
The

Architecture

Reference +
Specification
Book

Updated +
Revised

Everything Architects Need to Know Every Day

Computer guidelines
Architectural drawing types
Systems and components
Form and organization
Architectural elements
Building codes
ADA and accessibility
Characteristics of materials
Sustainable design
Specifications
Structural systems
The human scale
Measurements
Hand drafting
Mechanical issues



Julia McMorrough

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Architecture

Reference +
Specification
Book

**Updated +
Revised**



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INTRODUCTION

ARCHITECTURAL DESIGN is a complex activity that involves multiple levels of knowledge, communication, and production, even on a small project. Architects often speak their own language, both in terminology and through conventions of drawings, models, and diagrams. Moreover, to make a piece of architecture requires following countless rules of which an able practitioner must remain ever knowledgeable: building codes, human dimensions, drawing standards, material properties, and relevant technologies. Familiarity with so many issues comes with schooling and long years of experience, but even the most seasoned architect must avail him- or herself of a vast and exhaustive array of resources, from code books to graphic standards, from materials libraries to manufacturers' catalogs.

The Architecture Reference + Specification Book is a unique compilation of essential information for architects, students of architecture, and anyone contemplating an architectural project. Included here are the tables, charts, diagrams, dimensions, standards, codes, and general data that many architects need on a daily basis. This book is not a replacement for other sources that architects might consult regularly, but rather a handy “first-stop” reference that is always at the ready, on a desk or in a bag.

Part 1, “Materials,” provides a detailed catalog of the most common building materials—wood, masonry, concrete, metals—as well as various interior finishes. Parts 2, 3, and 4, “Systems,” “Measure and Drawing,” and “Codes and Guidelines,” address the major aspects of undertaking an architectural project. Topics include basic measurements and geometry, architectural drawing types and conventions, parking, building codes, accessibility, structural and mechanical systems, and building components. Parts 5 and 6, “Proportion and Form” and “Context,” bring together the human scale, architectural elements, a glossary, and a timeline of key moments in the history of architecture. Finally, because such a compact book cannot possibly contain everything, a directory of resources offers an extensive guide to the most helpful publications, organizations, and websites.

For every project, architects must take into account an endless number of external forces, not least of which are the codes and standards of design and construction. But these codes and standards should certainly not be viewed as limiting: Knowledge of them and their creative use can, in fact, liberate and empower.

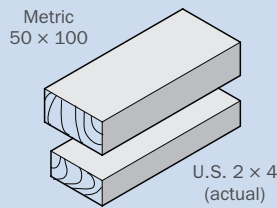
MATERIALS 1.

A NOTE ON METRIC AND CUSTOMARY UNITS

This book acknowledges the two primary measurement systems used in the world today: the metric system, also known as the *Système International d'Unités* (SI), and the U.S. customary units system, referred to in the United States as English units or standard units. While the metric system has become the universally accepted system of units in science, trade, and commerce, in the United States, federal laws have yet to mandate SI as the official system.

In this book, every attempt has been made to accurately represent the relationship between customary and SI units. Except where noted, soft conversions are used throughout and, due to constraints of space, are usually written as follows: 1'-6" (457), with the numbers in parentheses representing millimeters.

See Chapter 10 (page 100) for more details on metric conversions, and Chapter 1 (page 10) for more details on wood.



As an example of the factors that might influence translation from one system to the other, consider the North American 2 × 4:

Nominal dimension: 2" × 4"

Metric "soft" conversion

50.8 mm × 101.6 mm

Metric "hard" conversion

50 mm × 100 mm

Actual dimension: 1½" × 3½"

Metric "soft" conversion

38 mm × 89mm

Metric "hard" conversion

40 mm × 90 mm

Metric preferred dimension:

50 mm × 100 mm

During the design process, architects often use models as a quick way to realize and study a form or space. Frequently, the building's materials may not yet have been chosen or finalized, and there is a seductive simplicity to the foam, or wood, or cardboard model at this point: anything is still possible. Aside from the overarching impact of the project's budget, numerous factors influence the selection of materials for a building's structure, skin, and finishes. Some materials are more readily available in certain regions, or the local building trades may be more comfortable with specific construction practices. Other materials have very long lead times, and for some projects, time constraints may rule these out. Also, different climates have different material needs, and the building's program, size, and code requirements bear on the appropriateness of materials and methods of construction.

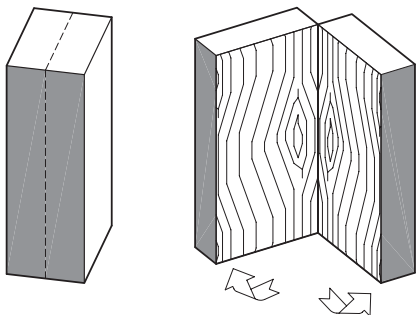
A basic sampling of common materials found in many buildings is presented here. Space limitations do not allow for discussion of other more innovative materials, but increasingly, for reasons of practicality, cost, or environmental concerns, architects are looking to less standard sources for building materials (textiles, plastics, and aerogels) or to unconventional uses for common products (concrete roof tiles, acrylic "glass blocks," and recycled cotton fabric insulation).

Chapter 1: Wood

Lightweight, strong, and durable, wood is an ideal construction material with uses that run the gamut from structure to interior finish. The two major classifications—softwood and hardwood—do not necessarily indicate relative hardness, softness, strength, or durability.

COMMON WOOD TERMS

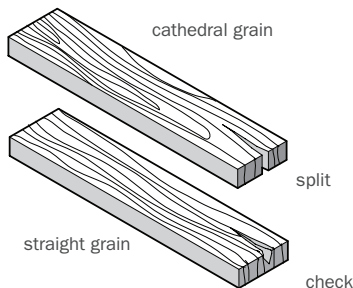
Book-matched: Result of resawing thick lumber into thinner boards, opening the two halves like a book, and gluing the boards together along the edge to create a panel with a mirrored grain pattern.



Burl: Irregular grain pattern that results from an unusual growth on the tree.

Cathedral grain: V-shaped grain pattern running the length of the board.

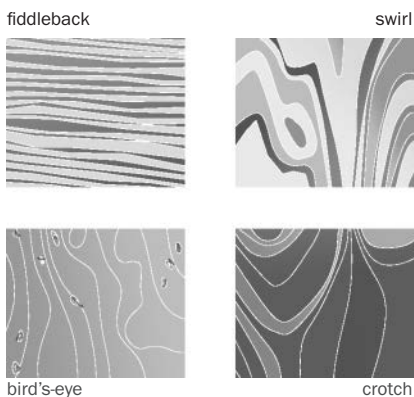
Check: Separation of the wood fibers running with the grain that do not go through the whole cross-section. Occurs as a result of tension and stress caused by wood movement during the drying process.



Dimensional stability: Ability of a section of wood to resist changes in volume at fluctuating moisture levels. Low dimensional stability produces expansion in humid environments and contraction in dry ones.

Early growth/late growth: In regions of little climatic change, trees tend to grow at a fairly consistent rate and have little variation in texture. In regions of seasonal climatic change, however, trees grow at different rates, depending on the season. Variations in growth contribute to the color and texture of the growth rings in the tree.

Figure: Patterns on a wood surface produced by growth rings, rays, knots, and irregular grains. Descriptors include interlocked, curly, tiger, wavy, and fiddleback, among others.

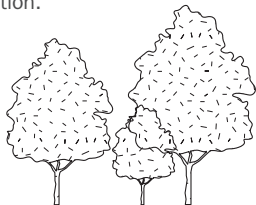


Grain: Size, alignment, and appearance of wood fibers in a piece of lumber.

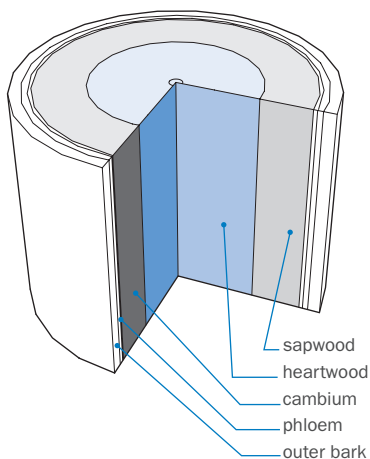
Gum pocket: Excessive accumulation of resin or gum in certain areas of the wood.

Hardness: Ability of wood to resist indentation. See Janka hardness test.

Hardwood: Wood from deciduous trees (which lose their leaves in the winter months). Oak and walnut constitute 50 percent of all hardwood production.



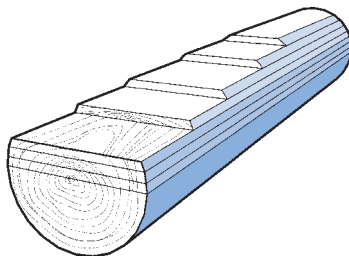
Heartwood: Harder, nonliving innermost layers of a tree. It is generally darker, denser, more durable, and less permeable than the surrounding sapwood. Good all-heartwood lumber may be difficult to obtain, and, depending on the species, it is common to find boards with both heartwood and sapwood combined.



Janka hardness test: Test that measures the pounds of force required to drive a 0.444" (11 mm) -diameter steel ball to half its depth into a piece of wood.

Moisture content: Percentage that represents a board's ratio of water weight to the weight of oven-dried wood.

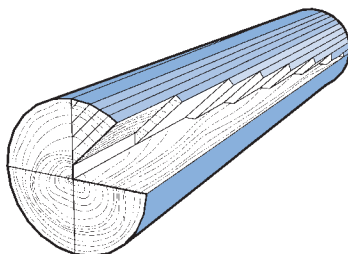
Plainsawn: Lumber cut with less than a 30-degree angle between the face of the board and the wood's growth ring.



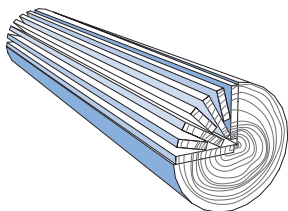
Plywood: Large sheet of wood made up of several layers of veneer that are glued together so that the grain of each layer lies perpendicular to the grain of the previous layer. There is always an odd number of layers, enabling the grain direction of both faces to run parallel to one another.

Pressure-treated lumber: Wood products that are treated with chemical preservatives to prevent decay brought on by fungi and to resist attack from insects and microorganisms. Under pressure, the preservatives are forced deep into the cellular structure of the wood.

Quartersawn: Lumber cut with a 60- to 90-degree angle between the face of the board and the wood's growth rings.

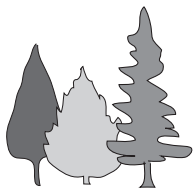


Riftsawn: Lumber cut with a 30- to 60-degree angle between the face of the board and the wood's growth rings.



Sapwood: Living outer layers of a tree, between the outer bark and the thin formative layers of the cambium and phloem, on the one side, and the heartwood, on the other. These layers contain the sap-conducting tubes. Generally lighter in color, less durable, less dense, and more permeable than heartwood, sapwood darkens with age and becomes heartwood. Sapwood and heartwood together make up the xylem of the tree.

Softwood: Wood from coniferous (evergreen) trees.



Split: Separation of wood fibers from one face through to the next. Occurs most often at the ends of boards.

Straight grain: Wood fibers that run parallel to the axis of a piece of lumber.

Stud: 2" x 4" and 2" x 6" dimension lumber used for load-bearing and stud walls.

Warp: Bowing, cupping, and twisting distortion in lumber that occurs after it has been planed, usually during the drying process.

SOFTWOOD LUMBER

Lumber Standards*

Rough Lumber

Sawed, trimmed, and edged lumber whose faces are rough and show marks.

Surfaced (Dressed) Lumber

Rough lumber that has been smoothed by a surfacing machine.

S1S: Surfaced one side

S1E: Surfaced one edge

S2S: Surfaced two sides

S2E: Surfaced two edges

S1S1E: Surfaced one side and one edge

S1S2E: Surfaced one side and two edges

S2S1E: Surfaced two sides and one edge

S4S: Surfaced four sides

Worked Lumber

Surfaced lumber that has been matched, patterned, shiplapped, or any combination of these.

Shop and Factory Lumber

Millwork lumber for use in door jambs, moldings, and window frames.

Yard (Structural) Lumber

Lumber used for house framing, concrete forms, and sheathing.

Boards: No more than 1" (25) thick and 4"-12" (102-305) wide

Planks: Over 1" (25) thick and 6" (152) wide

Timbers: Width and thickness both greater than 5" (127)

*From U.S. Department of Commerce American Lumber Standards of Softwood Lumber

Softwood Lumber Sizes

Nominal Size ¹ inches	Actual Size, Dry ² inches (mm)	Actual Size, Green ³ inches (mm)
1 (25)	3/4 (19)	25/32 (20)
1 1/4 (32)	1 (25)	1 1/32 (26)
1 1/2 (38)	1 1/4 (32)	1 9/32 (33)
2 (50)	1 1/2 (38)	1 9/16 (40)
2 1/2 (64)	2 (51)	2 1/16 (52)
3 (76)	2 1/2 (64)	2 9/16 (65)
3 1/2 (89)	3 (76)	3 1/16 (78)
4 (102)	3 1/2 (89)	3 9/16 (90)
4 1/2 (114)	4 (102)	4 1/16 (103)
5 (127)	4 1/2 (114)	4 5/8 (117)
6 (152)	5 1/2 (140)	5 9/16 (143)
7 (178)	6 1/2 (165)	6 5/8 (168)
8 (203)	7 1/4 (184)	7 1/2 (190)
9 (229)	8 1/4 (210)	8 1/2 (216)
10 (254)	9 1/4 (235)	9 1/2 (241)
11 (279)	10 1/4 (260)	10 1/2 (267)
12 (306)	11 1/4 (286)	11 1/2 (292)
14 (356)	13 1/4 (337)	13 1/2 (343)
16 (406)	15 1/4 (387)	15 1/2 (394)

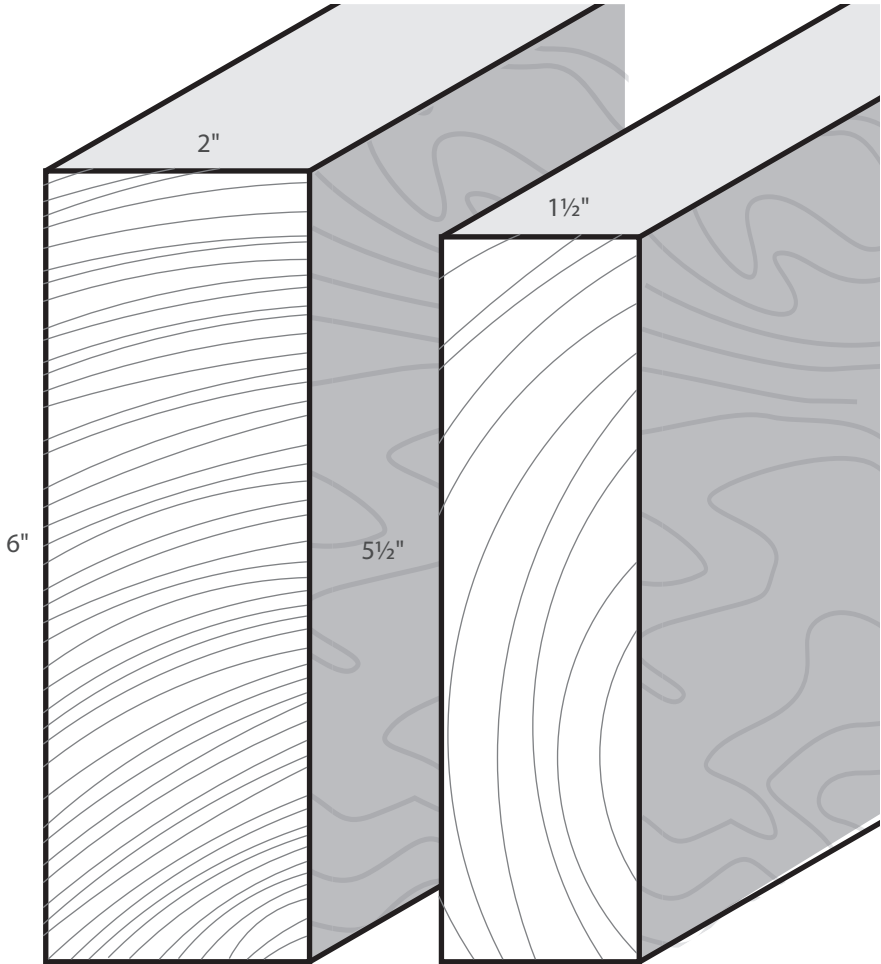
¹Nominal dimensions are approximate dimensions assigned to pieces of lumber and other materials as a convenience in referring to the piece.

²Dry lumber is defined as having a moisture content of less than 19 percent.

³Green (unseasoned) lumber is defined as having a moisture content of greater than 19 percent.

Softwood grading is based on the appearance, strength, and stiffness of the lumber. Numerous associations nationwide establish their own grading standards, though they must all conform to the U.S. Department of Commerce American Lumber Standards. Grading is often difficult to understand, and because it deals with both strength analysis and visual analysis, there is an allowable 5 percent variation below a given grade.

Dimensional Variations of a 2×6 Stud

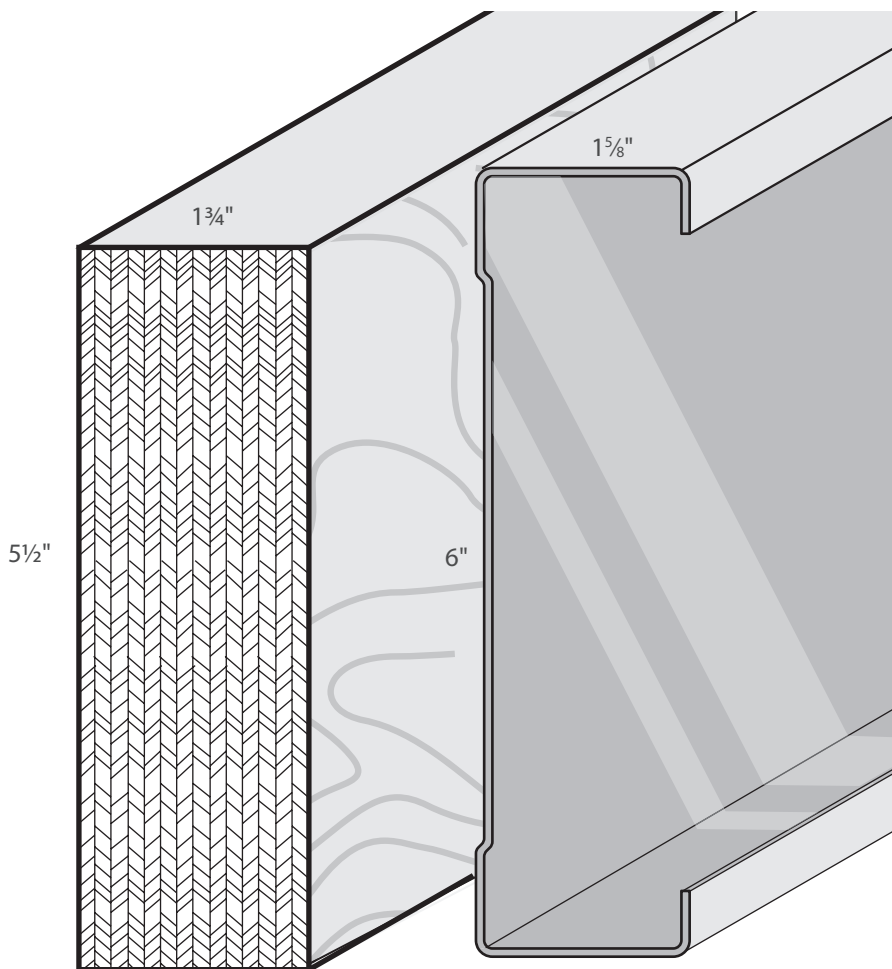


2×6 Old Growth

Typically, older growth wood is denser, stronger, and more dimensionally stable than younger wood. Before aggressive logging, older growth trees grew more slowly, as they competed for sunlight in more densely forested conditions, resulting in more rings per inch.

2×6 Farmed Wood

By contrast, farmed wood grows bigger faster, due to more aggressive watering, fertilizing, and exposure to sunlight. More rapid growing results in less dense wood.



**Laminated Veneer
Lumber (LVL)—Farmed & Glued**

Commonly referred to by its proprietary name of Microllam (Weyerhaeuser), LVL lumber is made of thin sheets of wood sandwiched and glued together, much like plywood, though resulting in heavy and dense wood members that resist warping and shrinkage, and are designed to carry significant loads.

Metal Stud

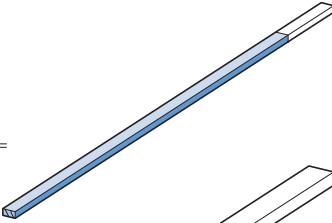
Though more expensive than wood framing members, steel studs offer more strength and dimensional stability.

Board Feet

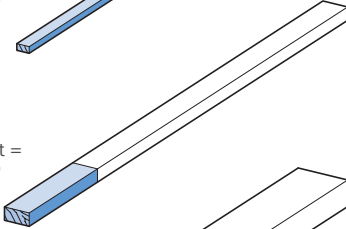
Most lumber is measured and sold in board feet (one board foot equals 144 cubic inches), calculated as follows:

$$\frac{\text{thickness} \times \text{face width} \times \text{length}}{144}$$

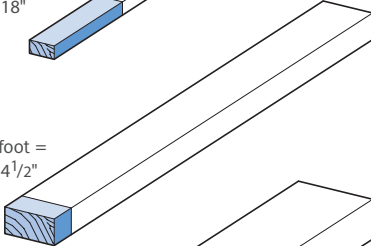
1 × 2
1 board foot =
1" × 2" × 72"



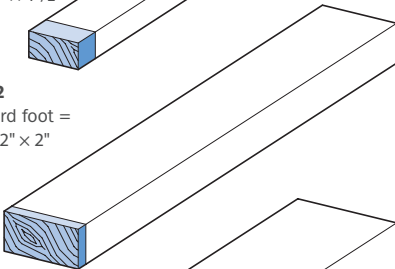
2 × 4
1 board foot =
2" × 4" × 18"



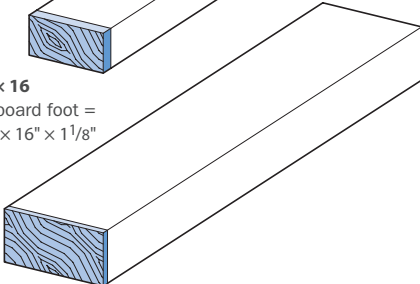
4 × 8
1 board foot =
4" × 8" × 4½"



6 × 12
1 board foot =
6" × 12" × 2"



8 × 16
1 board foot =
8" × 16" × 1⅞"



HARDWOOD

Hardwood Lumber Grades

First and Second (FAS): Best grade, normally required for a natural or stained finish. Boards must be at least 6" wide, 8'-16' long, and 83.3 percent clear on the worst face.

Select, No. 1 Common: Boards must be a minimum 3" wide, 4'-16' long, and 66.66 percent clear on the worst face.

Select, No. 2 Common

Select, No. 3 Common

Hardwood Lumber Thicknesses

Quarter*	Rough Dimension	Surfaced 1 Side (S1S)	Surfaced 2 Sides (S2S)
	¾" (10)	¼" (6)	⅜" (5)
	½" (13)	⅜" (10)	⅝" (8)
	⅝" (16)	½" (13)	⅞" (11)
	¾" (19)	⅝" (16)	⅞" (14)
¼	1" (25)	⅞" (22)	1⅜" (21)
½	1¼" (32)	1⅛" (29)	1⅞" (27)
¾	1½" (38)	1⅜" (35)	1⅞" (33)
8/4	2" (51)	1⅞" (46)	1¾" (44)
12/4	3" (76)	2⅞" (71)	2¾" (70)
16/4	4" (102)	3⅞" (97)	3¾" (95)

*Hardwood thickness is often referred to in "quarters": ¼ equals 1" (25), ⅝ is 1½" (38), and so on.

Exposure Durability

Exterior—Fully waterproof glue and minimum C-grade veneers—suitable for applications permanently exposed to the weather.

Exposure 1—Fully waterproof glue and minimum D-grade veneers suitable for applications with some exposure to weather.

Exposure 2—Glue of intermediate moisture resistance—suitable for applications of intermittent high humidity.

Interior: Protected indoor applications only.

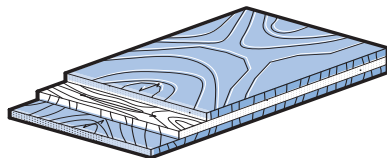
Veneer Grades

N	Premium grade available by special order. Select, all heartwood or all sapwood with a smooth surface and free of open defects. No more than six repairs, wood only, matched for grain and color, and parallel to the grain, allowed per 4' x 8' panel. Best for natural finish.
A	Smooth and paintable. Permits no more than eighteen neatly made repairs of boat, sled, or router type, and parallel to the grain. Used for natural finish in less demanding applications.
B	Solid surface that allows shims, circular repair plugs, and tight knots limited to 1" across grain, with minor splits permitted.
C Plugged	Improved C veneer with splits up to 1/8" width and knotholes and borer holes up to 1/4" x 1/2". Some broken grain is permitted, and synthetic repairs are allowed.
C	Tight knots and knotholes up to 1 1/2" permitted if total width of knots and knotholes is within specified limits. Synthetic or wood repairs allowed. Discoloration and sanding defects that do not impair strength, limited splits, and stitching all permitted. Lowest exterior use grade.
D	Knots and knotholes up to 2 1/2" across grain and 1/2" larger within specified limits permitted. Limited splits and stitching also permitted. Use restricted to Interior, Exposure 1, and Exposure 2 panels.

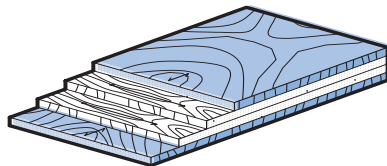
PLYWOOD

Plywood quality is rated by the American Plywood Association (APA) and is generally graded by the quality of the veneer on both front and back sides of the panel (A-B, C-D, and so on). Veneer grades describe appearance according to natural unrepaired growth characteristics and the size and number of repairs allowed during manufacture.

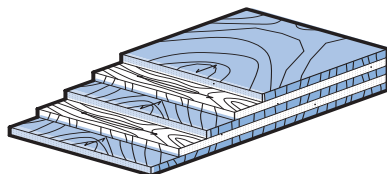
Typical Plywood Construction



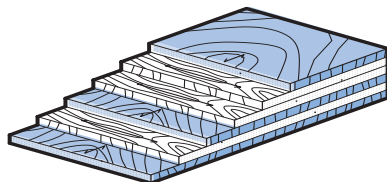
3-layer (3 ply)



3-layer (4 ply)



5-layer (5 ply)



5-layer (6 ply)

WOOD TYPES AND CHARACTERISTICS



ASH white <i>Fraxinus americana</i>			
Hardness		H	
Principal Finish Uses		Trim, cabinetry	
Color		Creamy white to light brown	
Paint	n/a	Transp.	Excellent



BIRCH <i>Betula alleghaniensis</i>			
Hardness		H	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		White to dark red	
Paint	Excellent	Transp.	Good



BUTTERNUT <i>Juglans cinerea</i>			
Hardness		M	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		Pale brown	
Paint	n/a	Transp.	Excellent



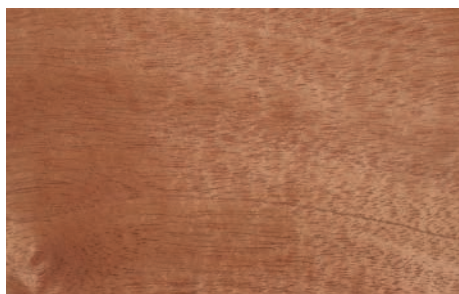
CEDAR western red <i>Thuja plicata</i>			
Hardness		S	
Principal Finish Uses		Trim, exterior & interior paneling	
Color		Reddish brown nearly white	
Paint	n/a	Transp.	Good

S=soft; M=medium; H=hard; VH=very hard; n/a=not normally used
 Finishes: Painted and Transparent

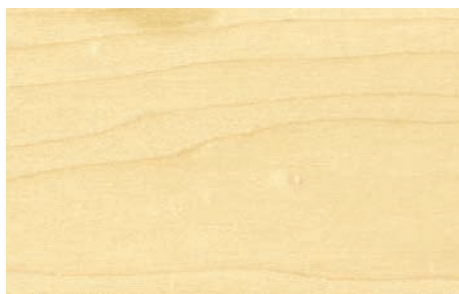
CHESTNUT <i>Castanea dentate</i>			
Hardness		M	
Principal Finish Uses		Trim, paneling	
Color		Grayish brown	
Paint	n/a	Transp.	Excellent



MAHOGANY Hond. <i>Sweitenia macrophylla</i>			
Hardness		M	
Principal Finish Uses		Trim, frames, paneling, cabinetry	
Color		Rich golden brown	
Paint	n/a	Transp.	Excellent



MAPLE <i>Acer saccharum</i>			
Hardness		VH	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		White to reddish brown	
Paint	Excellent	Transp.	Good



OAK English brown <i>Quercus robur</i>			
Hardness		H	
Principal Finish Uses		Veneered paneling, cabinetry	
Color		Leathery brown	
Paint	n/a	Transp.	Excellent



WOOD TYPES AND CHARACTERISTICS



OAK red <i>Quercus rubra</i>			
Hardness		H	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		Reddish tan to brown	
Paint	n/a	Transp.	Excellent



OAK white <i>Quercus alba</i>			
Hardness		H	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		Grayish tan	
Paint	n/a	Transp.	Excellent



PECAN <i>Carya species</i>			
Hardness		H	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		Reddish brown w/ brown stripes	
Paint	n/a	Transp.	Good



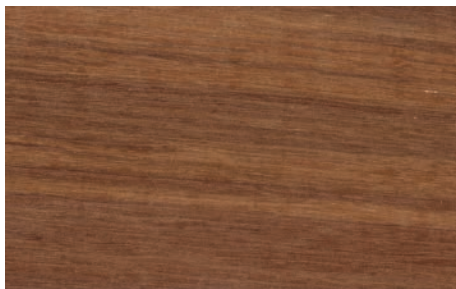
PINE east. or north. white <i>Pinus strobes</i>			
Hardness		S	
Principal Finish Uses		Trim, frames, paneling, cabinetry	
Color		Creamy white to pink	
Paint	Good	Transp.	Good

S=soft; M=medium; H=hard; VH=very hard; n/a=not normally used
 Finishes: Painted and Transparent

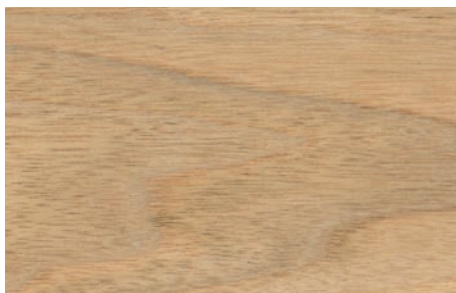
ROSEWOOD <i>Dalbergia nigra</i>			
Hardness		VH	
Principal Finish Uses		Veneered paneling, cabinetry	
Color		Mixed red/brown/ black	
Paint	n/a	Transp.	Excellent



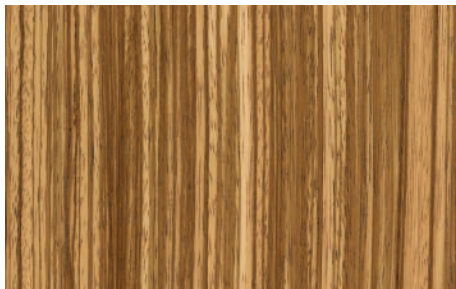
TEAK <i>Tectona grandis</i>			
Hardness		H	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		Tawny yellow to dark brown	
Paint	n/a	Transp.	Excellent



WALNUT <i>Juglans species</i>			
Hardness		H	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		Chocolate brown	
Paint	n/a	Transp.	Excellent



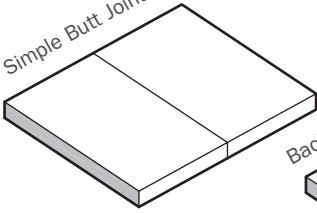
ZEBRAWOOD <i>Brachystegia fleuryana</i>			
Hardness		H	
Principal Finish Uses		Trim, paneling, cabinetry	
Color		Gold streaks on dark brown	
Paint	n/a	Transp.	Excellent



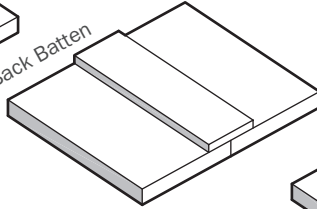
WOOD JOINERY

Edge Joints

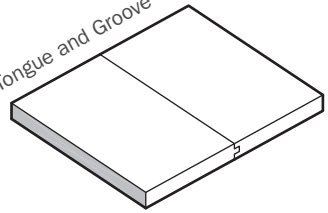
Simple Butt Joint



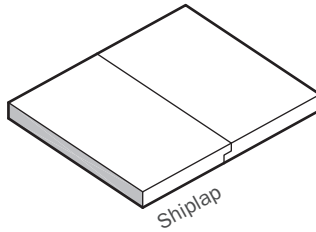
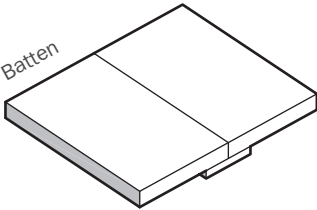
Back Batten



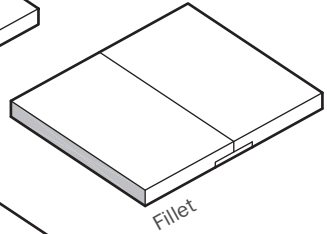
Tongue and Groove



Batten



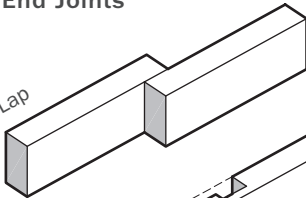
Shiplap



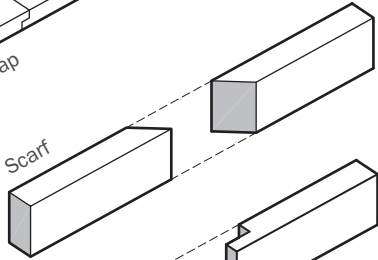
Fillet

End Joints

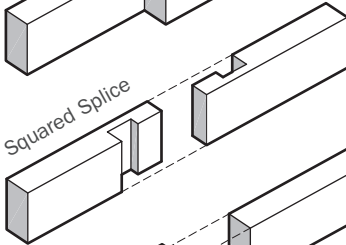
Lap



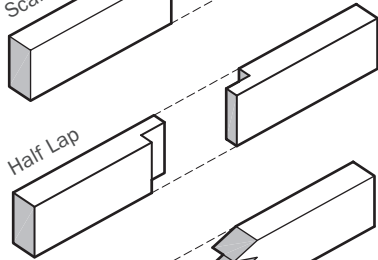
Scarf



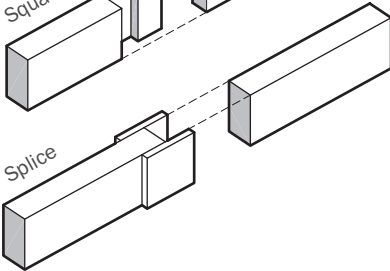
Squared Splice



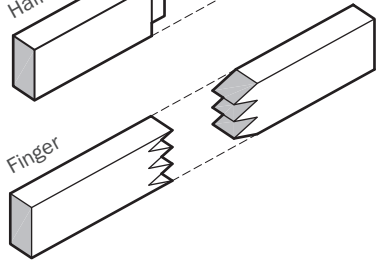
Half Lap



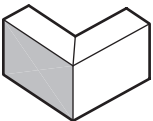
Splice



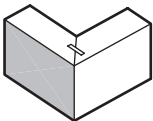
Finger



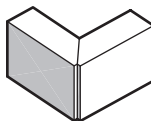
Right-Angle Joints (Miter)



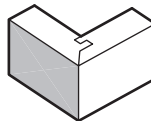
Plain



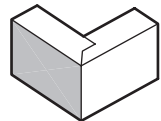
Wood Spine



Quirk

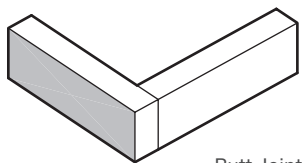


Tongue and Groove



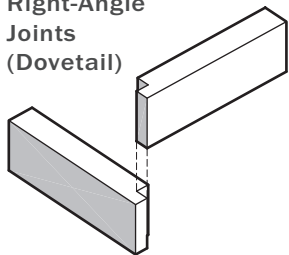
Shoulder

Right-Angle Joints

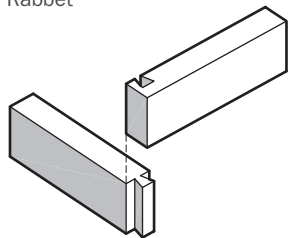


Butt Joint

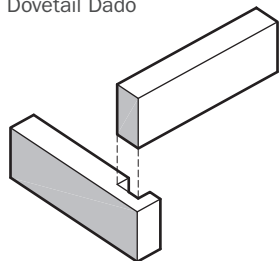
Right-Angle Joints (Dovetail)



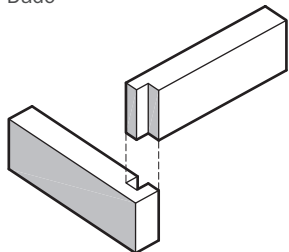
Rabbet



Dovetail Dado

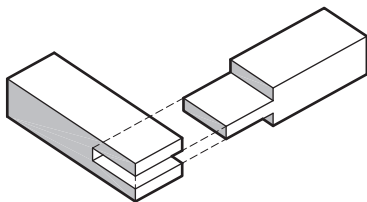


Dado

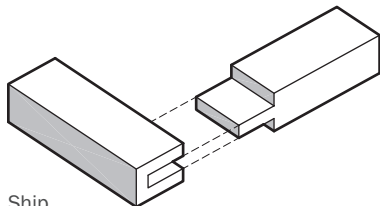


Dado and Rabbet

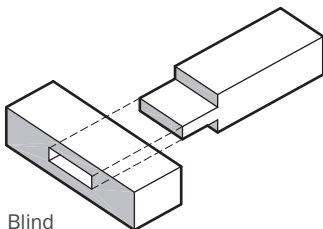
Right-Angle Joints (Mortise and Tenon)



Half Blind

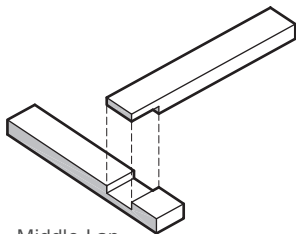


Ship

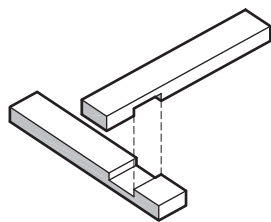


Blind

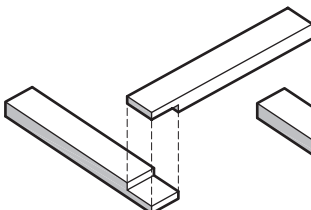
Right-Angle Joints (Lap)



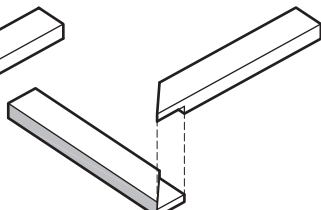
Middle Lap



Cross Lap



End Lap

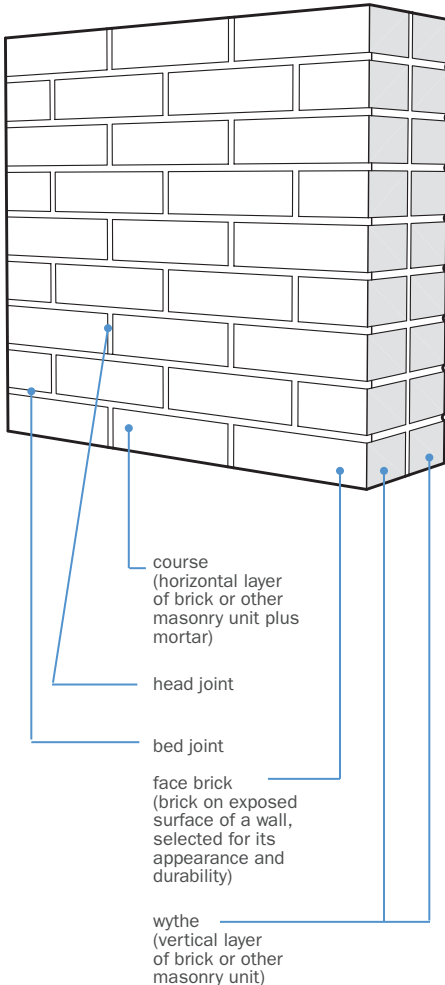


Miter Half Lap

Chapter 2: Masonry and Concrete

MASONRY

Masonry building has become quicker, stronger, and more efficient than in the past, but the basic principles of construction have changed very little since ancient times. Masonry units include bricks, stones, and concrete blocks, and because they all come from the earth, they are suitable for use as foundations, pavers, and walls embedded in the earth. The strength and durability of most masonry makes it ideal to resist fire and decay from water and air.



