}\right)^2\right)\right]$ (in²/FT, KSI)

$P_n = 0.8\left[123.12 - 0.7223\right] = 71.4 \text{ K/FT}$

$\phi P_n = 0.9(71.4) = 64 \text{ K/FT}$

7. Check that øPn is greater than Pu.

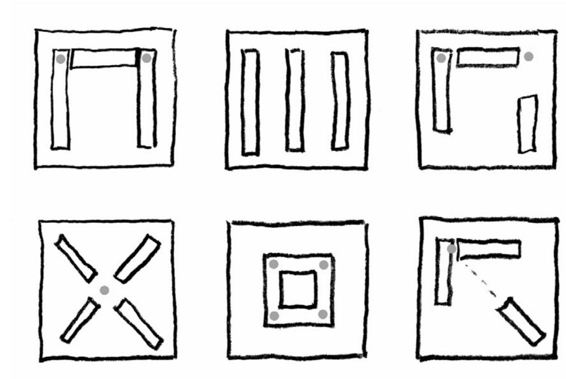
$P_U = 1.2(25) + 1.6(20) = 62 \text{ K/FT}$

$P_U = 62 \text{ K/FT} < 64 \text{ K/FT} = \phi P_n \quad \therefore$ OK ✓

Lateral Force Resistance

Stability requires at least 2 points of intersection.

Force is more evenly resisted with centroid of walls in the kern of slab



Empirical Approach

TMS 402-16 Tab. CC A.1.1
Checklist for use of empirical design

COMMENTARY

Table CC-A.1.1 — Checklist for use of Appendix A – Empirical Design of Masonry

1.	Risk Category IV structures, or portions thereof, are not permitted to be designed using Appendix A.
2.	Partitions are not permitted to be designed using Appendix A.
3.	Use of empirical design is limited based on Seismic Design Category, as described in the following table.

Seismic Design Category	Participating Walls	Non-Participating Walls, except partition walls
A	Allowed by Appendix A	Allowed by Appendix A
B	Not Allowed	Allowed by Appendix A
C	Not Allowed	With prescriptive reinforcement per 7.4.3.1[1]
D, E, and F	Not Allowed	Not Allowed

[1] Lap splices are required to be designed and detailed in accordance with the requirements of Chapters 8 or 9.

4.	Use of empirical design is limited based on wind speed at the project site, as described in Code A.1.2.3 and Code Table A.1.1.
5.	If wind uplift on roofs result in net tension, empirical design is not permitted (A.8.3.1).
6.	Loads used in the design of masonry must be listed on the design drawings (1.2.1b).
7.	Details of anchorage to structural frames must be included in the design drawings (1.2.1e).
8.	The design is required to include provisions for volume change (1.2.1h). The design drawings are required to include the locations and sizing of expansion, control, and isolation joints.
9.	If walls are connected to structural frames, the connections and walls are required to be designed to resist the interconnecting forces and to accommodate deflections (4.4). This provision requires a lateral load and uplift analysis for exterior walls that receive wind load and are supported by or are supporting a frame or roofing system.
10.	Masonry not laid in running bond (for example, stack bond masonry) is required to have horizontal reinforcement (4.5).
11.	A project quality assurance plan is required (3.1) with minimum requirements given in TMS 602 Tables 3 and 4 for Quality Assurance Level 1.
12.	The resultant of gravity loads must be determined and assured to be located within certain limitations for walls and piers (A.1.2.1).
13.	Ensure compliance of the design with prescriptive floor, roof, and wall-to-structural framing anchorage requirements, as well as other anchorage requirements (A.8.3 and A.8.4).
14.	Type N mortar is not permitted for foundation walls (A.6.3.1(g)).
15.	Design shear wall lengths, spacings, and orientations to meet the requirements of Code A.3.1.

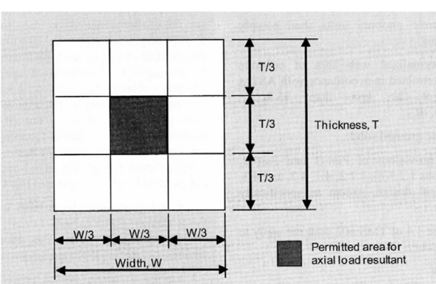
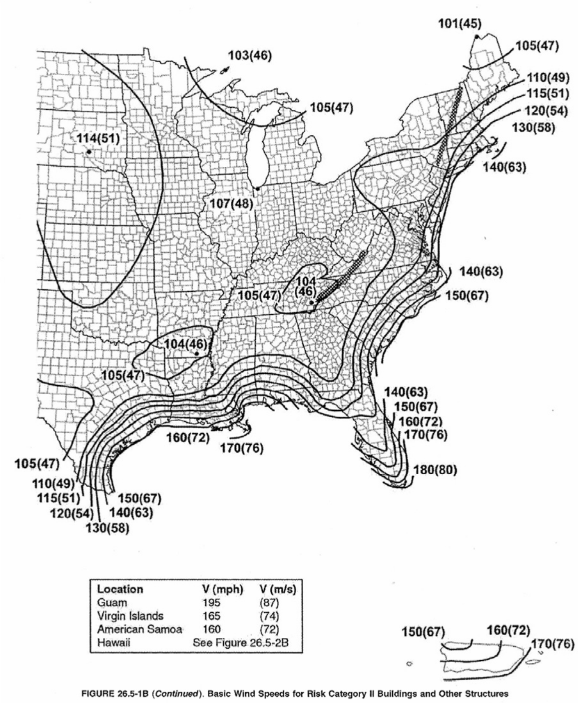