Bricks

The small scale of a single brick makes it a flexible material for use in walls, floors, and even ceilings. Brick production, in which the clay is fired at very high temperatures, gives brick excellent fire-resistive qualities.

Brick Grades (Building and Facing)

SW: Severe weathering (where water may collect)

MW: Moderate weathering

NW: Negligible weathering

Brick Types (Facing)

FBS: General use in exposed exterior and interior walls; most common type and default choice if architect does not specify

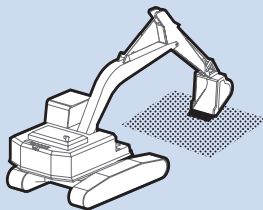
FBX: Special use in exposed exterior and interior walls, where a higher degree of mechanical perfection, narrower color range, and minimal variation in size are required

FBA: Special use in exposed exterior and interior walls, where non-uniformity in size, color, and texture are desired

Brick Manufacturing

Winning (Mining) and storage:

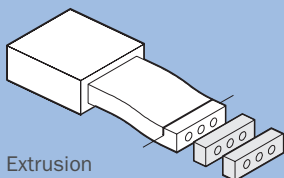
Clays are mined and enough raw material is stored for several days' use to allow continuous operation in any weather. The three principal types of clay are surface clays, shales, and fire clays.



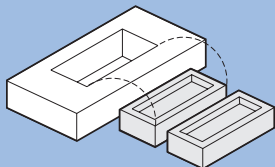
Preparation:

Clay is crushed and pulverized.

Forming Processes



Extrusion



Molding

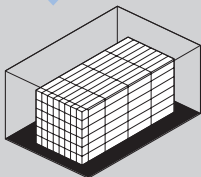
Stiff mud process (extrusion process): Clay is mixed with minimal amounts of water and then “pugged” (thoroughly mixed). Air pockets are removed from the clay as it is passed through a vacuum. Then it is extruded through a rectangular die and pushed across a cutting table where it is sliced into bricks by cutter wires.

Soft mud process (molding process): Moist clay is pressed into rectangular molds. Water or sand are used as media to prevent the clay from sticking to the molds. Water-struck bricks have a smooth surface, produced when the molds have been dipped into water before being filled; sand-struck, or sand-mold, bricks have a matte-textured surface, produced by dusting the molds with sand before forming the brick.

Dry-press process: Clay is mixed with a minimum of water and machine-pressed into steel molds.

Drying Process

Molded bricks are placed in a low-temperature kiln and dried for one to two days.



Firing Process

In periodic kilns, bricks are loaded, fired, cooled, and unloaded. In continuous tunnel kilns, bricks ride through a tunnel on railcars, where they are fired the entire time at various temperatures and emerge at the end fully burned. Firing can take from 40 to 150 hours.

Water-smoking and dehydration: Remaining water is removed from the clay.

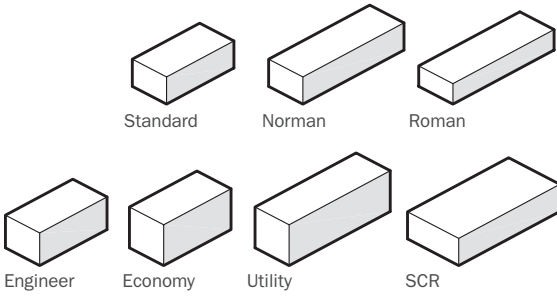
Oxidation and vitrification: Temperatures reach up to 1,800° F (982°C) and 2,400° F (1,316°C), for these respective processes.

Flashing: Fire is regulated to produce color variations in the brick.

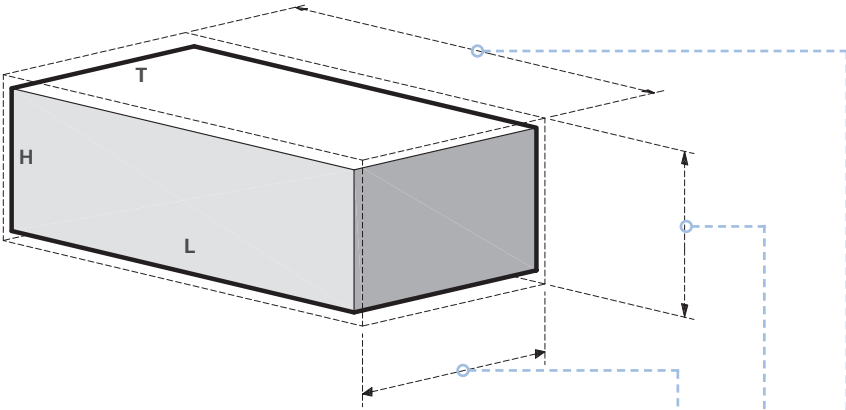
Bricks may also be glazed, either during the initial firing or in a special additional firing.

BRICK UNITS

Comparative Proportions



Nominal brick dimensions are derived from combining actual brick dimensions (length, thickness, and height) with their respective mortar joints. Typical mortar joints are $\frac{3}{8}$ " (10) and $\frac{1}{2}$ " (13).



Standard Sizes

Unit Type	Joint Thickness in. (mm)	Brick Thickness = T in. (mm)	Brick Height = H in. (mm)	Brick Length = L in. (mm)	Vertical Coursing = (C) in. (mm)	Nominal T in. (mm)	Nominal H in. (mm)	Nominal L in. (mm)
Standard Modular	$\frac{3}{8}$ (10)	$3\frac{5}{8}$ (92)	$2\frac{1}{4}$ (57)	$7\frac{5}{8}$ (194)	3C = 8 (203)	4 (102)	$2\frac{2}{3}$ (68)	8 (203)
	$\frac{1}{2}$ (13)	$3\frac{1}{2}$ (89)	$2\frac{3}{16}$ (56)	$7\frac{1}{2}$ (191)				
Norman	$\frac{3}{8}$ (9.5)	$3\frac{5}{8}$ (92)	$2\frac{1}{4}$ (57)	$11\frac{3}{8}$ (295)	3C = 8 (203)	4 (102)	$2\frac{2}{3}$ (68)	12 (305)
	$\frac{1}{2}$ (12.7)	$3\frac{1}{2}$ (89)	$2\frac{3}{16}$ (56)	$11\frac{1}{2}$ (292)				
Roman	$\frac{3}{8}$ (9.5)	$3\frac{5}{8}$ (92)	$1\frac{5}{8}$ (41)	$11\frac{3}{8}$ (295)	2C = 4 (102)	4 (102)	2 (51)	12 (305)
	$\frac{1}{2}$ (12.7)	$3\frac{1}{2}$ (89)	$1\frac{1}{2}$ (38)	$11\frac{1}{2}$ (292)				
Engineer Modular	$\frac{3}{8}$ (9.5)	$3\frac{5}{8}$ (92)	$2\frac{13}{16}$ (71)	$7\frac{5}{8}$ (194)	5C = 16 (406)	4 (102)	$3\frac{1}{5}$ (81)	8 (203)
	$\frac{1}{2}$ (12.7)	$3\frac{1}{2}$ (89)	$2\frac{11}{16}$ (68)	$7\frac{1}{2}$ (191)				
Economy	$\frac{3}{8}$ (9.5)	$3\frac{5}{8}$ (92)	$3\frac{5}{8}$ (92)	$7\frac{5}{8}$ (194)	1C = 4 (102)	4 (102)	4 (102)	8 (203)
	$\frac{1}{2}$ (12.7)	$3\frac{1}{2}$ (89)	$3\frac{1}{2}$ (89)	$7\frac{1}{2}$ (191)				
Utility	$\frac{3}{8}$ (9.5)	$3\frac{5}{8}$ (92)	$3\frac{3}{8}$ (92)	$11\frac{3}{8}$ (295)	1C = 4 (102)	4 (102)	4 (102)	12 (305)
	$\frac{1}{2}$ (12.7)	$3\frac{1}{2}$ (89)	$3\frac{1}{2}$ (89)	$11\frac{1}{2}$ (292)				
SCR	$\frac{1}{2}$ (12.7)	$5\frac{1}{2}$ (140)	$2\frac{1}{8}$ (54)	$11\frac{1}{2}$ (292)	3C = 8 (203)	6 (152)	$2\frac{2}{3}$ (68)	12 (305)

Preferred SI Dimensions for Masonry

Nominal Height (H) × Length (L)	Vertical Coursing (C)
---------------------------------	-----------------------

50 × 300 mm	[2C = 100]
-------------	------------

67 × 200 mm	[3C = 200]
67 × 300 mm	

75 × 200 mm	[4C = 300]
75 × 300 mm	

80 × 200 mm	[5C = 400]
80 × 300 mm	

100 × 200 mm	[1C = 100]
100 × 300 mm	
100 × 400 mm	

133 × 200 mm	[3C = 400]
133 × 300 mm	
133 × 400 mm	

150 × 300 mm	[2C = 300]
150 × 400 mm	

200 × 200 mm	[1C = 200]
200 × 300 mm	
200 × 400 mm	

300 × 300 mm	[1C = 300]
--------------	------------

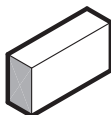
Acceptable Length Substitutions for Flexibility

200 mm	(100 mm)
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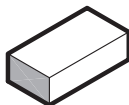
300 mm	(100 mm, 150 mm, 200 mm, 250 mm)
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400 mm	(100 mm, 200 mm, 300 mm)
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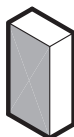
Orientations



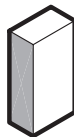
Rowlock



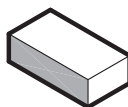
Header



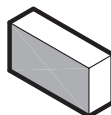
Sailor



Soldier

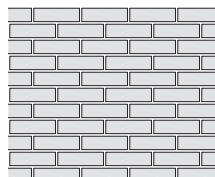


Stretcher

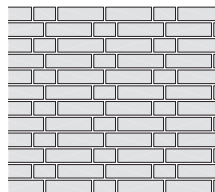


Shiner

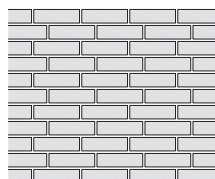
Bond Types



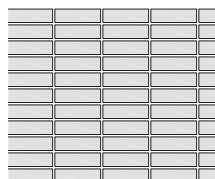
Running Bond



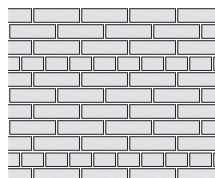
Flemish Monk Bond



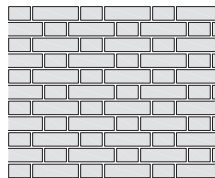
1/3 Running Bond



Stack Bond



Common Bond



Flemish Bond

Standard Modular Brick Coursing

no. of courses		no. of courses	
	9'-4" (2 845)		18'-8" (5 690)
42	8'-8" (2 642)	84	18'-0" (5 486)
41		83	
40		82	
39	8'-0" (2 438)	81	17'-4" (5 283)
38		80	
37		79	
36	7'-4" (2 235)	78	16'-8" (5 080)
35		77	
34		76	
33	6'-8" (2 032)	75	16'-0" (4 877)
32		74	
31		73	
30	6'-0" (1 829)	72	15'-4" (4 674)
29		71	
28		70	
27	5'-4" (1 626)	69	14'-8" (4 470)
26		68	
25		67	
24	4'-8" (1 422)	66	14'-0" (4 267)
23		65	
22		64	
21	4'-0" (1 219)	63	13'-4" (4 064)
20		62	
19		61	
18	3'-4" (1 016)	60	12'-8" (3 861)
17		59	
16		58	
15	2'-8" (813)	57	12'-0" (3 658)
14		56	
13		55	
12	2'-0" (610)	54	11'-4" (3 454)
11		53	
10		52	
9	1'-4" (406)	51	10'-8" (3 251)
8		50	
7		49	
6	8" (203)	48	10'-0" (3 048)
5		47	
4		46	
3		45	9'-4" (2 845)
2		44	
1		43	

Mortar

Mortar adheres masonry units together, cushions them while mediating their surface irregularities, and provides a watertight seal. Composed of portland cement, hydrated lime, an inert aggregate (generally sand), and water, there are four basic types of mortar:

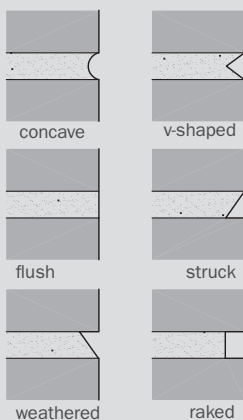
M: High strength (masonry below grade, or subjected to severe frost or to high lateral or compressive loads)

S: Medium-high strength (masonry subjected to normal compressive loads, but requiring high flexural bond strength)

N: Medium strength (masonry above grade, for general use)

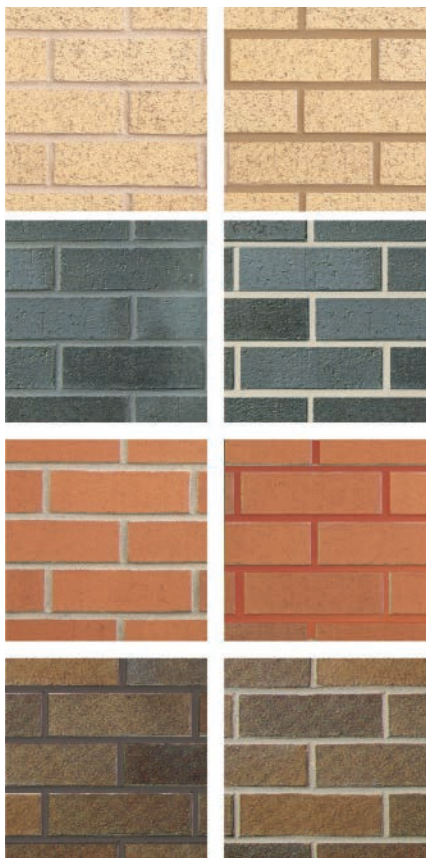
O: Medium-low strength (masonry in non-load-bearing interior walls and partitions)

Mortar Joints



Colors

Bricks come in numerous textures and patterns, and both bricks and mortar are available in almost endless varieties of color (especially if either is custom produced). Coordination of brick and mortar colors can be an effective way to achieve different qualities within one brick type and color. Matching mortar to brick color, for example, produces a more monolithic look for the wall. Similarly, darker mortars can make a wall feel darker overall, and lighter mortars can make it feel lighter. Full-scale mockups are helpful for testing color combinations.



CONCRETE MASONRY UNITS

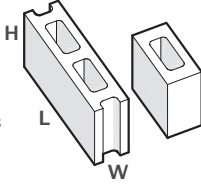
CMUs (also called concrete blocks) are available as bricks, large hollow stretcher units, and large solid units. The cores of hollow units can receive grout and reinforcing steel, making them a common element in masonry bearing-wall construction, either alone or as a backup for other cladding material. Like bricks, CMUs have nominal dimensions and accommodate mortar joints; 8" (203) nominal block heights correspond to three brick courses.

Typical Standard Sizes (W × H × L)

4" Block

4 × 8 × 16
(102 × 203 × 406)

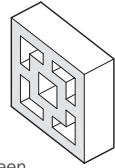
3⁵/₈ × 7⁵/₈ × 15⁵/₈
(92 × 194 × 397)



4 × 8 × 8
(102 × 203 × 203) nominal

3⁵/₈ × 7⁵/₈ × 7⁵/₈
(92 × 194 × 194)

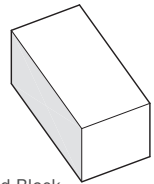
Other Shapes



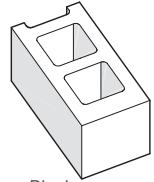
Screen



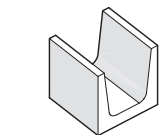
Brick



Solid Block



Corner Block

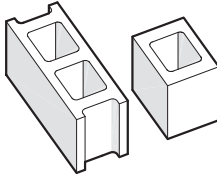


Bond Beam

6" Block

6 × 8 × 16
(152 × 203 × 406)

5⁵/₈ × 7⁵/₈ × 15⁵/₈
(143 × 194 × 397)



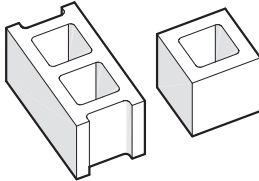
6 × 8 × 8
(152 × 203 × 203)

5⁵/₈ × 7⁵/₈ × 7⁵/₈
(143 × 194 × 194)

8" Block

8 × 8 × 16
(203 × 203 × 406)

7⁵/₈ × 7⁵/₈ × 15⁵/₈
(194 × 194 × 397)



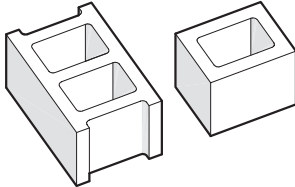
8 × 8 × 8
(203 × 203 × 203)

7⁵/₈ × 7⁵/₈ × 7⁵/₈
(194 × 194 × 194)

10" Block

10 × 8 × 16
(254 × 203 × 406)

9⁵/₈ × 7⁵/₈ × 15⁵/₈
(244 × 194 × 397)



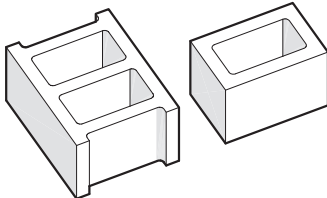
10 × 8 × 8
(254 × 203 × 203)

9⁵/₈ × 7⁵/₈ × 7⁵/₈
(244 × 194 × 194)

12" Block

12 × 8 × 16
(305 × 203 × 406)

11⁵/₈ × 7⁵/₈ × 15⁵/₈
(295 × 194 × 397)



12 × 8 × 8
(305 × 203 × 203)

11⁵/₈ × 7⁵/₈ × 7⁵/₈
(295 × 194 × 194)

All sizes may also be 4" (102) high and 8" (203), 12" (305), or 24" (610) long.

CMU Production

To produce CMUs, a stiff concrete mixture is placed into molds and vibrated. The wet blocks are then removed from the molds and steam cured.

Fire-resistance ratings for CMUs vary depending on the aggregate type used in the concrete and the size of the block.

CMU Grades

N: General use above and below grade

S: Use above grade only; good where wall is not exposed to weather; if used on exterior, wall must have weather-protective coating

CMU Types

I: Moisture-controlled, for use where shrinkage of units would cause cracking

II: Not moisture-controlled

CMU Weights

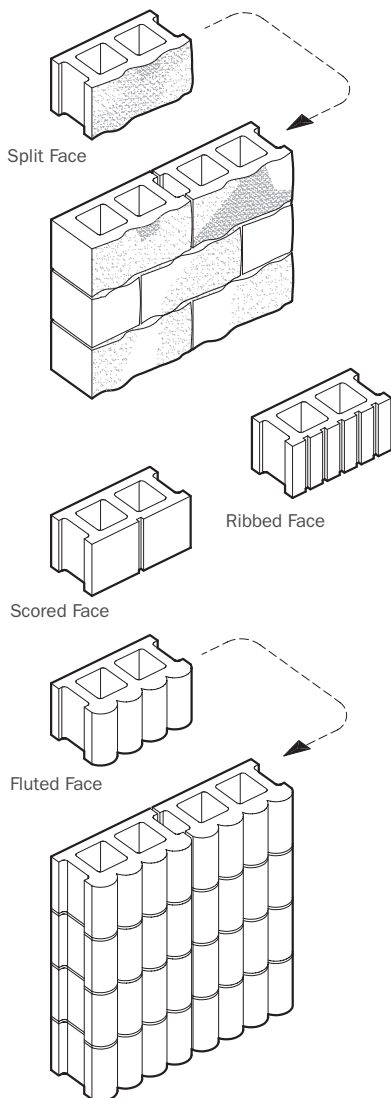
Normal: Made from concrete weighing more than 125 lb. per cu. ft. (pcf) (2 000 kg/m³)

Medium: Made from concrete weighing 105–25 pcf (1 680–2 000 kg/m³)

Light: Made from concrete weighing 105 pcf (1 680 kg/m³) or less

Decorative CMUs

Concrete blocks are easily produced in many different shapes, surface textures, and colors, allowing for a variety of wall surfaces. Numerous standard decorative units exist and units may be custom designed.

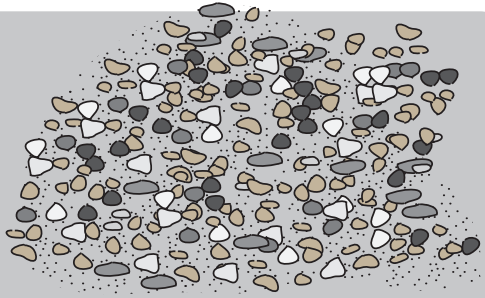


CONCRETE

Concrete comprises a mixture of aggregate (sand and gravel), portland cement, and water. Because these elements are found almost everywhere, concrete is employed as a construction material throughout the world. When combined correctly with steel reinforcing, concrete becomes virtually indestructible structurally and is generally not susceptible to burning or rotting. It can be shaped into almost any form.

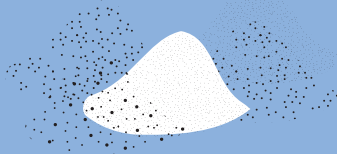
COMPOSITION

Aggregate: Mixture of sand and gravel. Gravel sizes can range from dust to 2 1/2" but should not exceed one-quarter of the thickness of the unit being poured (that is, for a 4" slab, gravel should not be greater than 1"). Rounded fragments are preferred. Larger gravel yields more cost-effective concrete and fewer problems from shrinkage.



Portland cement: Chemical combination of lime, silicon, aluminum, iron, small amounts of other ingredients, and gypsum, which is added in the final grinding process. Exact ingredients vary by region, based on local availability.

There are five basic types of portland cement.



Water: Clean and impurity free.



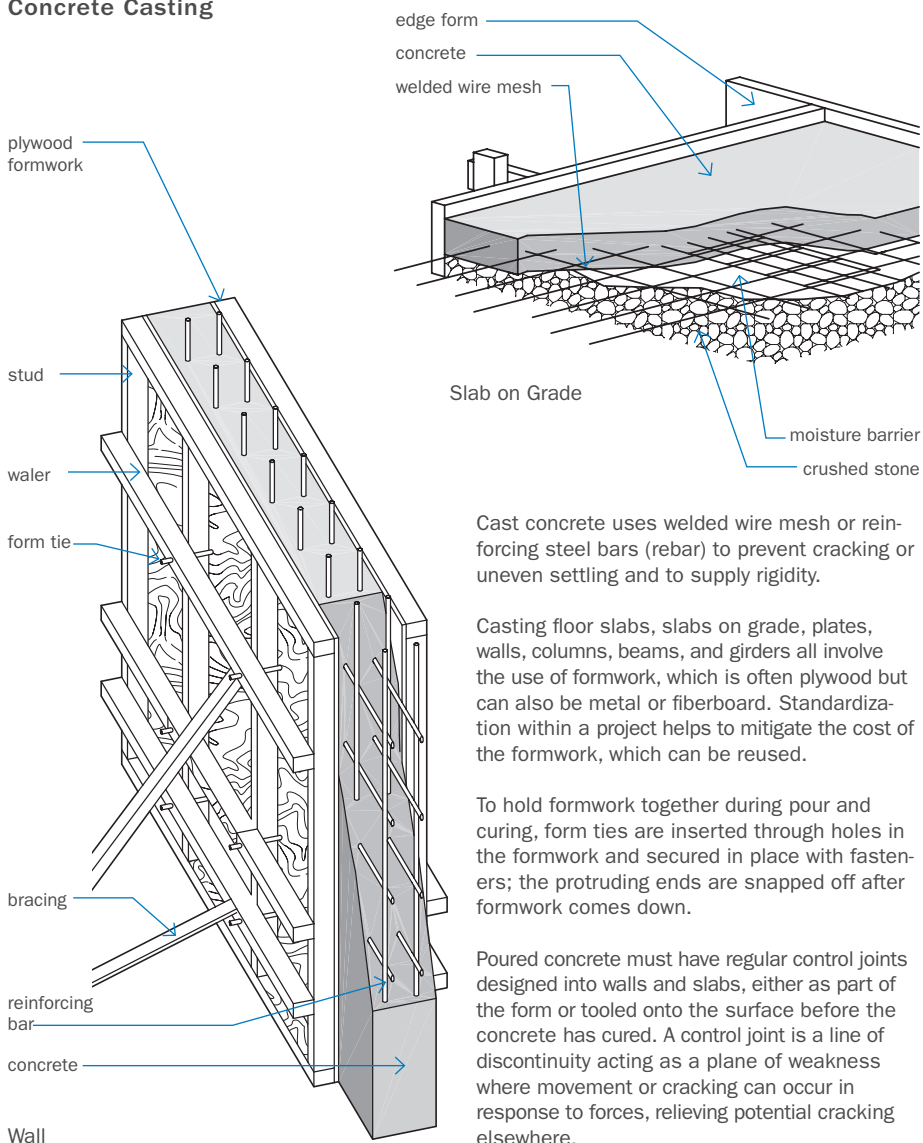
Air: Millions of tiny air bubbles in the mixture make up a fourth component of some mixes of concrete. Air makes the concrete lighter and more able to withstand the effects of freezing and thawing, and is thus useful in cold climates.



SITECAST CONCRETE FRAMING

Sitecast concrete is concrete that is cast into forms on the building site. It can be cast into any shape for which a form can be made; however, the work and time involved in building formwork, reinforcing and pouring the concrete, waiting for the concrete to cure, and dismantling the formwork makes sitecast concrete slower to erect than precast concrete or structural steel.

Concrete Casting



Cast concrete uses welded wire mesh or reinforcing steel bars (rebar) to prevent cracking or uneven settling and to supply rigidity.

Casting floor slabs, slabs on grade, plates, walls, columns, beams, and girders all involve the use of formwork, which is often plywood but can also be metal or fiberboard. Standardization within a project helps to mitigate the cost of the formwork, which can be reused.

To hold formwork together during pour and curing, form ties are inserted through holes in the formwork and secured in place with fasteners; the protruding ends are snapped off after formwork comes down.

Poured concrete must have regular control joints designed into walls and slabs, either as part of the form or tooled onto the surface before the concrete has cured. A control joint is a line of discontinuity acting as a plane of weakness where movement or cracking can occur in response to forces, relieving potential cracking elsewhere.

PLACING AND CURING

As concrete is poured and placed, care must be taken to ensure that it is not subjected to excessive vibration or sudden vertical drops, which could cause segregation of the materials (course aggregate to the bottom, water and cement to the top). For this reason, vertical transportation should be done with drop chutes. If the concrete must travel excessive distances from the mixer to the formwork, it should be pumped through hoses, not transported in the formwork.

Concrete cures by hydration, as a binding chemical combination of the cement and water; it must be kept moist during this period, generally twenty-eight days, before it is adequately cured. Surfaces may be kept moist by spraying them with water or a curing compound or by covering them with moisture-resistant sheets.

Admixtures

Other ingredients may be added to concrete for various desired effects.

Accelerating admixtures: Promote faster curing (may be used in cold weather, when curing is slowed down).

Air-entraining admixtures: Increase workability of wet concrete, aid in reducing freeze-thaw damage, and may produce lightweight, thermal-insulated concrete.

Blast furnace slag: Similar to fly ash in effect.

Coloring agents: Dyes and pigments.

Corrosion inhibitors: Reduce corrosion of reinforcing steel.

Fibrous admixtures: Short glass, steel, or polypropylene fibers that act as reinforcing.

Fly ash: Improves workability of wet concrete while also increasing strength and sulfate resistance, and decreases permeability, temperature rises, and needed water.

Pozzolans: Improve workability, reduce internal temperatures while curing, and reduce reactivity caused by sulfates.

Retarding admixtures: Promote slower curing and allow more time for working with wet concrete.

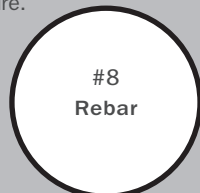
Silica fume: Produces extremely high strength concrete with very low permeability.

Super-plasticizers: High-range water-reducing admixtures that turn stiff concrete into flowing liquid for placing in difficult sites.

Water-reducing admixtures: Allow for more workability with less water in the mix.

Reinforcing Steel

Without reinforcing, concrete would have few or no structural uses. Fortunately, steel and concrete are chemically compatible and have a similar rate of dimensional change due to temperature.



FINISHES

Concrete can be finished in a variety of ways, allowing it to be used on virtually any surface in almost any kind of space.

As cast: Concrete remains as it is after removal of forms and often bears the imprint of wood grain from the plywood.

Blasted: Various degrees of sandblasting smooth the surface while exposing successive levels of cement, sand, and aggregate.

Chemically retarded: Chemicals are applied to the surface to expose the aggregate.

Mechanically fractured: Tooling, hammering, jackhammering, and scaling produce varied aggregate-exposing effects.

Polished: Heavy-duty polishing machines polish the surface to a high gloss, with or without polishing compounds.

Sealed: Acrylic resin helps protect concrete from spalling (chipping or flaking caused by improper drainage or venting and freeze/thaw damage), dusting, efflorescence (whitening caused by water leeching soluble salts out of concrete and depositing them on the surface), stains, deicing salts, and abrasion.

Color

Colored concrete provides numerous design opportunities. It is generally achieved in one of two ways:

Integral coloring: Color is added to the wet concrete or mixed in at the jobsite—in either case, the color is distributed throughout the concrete. Because so much concrete is involved, colors are limited to earth tones and pastels. Once cured, the surface is sealed, which provides protection and a sheen that enhances the color.

Dry-shake color hardeners: Color hardeners are broadcast onto freshly placed concrete and troweled into the surface. The hardeners produce a dense and durable surface. Because the color is concentrated on top of the concrete, more vibrant and intense tones are possible. Sealers applied after curing further accentuate the richness of the color.

As in all natural materials, variations in color outcome will occur. The base color of the cement determines the ranges possible.

Reinforcing bars: Bars come in the following sizes: 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 18. Nominal diameters of #8 and lower are the bar number in eighths of an inch; that is, #3 is $\frac{3}{8}$ " (9.52). Nominal diameters of #9 and higher are slightly larger.

Welded wire fabric: Reinforcing steel is formed into a grid of wires or round bars 2"–12" (51–305) on center. Lighter styles are used in slabs on grade and some precast elements; heavier styles may be used in walls and structural slabs.

Chapter 3: Metals

Metals play an enormous role in almost every component of many projects and building types, from structural steel to sheet-metal ductwork, from drywall partition studs to oxides used as paint pigments. Metals of most varieties occur in nature as oxide ores, which can be mined and worked to extract and refine the metals, separating them from other elements and impurities. Metals fall under two broad categories: ferrous (containing iron) and nonferrous. Ferrous metals are generally stronger, more abundant, and easier to refine, but they have a tendency to rust. Nonferrous metals tend to be easier to work and most form their own thin oxide layers that protect them from corrosion.

MODIFYING METAL PROPERTIES

Most metals in their chemically pure and natural form are not very strong. To be suitable for construction and other functions, their properties must be altered, which can be done in several ways, often dependent on the proposed use of the metal.

Alloys

Metals are mixed with other elements, usually other metals, to create an alloy. For example, iron mixed with small amounts of carbon produces steel. Generally, the alloy is stronger than its primary metal ingredient. In addition to improved strength and workability, alloys provide self-protecting oxide layers.

Heat-Treated Metals

Tempering: Steel is heated at a moderate rate and slowly cooled, producing a harder and stronger metal.

Annealing: Steel and sometimes aluminum alloys are heated to very high temperatures and cooled slowly, softening the metal so that it is easier to work.

Cold-Worked Metals

At room temperature, metals are rolled thin, beaten, or drawn, making them stronger but more brittle by altering their crystalline structures. Cold-worked metals may be reversed by annealing.

Cold rolling: Metal is squeezed between rollers.

Drawing: Drawing metal through increasingly smaller orifices produces the wires and cables used to prestress concrete, which have five times the structural strength of steel.

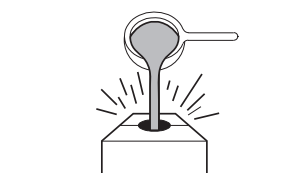
Coated Metals

Anodizing: A thin oxide layer of controlled color and consistency is electrolytically added to aluminum to improve its surface appearance.

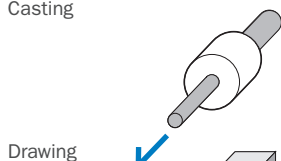
Electroplating: Chromium and cadmium are coated onto steel to protect it from oxidation and improve its appearance.

Galvanizing: Steel is coated with zinc to protect it against corrosion.

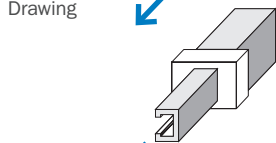
Other coatings: Coatings can include paints, lacquers, powders, fluoropolymers, and porcelain enamel.



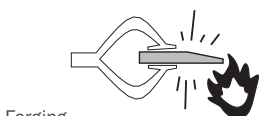
Casting



Drawing



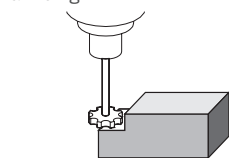
Extrusion



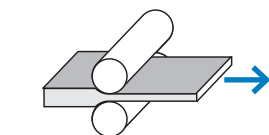
Forging



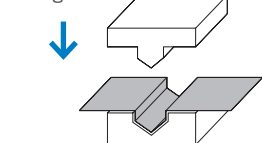
Grinding



Machining



Rolling



Stamping

FABRICATION TECHNIQUES

Casting: Molten metal is poured into a shaped mold. The metal produced is weak but can be made into many shapes, such as faucets or hardware.

Drawing: Wires are produced by pulling metal through increasingly smaller holes.

Extrusion: Heated (but not molten) metal is squeezed through a die, producing a long metal piece with a shaped profile.

Forging: Metal is heated until flexible and then bent into a desired shape. This process improves structural performance by imparting a grain orientation onto the metal.

Grinding: Machines grind and polish metal to create flat, finished surfaces.

Machining: Material is cut away to achieve a desired shape. Processes include drilling, milling (with a rotating wheel), lathing (for cylindrical shapes), sawing, shearing, and punching. Sheet metal is cut with shears and folded on brakes.

Rolling: Metal is squeezed between rollers. Hot rolling, unlike cold, does not increase the strength of metal.

Stamping: Sheet metal is squeezed between matching dies to give it shape and texture.

Joining Metals

Welding: In this high-temperature fusion, a gas flame or electric arc melts two metals and allows the point of connection to flow together with additional molten metal from a welding rod. Welded connections are as strong as the metals they join and can be used for structural work.

Brazing and soldering: In these lower-temperature processes, the two metals are not themselves melted but joined with the solder of a metal with a lower melting point: brass or bronze are used in brazing, lead-tin alloy is used in soldering. Too weak for structural connections, brazing and soldering are used for plumbing pipes and roofing.

Mechanical methods: Metals can also be drilled or punched with holes, through which screws, bolts, or rivets are inserted.

Interlocking and folding: Sheet metal can be joined by such connections.

METAL TYPES

Ferrous

Cast iron: Very brittle with high compressive strength and ability to absorb vibrations; ideal for gratings and stair components but too brittle for structural work.

Malleable iron: Produced by casting, reheating, and slowly cooling to improve workability; similar to cast iron in use.

Mild steel: Ordinary structural steel with a low carbon content.

Stainless steel: Produced by alloying with other metals, primarily chromium or nickel for corrosion resistance and molybdenum when maximum resistance is required (in sea water, for example). Though harder to form and machine than mild steel, its uses are many, including flashing, coping, fasteners, anchors, hardware, and finishes that can range from matte to mirror polish.

Steel: Iron with low amounts of carbon (carbon increases strength, but decreases ductility and welding capabilities); used for structural components, studs, joists, and fasteners, and in decorative work.

Wrought iron: Soft and easily worked, with high corrosion resistance, making it ideal for use below grade. Most often cast or worked into bars, pipes, or sheets, and fashioned for ornamental purposes. Other metals like steel have virtually replaced it today.

Steel Alloys

Aluminum: Hardens surfaces

Chromium and cadmium: Resists corrosion

Copper: Resists atmospheric corrosion

Manganese: Increases hardness and helps to resist wear

Molybdenum: Often combined with other alloys, increases corrosion resistance and raises tensile strength

Nickel: Increases tensile strength and resists corrosion

Silicon: Increases strength and resists oxidation

Sulfur: Allows for free machining of mild steels

Titanium: Prevents intergranular corrosion in stainless steel

Tungsten: With vanadium and cobalt, increases hardness and resists abrasions

Aluminum Alloy Series

Wrought		Cast	
Series	Alloying Element	Series	Alloying Element
1000	pure aluminum	100.0	pure aluminum
2000	copper	200.0	copper
3000	manganese	300.0	silicon plus copper and/or magnesium
4000	silicon	400.0	silicon
5000	magnesium	500.0	magnesium
6000	magnesium and silicon	600.0	unused series
7000	zinc	700.0	zinc
8000	other elements	800.0	tin
		900.0	other elements

1st digit is series no.; 2nd is modification of alloy; 3rd/4th are arbitrary identifiers

1st digit is series no.; 2nd/3rd are arbitrary identifiers; no. after decimal is casting if 0, ingot if 1 or 2

Nonferrous

Aluminum: When pure, it resists corrosion well, but is soft and lacks strength; with alloys, it can achieve various levels of strength and stiffness, at one-third the density of steel, and can be hot- or cold-rolled, cast, drawn, extruded, forged, or stamped. Sheets or foil, when polished to a mirror finish, have extremely high levels of light and heat reflectivity. Its uses include curtain wall components, ductwork, flashing, roofing, window and door frames, grills, siding, hardware, wiring, and coatings for other metals. Aluminum powder may be added to metallic paints and its oxide acts as an abrasive in sandpaper.

Brass: Alloy of copper, zinc, and other metals; can be polished to a high luster and is mostly used for weather stripping, ornamental work, and finish hardware.

Bronze: Alloy of copper and tin that resists corrosion; used for weather stripping, hardware, and ornamental work.

Cadmium: Similar to zinc; usually electroplated onto steel.

Chromium: Very hard and will not corrode in air; like nickel, often used as an alloy to achieve a bright polish and is excellent for plating.

Copper: Ductile and corrosion-, impact-, and fatigue-resistant; it has high thermal and electrical conductivity, and can be cast, drawn, extruded, hot-, or cold-rolled. Widely employed as an alloy with other metals, it can also be used for electrical wiring, flashing, roofing, and piping.

Lead: Extremely dense, corrosion resistant, limp, soft, and easy to work; most often combined with alloys to improve hardness and strength. Foil or sheets are ideal for waterproofing, blocking sound and vibrations, and shielding against radiation. Can also be used as roofing and flashing, or to coat copper sheets (lead-coated copper) for roofing and flashing. High toxicity of vapors and dust have made its use less common.

Magnesium: Strong and lightweight; as an alloy, serves to increase strength and corrosion resistance in aluminum. Often used in aircraft, but too expensive for most construction.

Tin: Soft and ductile; used in terneplate (80 percent lead, 20 percent tin) for plating steel.

Titanium: Low density and high strength; used in numerous alloys and its oxide has replaced lead in many paints.

Zinc: Corrosion resistant in water and air, but very brittle and low in strength. Primarily used in galvanizing steel to keep it from rusting; also electroplated onto other metals as an alloy. Other functions include flashing, roofing, hardware, and die-casting.

GALVANIC ACTION

Galvanic action is corrosion that occurs between metals under the following conditions: There exist two electrochemically dissimilar metals, an electrically conductive path between the two metals, and a conductive path for metal ions to move from the less noble metal to the more noble one. A good understanding of the material compatibilities in the galvanic series will minimize corrosion in design. The galvanic series lists metals from least noble (anodic, or most reactive to corrosion) to most noble (cathodic, or least reactive to corrosion). Generally, the farther apart two metals are on the list, the greater the corrosion of the less noble one. Therefore, combinations of metals that will be in electrical contact should be selected from groups as close together in the series as possible.

Note that the ranking of metals may differ, based on variations in alloy composition and nonuniform conditions. When specifying and detailing metals, always consult the manufacturer of the metal product.

Galvanic Series

+

Anode

Magnesium, magnesium alloys

Zinc, zinc alloys and plates

Zinc (hot-dipped), galvanized steel

Aluminum (non-silicon cast alloys), cadmium

Aluminum (wrought alloys, silicon cast)

Iron (wrought, malleable), plain carbon and low-alloy steel

Aluminum (wrought alloys —2000 series)

Lead (solid, plated), lead alloys

Tin plate, tin-lead solder

Chromium plate

High brasses and bronzes

Brasses and bronzes

Copper, low brasses and bronzes, silver solder, copper-nickel alloys

Nickel, titanium alloys, monel

Silver

Gold, platinum

Cathode

-

The series listed here is for general information only and does not consider the anodic index of any metals. The anodic index (V) of each metal determines more precisely its compatibility thresholds with other metals.

Accurate anodic index numbers should be obtained from the specific metal manufacturer.

GAUGES AND MILS

Sheet metal thicknesses have long been expressed in terms of gauge (ga.), an antiquated term based on weight (originally for reasons of taxation) and not a reference to the precise thickness of a sheet. Thus, a sheet of mild steel and one of galvanized steel may have the same gauge but different thicknesses. As the gauge number increases, the sheet becomes thinner; sheets thicker than 1/4" (6), or about 3-gauge, are referred to as plates.

Most steel manufacturers are adapting to mils. This straightforward system allows the actual thickness of the sheet to define its mil designation.

There is no equation for a strict translation from gauge to mil thickness; however—for reference purposes only—many common mil sizes may be associated with specific gauge sizes.

Gauge Reference Chart

Mil (μm)	Gauge (ga.)	Standard Steel		Galvanized Steel		Aluminum	
		in.	(mm)	in.	(mm)	in.	(mm)
	3	0.2391	(6.073)			0.2294	(5.827)
	4	0.2242	(5.695)			0.2043	(5.189)
	5	0.2092	(5.314)			0.1819	(4.620)
	6	0.1943	(4.935)			0.1620	(4.115)
	7	0.1793	(4.554)			0.1443	(3.665)
	8	0.1644	(4.176)			0.1285	(3.264)
	9	0.1495	(3.797)	0.1532	(3.891)	0.1144	(2.906)
118	10	0.1345	(3.416)	0.1382	(3.510)	0.1019	(2.588)
	11	0.1196	(3.030)	0.1233	(3.132)	0.0907	(2.304)
97	12	0.1046	(2.657)	0.1084	(2.753)	0.0808	(2.052)
	13	0.0897	(2.278)	0.0934	(2.372)	0.0720	(1.829)
68	14	0.0747	(1.879)	0.0785	(1.994)	0.0641	(1.628)
	15	0.0673	(1.709)	0.0710	(1.803)	0.0571	(1.450)
54	16	0.0598	(1.519)	0.0635	(1.613)	0.0508	(1.290)
	17	0.0538	(1.367)	0.0575	(1.461)	0.0453	(1.151)
43	18	0.0478	(1.214)	0.0516	(1.311)	0.0403	(1.024)
	19	0.0418	(1.062)	0.0456	(1.158)	0.0359	(0.912)
30 33	20	0.0359	(0.912)	0.0396	(1.006)	0.0320	(0.813)
	21	0.0329	(0.836)	0.0366	(0.930)	0.0285	(0.724)
27	22	0.0299	(0.759)	0.0336	(0.853)	0.0253	(0.643)
	23	0.0269	(0.683)	0.0306	(0.777)	0.0226	(0.574)
	24	0.0239	(0.607)	0.0276	(0.701)	0.0201	(0.511)
18	25	0.0209	(0.531)	0.0247	(0.627)	0.0179	(0.455)
	26	0.0179	(0.455)	0.0217	(0.551)	0.0159	(0.404)
	27	0.0164	(0.417)	0.0202	(0.513)	0.0142	(0.361)
	28	0.0149	(0.378)	0.0187	(0.475)	0.0126	(0.320)
	29	0.0135	(0.343)	0.0172	(0.437)	0.0113	(0.287)
	30	0.0120	(0.305)	0.0157	(0.399)	0.0100	(0.254)
	31	0.0105	(0.267)	0.0142	(0.361)	0.0089	(0.226)
	32	0.0097	(0.246)	0.0134	(0.340)	0.0080	(0.203)
	33	0.0090	(0.229)			0.0071	(0.180)
	34	0.0082	(0.208)			0.0063	(0.160)
	35	0.0075	(0.191)			0.0056	(0.142)
	36	0.0067	(0.170)				

33 mil is considered the thinnest material allowable for structural cold-formed steel framing

20-gauge material often comes in the following two thicknesses:

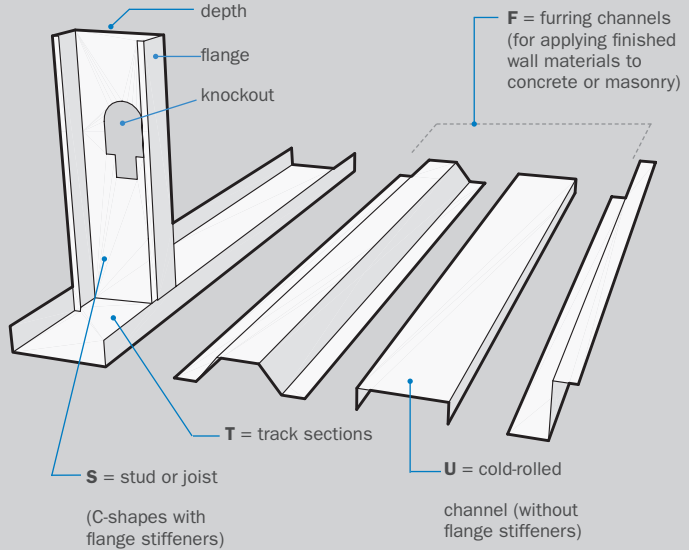
30 mil for nonstructural drywall studs;

33 mil for structural studs

18 mil is considered the thinnest material allowable for nonstructural, cold-formed steel framing

LIGHT-GAUGE FRAMING

Metal studs are generally made of cold-rolled corrosion-resistant steel in standard sizes. They work in both load-bearing and non-load-bearing capacities and as floor and roof framing elements. Studs are spaced 16" (406) or 24" (610) OC inside top and bottom tracks. Metal studs with gypsum sheathing provide greatly reduced combustibility, and can be built taller than wood stud walls. Knockouts or punchouts are provided at regular intervals to allow for bridging between studs or for the passing through of electrical conduit or plumbing.



The Steel Stud Manufacturers Association (SSMA) designations for light-gauge steel framing members are written as follows: web depth (in $1/100''$) + S, T, U, or F designation + flange width (in $1/100''$) + minimum base metal thickness (in mils).

Thus, a 250S 162-33 member is a $2\frac{1}{2}''$ ($250/100''$) stud with a flange of $1\frac{5}{8}''$ ($162/100''$), at 33 mils.

Common Metal Stud Sizes

Non-load-bearing Studs

depths: $1\frac{5}{8}''$ (41), $2\frac{1}{2}''$ (64), $3\frac{5}{8}''$ (92), 4" (102), 6" (152)
gauges [mils]: 25 [18], 22 [27], 20 [30]

Non-load-bearing Curtain Wall Studs

depths: $2\frac{1}{2}''$ (64), $3\frac{5}{8}''$ (92), 4" (102), 6" (152)
gauges [mils]: 20 [30], 18 [43], 16 [54], 14 [68]
flange: $1\frac{3}{8}''$ (35)

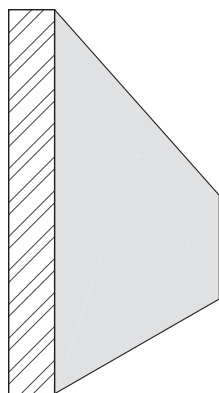
Structural C-Studs

depths: $2\frac{1}{2}''$ (64), $3\frac{5}{8}''$ (92), 4" (102), 6" (152), 8" (203), 10" (254), 12" (305)
gauges [mils]: 20 [33], 18 [43], 16 [54], 14 [68]
flange: $1\frac{5}{8}''$ (41)

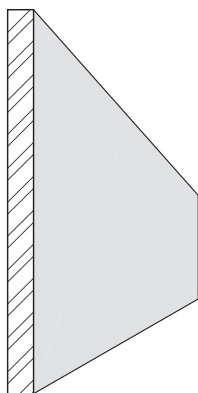
Structural Stud/Joist

depths: $2\frac{1}{2}''$ (64), $3\frac{5}{8}''$ (92), 4" (102), 6" (152), 8" (203), 10" (254), 12" (305)
gauges [mils]: 20 [33], 18 [43], 16 [54], 14 [68]
flange: 2" (51)

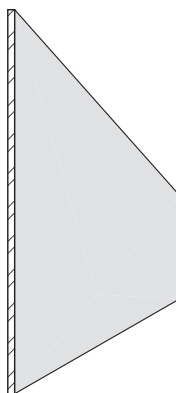
Sheet Thickness (actual size)



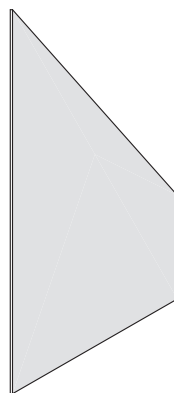
210 mils



97 mils

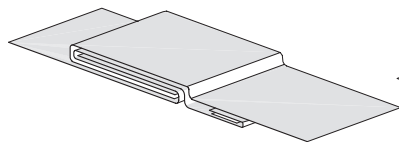


33 mils

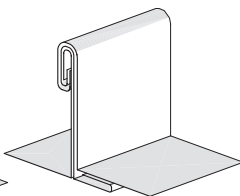


18 mils

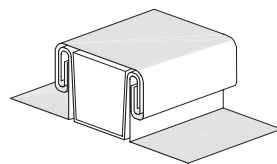
Metal Roofing Seams



Flat Seam

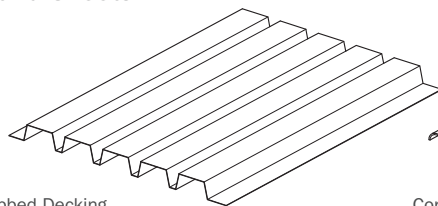


Standing Seam

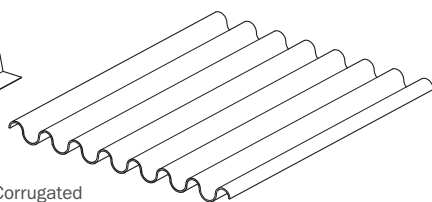


Batten Seam

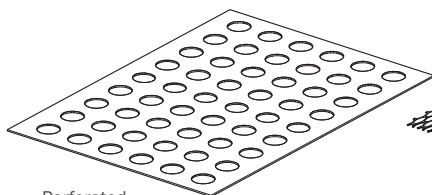
Forms and Sheets



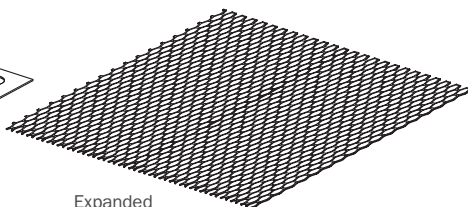
Ribbed Decking



Corrugated



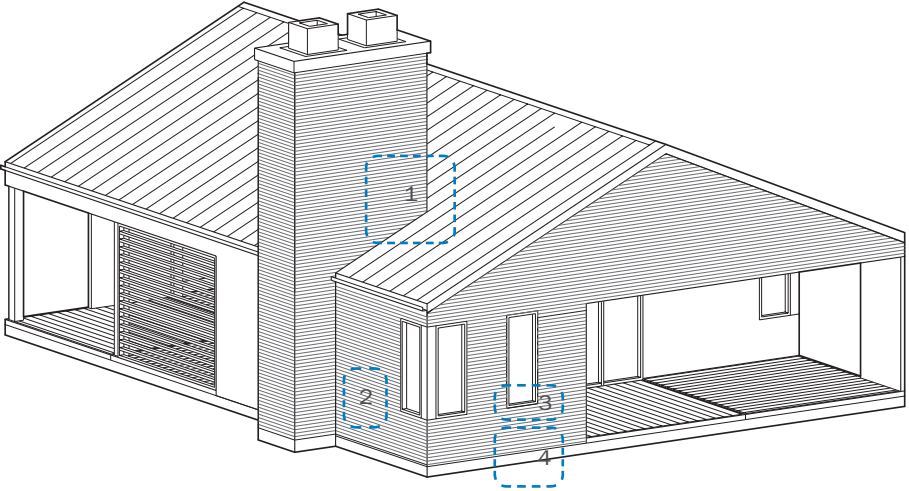
Perforated



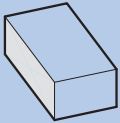
Expanded

Chapter 4: Building Enclosures

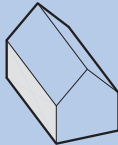
A building's enclosure systems serve many functions. Not only must they separate and protect interior from exterior, they must still allow the inside and outside to have a relationship that contributes to the most effective means of moisture, thermal, and ventilation control, all while presenting the building's public face.



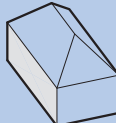
Roof Forms



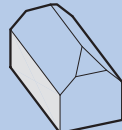
Flat



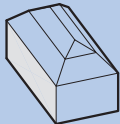
Pitched/Gable



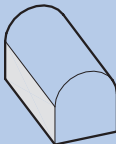
Hip



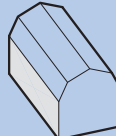
Hip Gable



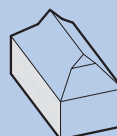
Mansard



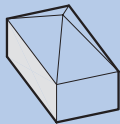
Barrel Vault



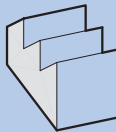
Gambrel



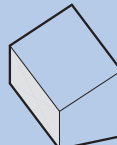
Gabled



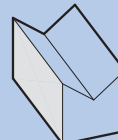
Pyramidal



Sawtooth



Shed



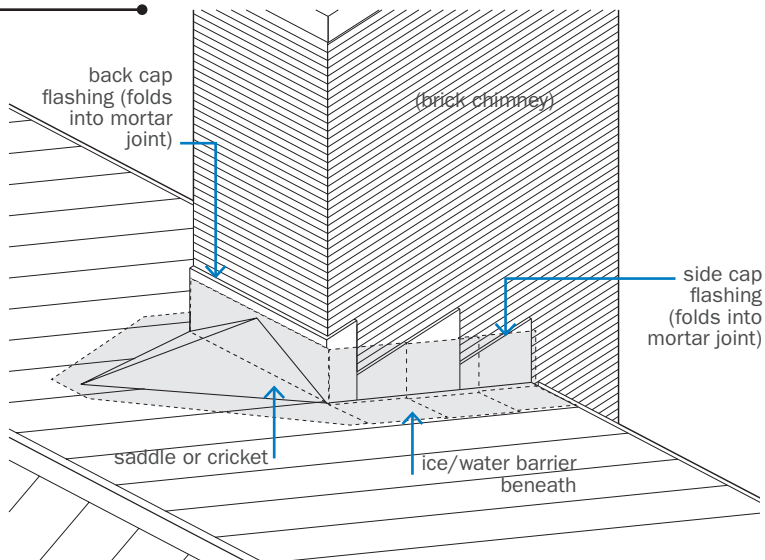
Butterfly

FLASHING

Flashing is used in several locations of a building's exterior to move water away and into the drainage system quickly and efficiently. Flashing is commonly thin sheet metal (copper, aluminum, stainless steel, or painted galvanized steel) or other impervious material such as rubber. Material choices often depend on whether the flashing will be exposed (metals are preferred) or concealed, and with which other materials it is likely to come into contact.

1. Roof

Flashing is wrapped around protruding objects such as chimneys and vents to keep water from settling into joints and seams.

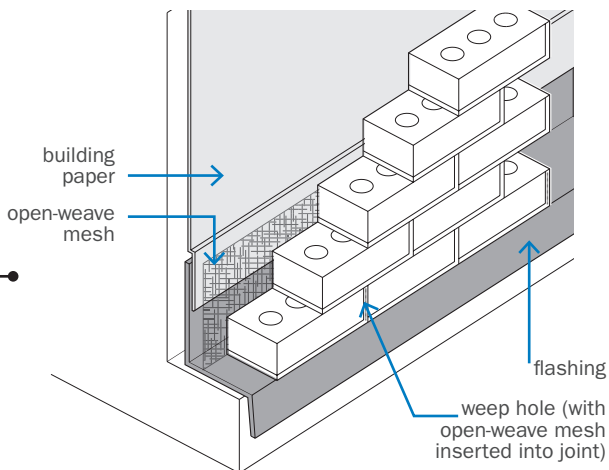


2. Wall

Flashing may prevent water from entering a wall, or may divert water that has entered a wall cavity.

3. Sill

Interruptions in a wall, such as doors and windows, are vulnerable to water penetration.

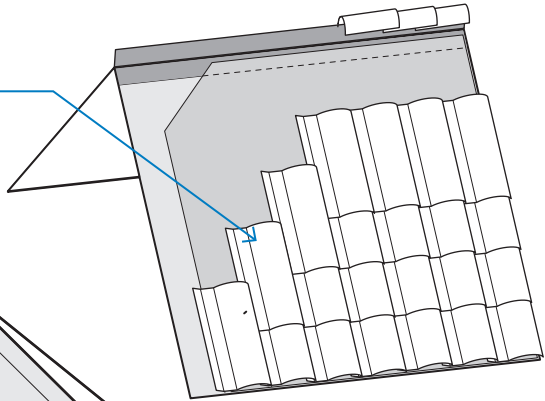


4. Base

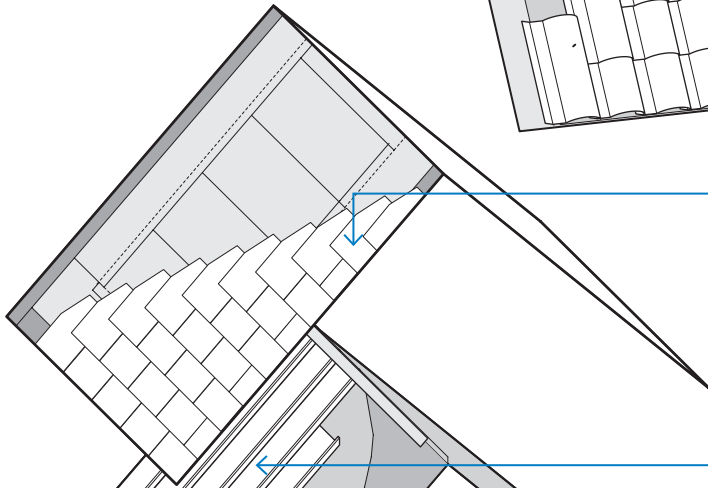
Gravity helps water escape walls down the sloped surfaces of the flashing, and out through weep holes.

ROOF SYSTEM TYPES: STEEP SLOPES

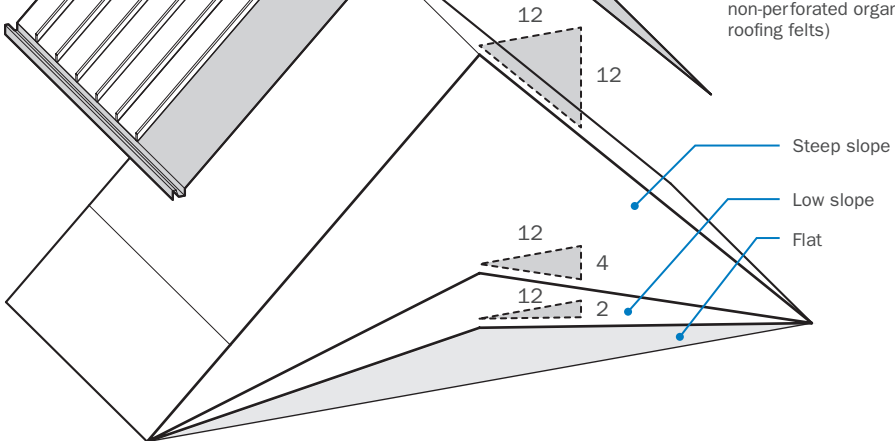
Tiles: (clay or concrete) sit on top of a weather-proofing underlayment (typically asphalt-saturated non-perforated organic roofing felts)



Shingles and shakes (asphalt, slate, wood, synthetic): sit on top of a weather-proofing underlayment (typically asphalt-saturated non-perforated organic roofing felts)



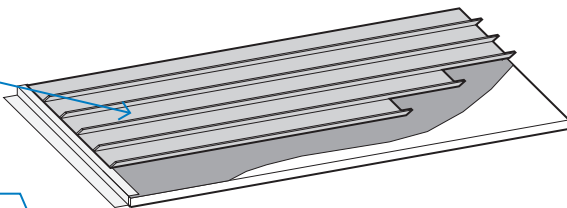
Metal: architectural metal panels sit on top of a weather-proofing underlayment (typically asphalt-saturated non-perforated organic roofing felts)



ROOF SYSTEM TYPES: LOW & FLAT SLOPES

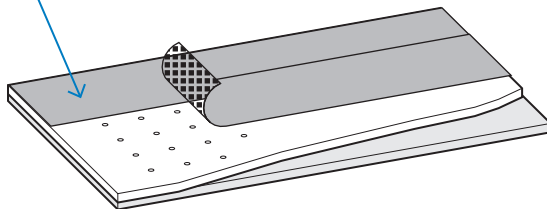
Structural metal panel:

over weather-proofing underlayment



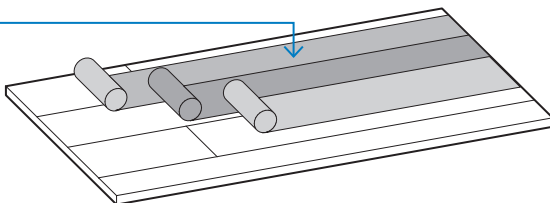
Single-ply membranes:

thermoplastic or thermoset membranes are factory-made. Methods of installing include fully-adhered, mechanically-fastened, or held down with a ballast material. Shown here, the membrane is fully adhered to the insulation, which itself is mechanically fastened to the substrate.



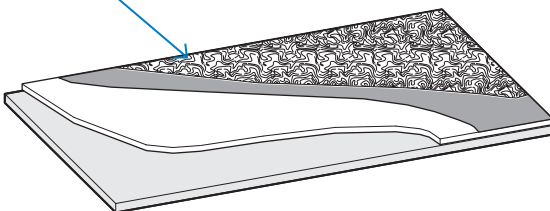
Polymer-modified bitumen sheet membranes (MB):

composed of multiple layers, and most often fully-adhered as a two-ply system.



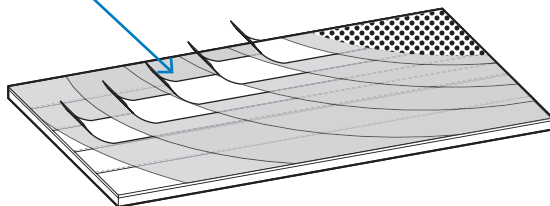
SPF (Spray polyurethane foam board):

base layer is a rigid, spray foam insulation, on top of which is a spray-applied elastomeric weather-proof coating. Sand or mineral granules may be added to this layer for reasons of durability and aesthetic concerns.



Built-up roof (BUR):

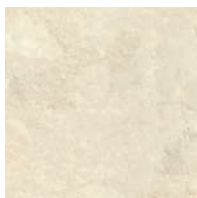
bitumen (asphalt, coal tar, or cold-applied adhesive) and reinforcing fabrics (roofing felts) are applied in alternating layers to create the membrane. Sometimes referred to as 'tar and gravel' roofs. Gravel or other minerals may be added on top.



STONE

As a building material, stone may be used in two different manners: as a masonry unit laid with mortar, similar to brick or concrete blocks, or as a thin, non-load-bearing veneer facing attached to a backup wall and structural frame. Stone colors, textures, and patterns are highly varied, as are the design and detailing of unit masonry and cladding systems.

limestone



SEDIMENTARY ROCK
(rock deposited as a result of natural action or wind)

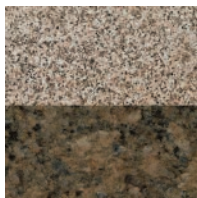
Limestone: Colors limited mostly to white, buff, and gray. Very porous and wet when quarried, though after air seasoning, quarry sap evaporates and stone becomes harder. Suitable for wall and floor surfaces, but does not accept a high polish.

sandstone



Sandstone: Colors range from buff to chocolate brown to red. Suitable for most building applications, but also does not accept a high polish.

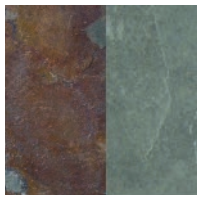
granite



IGNEOUS ROCK
(rock deposited in a molten state)

Granite: Wide range of grains and colors including gray, black, brown, red, pink, buff, and green. Nonporous and very hard. Suitable for use in the ground and with exposure to weather. Comes in many textures and may be highly polished.

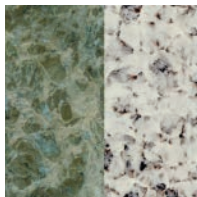
slate



METAMORPHIC ROCK
(sedimentary or igneous rock transformed into another rock type by heat or pressure)

Slate: Colors range from red and brown to grayish-green to purple and black. Sheetlike nature makes it ideal for paving, roofing, and veneer panels.

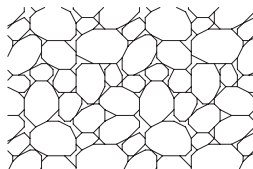
marble



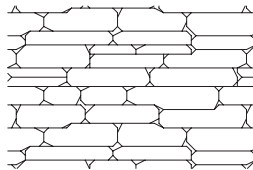
Marble: Highly varied in both color and streaking patterns. Color range includes white, black, blue, green, red, and pink, and all tones between. Suitable for use as a building stone but is most often highly polished and used as a veneer panel.

Stone masonry includes rubble stone (irregular quarried fragments), dimension stone (quarried and cut into rectangular forms called cut stone when large and ashlar when small), and flagstone (thin slabs of paving stone, irregular or cut).

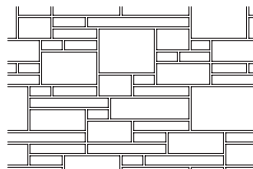
Masonry Patterns



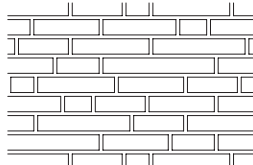
Random (Uncoursed) Rubble



Coursed Rubble



Random (Uncoursed) Ashlar



Coursed Ashlar

MASONRY BEARING WALLS

Brick, concrete block, and stone walls built as load-bearing walls will have many different characteristics, depending on whether or not they are reinforced, use more than one masonry unit type (composite wall), or are solid or cavity walls.

Reinforcing

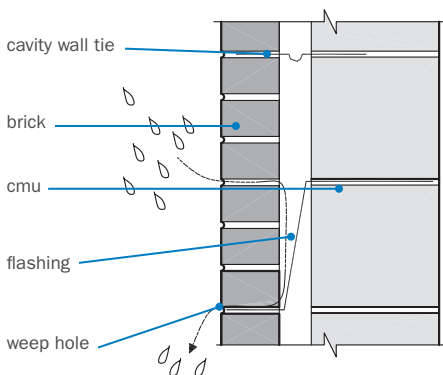
Reinforcing masonry allows the entire wall system to be thinner and taller.

Composite Walls

Composite masonry walls employ a concrete block backup with brick or stone veneer on the exterior wythe, with the two layers bonded with steel horizontal reinforcing. Masonry ties join wythes of masonry together or to supporting wood, concrete, or steel backup structures. Anchors connect masonry units to the supporting structure.

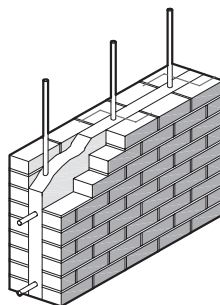
Cavity Walls

Cavity walls have an inner and outer wythe of masonry units, separated by an air space of a minimum 2" (51). Masonry ties hold the two wythes together. If rain penetrates the outer wythe, it runs down the inner surface of the outer wythe and is collected at the base with flashing materials that divert it back to the outside through weep holes.

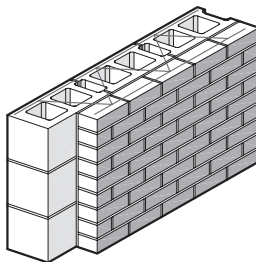


Common Wall Configurations

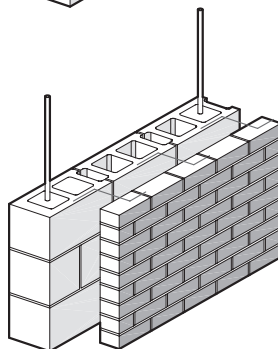
Double-wythe brick wall with concrete and steel reinforcing between



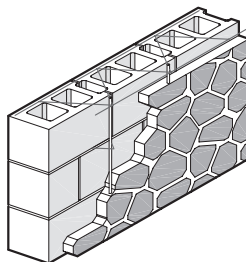
Brick wall on CMU backup (CMUs may or may not be reinforced), tied together with Z-ties



Brick and CMU cavity wall (CMU wall is reinforced)



Stone veneer on CMU backup, tied together with adjustable stone ties



EXTERIOR WALLS

Common configurations are shown here, though the combinations of backup systems and exterior cladding systems are interchangeable in many cases, with changes to fastening systems dependent on the type of material being attached to specific structural elements.

Wood stud wall

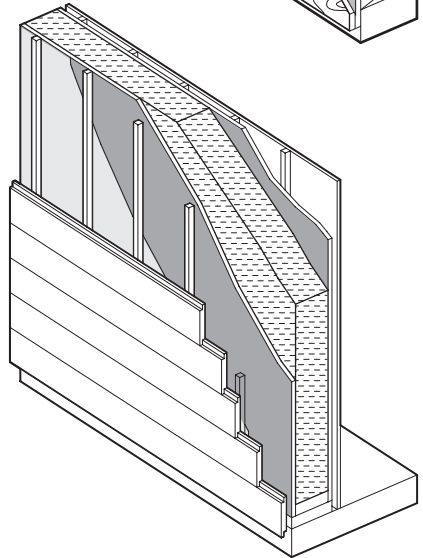
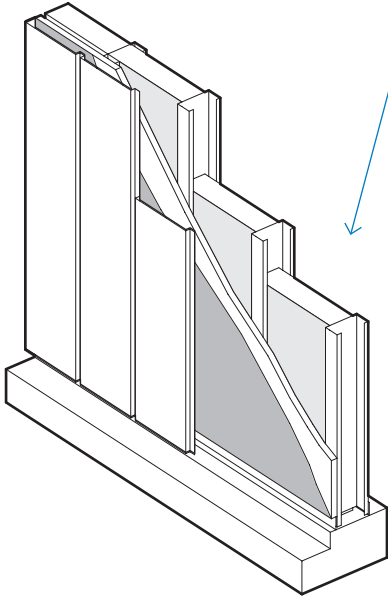
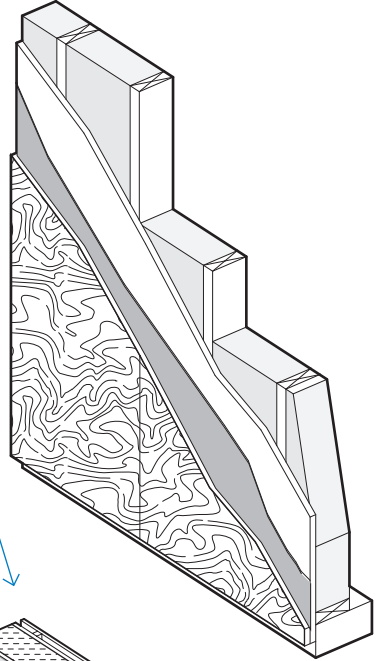
Wood studs with batt insulation between; exterior sheathing with weather-resistant barrier; exterior-grade plywood panels (sealed)

SIP (Structural Insulated Panel) wall

SIP (insulated foam-core with OSB skin, either side); weather-resistant barrier; exterior siding

Metal stud wall

Metal studs with batt insulation between; exterior sheathing with weather-resistant barrier; aluminum composite material (ACM)



The outer skin of a building is the vertical envelope that separates interior from exterior, and must effectively keep out water and contribute effectively to maintaining the desired interior climate. Most wall constructions include structural elements, insulation, water barriers, and an exterior cladding material. Depending on many factors, including the building's size and height, backup materials such as CMUs, concrete, and stud systems may be load-bearing, or act as infill within a structural frame.