Figure CC-A.1-1 - Area for gravity loads applied to foundation piers

TMS 402 - 2016

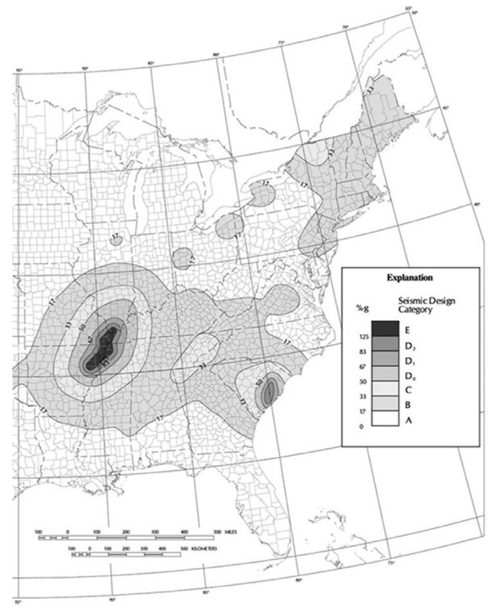
Empirical Approach

Wind limitations:
Basic wind speed ≤ 115 mph
(see TMS 402-16 Tab. A.1.1)



ASCE 7 – 2016 basic wind speeds for risk cat. II

Seismic limitations:
Can generally be used for Seismic Design Category (SDC) A, B, or C , or only A if part of the seismic lateral force resisting system.



Seismic zones A -E

Empirical Design of Masonry
TMS 402-16

Height limits by wind speed and application

Table A.1.1 Limitations based on building height and basic wind speed

Element Description	Building Height, ft (m)	Basic Wind Speed, mph (mps)[1]			
		Less than or equal to 115 (51)	Over 115 (51) and less than or equal to-120 (54)	Over 120 (54) and less than or equal to 125 (56)	Over 125 (56)
Masonry elements that are part of the lateral-force-resisting system	35 (11) and less	Permitted	Permitted	Permitted	Not Permitted
Interior masonry loadbearing elements that are not part of the lateral-force-resisting system in buildings other than enclosed as defined by ASCE 7	Over 180 (55)	Not Permitted	Not Permitted	Not Permitted	Not Permitted
	Over 60 (18) and less than or equal to 180 (55)	Permitted	Not Permitted	Not Permitted	Not Permitted
	Over 35 (11) and less than or equal to 60 (18)	Permitted	Permitted	Not Permitted	Not Permitted
	35 (11) and less	Permitted	Permitted	Permitted	Not Permitted
Exterior masonry elements that are not part of the lateral-force-resisting system	Over 180 (55)	Not Permitted	Not Permitted	Not Permitted	Not Permitted
	Over 60 (18) and less than or equal to 180 (55)	Permitted	Not Permitted	Not Permitted	Not Permitted
	Over 35 (11) and less than or equal to 60 (18)	Permitted	Permitted	Not Permitted	Not Permitted
Exterior masonry elements	35 (11) and less	Permitted	Permitted	Permitted	Not Permitted

[1] Basic wind speed as given in ASCE 7

Empirical Design of Masonry TEK 14-8B (also TMS 402 – Tab. A.5.1)

International Building Code (IBC) Limitations:

1. Lateral support requirements
2. Location of gravity load (in middle 1/3 of wall)
3. Maximum unreinforced spans

Table 2—Wall Lateral Support Requirements (ref. 1)

Construction (unreinforced)	Maximum wall length-to thickness or height-to thickness ratio[A]
Bearing walls	
Solid units or solid grouted	20
All others	18
Nonbearing walls	
Exterior	18
Interior	36
Cantilever walls[B]	
Solid	6
Hollow	4
Parapets (8-in. (203-mm) thick min.)[B]	3

[A] Ratios are determined using nominal dimensions. For multi-wythe walls where wythes are bonded by masonry headers, the thickness is the nominal wall thickness. When multiwythe walls are bonded by metal wall ties, the thickness is taken as the sum of the wythe thicknesses. Note that Reference 6 includes modified requirements for walls with openings.

[B] The ratios are maximum height-to-thickness ratios and do not limit wall length.

Table 3—Maximum Unreinforced Wall Spans, ft (m)[A]

Wall thickness, in. (mm)	6 (152)	8 (203)	10 (254)	12 (305)
Bearing walls				
Solid or solid grouted	10 (3.0)[B]	13.3 (4.1)	16.6 (5.1)	20 (6.1)
All other	9 (2.7)[B]	12 (3.7)	15 (4.5)	18 (5.5)
Nonbearing walls				
Exterior	9 (2.7)	12 (3.7)	15 (4.5)	18 (5.5)
Interior	18 (5.5)	24 (7.3)	30 (9.1)	36 (11)
Cantilever Walls[C]				
Solid	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Hollow	2 (0.6)	2.6 (0.8)	3.3 (1.0)	4 (1.2)
Parapets [C]	1.5 (0.5)	2 (0.6)	2.5 (0.8)	3 (0.9)

[A] Note that Ref. 6 includes modified requirements for walls with openings.