Composite wall

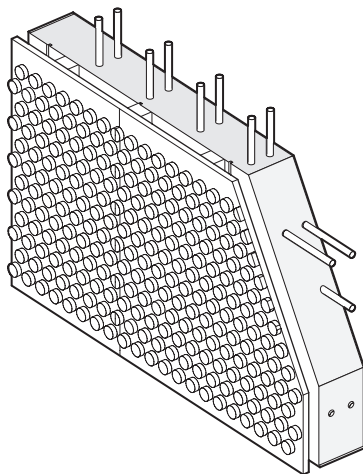
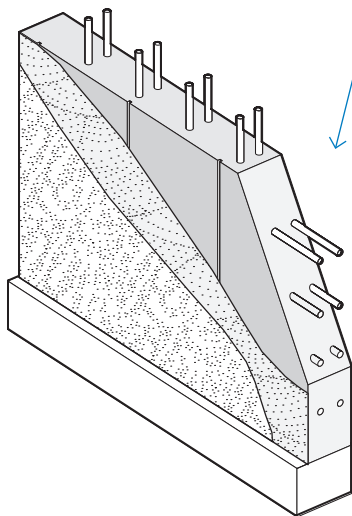
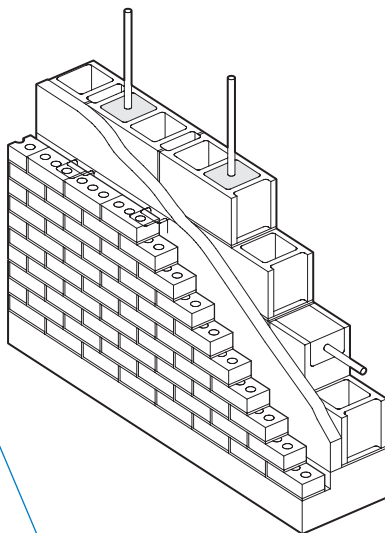
Reinforced CMU backup; rigid insulation; 1" (25) min. airspace; brick (or other masonry) tied to CMUs

UHPC concrete wall

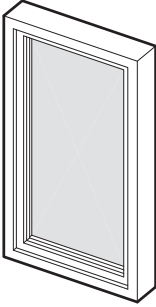
Poured-in-place or pre-cast concrete wall; ultra high performance concrete (UHPC) pre-cast panels (textured)

Stucco wall

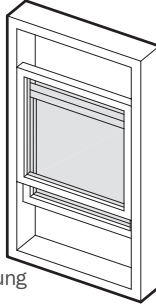
Concrete or masonry wall; two layers stucco



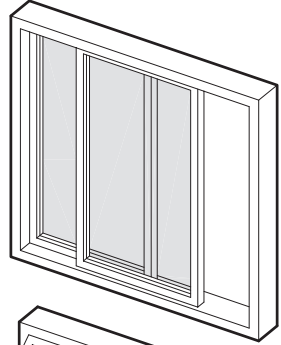
WINDOW TYPES



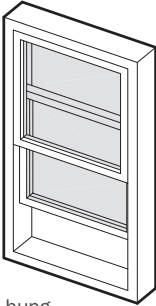
Fixed



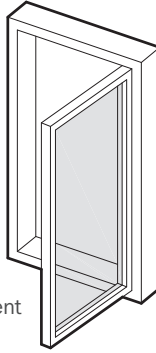
Double-hung



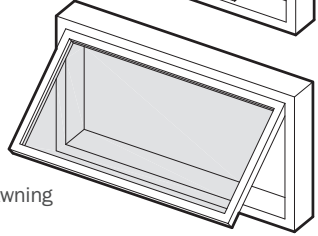
Sliding



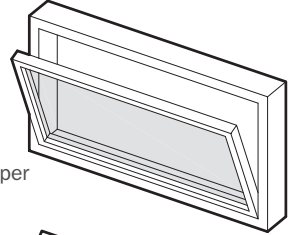
Single-hung



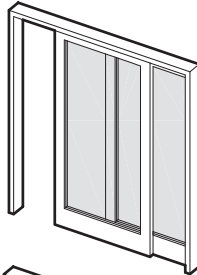
Casement



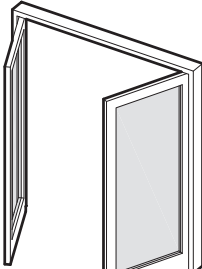
Awning



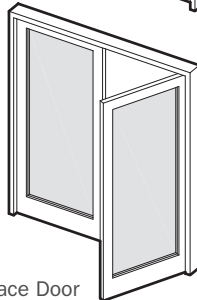
Hopper



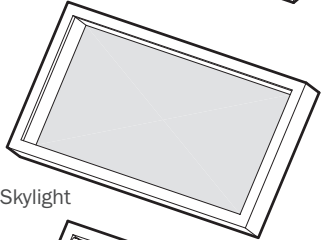
Sliding Doors



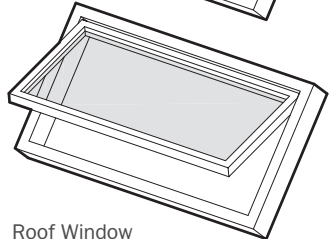
French Doors



Terrace Door



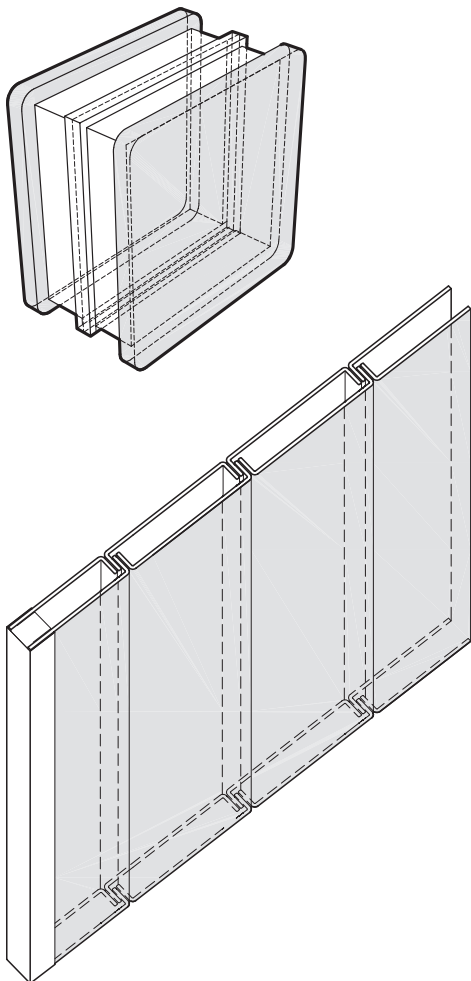
Skylight



Roof Window

GLASS FORMS

Glass Block: Glass blocks are considered to be masonry units. Typical units are made by fusing together two hollow halves, with a vacuum inside. Solid blocks, called glass bricks, are impact resistant but can be seen through. Glass block walls are constructed in a similar fashion to other masonry walls, with mortar, metal anchors, and ties; they can be applied to interiors or exteriors.



US Customary Sizes

4 $\frac{1}{2}$ " \times 4 $\frac{1}{2}$ "
 5 $\frac{3}{4}$ " \times 5 $\frac{3}{4}$ " (nominal 6" \times 6")
 7 $\frac{1}{2}$ " \times 7 $\frac{1}{2}$ "
 7 $\frac{3}{4}$ " \times 7 $\frac{3}{4}$ " (nominal 8" \times 8")
 9 $\frac{1}{2}$ " \times 9 $\frac{1}{2}$ "
 11 $\frac{3}{4}$ " \times 11 $\frac{3}{4}$ " (nominal 12" \times 12")
 3 $\frac{3}{4}$ " \times 7 $\frac{3}{4}$ " (nominal 4" \times 8")
 5 $\frac{3}{4}$ " \times 7 $\frac{3}{4}$ " (nominal 6" \times 8")
 9 $\frac{1}{2}$ " \times 4 $\frac{1}{2}$ "

thickness: 3"–4"

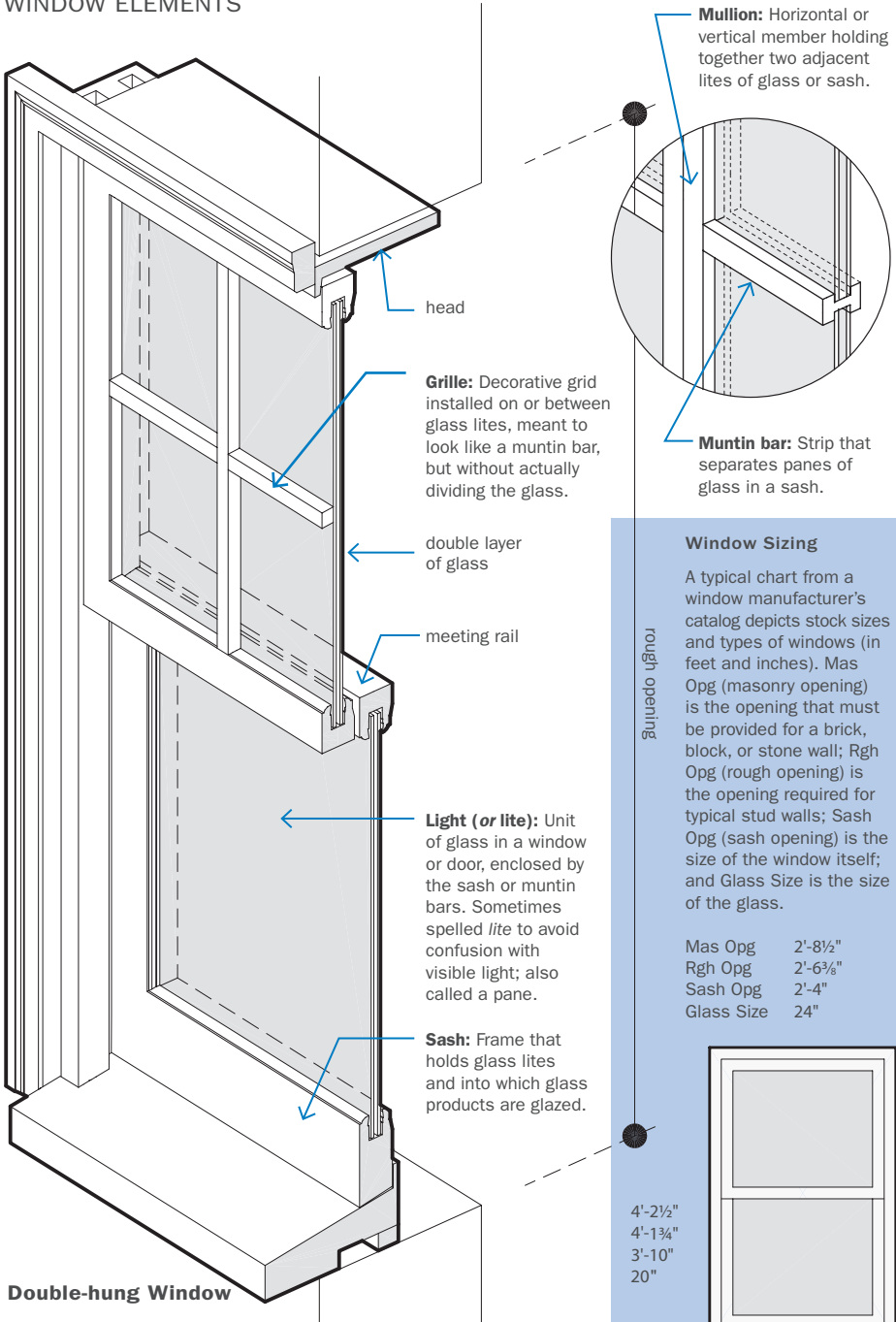
Preferred SI Sizes

115 \times 115 mm
 190 \times 190 mm
 240 \times 240 mm
 300 \times 300 mm
 240 \times 115 mm

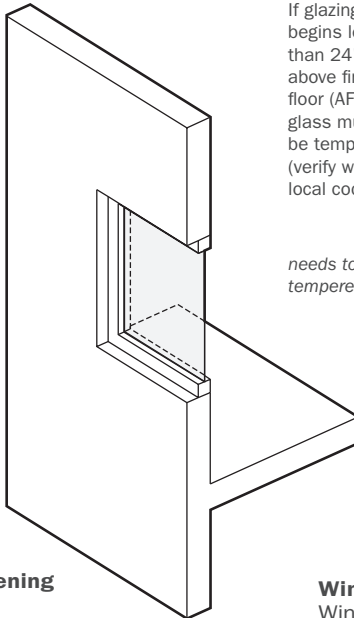
thickness: 80–100 mm

Cast or Channel Glass: U-shaped linear glass channels are self-supporting and contained within an extruded metal perimeter frame. One or two interlocking layers may be used, creating varying levels of strength, sound and thermal insulation, and translucence. Glass thicknesses are roughly $\frac{1}{4}$ " (6); channel widths range from 9" (230) to 19" (485), with heights varying depending on widths and wind loads. Cast glass can be employed vertically or horizontally, internally or externally, and as a curved surface. The glass itself can be made with wires, tints, and other qualities. Double layers of channels provide a natural air space that can be filled with aerogel, a lattice-work of glass strands with small pores, which results in an insulating substance that is 5 percent solid and 95 percent air.

WINDOW ELEMENTS



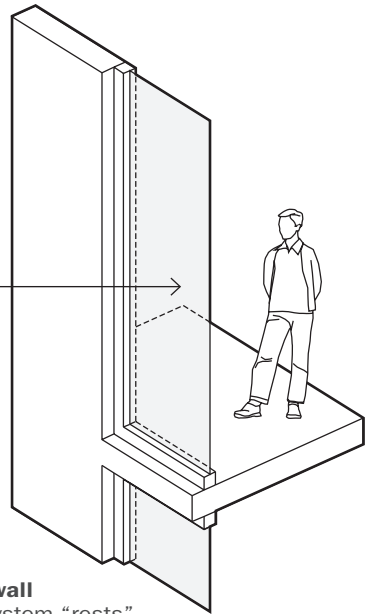
OPENING TYPES



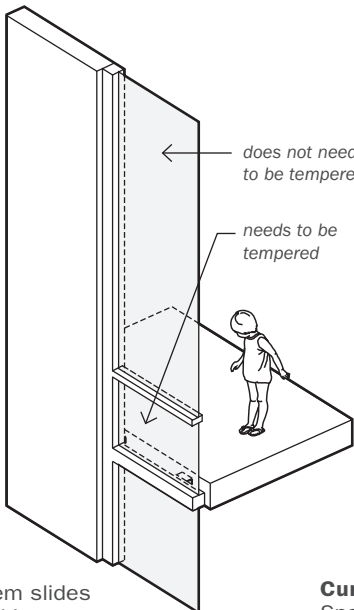
Punched opening

If glazing begins lower than 24" above finish floor (AFF), glass must be tempered (verify with local codes).

needs to be tempered



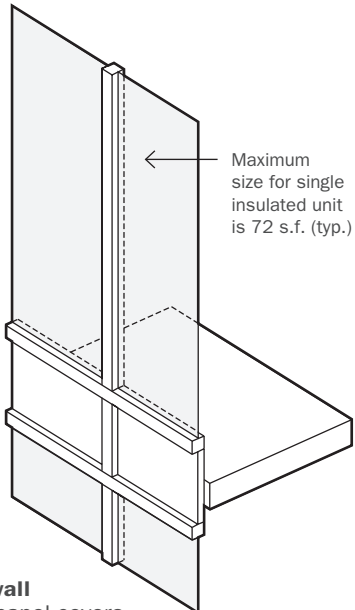
Window wall
Window system "rests" on floor



Curtain wall
Window system slides past floor and is anchored to structure

does not need to be tempered

needs to be tempered



Curtain wall
Spandrel panel covers edge of floor

Maximum size for single insulated unit is 72 s.f. (typ.)

GLASS AND GLAZING

Most architectural glass comprises three major raw materials that are found naturally: silica, lime, and sodium carbonate. Secondary materials may be added to facilitate the glass-making process or to give the glass special properties, which can be broken into three basic categories:

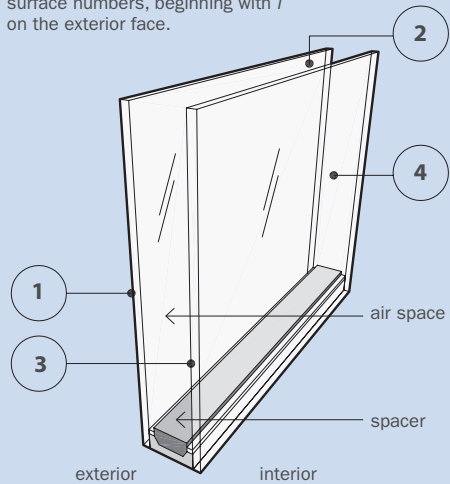
Soda-lime Glass: Accounts for the majority of commercially produced glass. Used for bottles, glassware, and windows, its composition of silica, soda, and lime does not give it good resistance to sudden thermal changes, especially high temperatures, or to chemical corrosion.

Lead Glass: Contains about 20 percent lead oxide, and its soft surface makes it ideal for decorative cutting and engraving, though it does not withstand sudden temperature changes.

Borosilicate Glass: Refers to any silicate glass with a composition of at least 5 percent boric oxide, and has greater resistance to thermal changes and chemical corrosion.

Nominal Thickness	Actual Range
3/32" single strength	0.085"–0.101" (2.16–2.57)
lamine	0.102"–0.114" (2.59–2.90)
1/8" double strength	0.115"–0.134" (2.92–3.40)
5/32"	0.149"–0.165" (3.78–4.19)
3/16"	0.180"–0.199" (4.57–5.05)
7/32"	0.200"–0.218" (5.08–5.54)
1/4"	0.219"–0.244" (5.56–6.20)
5/16"	0.292"–0.332" (7.42–8.43)
3/8"	0.355"–0.406" (9.02–10.31)
1/2"	0.469"–0.531" (11.91–13.49)
5/8"	0.595"–0.656" (15.09–16.66)
3/4"	0.719"–0.781" (18.26–19.84)
1"	0.969"–1.031" (24.61–26.19)
1 1/4"	1.125"–1.375" (28.58–34.93)

Numbers in bubbles represent glass surface numbers, beginning with 1 on the exterior face.



Insulating Glass: Two or more panes of glass enclose a hermetically sealed air space and are separated by a desiccant-filled spacer that absorbs the internal moisture of the air space. The multiple layers of glass and air space of these insulating glass units (IGUs) drastically reduce heat rates. Low-E or other coatings may be used on one or more of the glass surfaces to further improve thermal performance. Argon and sulfur hexafluoride gases may fill the space between glass sheets for even further efficiency as well as reduced sound transmission. Standard overall thickness for a double-glazed IGU is 1" (25.4), with 1/4" (6) thick glass and a 1/2" (13) air space.

Glass Production

The most common flat glass is float glass, in which properly weighed and mixed soda lime glass, silica sand, calcium, oxide, soda, and magnesium are melted in a 2 732°F (1 500°C) furnace. The highly viscous molten glass is floated across a bath of molten tin in a continuous ribbon. Because the tin is very fluid, the two materials do not mix, creating a perfectly flat surface between them. By the time the glass has left the molten tin, it has cooled enough to proceed to a lehr, where it is annealed, that is, cooled slowly under controlled conditions.

Glass may also be rolled, a process by which semimolten glass is squeezed between metal rollers to form a ribbon with predefined thicknesses and patterned surfaces. This process is used mostly for patterned and cast-glass production.

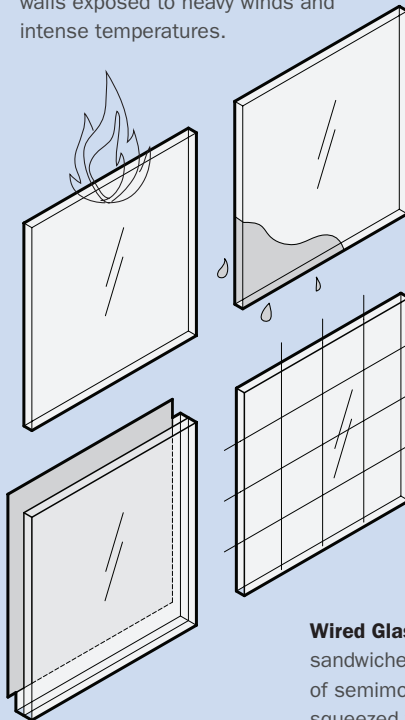
Safety Glass

Tempered Glass: Annealed glass is cut and edged before being reheated at about 1,200°F (650°C). If the glass is cooled rapidly, it is considered to be fully tempered; the glass can be up to four times as strong as annealed glass, and, when broken, it shatters into small, square-edged granules instead of into sharp shards. If cooled slowly, the glass is twice as strong as annealed glass, and the broken pieces are more linear but tend to stay in the frame.

Laminated Glass:

Interlayers of plastic or resin are sandwiched between two sheets of glass and the layers are bonded together under heat and pressure. When the glass breaks, the laminate interlayer holds the fragments together, making it ideal for use in overhead glazing, stair railings, and store fronts.

Tempered glass is ideal for floor-to-ceiling glass, glass doors, and walls exposed to heavy winds and intense temperatures.



Security Glass: Security glass (bullet-proof) is made of multiple layers of glass and vinyl, in many thicknesses.

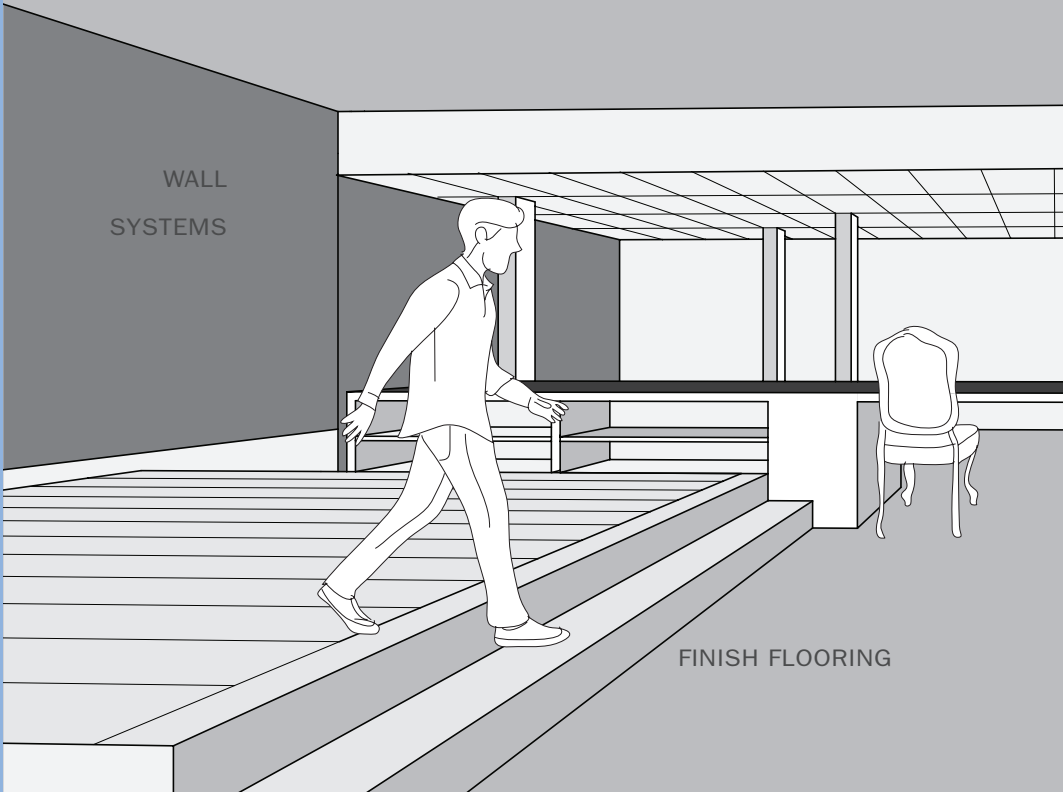
Chemically Strengthened Glass:

Glass is dipped in a chemical solution that produces a higher mechanical resistance, giving the glass similar properties to thermal-strengthened (tempered) glass, though it breaks into sharp shards similar to annealed glass.

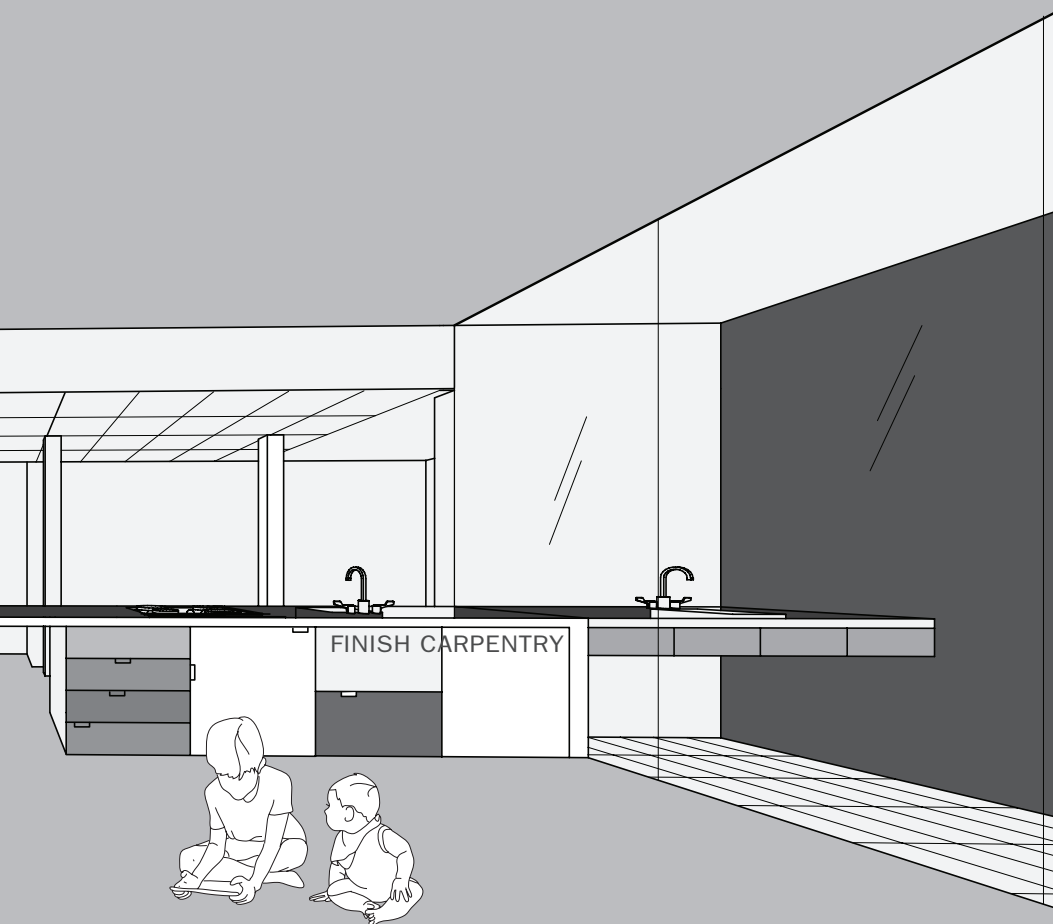
Wired Glass: A wire mesh is sandwiched between two ribbons of semimolten glass, which are squeezed together through a pair of metal rollers. When the glass breaks, the wire holds it in place. Wire glass is often acceptable for windows in fire doors and walls.

Chapter 5: Finishes

Interior finishes encompass all materials and surfaces that can be seen or touched. The choice of materials and the methods of construction should be based on the function of the space, the anticipated volume of traffic, acoustical effects, fire-resistance ratings, and aesthetic appearance.



CEILING

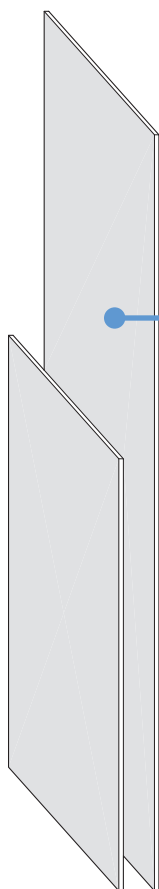


WALL SYSTEMS

Gypsum Board

Gypsum board goes by many names: gypsum wallboard (GWB), drywall, plasterboard, and Sheetrock (a trademarked brand name). Gypsum board is a less expensive alternative to plaster, because it requires less labor, time, and skill to install, but it still provides excellent fire-resistance and sound control.

Gypsum, a naturally occurring mineral, is formulated chemically when combined with water, starch, and other elements into a slurry and placed between paper faces to become gypsum board. When gypsum board is exposed to fire, the water is released as steam, providing a fire barrier until the water is completely eliminated (calcination). When the gypsum is completely calcined, its residue still acts as an insulating barrier to flames, preventing the structural members behind it from igniting.

**Customary Sizes**

Panel sizes may vary depending on the type of board, though generally they fall in the following range: 4' (1 220) wide by 8' (2 439) to 16' (4 877) high.

Widths of 2' (610) and 2'-6" (762) and heights of 6' (1 829) may also be available for certain prefinished boards and core boards.

SI Preferred Sizes

Standard panel size is 1 200 × 2 400 mm.

Other acceptable increments are 600 mm, 800 mm, and 900 mm.

Panel Types

Backing board: Used as a base layer when multiple layers are needed, improving fire resistance and sound control.

Coreboard: Thicker boards, 1" (25.4) and 2" (50.8), used to enclose vent shafts, emergency egress stairs, elevator shafts, and other vertical chases.

Foil-backed: Can work as a vapor barrier in exterior wall assemblies and as a thermal insulator.

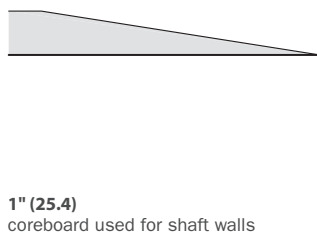
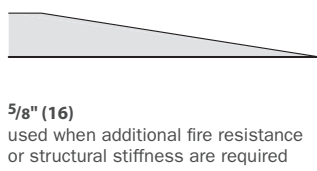
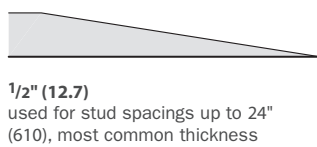
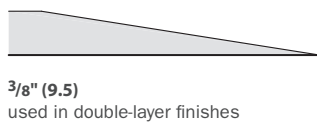
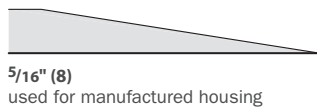
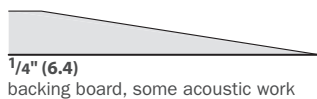
Prefinished: Covered in a variety of finishes such as paint, paper, or plastic film for installation without further finishing.

Regular: Used for most applications.

Type X: Short glass fibers in the core hold the calcined gypsum residue in place for increased fire resistance protection ratings.

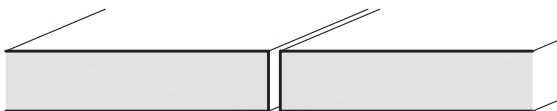
Water-resistant (green board): Water-resistant board with a water-repellent paper facing (colored light green to distinguish it from other walls) and a moisture-resistant core (also available in type X); used as base for tiles and other nonabsorbent materials in wet locations.

Board Thicknesses

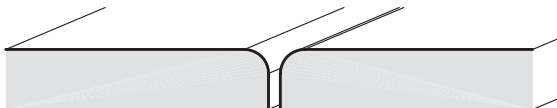


Edge Types

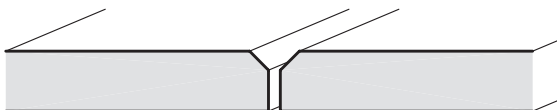
Square



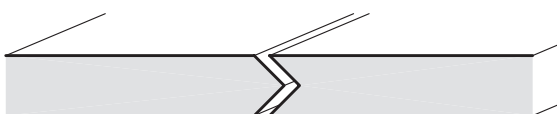
Rounded



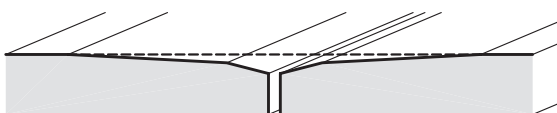
Beveled



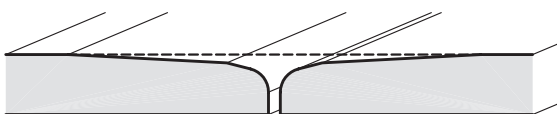
Tongue and Groove



Tapered



Rounded Taper



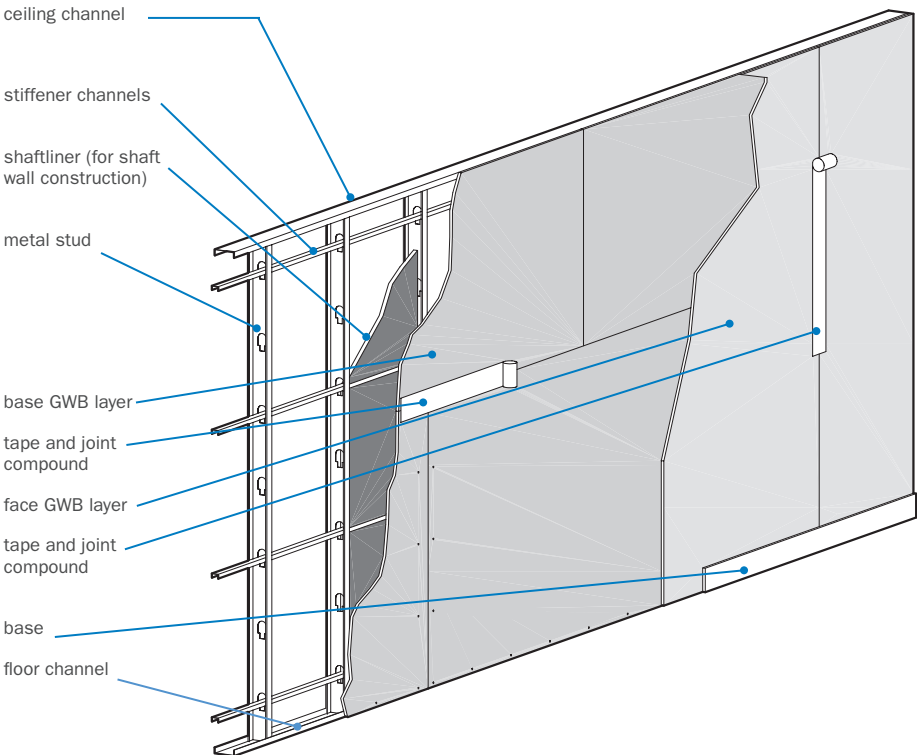
GWB Partition Wall Installation

Gypsum wallboard is placed over wood studs using nails or screws and over metal studs using screws. The orientation of the boards may differ based on the height of the wall, whether it is double-layer construction, and other factors.

Generally, it is best to minimize end joints between boards (boards have finished paper only on the face, back, and long edges, which themselves are finished in a variety of edge types), because these joints are more difficult to finish. If two or more layers of board are to be installed, joints between the layers should be staggered for added strength.

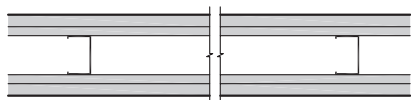
Joints are finished with joint compound and tape, usually in the following manner: A layer of joint compound is troweled into a tapered edge joint, then fiber-reinforcing mesh tape is applied; for some tapered edge joints, joint compound is forced through the tape to fill the V-shaped trough. After drying overnight, more joint compound is applied to completely smooth the joint, making it flush with the surrounding wall. Individual board manufacturers may suggest adding more layers of joint compound.

Nail or screw holes are also filled, and the whole wall receives a final light sanding before painting.



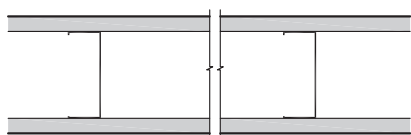
Common GWB Partition Assemblies

3⁵/₈" STC: 40-44: (1 layer ³/₈" GWB on either side of 1⁵/₈" metal studs; face layers of ¹/₂" GWB)



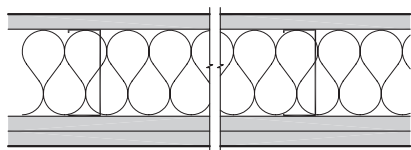
**1-HR
FIRE
RATING**

4⁷/₈" STC: 40-44: (1 layer ⁵/₈" type x GWB on either side of 3⁵/₈" metal studs)



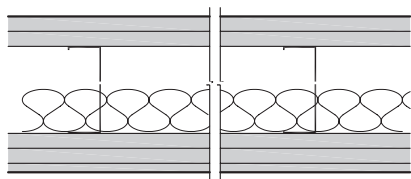
**1-HR
FIRE
RATING**

5¹/₂" STC: 45-49: (1 layer ⁵/₈" type x GWB on either side of 3⁵/₈" metal studs; one face layer ⁵/₈" GWB applied with laminating compound; 3¹/₂" glass fiber insulation in cavity)



**1-HR
FIRE
RATING**

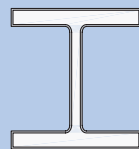
6¹/₄" STC: 55-59: (2 layers ⁵/₈" type x GWB on either side of 3 ⁵/₈" metal studs; one face layer ¹/₄" GWB applied with laminating compound; 1¹/₂" glass fiber insulation in cavity)



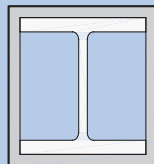
**2-HR
FIRE
RATING**

Fireproofing at Steel Structural Members

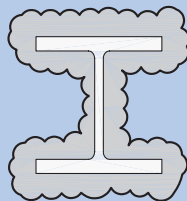
intumescent latex paint



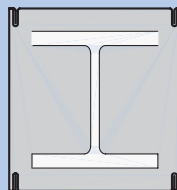
metal lath and plaster enclosure



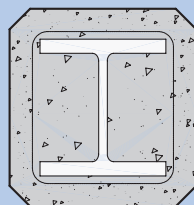
spray-on fireproofing



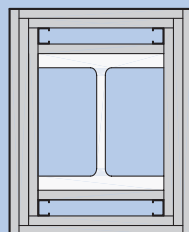
sheet-metal enclosure with loose insulating fill



reinforced concrete encasement



multiple layers of GWB enclosure



PLASTER

Today most plaster has a gypsum base. Gypsum is calcined and then ground into a fine powder. When mixed once again with water, it rehydrates and returns to its original state, expanding as it hardens into a plaster that possesses excellent fire-resistive qualities. This formulation can be mixed with an aggregate and applied by hand or by machine directly to masonry walls or to a lath system.

Plaster Types

Gauging plaster: Mixed with lime putty for accelerated setting and reduced cracking; may be mixed with finish lime to make a high-quality finish coat.

Gypsum plaster: Used with sand or lightweight aggregate.

High-strength basecoat: Used under high-strength finish coats.

Keenes cement: High-strength with a very strong and crack-resistant finish.

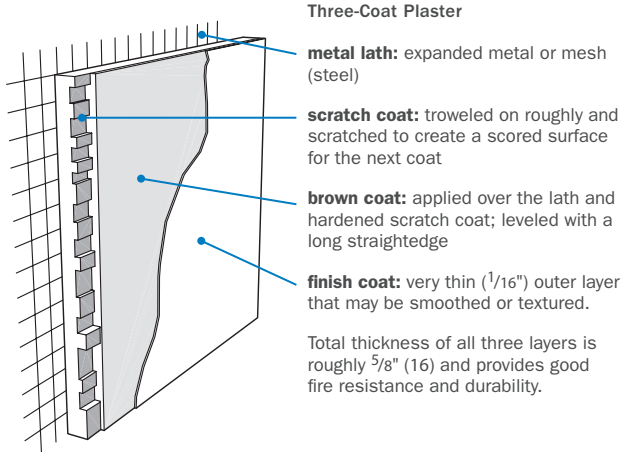
Molding plaster: Fast-setting for molding ornaments and cornices.

Stucco: Portland cement–lime plaster; used on exterior walls or where moisture is present.