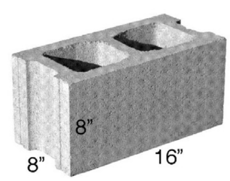
[B] Unreinforced 6-in. (152-mm) thick bearing walls are limited to one story in height.

[C] For these cases, spans are maximum wall heights.

Masonry Strength

Masonry strength, f'm, based on unit strength, fu, and mortar type

Clay Masonry



Concrete Masonry

Required Net Area Compressive Strength of Clay Masonry Units (psi) fu		f'm For Net Area Compressive Strength of Masonry (psi)
When Used With Type M or S Mortar	When Used With 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

(*From Masonry Standards Joint Committee* Specifications for Masonry Structures, *ACI 530.1/ASCE 6/TMS 602-99*)

Required Net Area Compressive Strength of Concrete Masonry Units (psi) fu		f'm For Net Area Compressive Strength of Masonry (psi)
When Used With Type M or S Mortar	When Used With Type N Mortar	
1,250	1,300	1,000
1,900	2,150	1,500
2,800	3,050	2,000
3,750	4,050	2,500
4,800	5,250	3,000

(*From* International Building Code 2000 *and Masonry Standards Joint Committee* Specifications for Masonry Structures, *ACI 530.1/ASCE 6/TMS 602-99*)

Empirical Design of Masonry TEK 14-8B (also TMS 402 – Tab. A.4.2)

Allowable compressive stress of concrete masonry:

Solid or solidly grouted walls

Table 4—Allowable Compressive Stress for Empirical Design of Masonry

Gross area compressive strength of unit, psi (MPa)	Allowable compressive stresses based on gross cross-sectional area, psi (MPa)[A] Type M or S mortar	Type N mortar
Solid and Solidly Grouted Masonry (refs. 1, 6):		
Solid concrete brick:		
8,000 (55) or greater	350 (2.41)	300 (2.07)
4,500 (31)	225 (1.55)	200 (1.38)
2,500 (17)	160 (1.10)	140 (0.97)
1,500 (10)	115 (0.79)	100 (0.69)
Grouted concrete masonry:		
4,500 (31) or greater	225 (1.55)	200 (1.38)
2,500 (17)	160 (1.10)	140 (0.97)
1,500 (10)	115 (0.79)	100 (0.69)
Solid concrete masonry units:		
3,000 (21) or greater	225 (1.55)	200 (1.38)
2,000 (14)	160 (1.10)	140 (0.97)
1,200 (8.3)	115 (0.79)	100 (0.69)
Hollow walls (noncomposite masonry bonded[B]):		
Solid units:		
2,500 (17) or greater	160 (1.10)	140 (0.97)
1,500 (10)	115 (0.79)	100 (0.69)

Hollow unit walls

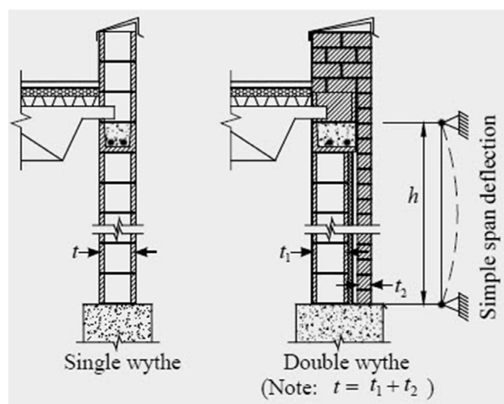
Gross area compressive strength of unit, psi (MPa)	Allowable compressive stresses based on gross cross-sectional area, psi (MPa)[A] Type M or S mortar	Type N mortar
Hollow Unit Masonry (Units Complying With ASTM C 90-06 or Later) (ref. 6)[C]:		
Hollow loadbearing CMU, $t \leq 8$ in. (203 mm)[D]:		
2,000 (14) or greater	140 (0.97)	120 (0.83)
1,500 (10)	115 (0.79)	100 (0.69)
1,000 (6.9)	75 (0.52)	70 (0.48)
700 (4.8)	60 (0.41)	55 (0.38)
Hollow loadbearing CMU, 8 in. $< t <$ 12 in. (203 to 305 mm)[D]:		
2,000 (14) or greater	125 (0.86)	110 (0.76)
1,500 (10)	105 (0.72)	90 (0.62)
1,000 (6.9)	65 (0.49)	60 (0.41)
700 (4.8)	55 (0.38)	50 (0.35)
Hollow loadbearing CMU, $t \geq 12$ in (305 mm)[D]:		
2,000 (14) or greater	115 (0.79)	100 (0.69)
1,500 (10)	95 (0.66)	85 (0.59)
1,000 (6.9)	60 (0.41)	55 (0.38)
700 (4.8)	50 (0.35)	45 (0.31)
Hollow walls (noncomposite masonry bonded[B]):		
$t \leq 8$ in. (203 mm)[D]	75 (0.52)	70 (0.48)
$8 < t < 12$ in (203 to 305 mm)[D]	70 (0.48)	65 (0.45)
$t \geq 12$ in (305 m.m)[D]	60 (0.41)	55 (0.38)