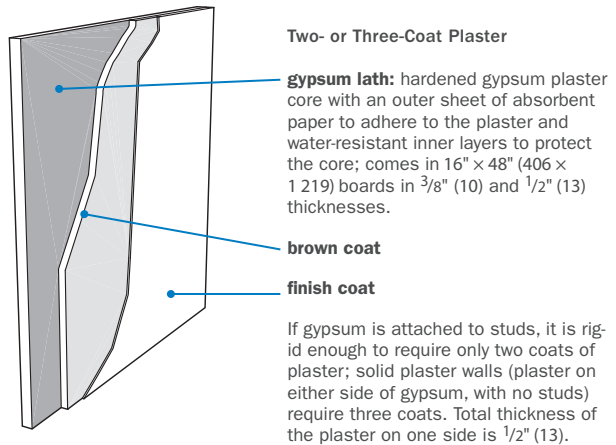
With wood fiber or perlite aggregate: Lightweight with good fire resistance.

Lath Assemblies

Plaster over Metal Lath



Plaster over Gypsum Lath



Veneer Plaster

Veneer plaster is a less expensive and less labor-intensive plaster system. The special veneer base works much like a standard gypsum board wall system and is finished smooth and flat to provide the best surface for the very dense veneer plaster. The plaster is applied in two coats in quick succession; the second coat, called a skim coat, dries almost immediately. The total plaster thickness is about $\frac{1}{8}$ " (3).

Plaster over Masonry

Plaster can be applied directly to brick, concrete block, poured concrete, and stone walls. Walls should be dampened first to keep the plaster from dehydrating during application. Generally, three coats will be needed, totaling $\frac{5}{8}$ " (16) in plaster thickness, though the roughness of the masonry surface will dictate the thickness in many cases. Where the masonry or other wall is unsuitable for direct plaster application (if moisture or condensation are present or if an air space is required for insulation), plaster and lath are applied over furring channels attached to the wall.

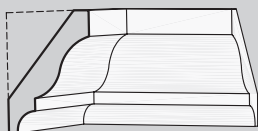
Wall Assemblies

Plaster and lath assemblies can be applied to truss studs, steel studs, or wood studs, in addition to furring strips. Solid plaster walls of roughly 2" (51) thick are sometimes used where space is at a premium. They generally consist of plaster on either side of expanded metal mesh or gypsum lath, supported at the floor and ceiling by metal runners.

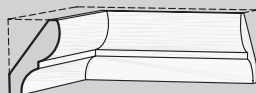
Wood lath is rarely used today in favor of cheaper and more durable lath types.

TRIM SHAPES

Ceiling Moldings



crown



bed

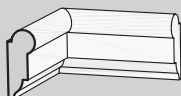


cove

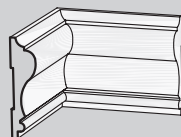


quarter-round

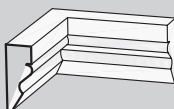
General Moldings



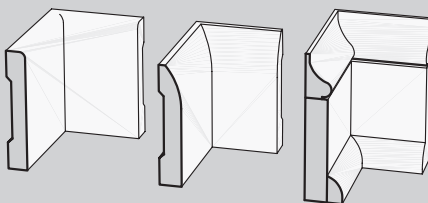
picture rail



chair rail

panel
molding for
wainscoting

Baseboards

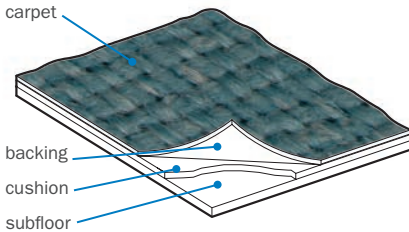


FINISH FLOORING

Floors receive regular wear and abuse, from feet, furniture, dirt, and water. Floor finish materials should be carefully chosen based on the function of the space and the amount of traffic they must endure. A wide array of finish floor types and methods of installation exist, of which the small sampling shown here represents the most common residential and commercial applications.

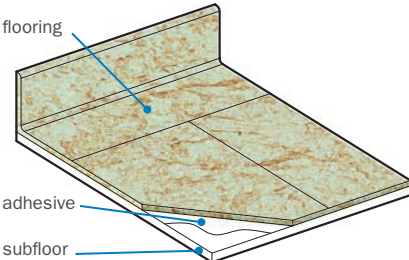
Carpet

Wool, nylon, polypropylene, and polyester account for most carpet fibers, with nylon the most widely used. Construction types include velvet, Axminster, Wilton, tufted, knitted, flocked, needle-punched, and fusion-bonded. Installation methods include stretch-in (using staples), direct glue down, and double glue down.



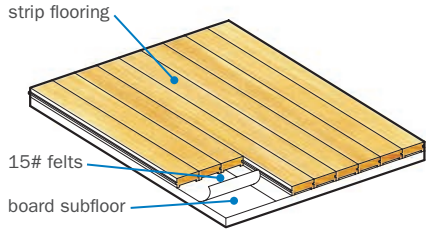
Resilient Flooring

Vinyl sheet, homogeneous vinyl tile, vinyl composition tile (VCT), cork tile, rubber tile, and linoleum are the common types. The flooring, either $\pm 1/8"$ (3) thick sheets or tiles, is glued to a concrete or wood subfloor. Most types can be installed to include a seamless integral cove base.



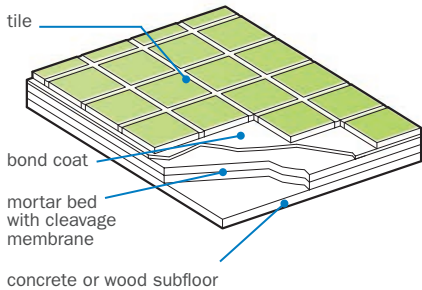
Wood

Wood offers a variety of widths and thicknesses, as well as methods of installation. Almost any wood can be made into strip flooring, though oak, pecan, and maple are the most common. Thicker boards should be installed in areas of heavier use.



Ceramic Tile and Quarry Tile

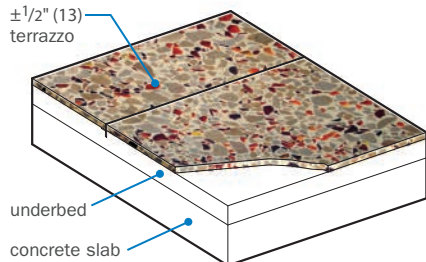
For thick-set installation, tiles are laid on $\pm 1"$ (25) portland cement mortar. For thin-set installation, tiles are laid on $\pm 1/8"$ (3) dry-set mortar, latex-portland cement mortar, organic adhesive, or modified epoxy emulsion mortar.



Terrazzo

Terrazzo is a poured or precast material composed of stone chips and a cement matrix (epoxy, polyester, polyacrylate, latex, or electrically conductive).

Appearance types vary from Standard (small chip sizes) to Venetian (large chips with small chips between), Palladiana (large random marble slabs with small chips between) to Rustic (uniform texture with suppressed matrix to expose chips).



CEILINGINGS

Attached Ceilings

Gypsum board, plaster, metal, and other materials can be attached directly to joists, rafters, and concrete slabs. Attached ceilings are constructed in a similar manner to wall systems.

Suspended Ceilings

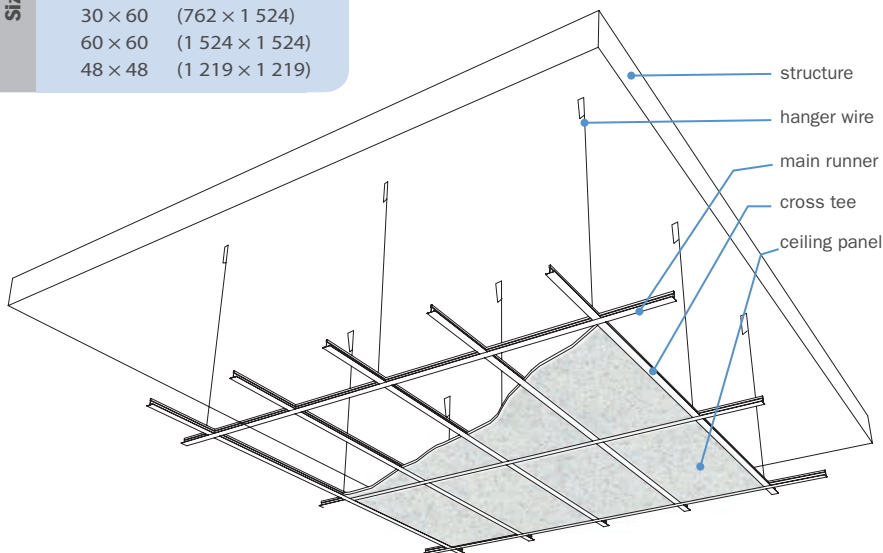
Suspended ceiling systems can support almost any material, although gypsum board, plaster, or fibrous board panels are most common. Regular grids of sheet metal cee channels suspended from the structure above with hanger wires support the gypsum board and plaster. The space between the structure above and the suspended ceiling, called the plenum, provides a zone for ductwork, piping, conduit, and other equipment.

Common Panel Sizes in. (mm)

12 × 12	(305 × 305)
12 × 24	(305 × 610)
24 × 24	(610 × 610)
24 × 48	(610 × 1 219)
24 × 60	(610 × 1 524)
20 × 60	(508 × 1 524)
30 × 60	(762 × 1 524)
60 × 60	(1 524 × 1 524)
48 × 48	(1 219 × 1 219)

Fibrous panels known as acoustic ceiling tiles (ACT) are lightweight boards made of mineral or glass fibers that are highly sound absorptive. They are easily laid into an exposed, recessed, or concealed grid of light-gauge metal tees suspended with hanger wires. Good ACT has a very high noise reduction coefficient (NRC), meaning that it absorbs the majority of the sound that reaches it. The NRC for gypsum and plaster, by contrast, is very low. Lightweight panels, however, tend to pass the sound through, which limits acoustical privacy in spaces with a shared plenum. Composite panels with acoustic material laminated to a substrate can alleviate this problem. Acoustical panels may involve other materials such as perforated metal, Mylar, and tectum.

Ceiling tiles can be easily removed, allowing access to the plenum area for maintenance of equipment and systems.

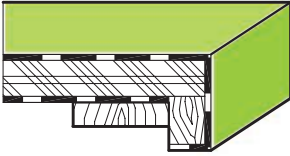


FINISH CARPENTRY

The wood interior finish components of a building are called millwork, and their installation is known as finish carpentry. Wood used for millwork encompasses various arrangements of solid and veneer wood, but in general it is of a higher quality than that used for framing. Millwork related to cabinetry and its assembly is called casework.

Common Countertops

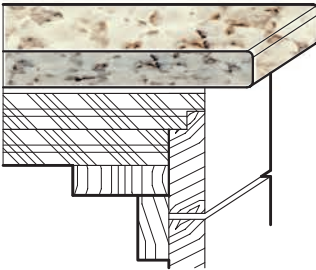
Plastic Laminate



Plastic laminate counters may come postformed, with the laminate already glued to a particle board platform, complete with a backsplash and bull-nosed front edge.

It is also possible to apply p-lam as thin sheets—generally $\frac{1}{16}$ " (1.6) thick—using a contact adhesive. Decorative plastic laminates have a top sheet of paper printed with wood-grain patterns or other images.

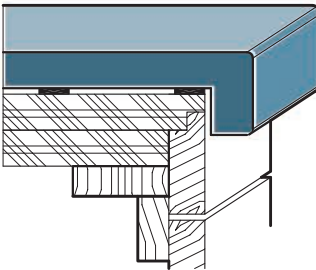
Stone



Solid stone countertops of granite, soapstone, marble, or slate (typically resting on a thin-set bed of cement) are durable and resistant to most common kitchen or bathroom wear and tear. Substrates are generally two layers of plywood or particle board. The thickness of the stone varies based on type, but is in the general range of $\frac{3}{4}$ "– $1\frac{5}{16}$ " (19–33).

Grouted stone tiles offer a lighter, less expensive alternative.

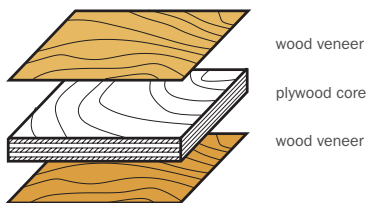
Solid Surface



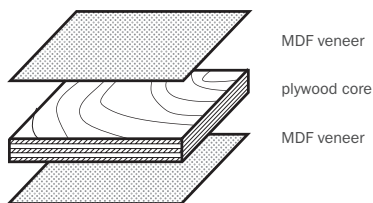
The general composition of solid surface is polymer (acrylic-based resin or unsaturated polyester resin), aluminum trihydrate filler, pigment (colorant), and a catalyst. Solid surface materials are nonporous, homogeneous (maintaining the same appearance all the way through), strong, and have UV stability and surface hardness. They resist water, impacts, chemicals, stains, and high temperatures. Moreover, solid surface can be repaired by being sanded and polished back to its original finish.

Solid surface materials are highly versatile and come in a wide variety of colors, textures, patterns, and translucencies.

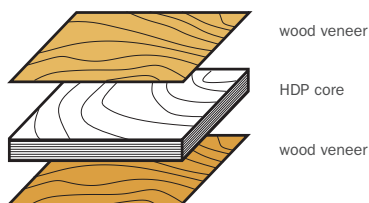
Wood-based Board Types



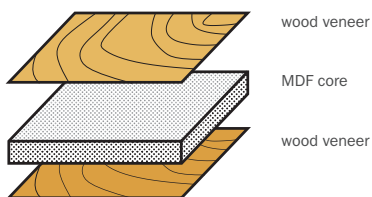
Veneer core hardwood plywood: VC is common plywood (typically, fir) with a finished wood grain surface veneer; it is relatively lightweight and easy to handle.



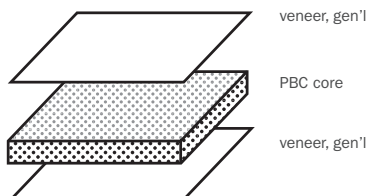
Medium- and high-density overlay plywood: MDO and HDO are generally common plywood with an MDF surface, resulting in panels that weigh less than full MDF but have smoother and more stable surfaces than VC.



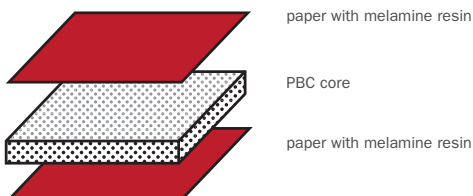
High-density plywood: HDP has more plies and fewer voids than common plywood. Its strength and stability make it useful for cabinetry, and it typically comes in birch (Baltic) or maple (Appleby).



Medium-density fiber core hardwood plywood: MDF is produced by heat-pressing a mixture of fine wood dust and a binder into panels. Paint-grade blank sheets can be used as they are or with a veneer skin, while dyed MDF has a consistent color from face to core. Though ideal for use in cabinetry and shelving, full MDF is very heavy.



Particle board core plywood: PBC produced by heat-pressing a coarse wood dust and a binder into panels, which are lower in weight than full MDF, due to the coarser dust. As the surface is rougher and less consistent, it is an ideal substrate for many other products.



Melamine: Melamine consists of a particle board core with a thermally fused, resin-saturated paper finish. Though the name refers to the resin in the paper liner, and not the paper or board, the entire product is commonly referred to as melamine. Melamine is ideal for use in cabinetry and comes in a wide variety of colors. MDF can also be used as the substrate.

SYSTEMS **2.**

A single person rarely designs all aspects of a building. Numerous teams of professionals are needed to create the systems that make a building stand and function well. Coordination of these systems begins early and may continue even after the building is occupied. During design, the building is an ever-changing organism, growing and shrinking to accommodate more systems as they are shaped and sized, designed and refined, requiring continual communication between the architect and the consulting trades.

Many decisions cannot be made until specific systems are in place. For example, the materials, structure, occupancy, and layout of a building must be known before a preliminary code analysis can be attempted. This analysis may yield new information, such as the need for wider egress stairs, more exit corridors, or further provisions for sprinkler systems. The accommodation of larger stairs and more corridors will affect the arrangement of spaces—or it may generate an overall change to the size of the building, which could, in turn, require less expensive cladding materials—and more sprinklers might entail more plumbing requirements. This give-and-take process continues throughout design, resulting in a (usually) happy coexistence of systems, spaces, and materials.

Chapter 6: Structural Systems

Structural elements of a building—its walls, frame, and foundation—hold it up (or keep it down) by resisting gravity (vertical forces) and lateral (horizontal) loads such as winds and earthquakes. The primary components of a building's structural system are its foundation system and framing system. The type selected for either is contingent on many factors, including the building's use, desired height, soil conditions of the site, local building codes, and available materials. Elements of a building's structure cannot be removed without compromising its strength and stability.

Loads

All stresses acting on a building's structure, no matter how complex, can be reduced to either tension or compression. In basic terms, a building's structure must press up with the same force that the weight of the building is pressing down, which includes all fixed dead loads and varying live loads.

Tension is a pulling and stretching force.

Compression is a pressing, pushing, or squeezing force.

Dead loads: Fixed, static loads made up of the building's own structure, skin, equipment, and other fixed elements.

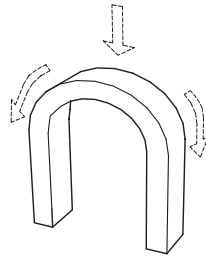
Live loads: Moving or transient loads such as occupants, furnishings, snow, ice, and rain.

Wind loads: Pressure from wind that affects lateral loads as well as possible uplift forces on roofs or downward pressure.

Other loads: Impact loads, shock waves, vibrations, and seismic loads.

STRUCTURAL TERMINOLOGY

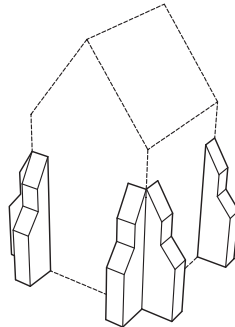
Arch: Structural device that supports vertical loads by translating them into axial forces.



Axial force: System of internal forces whose outcome is a force acting along the longitudinal axis of a structural member or assembly.

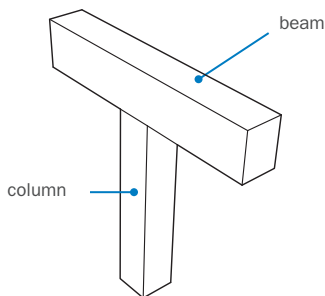
Beam: Horizontal linear element that spans an opening and is supported at both ends by walls or columns.

Buttress: Vertical mass built against a wall to strengthen it and to resist the outward pressure of a vault.



Cantilever: Horizontal beam or slab that extends beyond its last point of support.

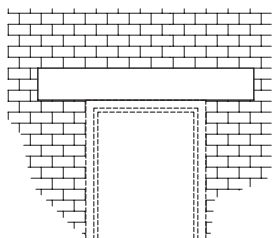
Column: Upright structural member acting in compression.



Dome: Arch rotated in plan to produce an inverted bowl-shaped form.

Girder: Horizontal beam, which is usually very large, that supports other beams.

Lintel: Beam used to span the opening in a wall left for a window or a doorway. The lintel supports and distributes the load of the wall above the opening.



Prestressing: Applying a compressive stress to a concrete structural member, either by pre-tensioning (pouring concrete around stretched steel strands, then releasing the external tensioning force on the strands once the concrete has cured) or post-tensioning (tensioning high-strength steel tendons against a concrete structural member after the concrete has cured).

Retaining wall: Wall used to mediate abrupt changes in ground elevation and to resist lateral soil pressures.

Shear: System of internal forces whose outcome is a force acting perpendicular to the longitudinal axis of a structural member or assembly.

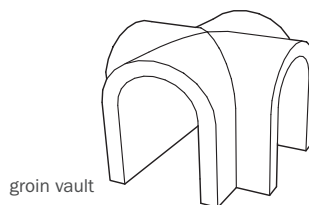
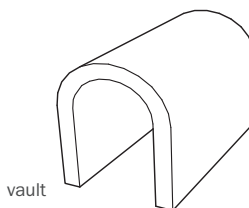
Shoring: Temporary vertical or sloping supports.

Slump test: Test in which wet concrete or plaster is placed in a metal cone-shaped mold of specific dimensions and allowed to slump under its own weight after the cone is removed. The index of the material's working consistency is determined by the distance between the height of the mold and the height of the slumped mixture.

Strain: Intensity of deformation at a point in an object.

Stress: Intensity of internal force acting at a point in an object.

Vault: Extruded arch.

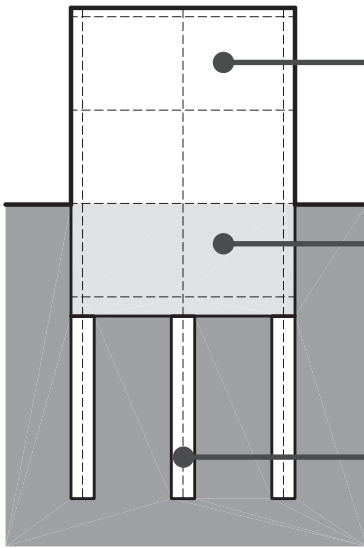


Materials

Structural framing elements may be made of wood, heavy timbers, concrete, masonry, steel, or a combination of these.

FOUNDATION SYSTEMS

The selection of a foundation system depends on many factors, including the building size and height, the quality of the subsurface soil and groundwater conditions, construction methods, and environmental concerns.



Superstructure

The above-ground portion of a building, composed of a framing system and exterior cladding.

Substructure

The portion of a building below ground (which may be habitable).

Foundation

The below-ground elements of the building's structural system that transfer the building's loads into the soil.

Shallow Foundation

Transfers the building's load at the base of a column or bearing wall of the substructure.

Less expensive than deep foundations and commonly used when good soil conditions exist within a few stories below the substructure.

Deep Foundation

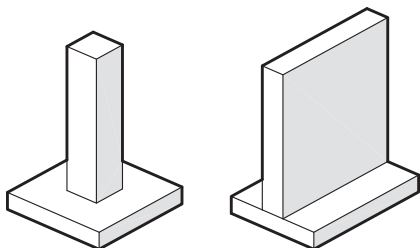
Transfers the building's load at a point well below the substructure.

Penetrates upper layers of incompetent soil to get to more competent soil or bedrock deeper down.

SHALLOW SYSTEMS

Footings

Concrete footings may be in the form of a column pad, for distributing the load of a column, or a strip footing, which does the same for a bearing wall.

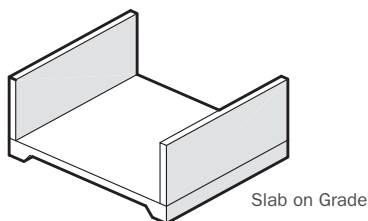


Column Footing

Strip Footing

Slab on Grade

Used for one- and two-story structures, this inexpensive foundation has thickened edges and rests as a continuous slab on the surface of the ground.



Slab on Grade

Mat Foundation

In this foundation system (also known as raft foundation), the whole building rests on a large continuous footing. It is often used to resolve special soil or design conditions. "Floating" or "compensated" mat foundations are sometimes employed in situations with weak soil. The floating foundation is placed beneath the building to a point that the amount of soil removed is equal to the total weight of the building.

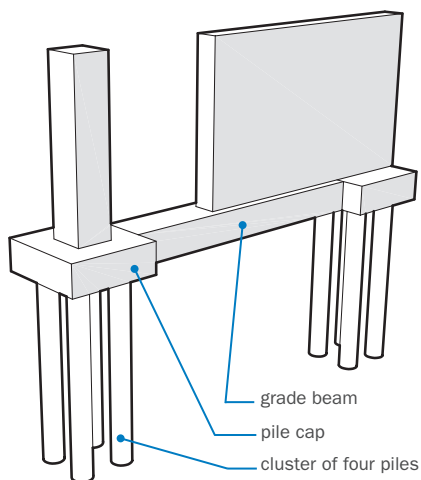
DEEP SYSTEMS

Caissons

To construct a caisson (also referred to as a "drilled pier"), a hole is drilled or dug (a process known as augering) through unsatisfactory soil beneath a building's substructure, until rock, dense gravel, or firm clay is reached. If the caisson will rest on soil at the bottom, the hole is sometimes belled out to achieve a bearing area similar to a footing and the hole is then filled with concrete. Caissons may range from 18" (457) to 6' (1 829) in diameter.

Piles

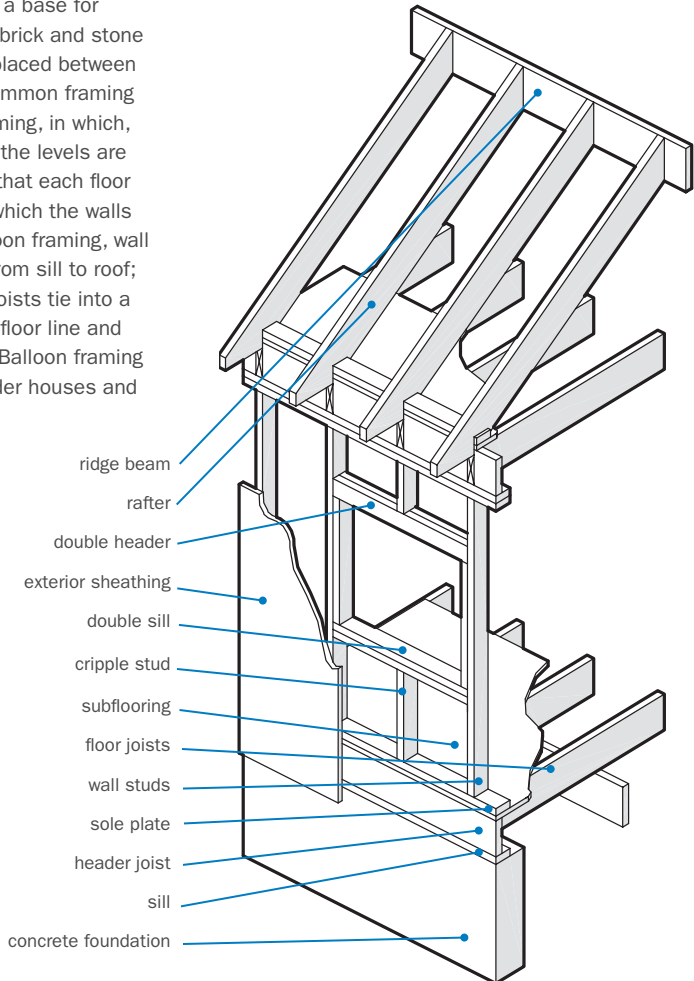
Piles are similar to caissons, but are driven into place, not drilled or poured. They may be made from concrete, steel, or timber, or a combination of these materials. Piles are driven closely together in clusters and then cut off and capped in groups of two to twenty-five. The building's columns rest on top of the pile caps. Load-bearing walls, where used, rest on reinforced-concrete grade beams that span between pile caps, transmitting the walls' loads to the piles.



WOOD LIGHT-FRAMING

Wood light-frame construction uses a system of wood wall studs, floor joists, rafters, columns, and beams to create both structure and framework for applied interior and exterior finished surfaces. As a building material, wood is relatively inexpensive, versatile, and quick to erect. Typical spacing for studs and floor joists is 12" (305), 16" (406), or 24" (610) on center. These dimensions are compatible with typical wall, floor, and ceiling material unit dimensions, such as gypsum wallboard and plywood sheets. When complete SI conversion occurs in the United States, these building materials will undergo a change in unit size, and framing dimensions will shift to the metric planning grid used elsewhere in the world.

Exterior wall sheathing is typically plywood, which acts as a base for stucco, siding, or even brick and stone façades; insulation is placed between the studs. The most common framing method is platform framing, in which, in multistory buildings, the levels are built one at a time, so that each floor acts as a platform on which the walls above can rest. In balloon framing, wall studs are continuous from sill to roof; the intermediate floor joists tie into a ribbon occurring at the floor line and attached to the studs. Balloon framing is more prevalent in older houses and is seldom used today.



HEAVY TIMBERS

Heavy-timber construction uses specifically engineered woods of minimum dimensions to achieve greater structural strength and fire resistance than is possible with wood light-frame construction, while also taking advantage of the aesthetic benefits of exposed wood. To achieve high levels of fire resistance, construction details, fastenings, and wood treatment are closely regulated in heavy-timber construction.

Decking

Floor deck planking spans between floor beams; finished floor material is placed above the planking, running perpendicular to it. Planks should be a minimum 3" nominal (76) thick if splined or tongue-and-grooved together, or a minimum 4" (102) nominal if set on edge and spiked together. Flooring should be 1/2"-1" (13-25) thick.

Floors

Beams and girders may be sawn or glue-laminated.

They should not be less than 6" wide x 10" deep nominal (152 x 254).

Truss members must be a minimum 8" x 8" nominal (203 x 203).

Decay

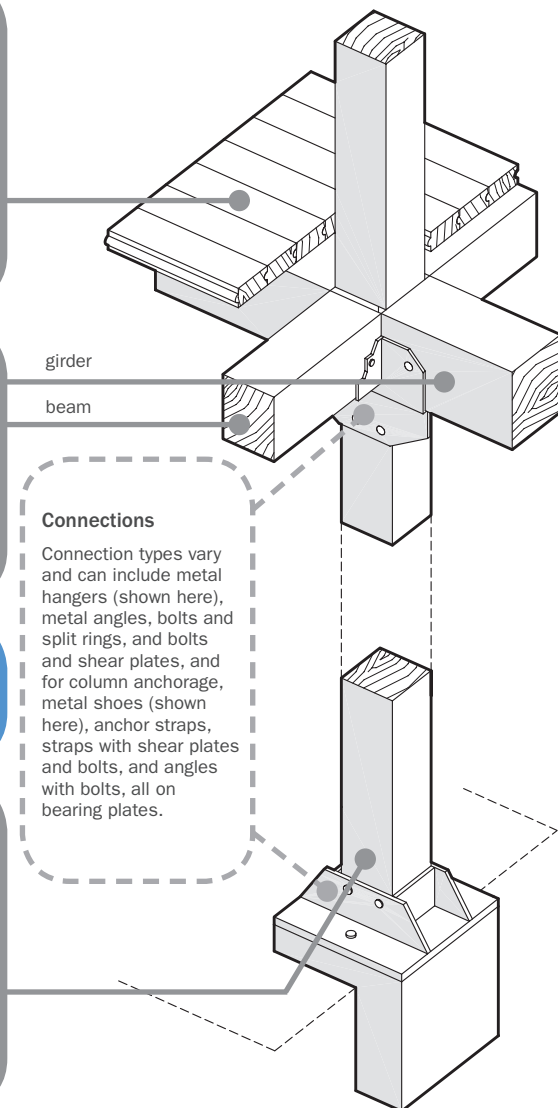
Structural members must be preservative-treated or be from the heart-wood of a naturally durable wood.

Columns

Columns may be sawed or glue-laminated.

Supporting floor loads, must be a minimum 8" wide x 8" deep nominal (203 x 203).

Supporting roof and ceiling loads, must be a minimum 6" wide x 8" deep nominal (152 x 203).

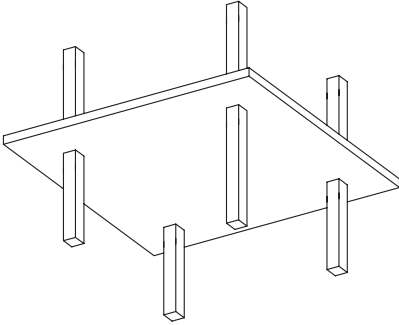


Connections

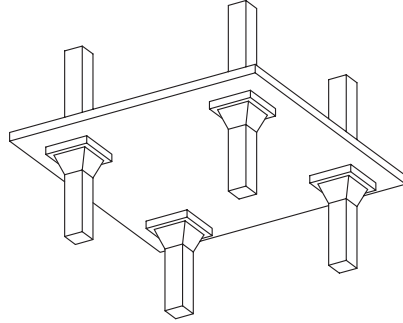
Connection types vary and can include metal hangers (shown here), metal angles, bolts and split rings, and bolts and shear plates, and for column anchorage, metal shoes (shown here), anchor straps, straps with shear plates and bolts, and angles with bolts, all on bearing plates.

Concrete Floor and Roof Systems

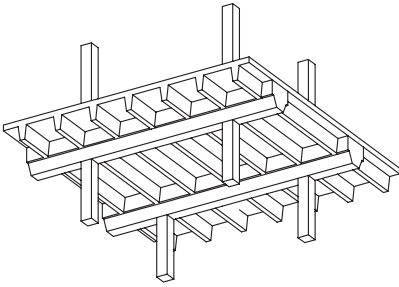
Different systems, in order of increasing load capacity, spans, and cost, are one-way solid slab (spans across parallel lines of support), two-way flat plate (uses no beams, dropped plate, or column capitals, but rather, reinforcing of various stresses), two-way flat slab (uses column capitals and/or drop panels instead of beams), one-way joist, waffle slab, one-way beam and slab, and two-way beam and slab. Two-way systems tend to be square in proportion and are supported on four sides; one-way systems have a 1:>1.5 proportion and are supported on two sides.