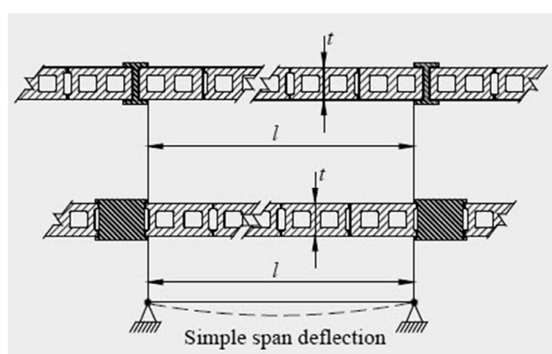
Empirical Concrete Masonry

Procedure using TMS 402 - 2016

Given: location, geometry, material
Find: strength (load capacity)

1. Check axial loading – must be within middle 1/3
2. Check seismic category to be A, B, or C , or only A if part of the seismic lateral force resisting system.
3. Check wind speed (ASCE-7 2016) compare with Tab. A.1.1
4. Check minimum thickness.
   1 story = 6" min. 2 story = 8" min.
5. Check lateral support (vertical or horizontal) tables 2 and 3 TEK 14-8B or TMS 402 – Tab. A.5.1
6. Determine allowable compressive stress from table 4 TEK 14-8B or TMS 402 – Tab. A.4.2
7. Allowable load = (stress) (gross area) (not LRFD so no γ factors)





$$P = F \times A_g$$

Empirical Design Example

Given:
8” hollow non-reinforced CMU wall
interior wall, Ann Arbor, Mich.
DL = 150 psf

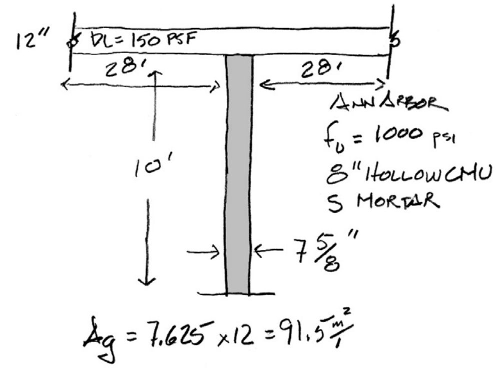
Find:
LL capacity

Checks:

Axially loaded :
  loaded within middle 1/3 (kern)

Seismic Category:
  A, B, or C , or only A if part of the seismic lateral force resisting system

Wind:
  less that 115 mph (ASCE 7 - 2016)

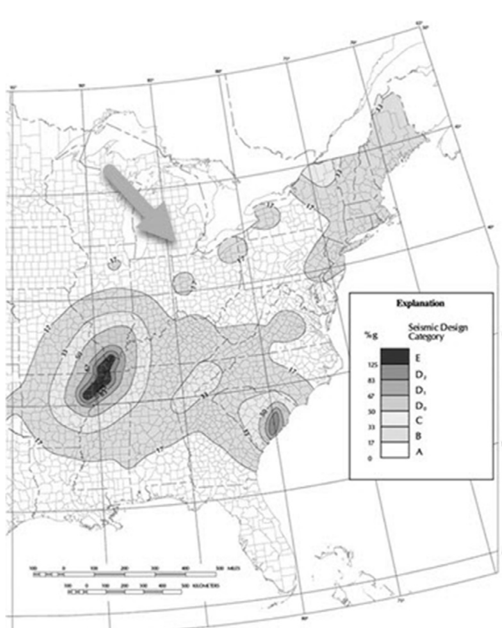


AXIAL LOADING ✓

FOR ANN ARBOR :
  SDC → A ✓
  WIND LOAD 107 MPH < 115 ✓

Wind and Seismic Limits

Wind for Ann Arbor – 107 mph
SCD for Ann Arbor - Zones A



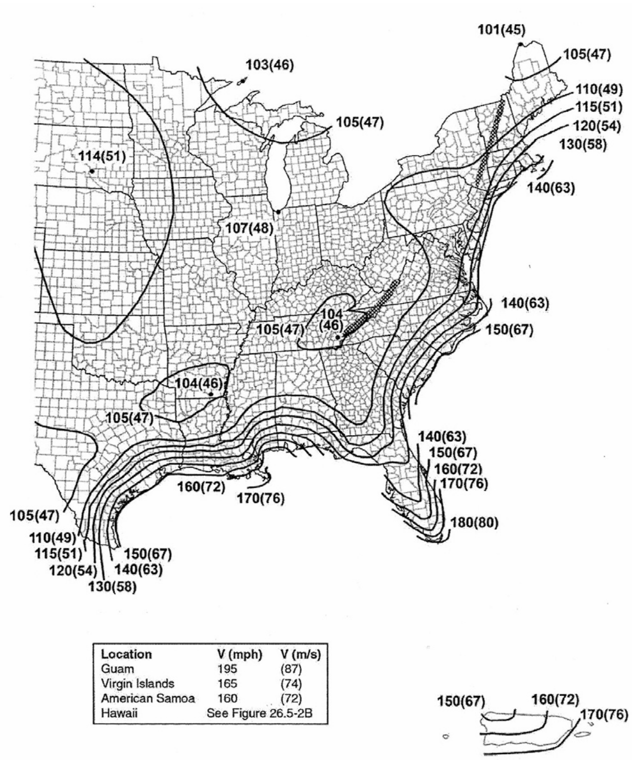


FIGURE 26.5-1B (*Continued*). Basic Wind Speeds for Risk Category II Buildings and Other Structures

Empirical Design Example

Checks:

Maximum height – Table A.1.1

- wind speed = 107 mph
- interior, loadbearing
- h < 35 ft

MAX HEIGHT
TABLE 1 10' ✓

H/t (TABLE 2)
$\frac{120''}{8''} = 15 < 18$ ✓

MAX. UNREINF. HEIGHT
TABLE 3 → 10' < 12' ✓

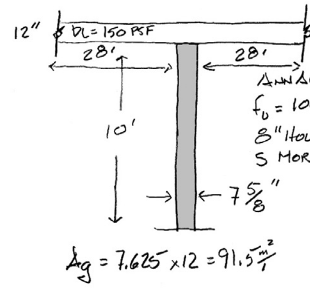


Table A.1.1 Limitations based on building height and basic wind speed

Element Description	Building Height, ft (m)	Basic Wind Speed, mph (mps)[1]: Less than or equal to 115 (51)	Over 115 (51) and less than or equal to-120 (54)	Over 120 (54) and less than or equal to 125 (56)	Over 125 (56)
Masonry elements that are part of the lateral-force-resisting system	35 (11) and less	Permitted			Not Permitted
Interior masonry loadbearing elements that are not part of the lateral-force-resisting system in buildings other than enclosed as defined by ASCE 7	Over 180 (55)	Not Permitted			
	Over 60 (18) and less than or equal to 180 (55)	Permitted	Not Permitted		
	Over 35 (11) and less than or equal to 60 (18)	Permitted		Not Permitted	
	35 (11) and less		Permitted		Not Permitted
Exterior masonry elements that are not part of the lateral-force-resisting system	Over 180 (55)	Not Permitted			
	Over 60 (18) and less than or equal to 180 (55)	Permitted	Not Permitted		
	Over 35 (11) and less than or equal to 60 (18)	Permitted		Not Permitted	
Exterior masonry elements	35 (11) and less	Permitted			Not Permitted

[1] Basic wind speed as given in ASCE 7

Empirical Design Example

Checks:

Minimum bracing – table 2

Maximum unreinforced height - table 3

MAX HEIGHT
TABLE 1 10' ✓

H/t (TABLE 2)
$\frac{120''}{8''} = 15 < 18$ ✓

MAX. UNREINF. HEIGHT
TABLE 3 → 10' < 12' ✓

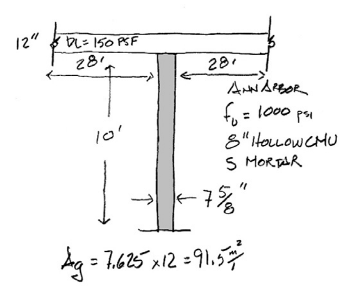


Table 2—Wall Lateral Support Requirements (ref. 1)

Construction (unreinforced)	Maximum wall length-to thickness or height-to thickness ratio[A]
Bearing walls	
Solid units or solid grouted	20
All others	18
Nonbearing walls	
Exterior	18
Interior	36
Cantilever walls[B]	
Solid	6
Hollow	4
Parapets (8-in. (203-mm) thick min.)[B]	3

Table 3—Maximum Unreinforced Wall Spans, ft (m)[A]

Wall thickness, in. (mm)	6 (152)	8 (203)	10 (254)	12 (305)
Bearing walls				
Solid or solid grouted	10 (3.0)[B]	13.3 (4.1)	16.6 (5.1)	20 (6.1)
All other	9 (2.7)[B]	12 (3.7)	15 (4.5)	18 (5.5)
Nonbearing walls				
Exterior	9 (2.7)	12 (3.7)	15 (4.5)	18 (5.5)
Interior	18 (5.5)	24 (7.3)	30 (9.1)	36 (11)
Cantilever Walls[C]				
Solid	3 (0.9)	4 (1.2)	5 (1.5)	6 (1.8)
Hollow	2 (0.6)	2.6 (0.8)	3.3 (1.0)	4 (1.2)
Parapets [C]	1.5 (0.5)	2 (0.6)	2.5 (0.8)	3 (0.9)

[A] Note that Ref. 6 includes modified requirements for walls with openings.