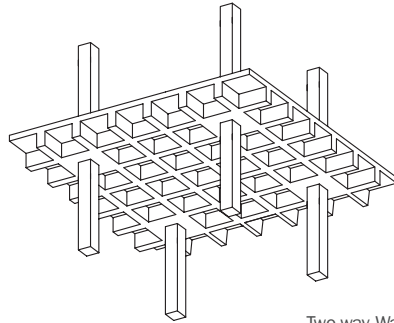
Two-way Flat Plate



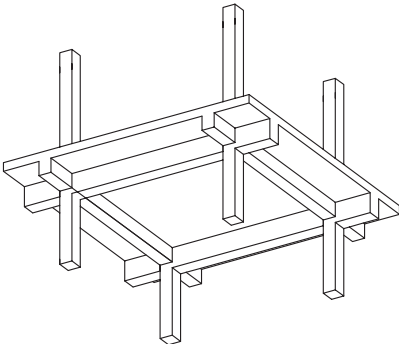
Two-way Flat Slab



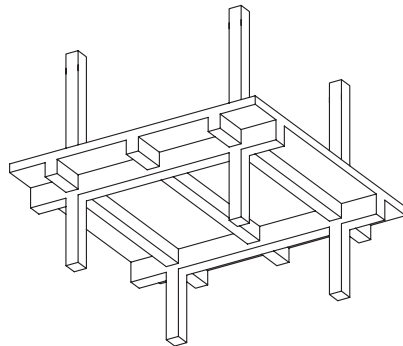
One-way Ribbed Slab (joist)



Two-way Waffle Slab



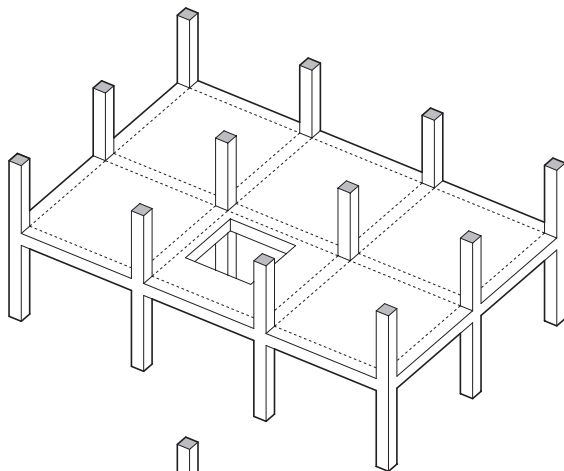
Flat Beam and Slab



One-way Beam and Slab

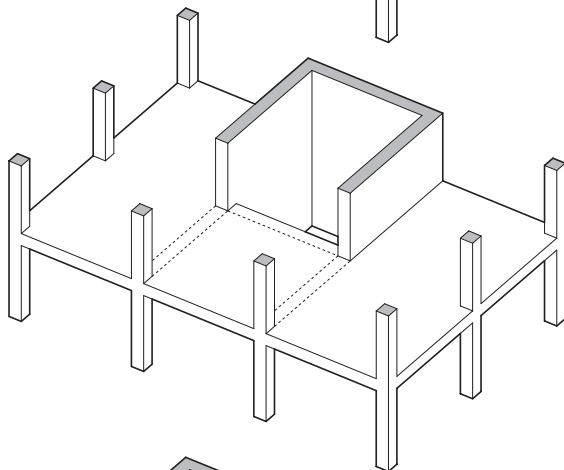
Moment Frame

Rigid framework resists lateral forces



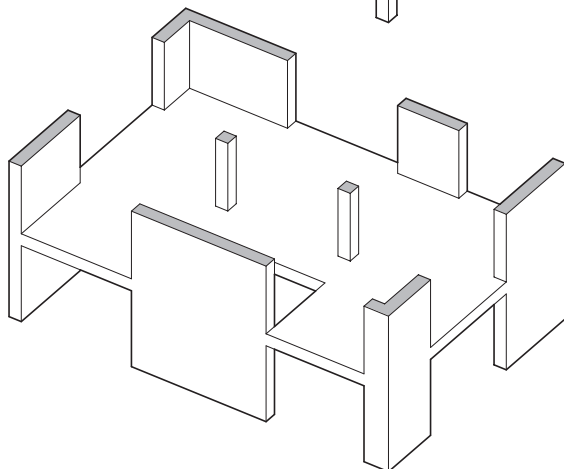
Braced Frame

Internal structure braces light frame



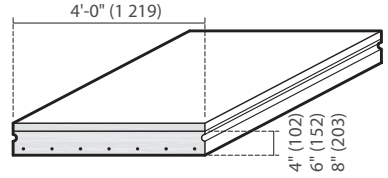
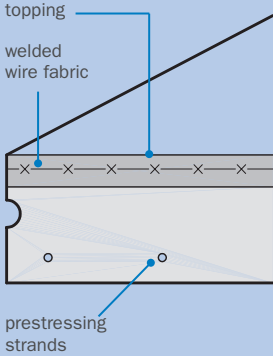
Tube

Exterior walls contribute to structural stability

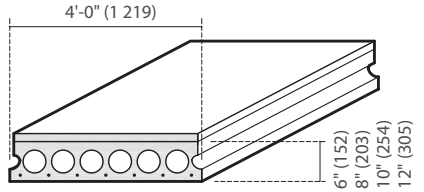


PRECAST CONCRETE FRAMING

Slab Detail

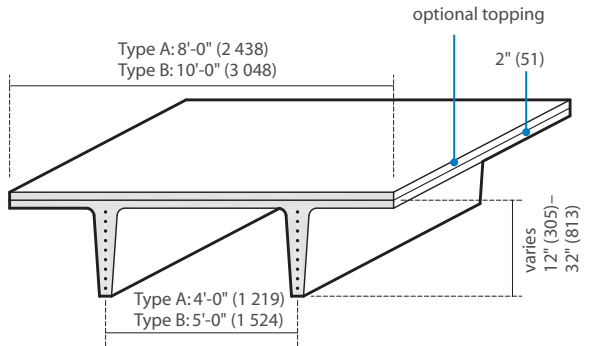
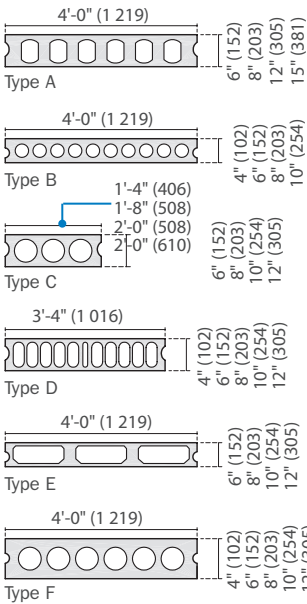


Solid Flat Slab

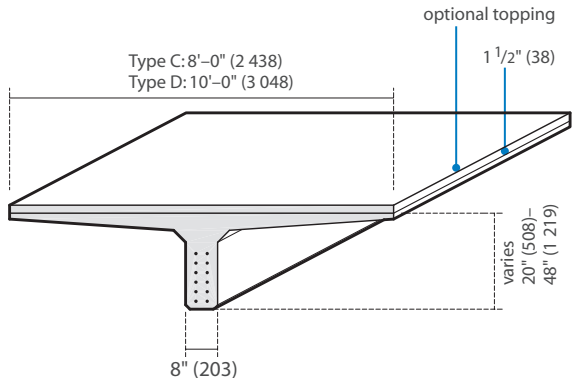


Hollow Core Slab

Hollow Core Slab Types

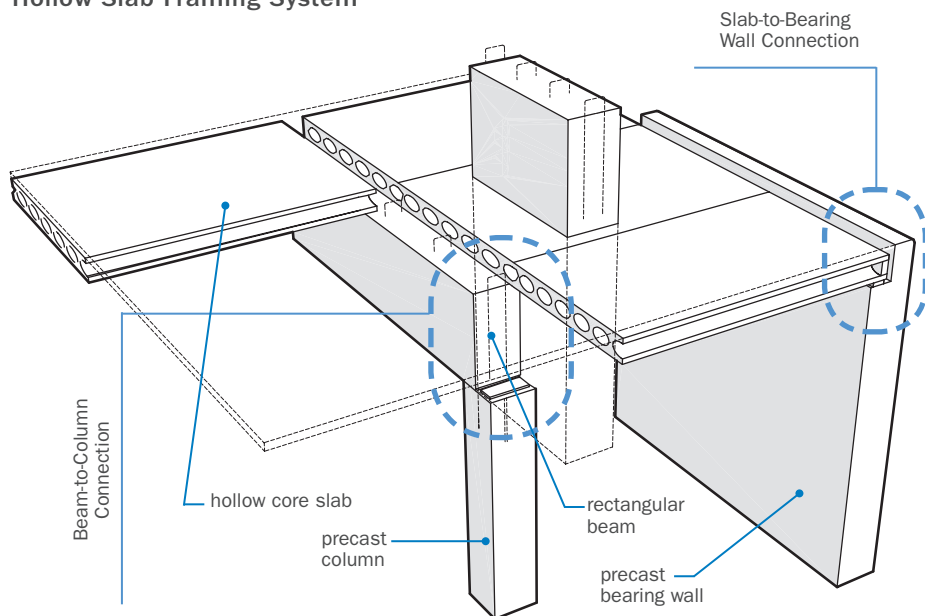


Stemmed Deck, Double Tee (DT)

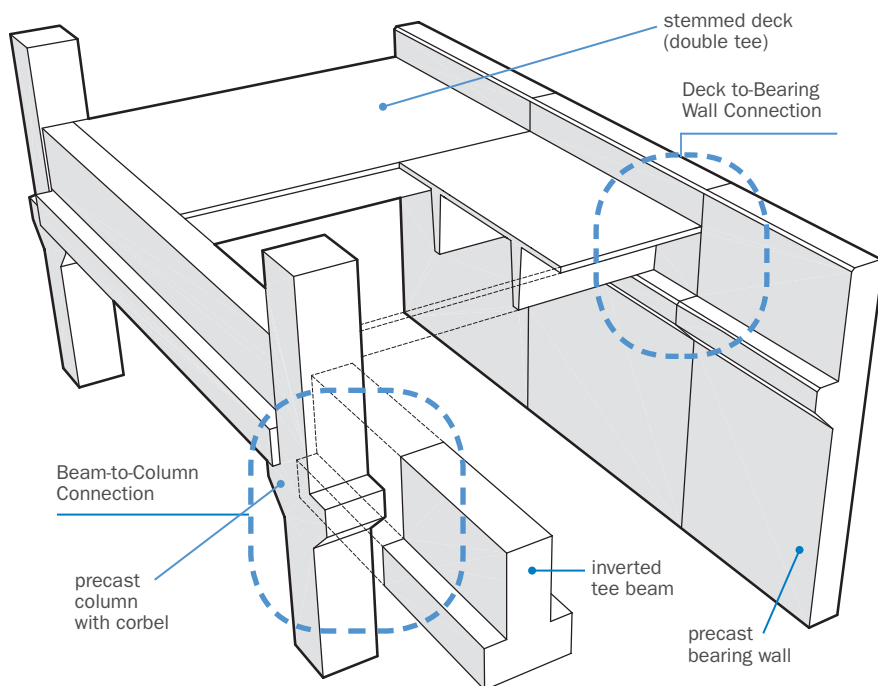


Stemmed Deck, Single Tee (ST)

Hollow Slab Framing System



Stemmed Deck DT Framing System



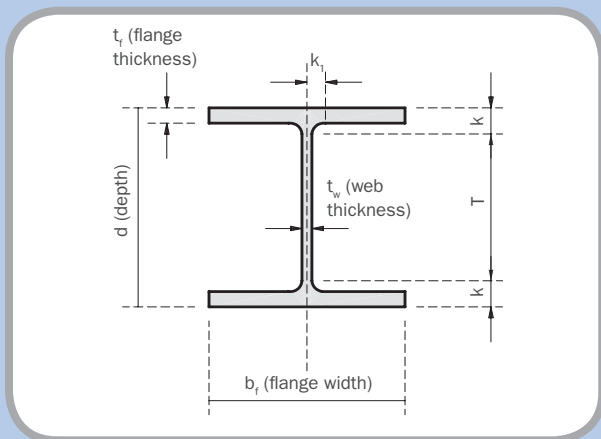
STEEL FRAMING

Structural Steel Shape Designations

	Shape	Description
W	Wide-flange	hot-rolled, doubly symmetric wide-flange shapes used as beams and columns
HP	Wide-flange	hot-rolled, wide-flange shapes whose flanges and webs are of the same nominal thickness and whose depth and width are essentially the same; often used as bearing piles
S	American Standard beam	hot-rolled, doubly symmetric shapes produced in accordance with AASM* dimensional standards; generally being superseded by wide-flange beams, which are more structurally efficient
M	Miscellaneous	doubly symmetrical shapes that cannot be classified as W or HP shapes
L	Angle	equal leg and unequal leg angles
C	American Standard channel	hot-rolled channels produced in accordance with AASM dimensional standards
MC	Channel	hot-rolled channels from miscellaneous shape
WT	Structural tee	hot-rolled tees cut or split from W shapes
ST	Structural tee	hot-rolled tees cut or split from S shapes
MT	Structural tee	hot-rolled tees cut or split from M shapes
TU	Tube	hollow structural steel members shaped like a square or rectangle; used as beams or columns, or in bracing

*AASM: Association of American Steel Manufacturers

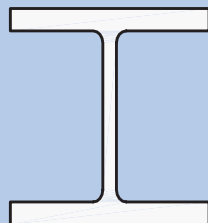
Steel Shape Examples



Wide-flange

W8×67

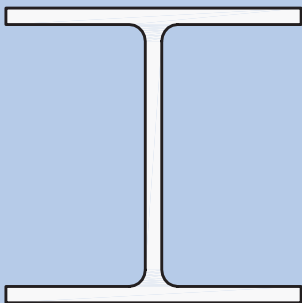
8 = nominal depth (in.);
67 = weight per foot of
length (lb.)



Wide-flange

HP12×84

12 = nominal depth (in.);
84 = weight per foot of length (lb.)



American Standard

S8×18.4

8 = nominal depth (in.);
18.4 = weight per foot of
length (lb.)



Miscellaneous

M10×8

10 = nominal depth (in.);
8 = weight per foot of length (lb.)



Structural Tees

WT25×95



Angle

L6×4× $\frac{7}{8}$

6 and 4 = nominal depths of
legs (in.); $\frac{7}{8}$ = nominal
thickness of legs (in.)



Channel

MC7×22.7

7 = nominal depth (in.);
22.7 = weight per foot of
length (lb.)



ST15×3.75



Tube

TU2×2× $\frac{1}{8}$ 

Steel-Frame Connections

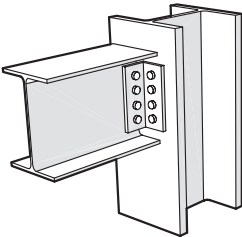
Steel is proportionally light in weight relative to its strength and can be erected quickly but precisely. Steel-frame construction uses a combination of structural steel shapes that act as columns, beams, girders, lintels, trusses, and numerous means of connection.

The integrity and strength of steel connections are just as important as the steel shapes themselves, because a failed connection results in a failed system. Steel-frame connections include angles, plates, and tees for transitioning between members being joined.

Connections that join only the web of the beam to the column are called framed connections; they can transmit all the vertical (shear) forces from the beam to the column. If the flanges of the beam are also connected to the column, it is then capable of transmitting bending moment from beam to column.

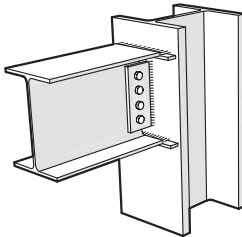
Framed Connec-

tion: Shear connection with beam web bolted to column flange using connecting angles.



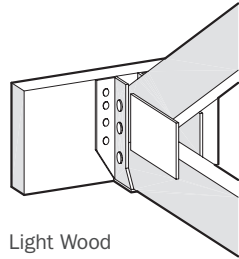
Welded Moment

Connection: Moment connection between beam and column using groove welds at beam web and flange.

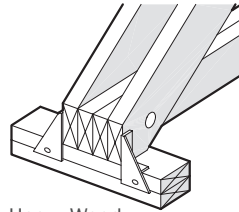


TRUSS DESIGN

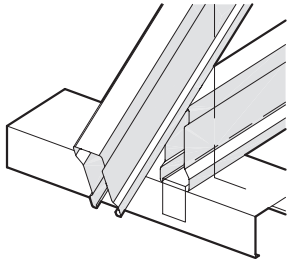
Heel Conditions



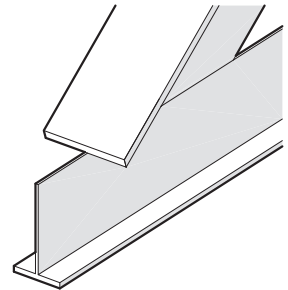
Light Wood



Heavy Wood

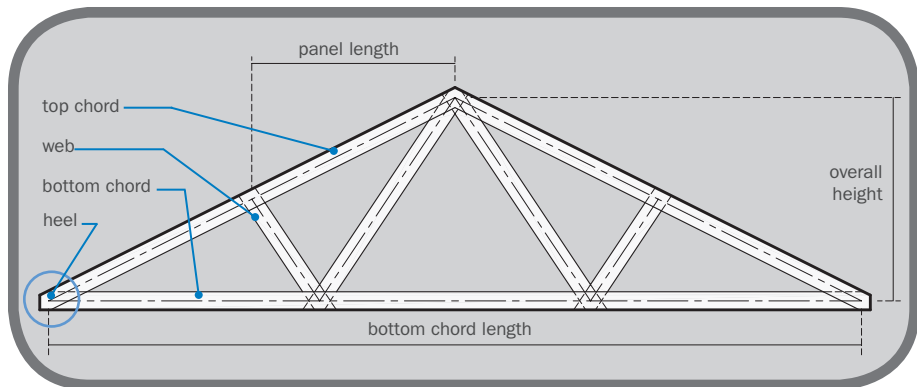


Cold-rolled Steel Channel

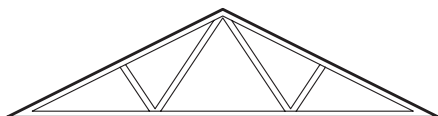


Welded Steel

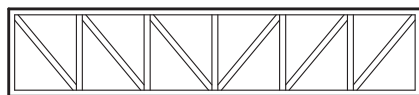
A truss is a structural framework of triangular units for supporting loads over long spans. The framework of the structural members reduces nonaxial forces to a set of axial forces in the members themselves.



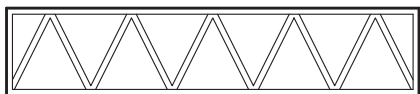
Truss Types



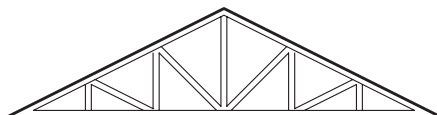
Belgian



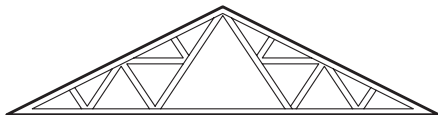
Flat Pratt



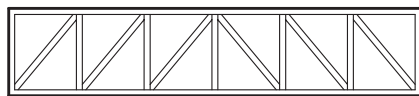
Warren



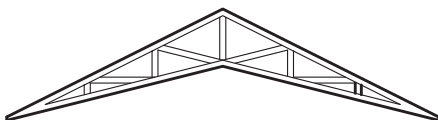
Pitched Howe



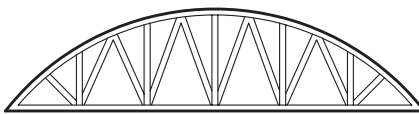
Fink



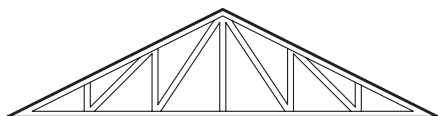
Flat Howe



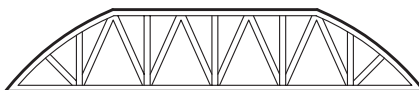
Scissors



Bowstring



Pitched Pratt



Modified Bowstring

Chapter 7: Mechanical Systems

A building's mechanical systems involve control of heat, ventilation, air-conditioning, refrigeration, plumbing, fire protection, and noise reduction, all of which must be integrated with the architectural, structural, and electrical design.

ENERGY DISTRIBUTION SYSTEMS

All-air Systems: Conditioned air is circulated to and from spaces by central fans that direct it through runs of ductwork.

Air and Water Systems: Conditioned air is ducted to each space, and chilled and heated water are piped to each space to modify the temperature of the air at each outlet.

All-water Systems: No ductwork is used, and air is circulated within each space, not from a central source. Chilled and heated water are furnished to each space. Because water piping is much smaller than ductwork for air, all-water systems are very compact.

Air duct: Pipe that carries warm and cold air to rooms and back to a furnace or air-conditioning system.

ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Cavity wall: Hollow wall formed with two layers of masonry, providing an insulating air space between.

Chase wall: Cavity wall containing electrical runs or plumbing pipes in its cavity.

Closed loop: Evaporator side of chiller system, closed to the atmosphere.

Dry bulb: Ambient outside temperature.

Furnace: Device that generates heated air, and is powered by natural gas, fuel oil, or electricity. Most often used in small commercial or residential applications.

Heat pump: A device that warms or cools by transferring thermal energy from a heat source to a heat sink.

HVAC: Heating, ventilating, and air-conditioning.

IAQ: Indoor air quality.

Louver: Opening with horizontal slats that permit passage of air, but not rain, sunlight, or view, into a structure.

Open loop: Condenser/tower side of chiller system; open to the atmosphere.

Plenum: Chamber that serves as a distribution area for heating or cooling systems, usually found between a false ceiling and the actual ceiling.

Radiant heat: Heating system that uses coils of electricity, hot water, or steam pipes embedded in floors, ceilings, or walls to heat rooms.

Shaft: Enclosed vertical space (usually with fire-resistive walls) containing all vertical runs of pipes, ducts, and elevators.

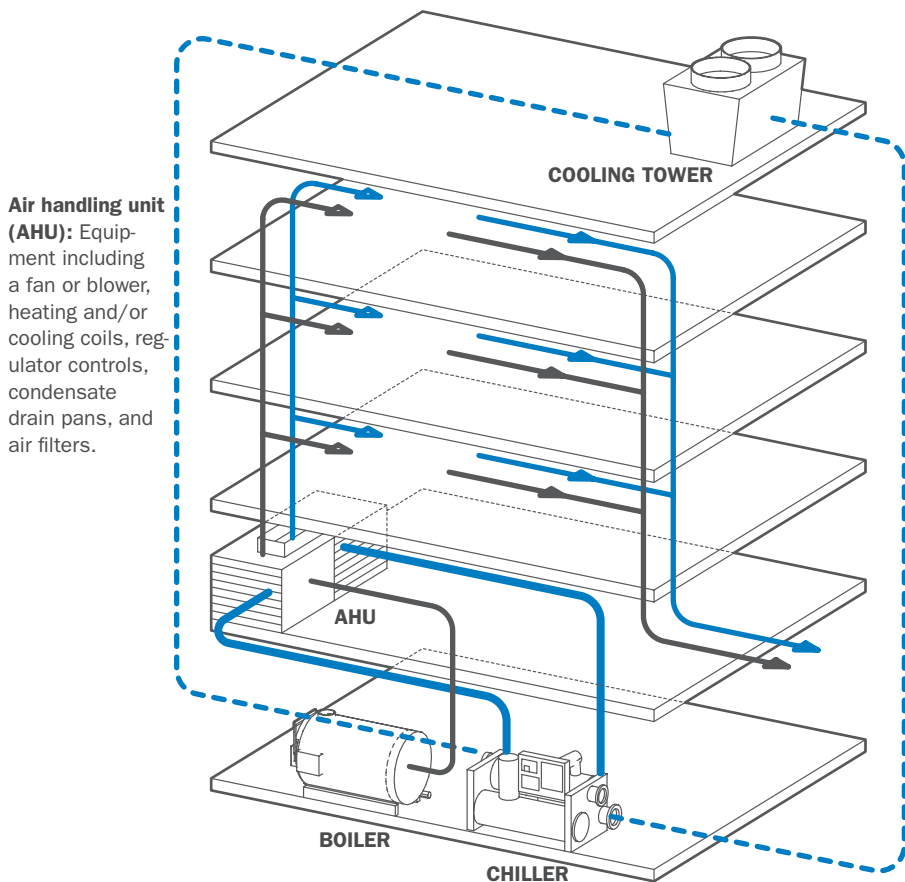
Variable air volume (VAV): Air-handling system that conditions air to a constant temperature and varies airflow to ensure thermal comfort.

Wet bulb: Combination of outside air temperature and relative humidity; higher relative humidity makes it more difficult for a cooling tower to evaporate water into the atmosphere.

HVAC SYSTEMS

The systems for accomplishing heating, ventilation, and air conditioning of indoor spaces vary considerably, based on factors including building type and program, cost, climate, and building size. The basic principals and components of heating, cooling, and circulating are similar across all systems.

Cooling tower: Open recirculating system where heat exchange occurs by evaporation.



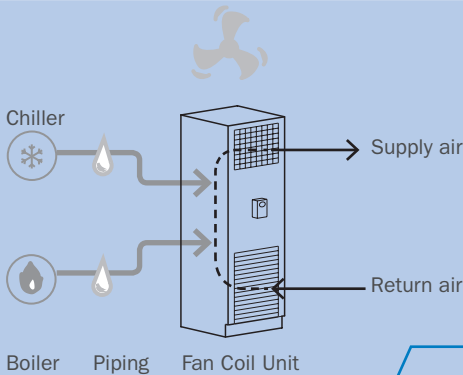
Boiler: Tank where the heat produced from the combustion of fuels (natural gas, fuel oil, wood, or coal) generates hot water or steam for use in heating.

Chiller: Heat exchanger (evaporator, condenser, and compressor system) that uses air, a refrigerant, water, and evaporation to transfer heat and produce air-conditioning.

MECHANICAL DISTRIBUTION TYPES

FAN COIL UNITS

Fan coil units (FCUs) contain cooling or heating coils and a fan. Typically, hot or chilled water is piped to the unit from a central boiler and chiller. Air from the room is drawn into the unit (return air) and blown over the coil by a fan. The air is then heated or cooled and discharged (supply air) to the room. FCUs may be vertical or horizontal, mounted on walls, ceilings, or freestanding.



2-Pipe: System has one supply and one return pipe. Must be changed over from hot to cold with change in seasons.

4-Pipe: System has hot supply, hot return, cold supply, and cold return pipes, allowing the system to change between heating and cooling at any time.

Horizontal Console

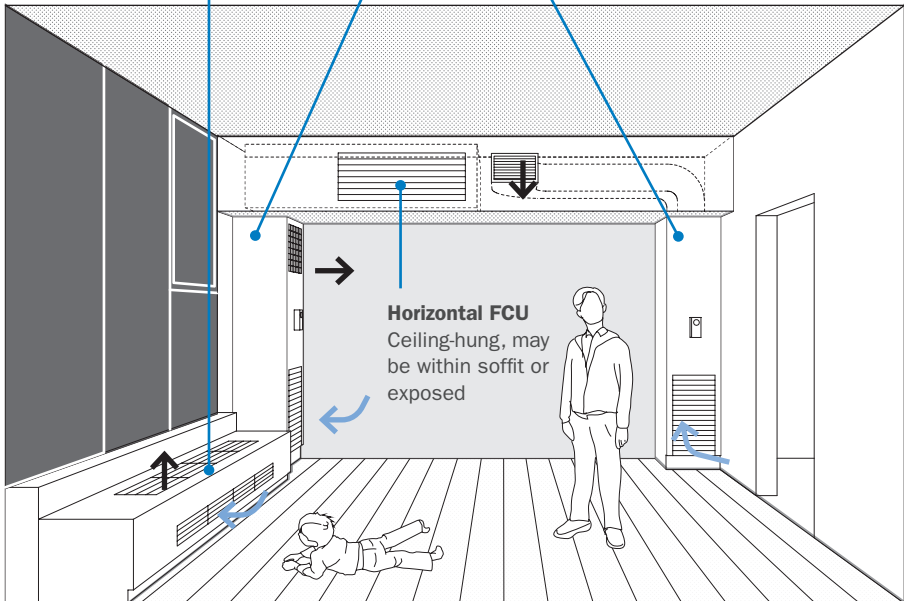
Floor-mounted, often at exterior wall

Vertical Stack

May be concealed within wall system, or freestanding

Vertical Stack—ducted

May be concealed within wall system, or freestanding

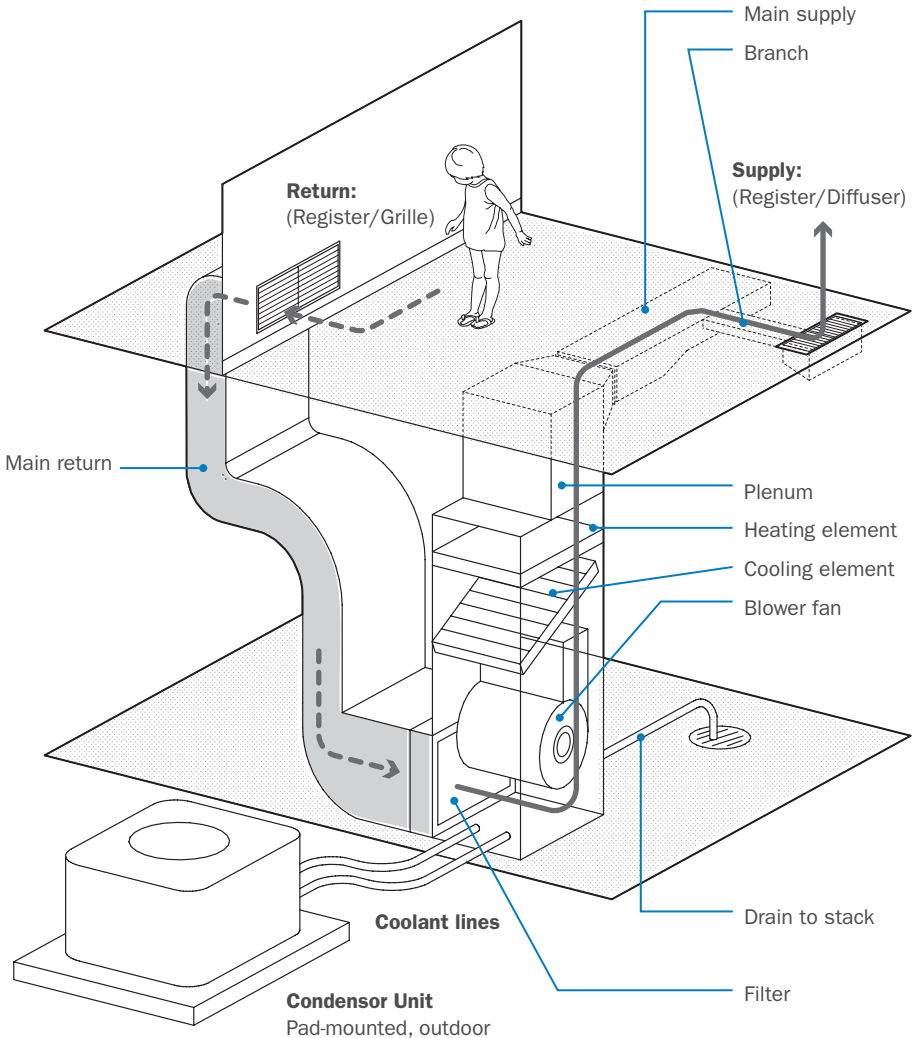


FORCED AIR DUCT SYSTEM

A duct system distributes heated, cooled, and fresh air throughout the building, while also filtering and dehumidifying the air.

HYDRONIC SYSTEMS

Hydronic systems provide heating, but typically not cooling. Hot water is circulated through tubing, from the central heat source to radiators throughout the space to be heated. The radiators may be wall-mounted or floor-mounted. Tubes may also be designed into floor systems, providing consistent radiant heat. Heat sources may include boilers, water heaters, and solar power.



FORCED AIR FURNACE — Typical residential heating and cooling system

SUSTAINABLE DESIGN

The issue of sustainable design shines a bright light on architecture's need to grow, learn, and adapt to a changing world. By nature, architecture is subject to inertia: buildings take years to design and realize, and architects, engineers, and contractors take years to train. This process once ensured painstaking attention to detail and craftsmanship that resulted in a building that could last forever. Today architecture must too often bend to economic pressures to build quickly and inexpensively. Technological and engineering advances allow for such economy, though often at the risk of producing disposable buildings, ultimately unable to stand the test of time and frequently at odds with the well-being of the environment. Sustainable design proposes using systems that meet present needs without compromising those of future generations. Architects, for their part, are increasingly compelled to understand and implement such new systems and methods as they envision ways in which buildings may work with the environment and the living world. The result is a built world that enhances instead of diminishes its surroundings and resources. Designing sustainably is not just one thing or a static set of rules, but a conscious and informed confluence of many approaches.

KEY TERMS

Adaptive reuse:

Changing a building's function in response to the changing needs of its users.

Embodied energy:

All of the energy consumed by all of the processes associated with the production of a building, including transportation.

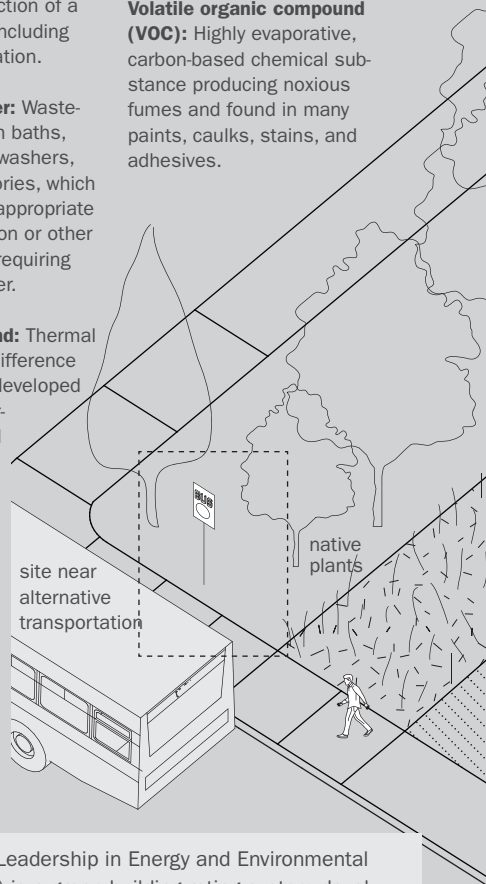
Gray water: Wastewater from baths, showers, washers, and lavatories, which might be appropriate for irrigation or other uses not requiring clean water.

Heat island: Thermal gradient difference between developed and under-developed areas.

Passive solar: Technology of heating and cooling a building naturally, through the use of energy-efficient materials and proper site placement.

Renewable: Resource that comes into being through a relatively quick natural process. Bamboo is an excellent example.

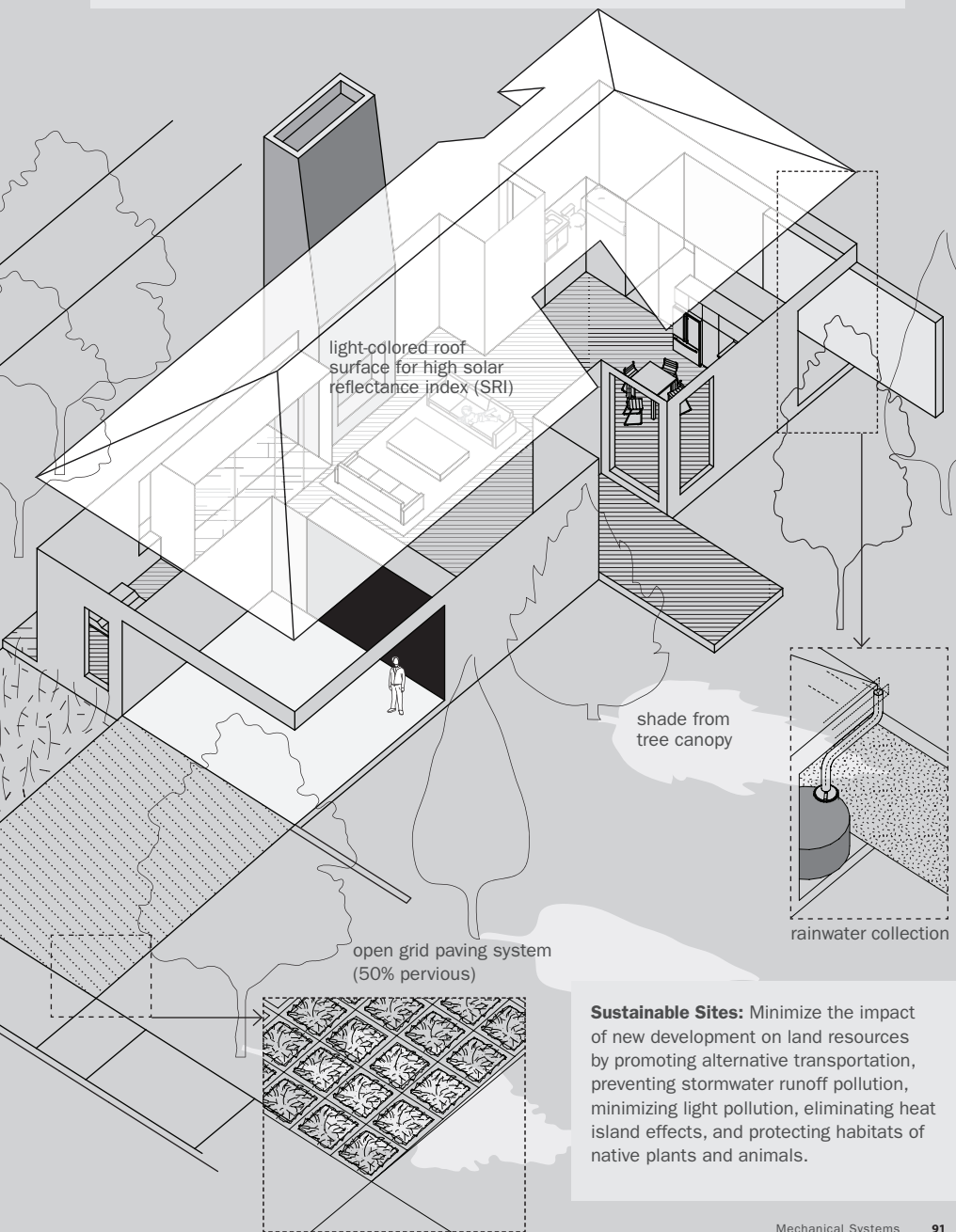
Volatile organic compound (VOC): Highly evaporative, carbon-based chemical substance producing noxious fumes and found in many paints, caulks, stains, and adhesives.



LEED (Leadership in Energy and Environmental Design) is a green building rating system developed by the U.S. Green Building Council, and is a recognized national standard for developing high-performing and sustainable buildings. A handful of LEED points are described and explored here.

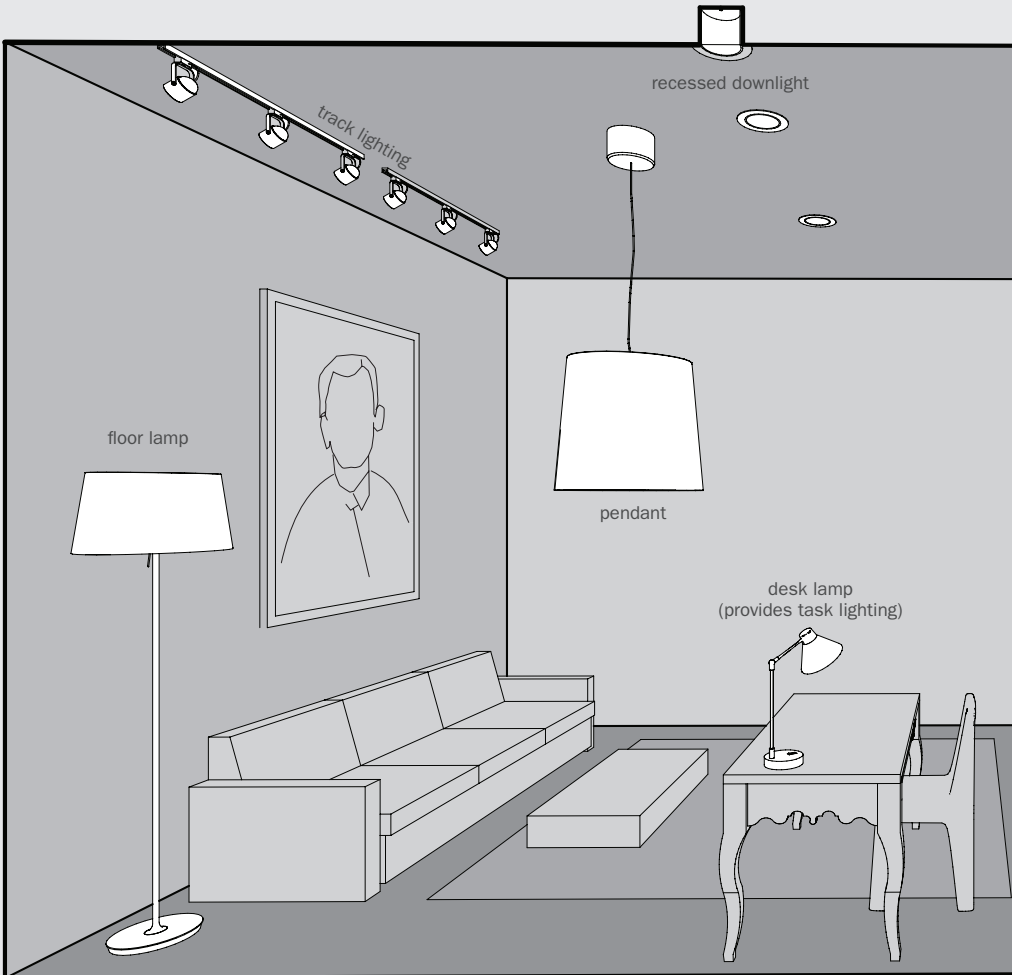
Materials and Resources: Make responsible material choices that privilege salvaged materials and those with recycled content, have low embodied energy, or come from renewable sources.

Indoor Environment: Strive for good ventilation, thermal comfort, use of low-VOC materials that will minimize off-gassing pollutants, and natural daylight and views.



Chapter 8: Lighting

Lighting has a tremendous effect on the manner in which a space will be experienced and perceived. Architects often work closely with lighting designers, who provide expertise on the technical aspects and effects of lighting and how they can best serve the design and function of a space. Lighting designers provide lighting specifications for the project and coordinate much of their design information with the electrical drawings and reflected ceiling plans.



Ambient lighting: General lighting for an entire space.

Ballast: Device that provides starting voltage for a fluorescent or HID lamp, then limits and regulates the current in the lamp during operation.

Bulb: Decorative glass or plastic housing that diffuses light distribution.

Candela: SI unit of the luminous intensity of a light source in a specific direction. Also called candle.

Candlepower (CP): Measure (in candelas) of the luminous intensity of a light source in a specific direction.

Foot-candle (FC): English unit of measuring the light level on a surface, equal to one lumen per square foot.