Empirical Design Example

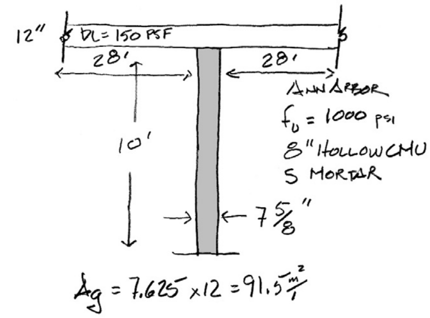
Find allowable stress – table 4

Find load

P = F Ag

Calculate per foot using gross Area

Hollow Unit Masonry (Units Complying With ASTM C 90-06 or Later) (ref. 6)[C]:	Type M or S mortar psi (Mpa)	Type N mortar psi (Mpa)
Hollow loadbearing CMU, $t \le 8$ in		
2,000 (14) or greater	140 (0.97)	120 (0.83)
1,500 (10)	115 (0.79)	100 (0.69)
1,000 (6.9)	75 (0.52)	70 (0.48)
700 (4.8)	60 (0.41)	55 (0.38)
Hollow loadbearing CMU, 8 in. $< t <$ 12 in. (203 to 305 mm)[D]:		
2,000 (14) or greater	125 (0.86)	110 (0.76)
1,500 (10)	105 (0.72)	90 (0.62)
1,000 (6.9)	65 (0.49)	60 (0.41)
700 (4.8)	55 (0.38)	50 (0.35)
Hollow loadbearing CMU, $t \ge 12$ in (305 mm)[D]:		
2,000 (14) or greater	115 (0.79)	100 (0.69)
1,500 (10)	95 (0.66)	85 (0.59)
1,000 (6.9)	60 (0.41)	55 (0.38)
700 (4.8)	50 (0.35)	45 (0.31)
Hollow walls (noncomposite masonry bonded[B]):		
$t \le 8$ in. (203 mm)[D]	75 (0.52)	70 (0.48)
$8 < t < 12$ in (203 to 305 mm)[D]	70 (0.48)	65 (0.45)
$t \ge 12$ in (305 m.m)[D]	60 (0.41)	55 (0.38)



$A_g = 7.625 \times 12 = 91.5 \text{ in}^2/1$

TABLE 4 HOLLOW 8" f_U = 1000
TYPE S → 75 PSI

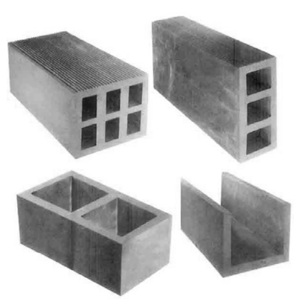
$P = F A_g = 75\,(7.625 \times 12)$
$= 6862$ #/1

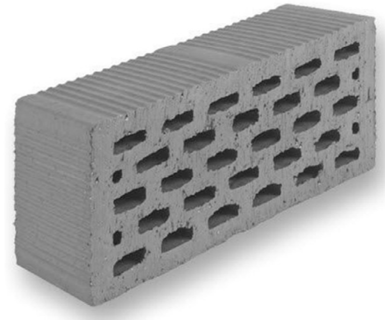
TRIBUTARY STRIP = 28'