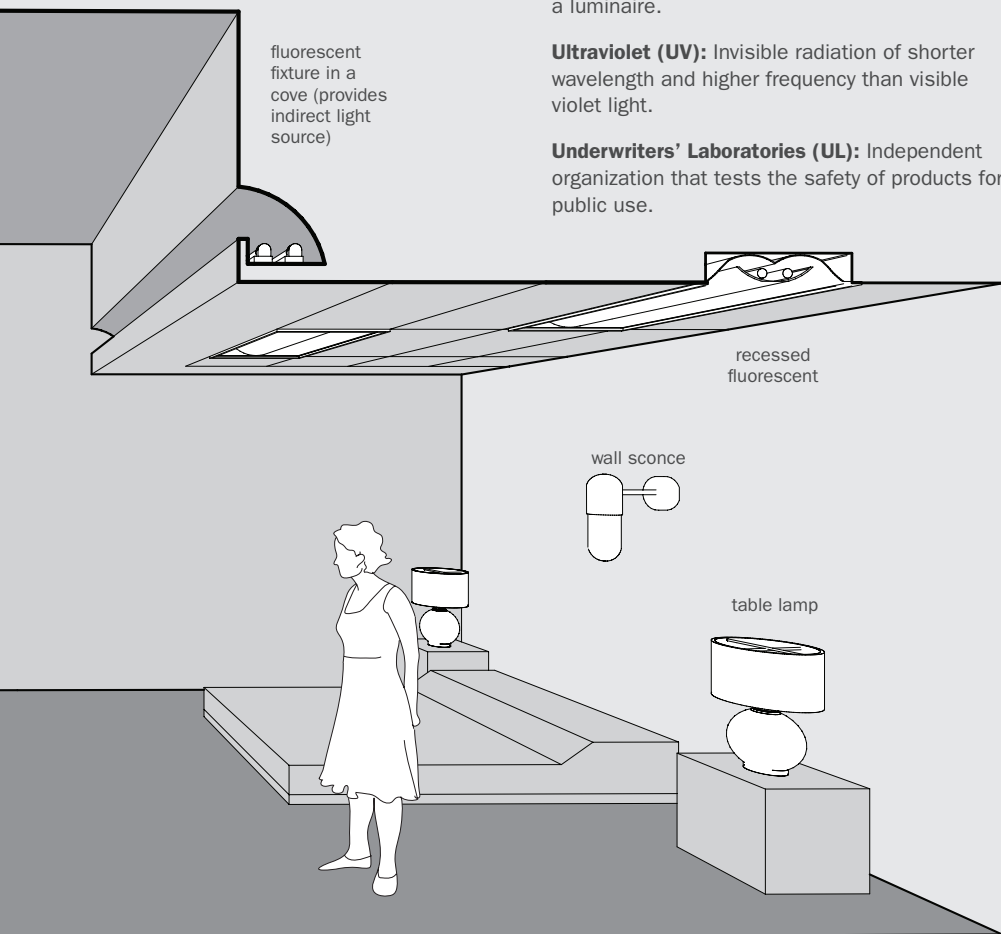
IALD: International Association of Lighting Designers.

IESNA: Illuminating Engineering Society of North America.

Optics: Components of a light fixture—reflectors, refractors, lenses, louvers, and so on; or, the light-emitting performance of a luminaire.

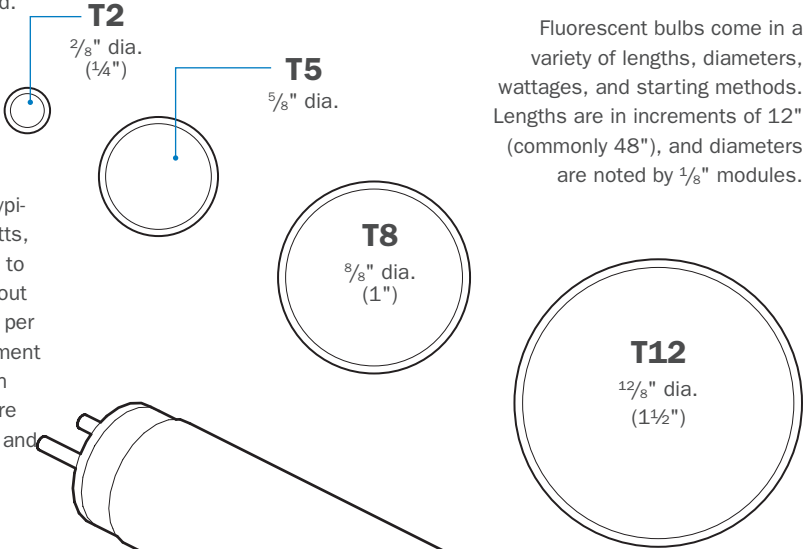
Ultraviolet (UV): Invisible radiation of shorter wavelength and higher frequency than visible violet light.

Underwriters' Laboratories (UL): Independent organization that tests the safety of products for public use.



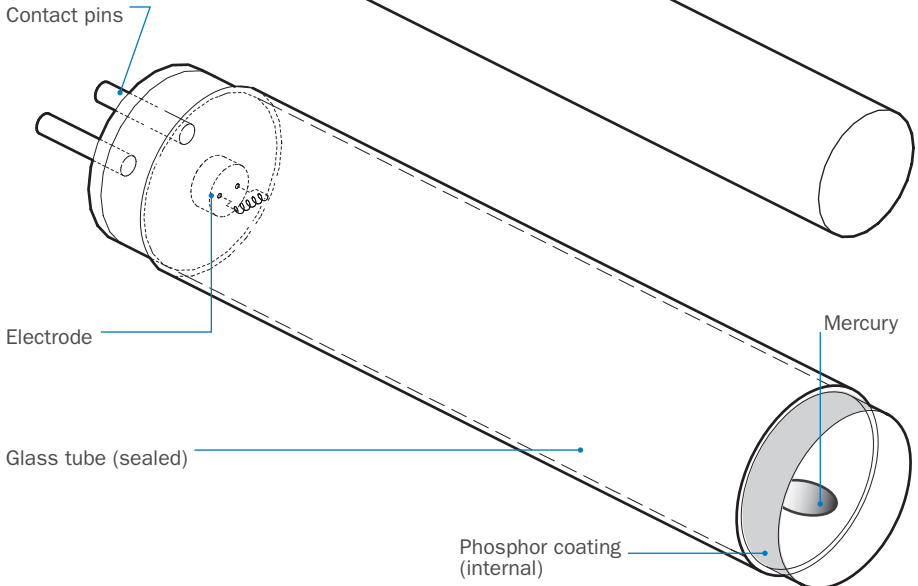
COMMON BULB TYPES

Fluorescent lamps are long, sealed glass tubes, coated inside with a phosphor powder. Fluorescent bulbs contain mercury, which is converted from a liquid to a gas by the energy produced by electrodes at either end.

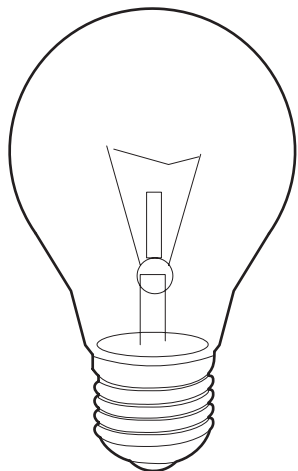


T12 bulbs, which are typically 40 watts, have begun to be phased out in the U.S., per the Department of Energy, in favor of more efficient T8 and T5 lamps.

Fluorescent bulbs come in a variety of lengths, diameters, wattages, and starting methods. Lengths are in increments of 12" (commonly 48"), and diameters are noted by 1/8" modules.

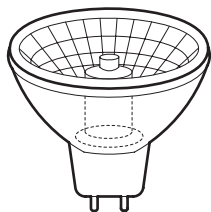


Bulbs are typically identified by a letter or letters that indicate its type or shape, and a number that indicates the greatest diameter of the bulb in $\frac{1}{8}$ ".



Incandescent

The A-series incandescent light bulb has long been the "classic" multi-purpose bulb type. The most common size is the A19 ($2\frac{3}{8}$ " dia.)



MR (Multi-faceted Reflector)

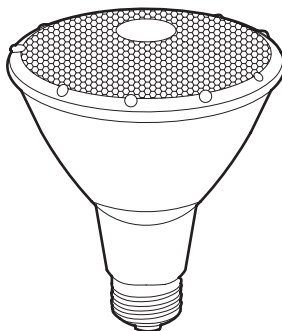
The inside surface of MR lamps is faceted and covered in a reflective coating. The light is produced by a single-ended quartz halogen filament capsule.

Common sizes are MR16 (2" dia.), MR11 ($1\frac{3}{8}$ " dia.), and MR8 (1" dia.)



CFL (Compact Fluorescent Lamp)

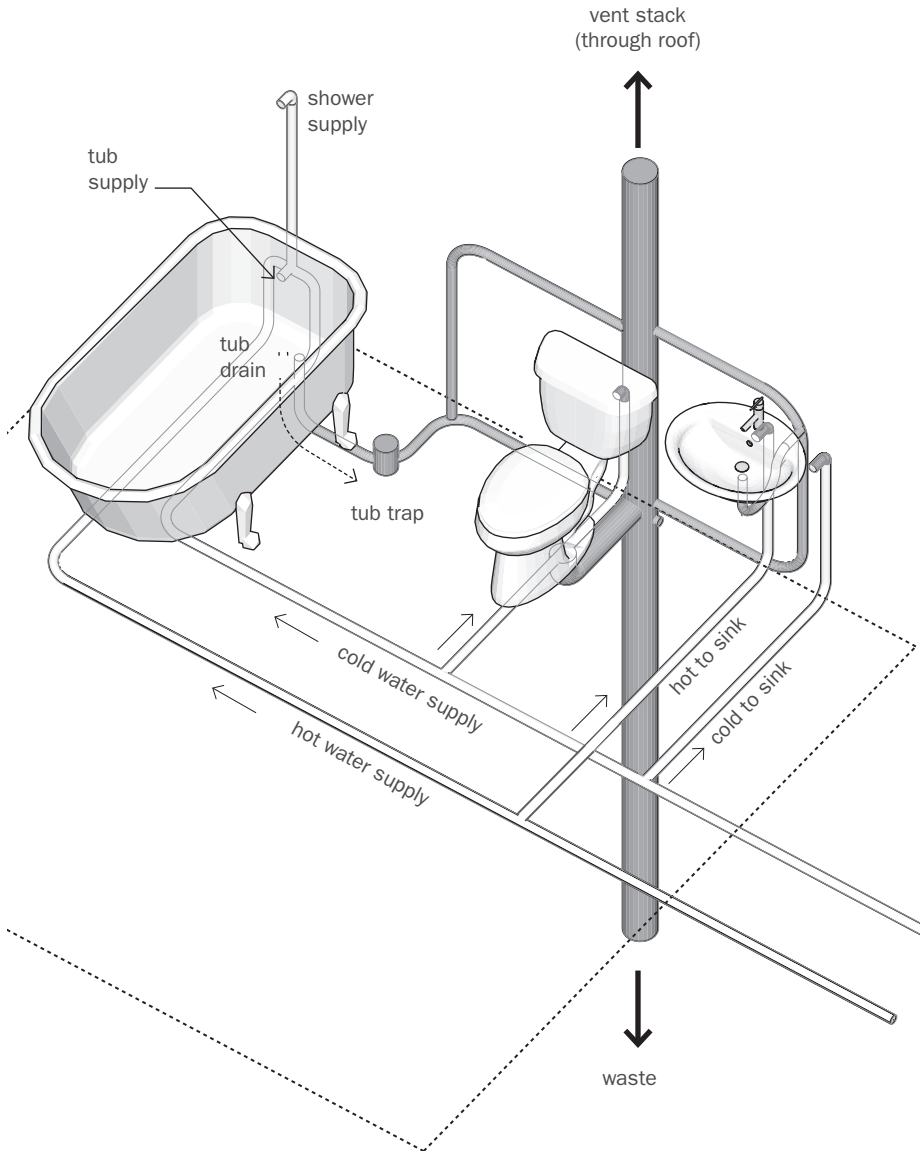
CFLs are fluorescent lights designed to replace incandescent bulbs - many screw into the same fixtures, and the fluorescent tube has been folded and curved to fit the same volume as a typical incandescent bulb. CFLs use less power and last longer than incandescent, though their mercury content makes safe disposal difficult.



PAR (Parabolic Aluminized Reflector)

PARs contain the light bulb, reflector, and lens within one unit, allowing them to shape and concentrate light for specific tasks and settings. The light is a sealed beam incandescent. Sizes vary, and include PAR 16 (2" dia.), PAR 30 ($3\frac{3}{4}$ " dia.), PAR 38 ($4\frac{3}{4}$ " dia.), and PAR 64 (8" dia.)

Chapter 9: Plumbing

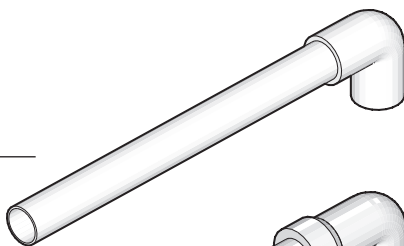


Common Bathroom Pipe Layout

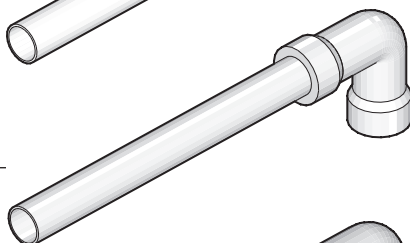
PIPES

SUPPLY

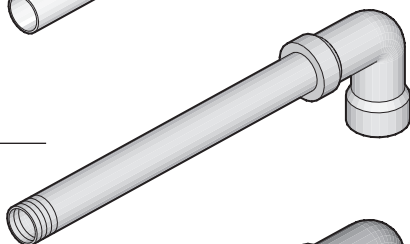
Water Supply: _____
white plastic (PVC)
½"–1" dia.



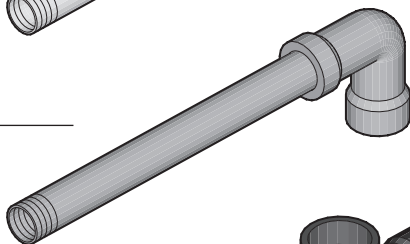
Water or Gas Supply: _____
copper
½"–1" dia.



Water Supply: _____
galvanized iron
½"–1" dia.

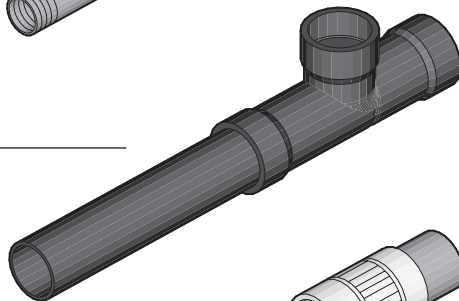


Gas Supply: _____
black iron
½"–1" dia.

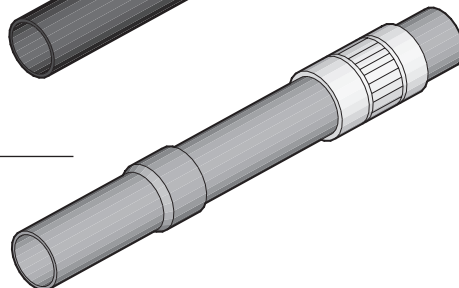


DRAIN

Drain and Vent: _____
black plastic
1½" + dia.



Drain and Vent: _____
cast iron
1½" + dia.



MEASURE AND DRAWING **3.**

For an architect's ideas to evolve into fully considered designs, they require constant evaluation, investigation, and experimentation. Scribbled notes and sketches are quickly put to the test as real scales and measures are applied; flat plans grow into volumes, and spaces are examined inside and out. To become built form, ideas must be communicated to the various groups involved in the design process, and so the architect embarks on a cycle of production and presentation.

For presentation to the client whose building this will become, communication can take the form of sketches, cardboard models, computer models, and digital animations—whatever is needed to ensure that the design is understood. In preparing such materials, the architect often discovers new aspects of the design that prompt further study and presentation.

For construction, the architect prepares documents to certain standards. Technical measured drawings describe everything necessary to erect the building. Depending on the size of the project, many other parties will also be involved, from structural and mechanical engineers to electrical engineers and lighting designers. Each of these trades also produces construction documents specific to their work and coordinated with the entire set. In every case, these drawings and written specifications must be clear and precise to ensure a well-built structure.

Chapter 10: Measurement and Geometry

The two primary measurement systems used in the world today are the metric system, also known as the *Système International d'Unités* and commonly abbreviated to SI in all languages, and the U.S. customary units system, referred to in the United States as English units or standard units. The latter is an irregular system based on imperial units once used in the United Kingdom and the British Commonwealth.

The metric system has become the universally accepted system of units in science, trade, and commerce. In the United States, however, where the Metric Conversion Act of 1975 established SI as the preferred system of weights and measures for trade and commerce, federal laws have yet to mandate SI as the official system, making its use still primarily voluntary. Several U.S. agencies, including the American National Metric Council (ANMC) and the United States Metric Association (USMA), are working to establish SI as the official measurement system, a process known as metrication. Though the architectural, engineering, and building trades have been slow to make a full transition, nearly all federally funded building projects are now required to be in SI units.

UNITS OF MEASURE: CUSTOMARY UNIT DATA

Customary units may be shown in a number of ways, including as fractions ($1\frac{1}{2}$ " or as decimals (1.5 " or 0.125 '), depending on the more common usage for a particular situation. It should be noted that, though not the case here, exponents can be used with abbreviations that designate area or volume—for example, 100 ft.^2 for area or 100 ft.^3 for volume.

Linear Equivalents

Customary Unit of Measure	Relation to Other Customary Units
inch (in. or ")	$\frac{1}{12}$ ft.
foot (ft. or')	12 in. $\frac{1}{3}$ yd.
yard (yd.)	36 in. 3 ft.
rod (rd.), pole, or perch	$16\frac{1}{2}$ ft. $5\frac{1}{2}$ yd.
chain	4 rd. 22 yd.
furlong	220 yd. or 40 rd. or 10 chains or $\frac{1}{8}$ mi.
mile (mi.), statute	5,280 ft. or 1,760 yd. or 8 furlongs
mile (mi.), nautical	2,025 yd.

Area Equivalents

Customary Unit of Measure	Relation to Other Customary Units
square inch (sq. in.)	$0.007\ (\frac{1}{144})$ sq. ft.
square foot (sq. ft.)	144 sq. in.
square yard (sq. yd.)	1,296 sq. in. 9 sq. ft.
square pole	$30\frac{1}{4}$ sq. yd.
acre	43,560 sq. ft. $40\text{ rd. (1 furlong)} \times 4\text{ rd. (1 chain)}$
square mile (sq. mi.)	640 acres

Fraction to Decimal Equivalents

Fraction	Decimal
$1/32$	0.03125
$1/16$	0.0625
$3/32$	0.0938
$1/8$	0.1250
$5/32$	0.1563
$3/16$	0.1875
$7/32$	0.2188
$1/4$	0.2500
$9/32$	0.2813
$5/16$	0.3125
$11/32$	0.3438
$3/8$	0.3750
$13/32$	0.4063
$7/16$	0.4375
$15/32$	0.4688
$1/2$	0.5000
$17/32$	0.5313
$9/16$	0.5625
$19/32$	0.5938
$5/8$	0.6250
$21/32$	0.6563
$11/16$	0.6875
$23/32$	0.7188
$3/4$	0.7500
$25/32$	0.7813
$13/16$	0.8125
$27/32$	0.8438
$7/8$	0.8750
$29/32$	0.9063
$15/16$	0.9375
$31/32$	0.9688
$1/1$	1.0000

METRIC CONVERSION

Conversion Factors for Length

Customary	Metric
1 in.	25.4 mm
1 ft.	0.3048 m or 304.8 mm
1 yd.	0.9144 m
1 mi.	1.609344 km

Customary	Metric
1 sq. in.	645.16 mm ²
1 sq. ft.	0.092903 m ²
1 sq. yd.	0.836127 m ²
1 acre	0.404686 ha or 4046.86 m ²
1 sq. mi.	2.59000 km ²

Conversion Factors for Length

Metric	Customary
1 micrometer (μm)	0.0000394 in. or 0.03937 mils
1 mm	0.0393701 in.
1 m	3.28084 ft. or 1.09361 yd.
1 km	0.621371 mi.

Conversion Factors for Area

Metric	Customary
1 mm ²	0.001550 sq. in.
1 m ²	10.7639 sq. ft. or 1.19599 sq. yd.
1 ha	2.47105 acres
1 km ²	0.368102 sq. mi.

UNITS OF MEASURE: SI METRIC UNIT DATA

The General Conference on Weights and Measures (abbreviated to CGPM from the French *Conférence Générale des Poids et Mesures*), which meets every four years concerning issues related to the use of the metric system, has established specific rules for use, type style, and punctuation of metric units. The National Institute of Standards and Technology (NIST)—formerly the National Bureau of Standards (NBS)—determines metric usage in the United States. Millimeters are the preferred unit for dimensioning buildings, with no symbol necessary if they are used consistently. Meters and kilometers are reserved for larger dimensions such as land surveying and transportation.

Unit names and symbols employ standard, lowercase type, except for symbols derived from proper names (for example, N for newton). Another exception is L for liter, to avoid confusing the lowercase l with the numeral 1. Prefixes describing multiples and submultiples are also lowercase, except for M, G, and T (mega-, giga-, and tera-), which are capitalized in symbol form to avoid confusion with unit symbols, but which maintain the lowercase standard when spelled out. No space is left between the prefix and the letter for the unit name (mm for millimeter and mL for milliliter). A space is left between the numeral and the unit name or symbol—for example, 300 mm.

Linear Metric Equivalents

Millimeters (mm)	Centimeters (cm)	Decimeters (dm)	Meters (m)	Decameters (dam)	Hectometers (hm)	Kilometers (km)
1	0.1	0.01	0.001	0.000 1	0.000 01	0.000 001
10	1	0.1	0.01	0.001	0.000 1	0.000 01
100	10	1	0.1	0.01	0.001	0.000 1
1 000	100	10	1	0.1	0.01	0.001
10 000	1 000	100	10	1	0.1	0.01
100 000	10 000	1 000	100	10	1	0.1
1 000 000	100 000	10 000	1 000	100	10	1

Area Metric Equivalents

Square Millimeters (mm ²)	Square Centimeters (cm ²)	Square Decimeters (dm ²)	Square Meters (m ²)	Ares	Hectares (ha)	Square Kilometers (km ²)
1	0.0 1	0.001	0.000 001			
100	1	0.01	0.000 1	0.000 001		
10 000	100	1	0.01	0.000 1	0.000 001	
1 000 000	10 000	100	1	0.01	0.000 1	0.000 001
	1 000 000	10 000	100	1	0.01	0.000 1
		1 000 000	10 000	100	1	0.01
			1 000 000	10 000	100	1

Although the United States and Canada mark the decimal with a point, other countries use a comma (for example: 5,00 vs. 5.00). For this reason, commas should not be used to separate groups of digits. Instead, the digits should be separated into groups of three, both to the left and the right of the decimal point, with a space between each group of three digits (for example, 1,000,000 is written as 1 000 000). This convention for metric units is used throughout the book.

Units with Compound Names

Physical Quantity	Unit	Symbol
Area	square meter	m ²
Volume	cubic meter	m ³
Density	kilogram per cubic meter	kg/m ³
Velocity	meter per second	m/s
Angular velocity	radian per second	rad/s
Acceleration	meter per second squared	m/s ²
Angular acceleration	radian per second squared	rad/s ²
Volume rate of flow	cubic meter per second	m ³ /s
Moment of inertia	kilogram meter squared	kg m ²
Moment of force	newton meter	N m
Intensity of heat flow	watt per square meter	W/m ²
Thermal conductivity	watt per meter kelvin	W/m K
Luminance	candela per square meter	cd/m ²

Area in Metrics

SI metric units for area, like volume, are derived from the base units for length. They are expressed as powers of the base unit: for example, square meter = m² = 10⁶ mm².

The square centimeter is not a recommended unit for construction and should be converted to square millimeters.

The hectare is acceptable only in the measurement of land and water.

When area is expressed by linear dimensions, such as 50 × 100 mm, the width is written first and the depth or height second.

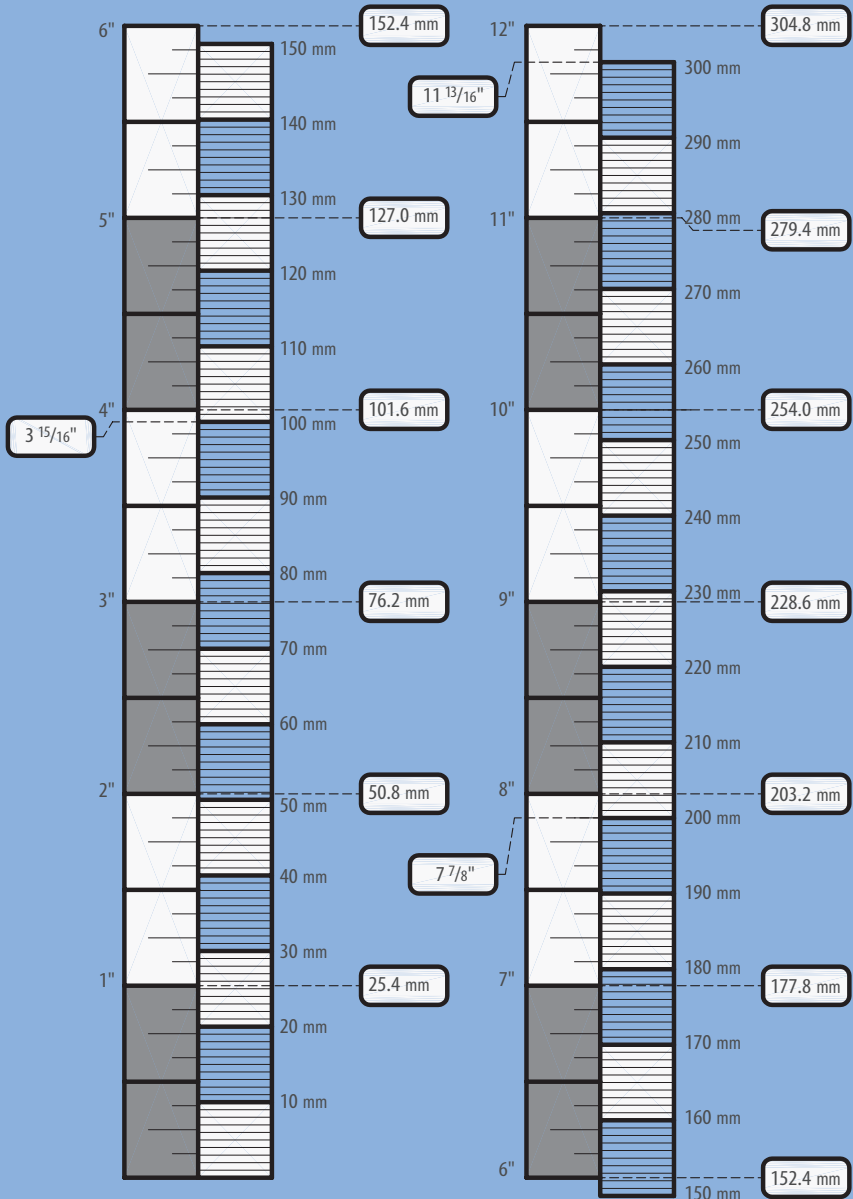
SOFT AND HARD CONVERSIONS

Conversions of customary and SI units can be either “soft” or “hard.” In a soft conversion, 12 inches equals 305 millimeters (already rounded up from 304.8). In a hard conversion of this same number, 12 inches would equal 300 millimeters, which makes for a cleaner and more rational equivalency. This is the ultimate goal of total metrication within the building trades. The process, however, is an extensive one, which will require many building products whose planning grid is in customary units to undergo a hard metric conversion of their own, making 6 inches equal 150 millimeters (instead of 152) and 24 inches equal 600 millimeters (instead of 610). Thus, to conform to a rational metric grid, the actual sizes of standard products such as drywall, bricks, and ceiling tiles will need to change.

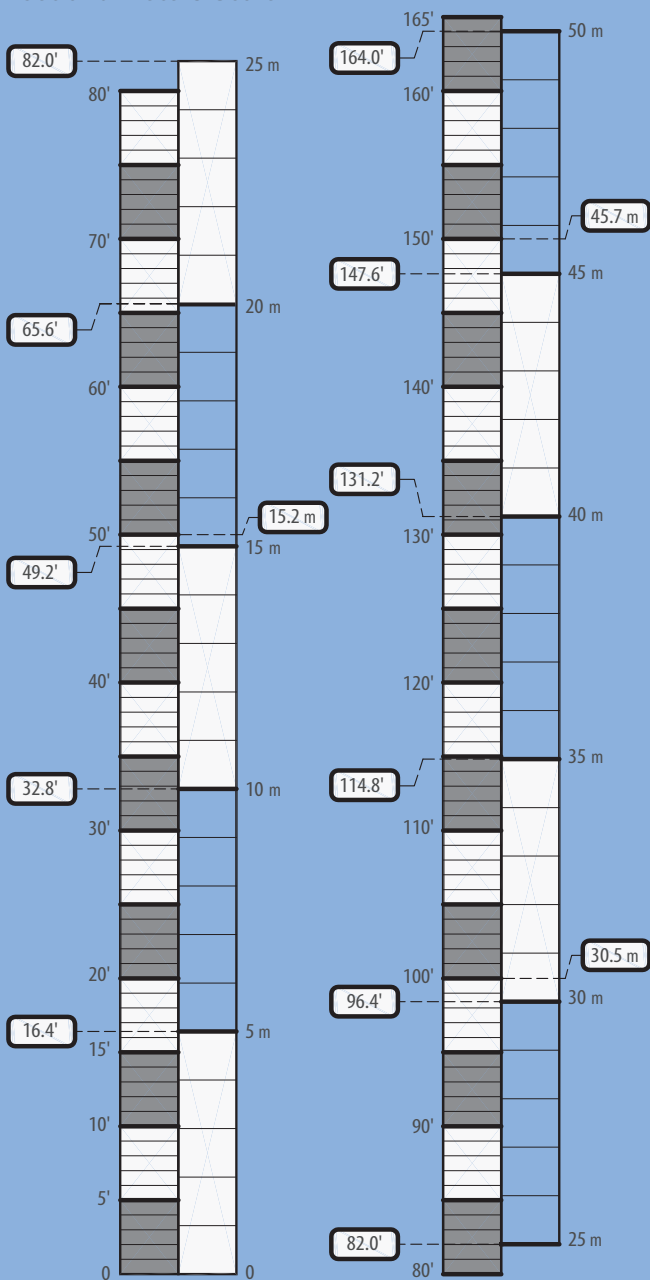
Every attempt has been made in this book to represent accurately the relationship between customary and SI units. Except where noted, soft conversions are used throughout and, due to constraints of space, are usually written as follows: 1'-6" (457).

METRIC CONVERSION

Inches and Millimeters Scale



Feet and Meters Scale



Feet	Inches
1	12
2	24
3	36
4	48
5	60
6	72
7	84
8	96
9	108
10	120
11	132
12	144
13	156
14	168
15	180
16	192
17	204
18	216
19	228
20	240
21	252
22	264
23	276
24	288
25	300
26	312
27	324
28	336
29	348
30	360
31	372
32	384
33	396
34	408
35	420

SLOPES AND PERCENTAGE GRADE

Note: Entries in blue indicate frequently used slopes. Slopes gentler than 1:20 do not require handrails; 1:12 is the maximum ADA-approved slope for ramps and 1:8 is the maximum code-approved slope for ramps (non-ADA).

Degrees	Gradient	% Grade	Degrees	Gradient	% Grade	Degrees	Gradient	% Grade
0.1	1:573.0	0.2	23.0	1:2.4	42.4	57.0	1:0.6	154.0
0.2	1:286.5	0.3	24.0	1:2.2	44.5	58.0	1:0.6	160.0
0.3	1:191.0	0.5	25.0	1:2.1	46.6	59.0	1:0.6	166.4
0.4	1:143.2	0.7	26.0	1:2.1	48.8	60.0	1:0.6	173.2
0.5	1:114.6	0.9	27.0	1:2.0	51.0	61.0	1:0.6	180.4
0.6	1:95.5	1.0	28.0	1:1.9	53.2	62.0	1:0.5	188.1
0.7	1:81.8	1.2	29.0	1:1.8	55.4	63.0	1:0.5	196.2
0.8	1:71.6	1.4	30.0	1:1.7	57.7	64.0	1:0.5	205.0
0.9	1:63.7	1.6	31.0	1:1.7	60.1	65.0	1:0.5	214.5
1.0	1:57.3	1.7	32.0	1:1.6	62.5	66.0	1:0.4	224.6
2.0	1:28.6	3.5	33.0	1:1.5	64.9	67.0	1:0.4	235.6
2.86	1:20.0	5.0	34.0	1:1.5	67.5	68.0	1:0.4	247.5
3.0	1:19.1	5.2	35.0	1:1.4	70.0	69.0	1:0.4	260.5
4.0	1:14.3	7.0	36.0	1:1.4	72.7	70.0	1:0.4	274.7
4.76	1:12.0	8.3	37.0	1:1.3	75.4	71.0	1:0.3	290.4
5.0	1:11.4	8.7	38.0	1:1.3	78.1	72.0	1:0.3	307.8
6.0	1:9.5	10.5	39.0	1:1.2	81.0	73.0	1:0.3	327.1
7.0	1:8.1	12.3	40.0	1:1.2	83.9	74.0	1:0.3	348.7
7.13	1:8.0	12.5	41.0	1:1.2	86.9	75.0	1:0.3	373.2
8.0	1:7.1	14.1	42.0	1:1.1	90.0	76.0	1:0.2	401.1
9.0	1:6.3	15.8	43.0	1:1.1	93.3	77.0	1:0.2	433.1
10.0	1:5.7	17.6	44.0	1:1.0	96.6	78.0	1:0.2	470.5
11.0	1:5.1	19.4	45.0	1:1.0	100.0	79.0	1:0.2	514.5
12.0	1:4.7	21.3	46.0	1:1.0	103.6	80.0	1:0.2	567.1
13.0	1:4.3	23.1	47.0	1:0.9	107.2	81.0	1:0.2	631.4
14.0	1:4.0	24.9	48.0	1:0.9	111.1	82.0	1:0.1	711.5
15.0	1:3.7	26.8	49.0	1:0.9	115.0	83.0	1:0.1	814.4
16.0	1:3.5	28.7	50.0	1:0.8	119.2	84.0	1:0.1	951.4
17.0	1:3.3	30.6	51.0	1:0.8	123.5	85.0	1:0.1	1,143.0
18.0	1:3.1	32.5	52.0	1:0.8	128.0	86.0	1:0.1	1,430.1
19.0	1:2.9	34.4	53.0	1:0.8	132.7	87.0	1:0.1	1,908.1
20.0	1:2.7	36.4	54.0	1:0.7	137.6	88.0	1:0.0	2,863.6
21.0	1:2.6	38.4	55.0	1:0.7	142.8	89.0	1:0.0	5,729.0
22.0	1:2.5	40.4	56.0	1:0.7	148.3	90.0	1:0.0	∞

Calculating Slope Degrees:

$$\text{Slope} = \frac{\text{Vertical Rise Distance (V)}}{\text{Horizontal Distance (H)}} = \text{tangent } m$$

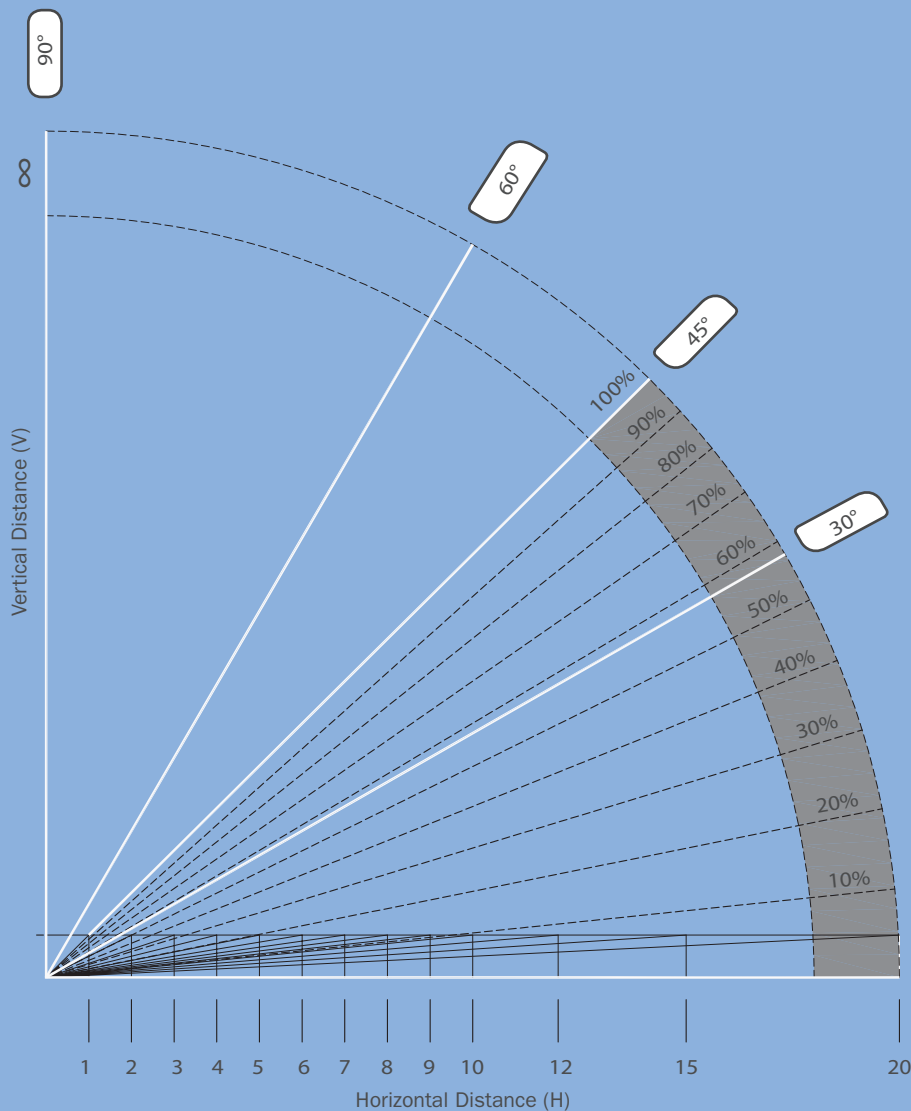
$$\text{Slope Angle} = \text{tangent } m$$

Calculating Gradient:

$$= 1 \text{ unit in } \frac{\text{Horizontal Distance (H)}}{\text{Vertical Distance (V)}}$$

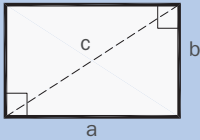
Calculating % Grade:

$$= 100 \times \text{Tangent (Slope) or } 100 \times V/H$$



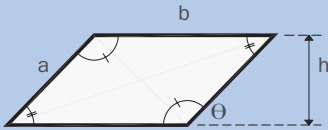
PLANE FIGURE FORMULAS

Rectangle



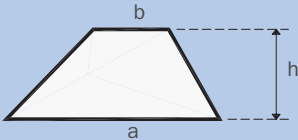
$$\begin{aligned} \text{area} &= ab \\ \text{perimeter} &= 2(a+b) \\ a^2 + b^2 &= c^2 \end{aligned}$$

Parallelogram



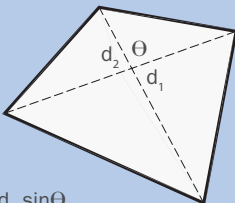
$$\begin{aligned} \text{area} &= ah = ab \sin \theta \\ \text{perimeter} &= 2(a+b) \end{aligned}$$

Trapezoid



$$\begin{aligned} \text{area} &= \frac{(a+b)}{2} h \\ \text{perimeter} &= \text{sum of length of sides} \end{aligned}$$

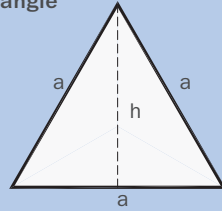
Quadrilateral



$$\text{area} = \frac{d_1 d_2 \sin \theta}{2}$$

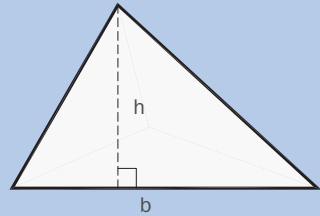
Equilateral Triangle

(all sides equal)



$$\begin{aligned} \text{area} &= a^2 \frac{\sqrt{3}}{4} = 0.433 a^2 \\ \text{perimeter} &= 3a \\ h &= \frac{a}{2} \sqrt{3} = 0.866a \end{aligned}$$

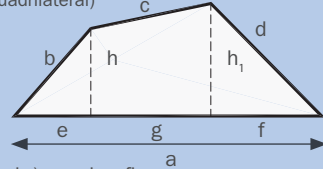
Triangle



$$\begin{aligned} \text{area} &= \frac{bh}{2} \\ \text{perimeter} &= \text{sum of length of all sides} \end{aligned}$$

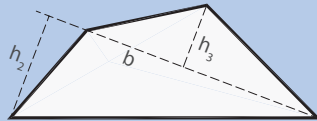
Trapezium

(irregular quadrilateral)



$$\begin{aligned} \text{area} &= \frac{(h + h_1)g + eh + fh_1}{2} \\ \text{perimeter} &= \text{sum of length of all sides} \end{aligned}$$

or

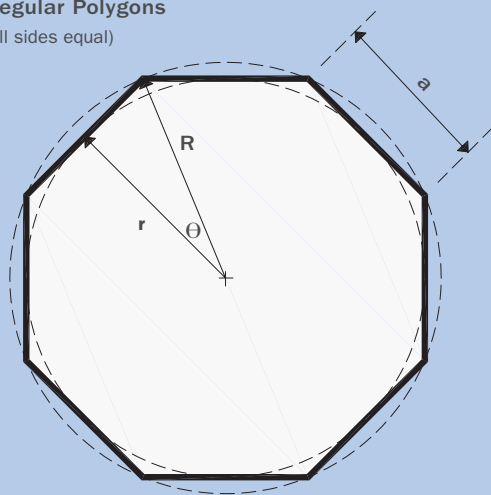


$$\text{area} = \frac{bh_2 + bh_3}{2}$$

(Divide figure into two triangles and add their areas together.)