$P = 6862 = DL(28') + LL(28')$
$= 150(28) + LL(28)$

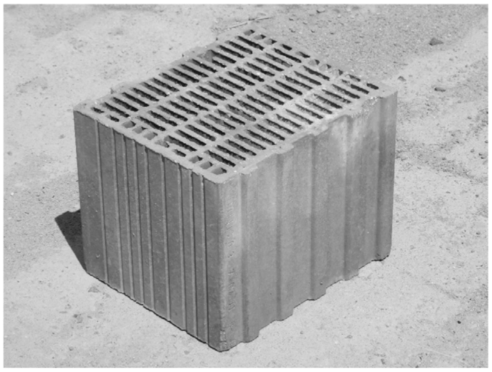
LL = 95 PSF CAPACITY

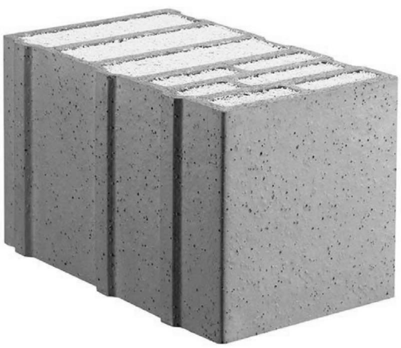
Clay Tile

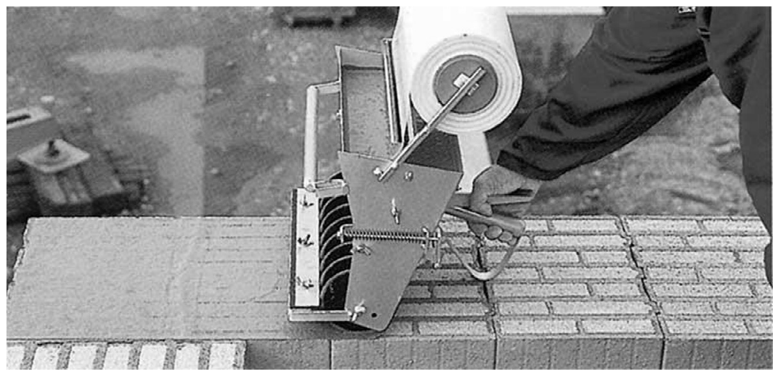




Insulated Clay Tile



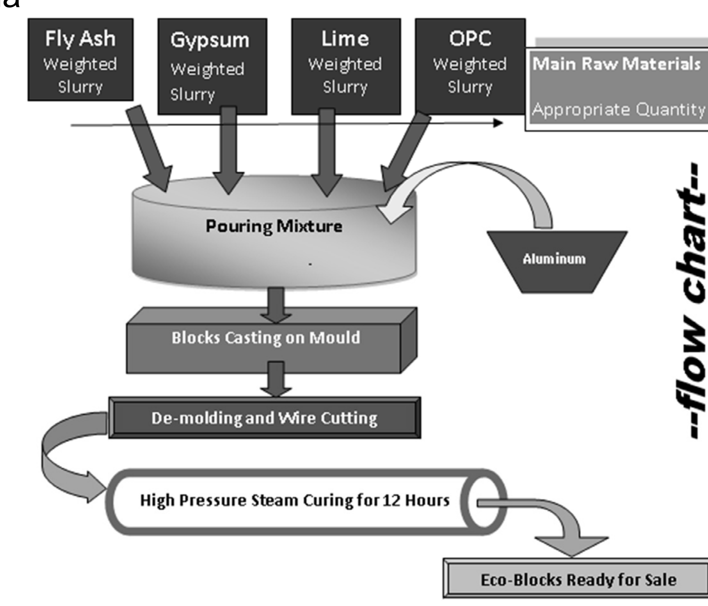


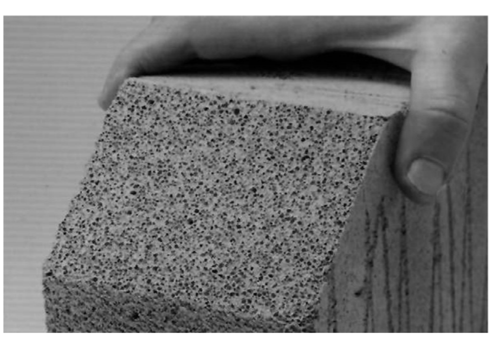


Autoclaved Aeriated Concrete
(AAC)

Used predominately in Europe
Developed by Dr. Johan Axel Eriksson in
- mid- 1920s in Sweden as “Ytong”
- since 1943, Hebel blocks in Germany
- Current largest production in China

Lighter weight
Better insulation value
Better fire resistance
Better moisture transmission
Larger blocks for faster erection
Can be shaped on site





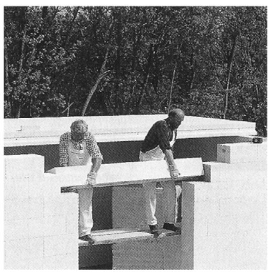
Autoclaved Aeriated Concrete
(AAC)

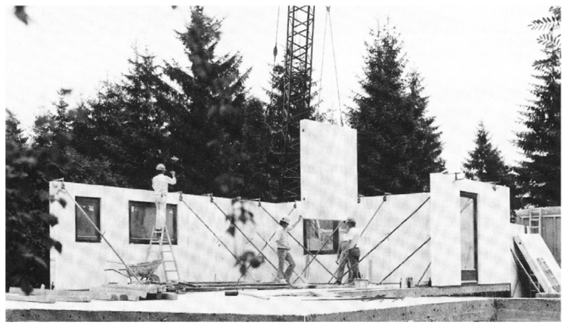
Density – 20 to 50 PCF (floats)

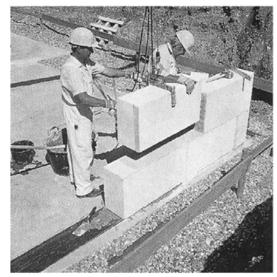
Compressive strength – 300 to 900 PSI

Allowable Shear Stress – 8 to 22 PSI

Thermal Resistance - 0.8 to 1.25 R/ IN





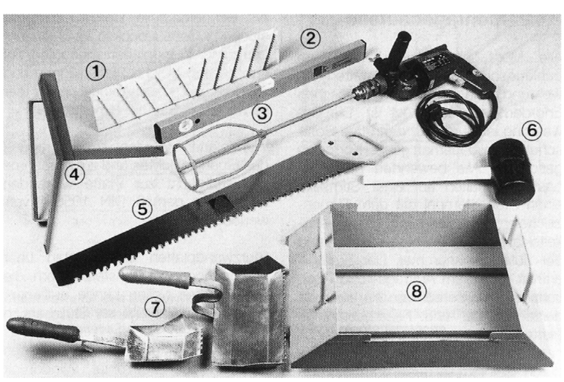


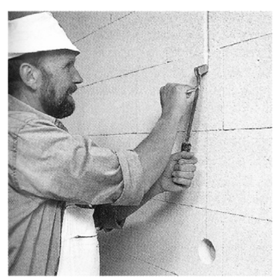
Autoclaved Aeriated Concrete
(AAC)

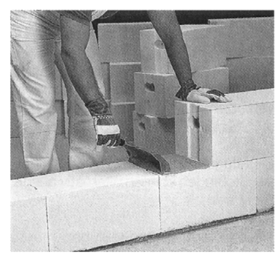
Easily shaped on site

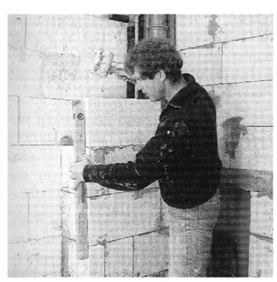
Thin mortar bed – 1/8” (1mm to 3mm)

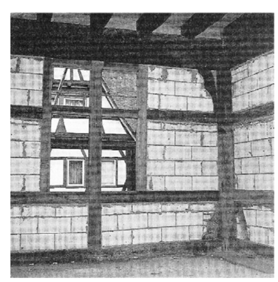
Tools for placement (below)

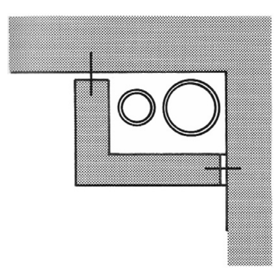








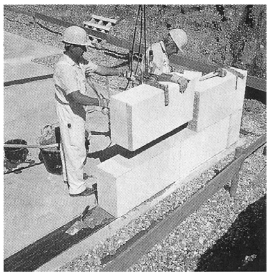


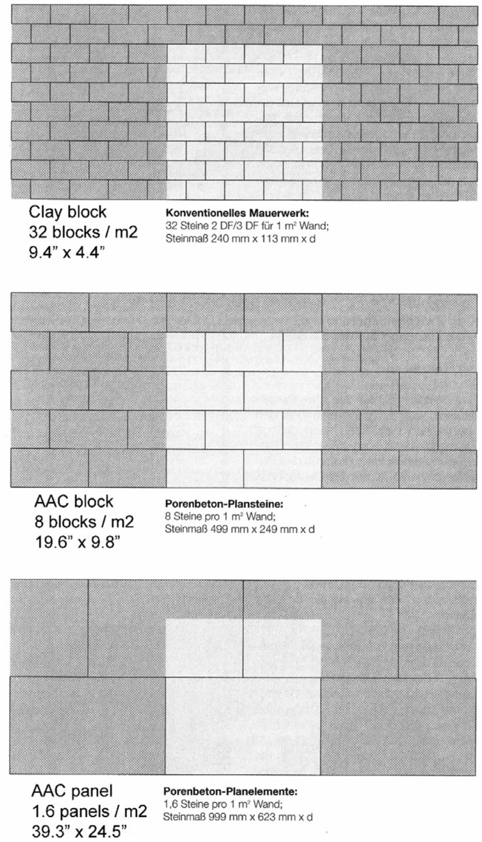


Autoclaved Aeriated Concrete
(AAC)

Larger blocks so faster layup – e.g. 8”x8”x24”

Panel layup with onsite crane





Autoclaved Aeriated Concrete
(AAC)

Finish with stucco

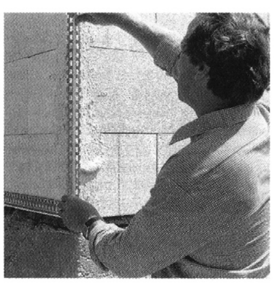


Abb. 2.4.4-1
Anbringen der Sockelabschluß- und Eckschutzschiene zur Sicherung der Mauerwerkskanten

Abb. 2.4.4-2
Auftrag des Grundputzes von Hand

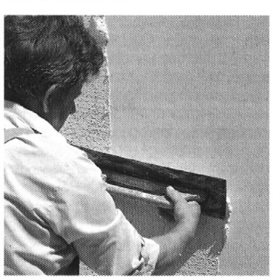


Abb. 2.4.4-3
Auftrag der Deckschicht

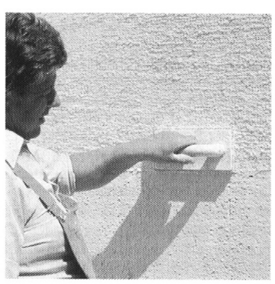


Abb. 2.4.4-4
Verreiben der Putzoberfläche mit Filzbrett oder Schwammscheibe

Member Types

Compression members based on proportions.

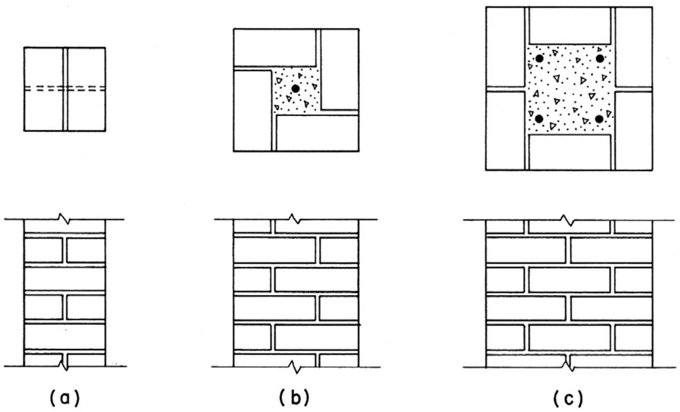


FIGURE 4.12. Forms of brick columns.

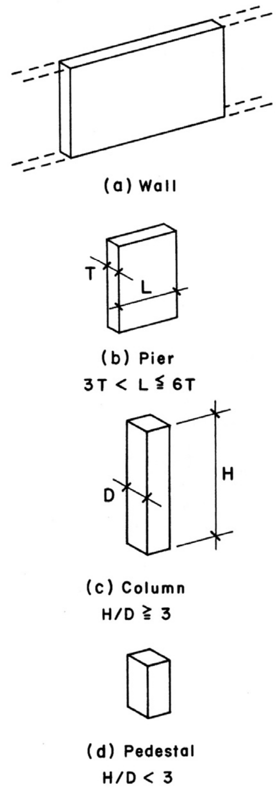


FIGURE 4.6. Classification of vertical compression members.

Member Details

Floor / Column details.