Regular Polygons

(all sides equal)



n = number of sides

$$\text{area} = \frac{nar}{2} = nr^2$$

$$\tan \theta = \frac{nR^2}{2} \sin 2\theta$$

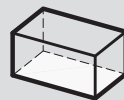
$$\text{perimeter} = n a$$

Polygon	Sides	Area
Triangle (equilateral)	3	$0.4330 a^2$
Square	4	$1.0000 a^2$
Pentagon	5	$1.7205 a^2$
Hexagon	6	$2.5981 a^2$
Heptagon	7	$3.6339 a^2$
Octagon	8	$4.8284 a^2$
Nonagon	9	$6.1818 a^2$
Decagon	10	$7.6942 a^2$
Undecagon	11	$9.3656 a^2$
Dodecagon	12	$11.1962 a^2$

VOLUMES

Prism or Cylinder (right or oblique, regular or irregular)

volume = area of base \times altitude



Altitude (h) = distance between parallel bases, measured perpendicular to the bases. When bases are not parallel, then altitude = perpendicular distance from one base to the center of the other.



Pyramid or Cone (right or oblique, regular or irregular)

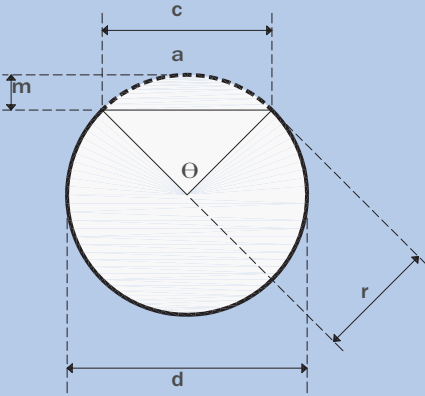
volume = area of base $\times \frac{1}{3}$ altitude



Altitude (h) = distance from base to apex, measured perpendicular to base.



CIRCLE



a = arc
 r = radius
 d = diameter
 c = cord
 m = distance
 Θ = degrees
 π = 3.14159

$$\text{circumference} = 2 \pi r = \pi d = 3.14159 d$$

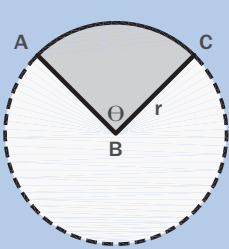
$$\text{area} = \pi r^2 = \pi \frac{d^2}{4} = 0.78539 d^2$$

$$\text{length of arc } a = \Theta \frac{\pi}{180} r = 0.017453 \Theta r$$

$$r = \frac{m^2 + c^2/4}{2m} = \frac{c/2}{\sin 1/2\Theta}$$

$$c = 2\sqrt{2mr - m^2} = 2r \sin 1/2\Theta$$

$$m = r \pm \frac{\sqrt{r^2 - c^2}}{4} \quad \begin{array}{l} \text{use + if arc } \geq 180^\circ \\ \text{use - if arc } < 180^\circ \end{array}$$



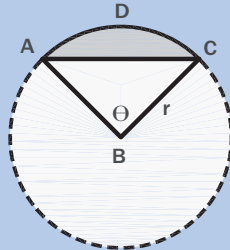
Sector of Circle

$$\text{arc length AC} = \frac{\pi r \Theta}{180}$$

$$\text{area ABCA} = \frac{\pi \Theta r^2}{360}$$

or

$$\text{area ABCA} = \frac{\text{arc length AC} \times r}{2}$$



Segment of Circle

$$\text{area ACDA} =$$

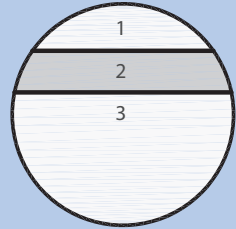
$$\frac{r^2}{2} \times \left(\frac{\pi \Theta}{180} - \sin \Theta \right)$$

r = radius

Θ = degrees

A, B, C, D = points

π = 3.14159



Circular Zone

$$\text{area 2} = \text{circle area} - \text{area 1} - \text{area 3}$$

1 = segment

2 = zone

3 = segment

ELLIPSE

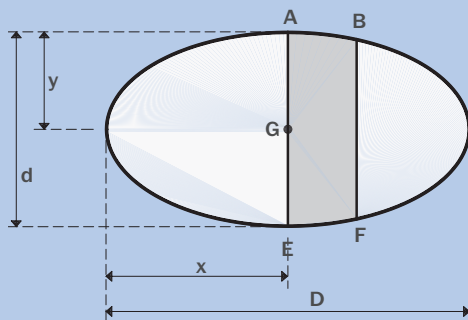
perimeter (approximate) =

$$\pi [1.5(x+y) - \sqrt{xy}]$$

(Assume point G is the center point of the ellipse, with x, y coordinates of O, O , and point B coordinates of B_x and B_y .)

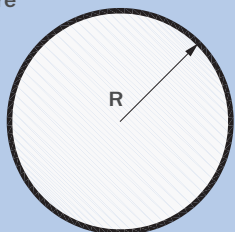
area ABFEA =

$$(B_x \times B_y) + ab \sin^{-1}(B_x/a)$$



DOUBLE-CURVED SOLIDS

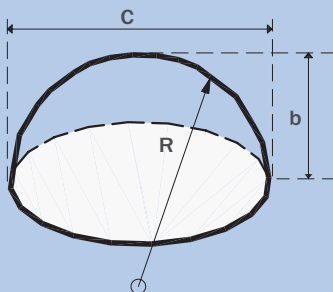
Sphere



$$\text{volume} = \frac{4 \pi R^3}{3}$$

$$\text{surface} = 4 \pi R^2$$

Segment of Sphere

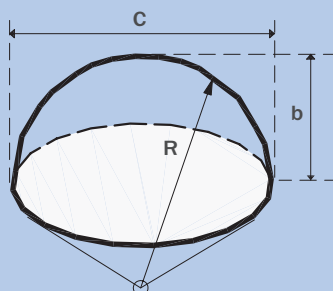


$$\text{volume} = \frac{\pi b^2 (3R - b)}{3}$$

(sector - cone)

$$\text{surface} = 2 \pi R b$$

Sector of Sphere

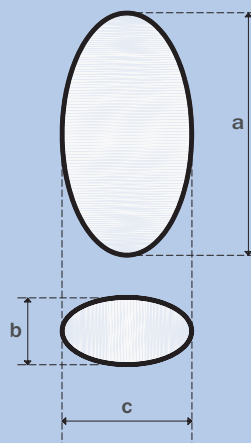


$$\text{volume} = \frac{2 \pi R^2 b}{3}$$

$$\text{surface} = \frac{\pi R (4b + C)}{2}$$

(segment + cone)

Ellipsoid



$$\text{volume} = \frac{\pi abc}{6}$$

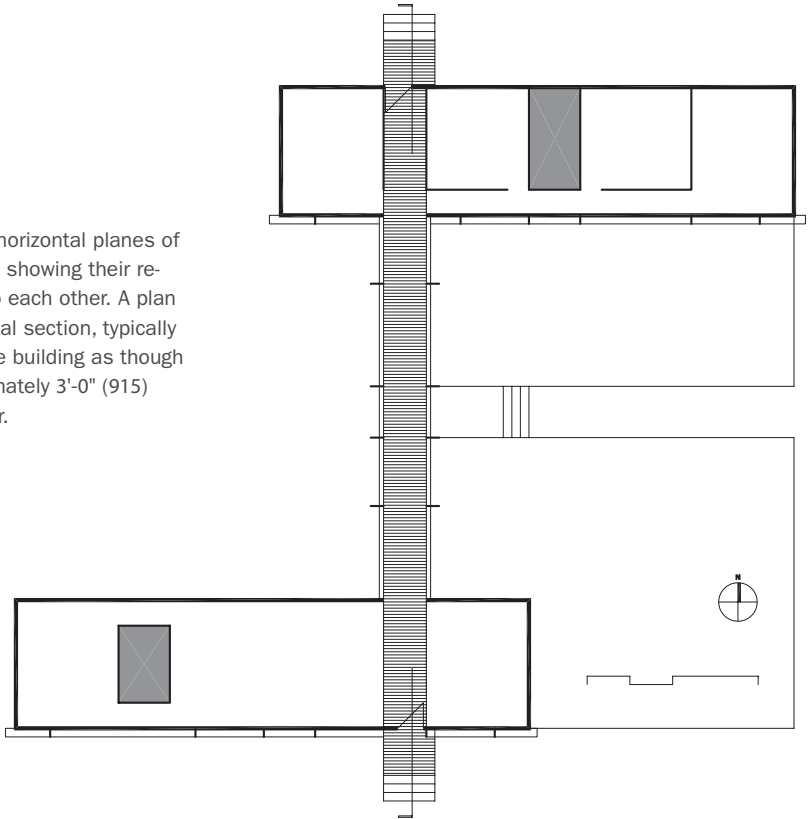
surface = no simple equation

Chapter 11: Architectural Drawing Types

An architect uses eight basic drawing types within the drawing set to most completely describe the design of a building.

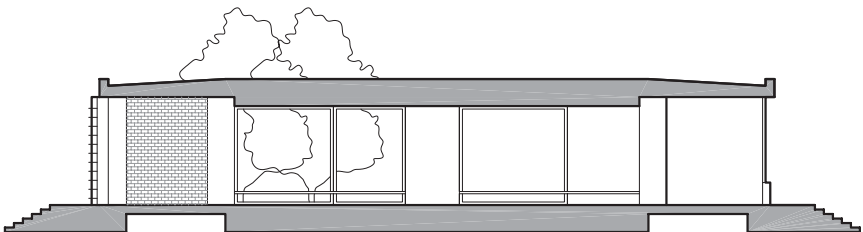
PLAN

View of the horizontal planes of the building, showing their relationship to each other. A plan is a horizontal section, typically depicting the building as though cut approximately 3'-0" (915) from its floor.



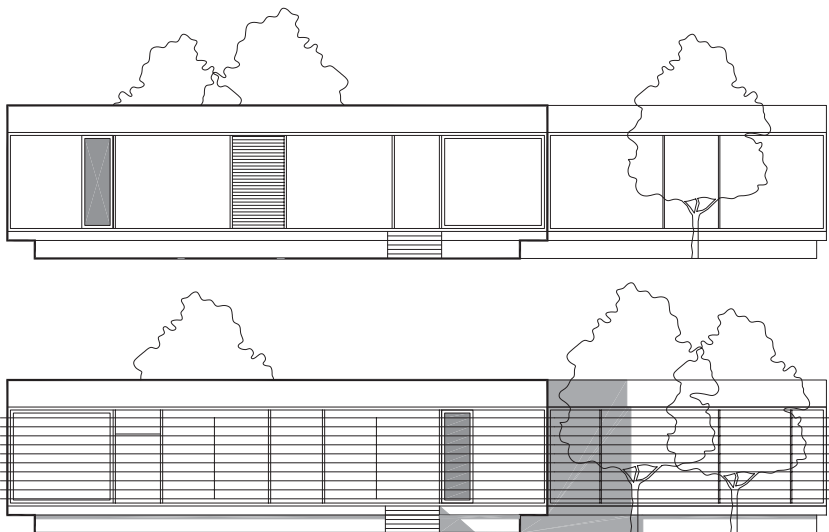
SECTION

View of a vertical cut through the building's components. A section acts as a vertical plan and often contains elevational information, such as doors and windows. This information is shown with a lighter line weight than the section cuts.



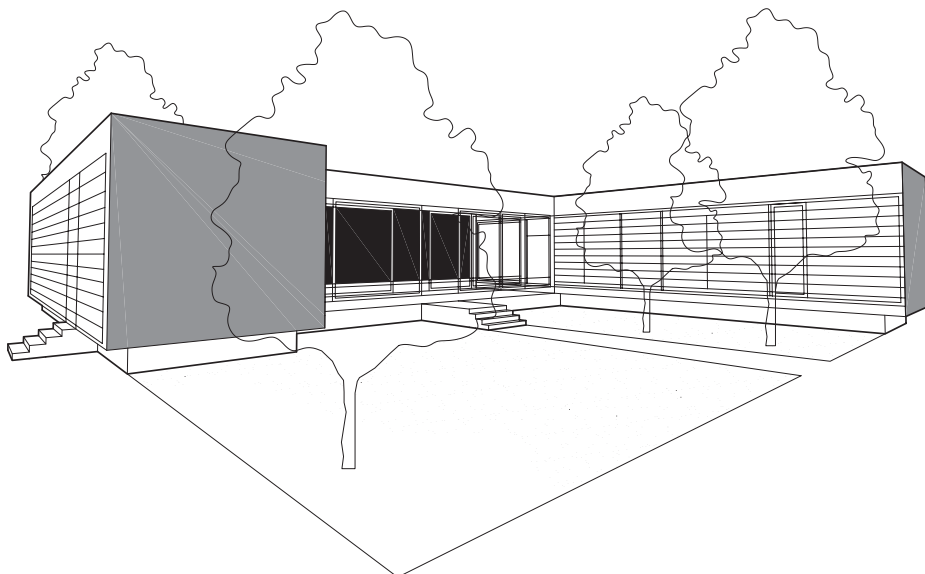
ELEVATION

View of the vertical planes of the building, showing their relationship to each other. An elevation is viewed perpendicularly from a selected plane.



THREE-DIMENSIONAL REPRESENTATIONS

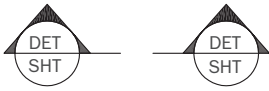
Perspectives (not scaled), axonometrics, and isometrics describe the building or space in a way that conventional plans, elevations, and sections cannot. Perspectives are particularly effective in producing a view that would actually be experienced by being in the space designed.



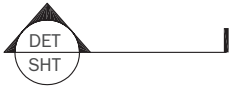
READING THE DRAWING SET

Drawing Symbols

Symbols and reference markers are necessary for navigating the drawing set. They tell whoever is looking at a drawing where to go to find out more information about certain elements.



building
section



wall or
detail section



detail section
(nondirectional)



enlarged
detail reference



elevation target



exterior elevation



interior elevation



room name and
room number



ceiling height

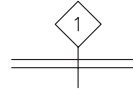


window number



door number

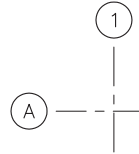
partition type



north arrow



column grid
and bubbles



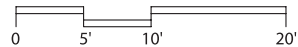
centerline



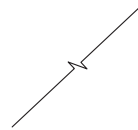
drawing
label



graphic
scale



break line



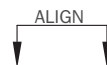
revision
cloud and number



spot elevation

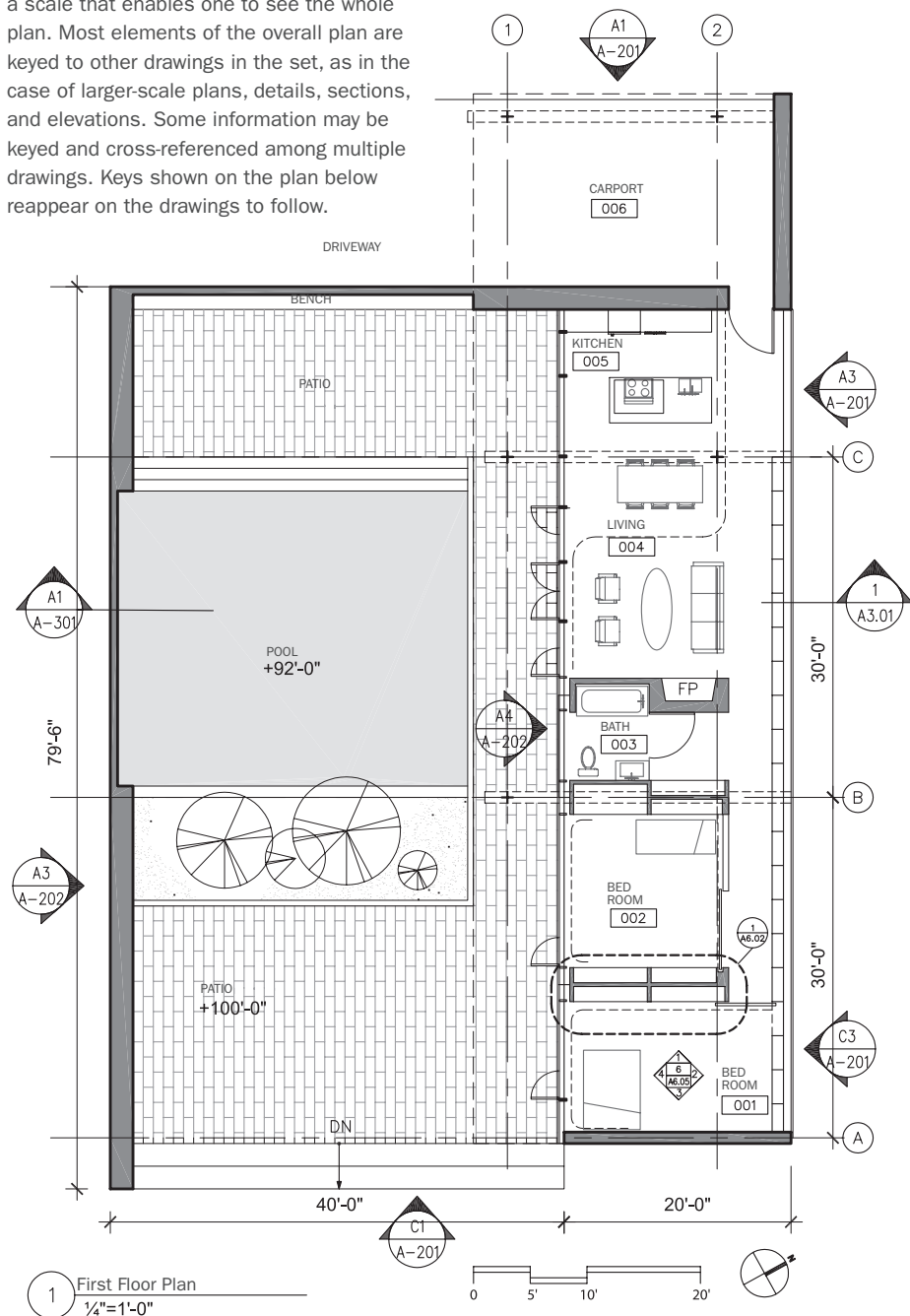
+100'-0"

align note



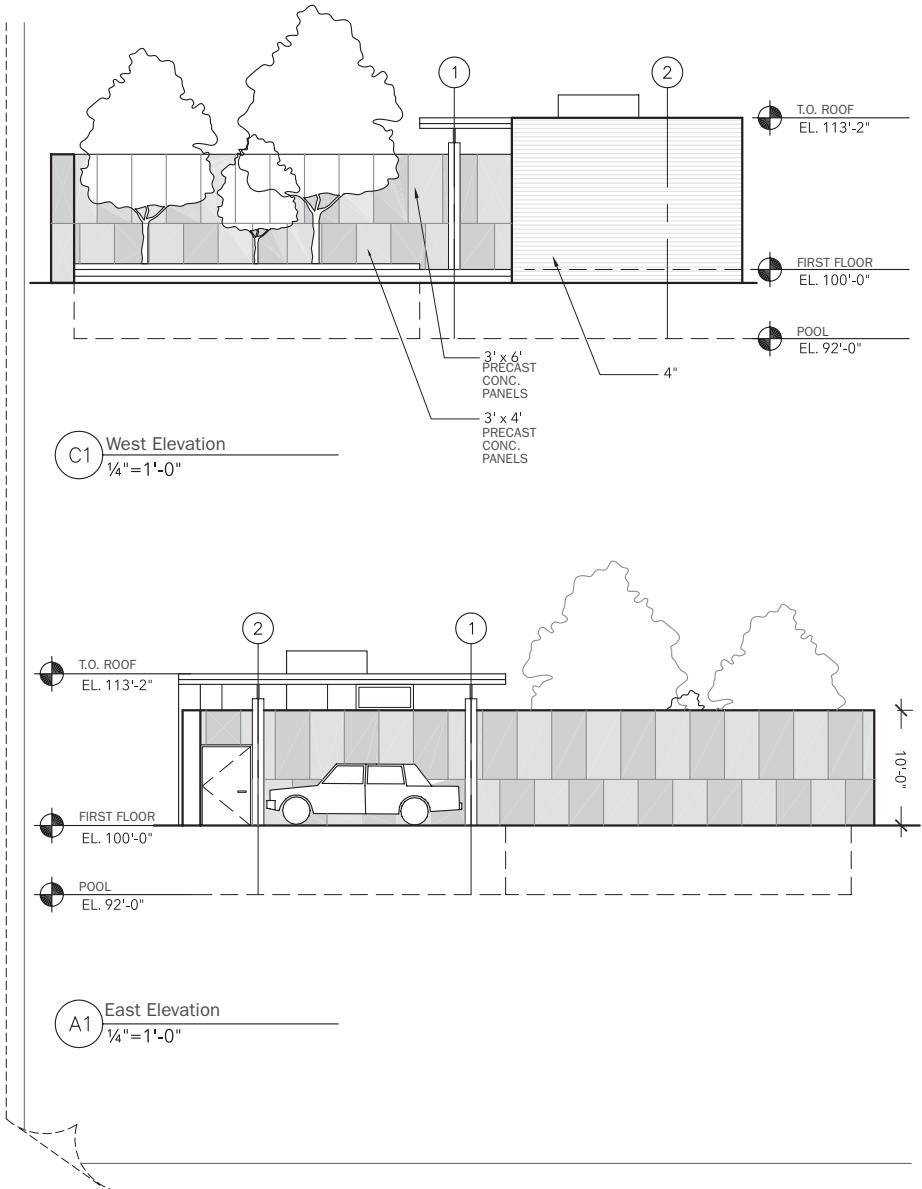
Floor Plans

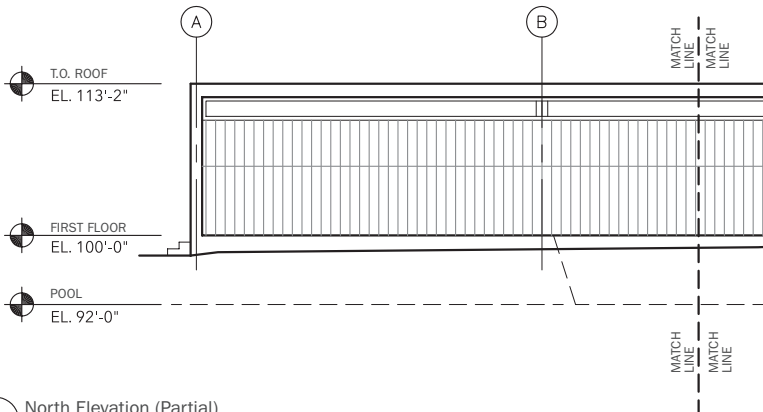
Overall building plans are usually drawn at a scale that enables one to see the whole plan. Most elements of the overall plan are keyed to other drawings in the set, as in the case of larger-scale plans, details, sections, and elevations. Some information may be keyed and cross-referenced among multiple drawings. Keys shown on the plan below reappear on the drawings to follow.



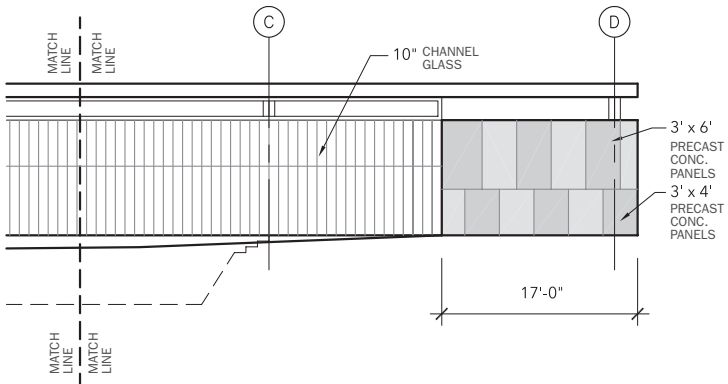
Building Elevations

Building elevations depict the exterior conditions of the building, describing materials and important vertical dimensions. In instances where a drawing is too large to fit on a standard sheet, it must be broken apart and continued on the same sheet or another sheet, requiring the use of match lines for alignment.





C3 North Elevation (Partial)
 1/4"=1'-0"



A3 North Elevation (Partial)
 1/4"=1'-0"

EXTERIOR BUILDING ELEVATIONS
 A-201

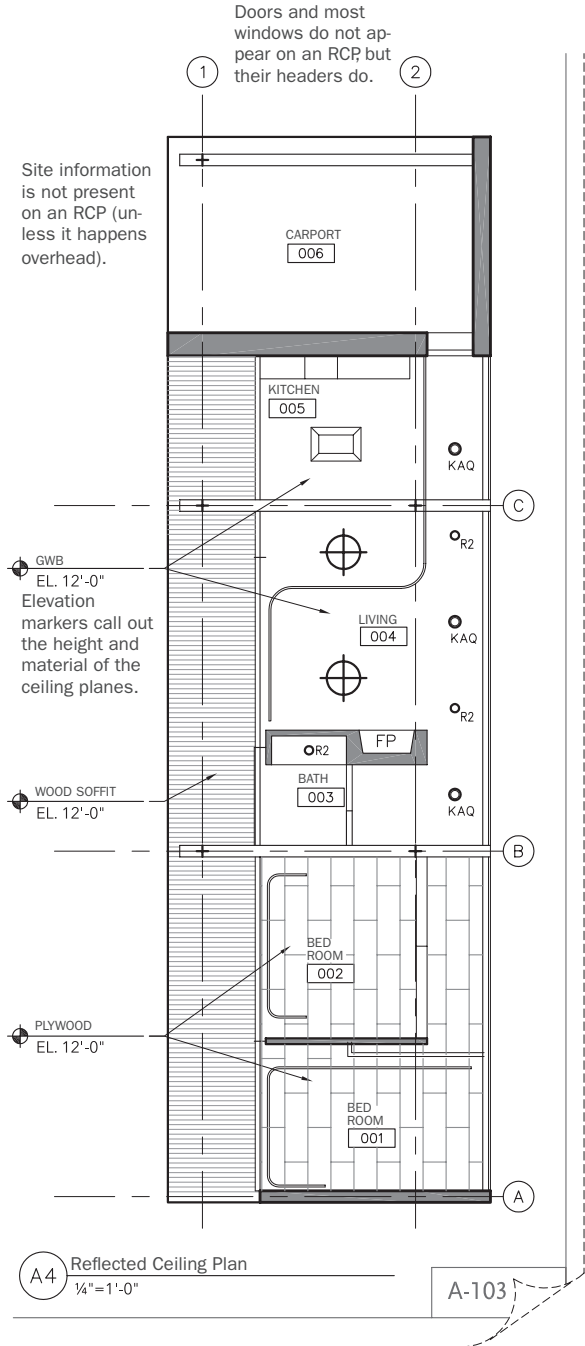
Reflected Ceiling Plans

Reflected ceiling plans (RCPs) may be thought of as upside-down floor plans, for they are literally a plan of the ceiling. They are used to describe light fixture placement and types, ceiling heights and materials, and anything else found on the ceiling plane. RCPs employ standard keys and symbols as well as some specific to the ceiling plan.

Light fixtures often bear tags that refer to their descriptions in the lighting specifications.

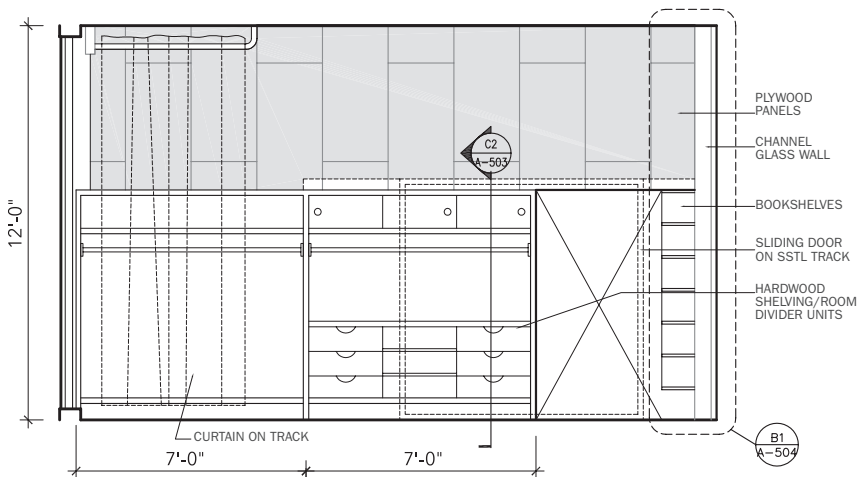
	return-air diffuser	2 x 4 fluorescent	
	supply-air diffuser	2 x 2 recessed fluorescent	
	smoke detector	fluorescent pendant	
	smoke detector w/ audible device	decorative pendant	
	ADA light/speaker	recessed wall washer	
	ceiling-mounted exit sign	recessed downlight	
	wall-mounted exit sign	wall sconce	
	ceiling sprinkler head		
	wall sprinkler head		
	Mylar-coated ACT	ACT	

Site information is not present on an RCP (unless it happens overhead).



Interior Elevations

Interior elevations are drawn at a larger scale than the overall building plans, allowing for more details, notes, and dimensions to be represented. Keyed from the building plan, interior elevations are, in turn, keyed to other, larger-scale views, such as section and plan details of cabinetry construction and wall sections.

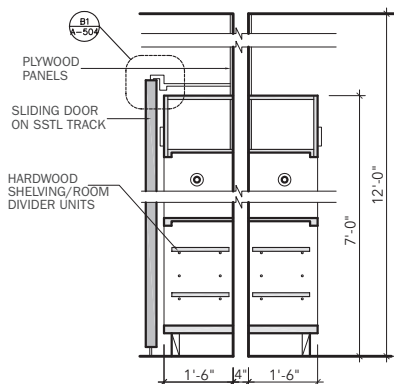


1 Bedroom
1/2" = 1'-0"

A-203

Details

Details are drawn at scales such as 1 1/2" = 1'-0", 3" = 1'-0", 6" = 1'-0", and sometimes even at full scale, and are keyed from and to numerous other drawings.



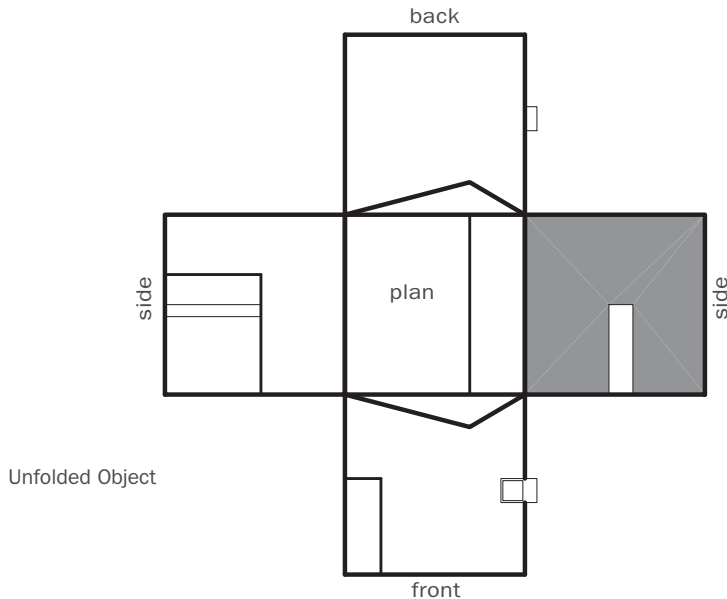
C2 Bedroom Shelving
1 1/2" = 1'-0"

A-503

THREE-DIMENSIONAL DRAWINGS

Paraline Drawings

Paraline drawings are projected pictorial representations of the three-dimensional qualities of an object. Unlike in perspective drawings, the projection lines in a paraleine drawing remain parallel instead of converging to a point on the horizon.



Unfolded Object

OBLIQUES

One face of the object (either the plan or elevation) is drawn directly on the picture plane. From this, projected lines are drawn at an angle to the picture plane. The length of the projecting lines can vary (examples are shown opposite).

AXONOMETRICS

Dimetric

In a dimetric drawing, the object is rotated so that only one corner touches the picture plane.

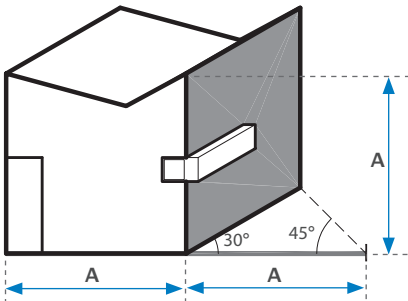
Isometric

An isometric drawing is a dimetric drawing where all axes of the object are simultaneously rotated away from the picture plane and kept at 30 degrees of projection. All legs are equally distorted in length and maintain an exact 1:1:1 proportion.

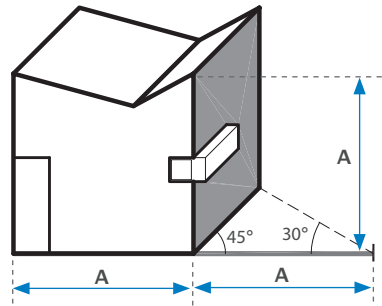
Trimetric

A trimetric drawing is similar to a dimetric drawing, except that the plan of the object is rotated so that the scales of all three axes are varied.

Oblique Projections

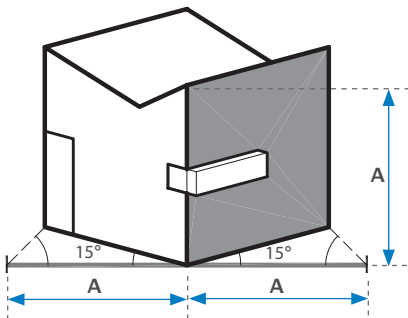
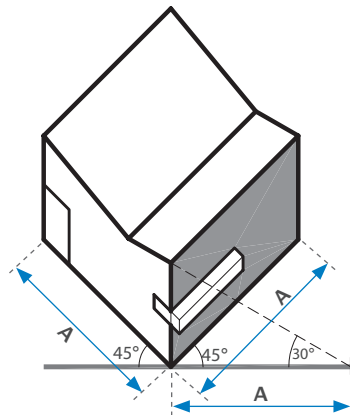
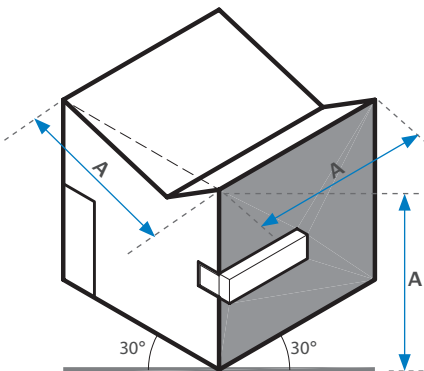
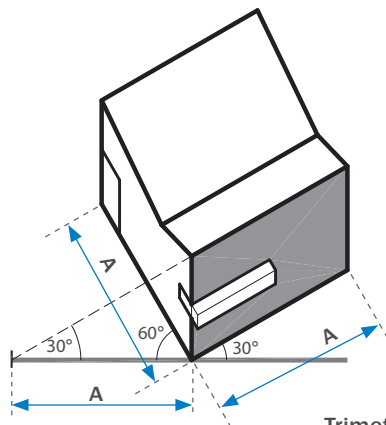


30° Oblique



45° Oblique

Orthographic Projections

15° Dimetric
Axonometric45° Dimetric
AxonometricIsometric
(30° Dimetric)

Trimetric

Two-Point Common Method Perspective

Station Point (SP): Locates the fixed position of the viewer.

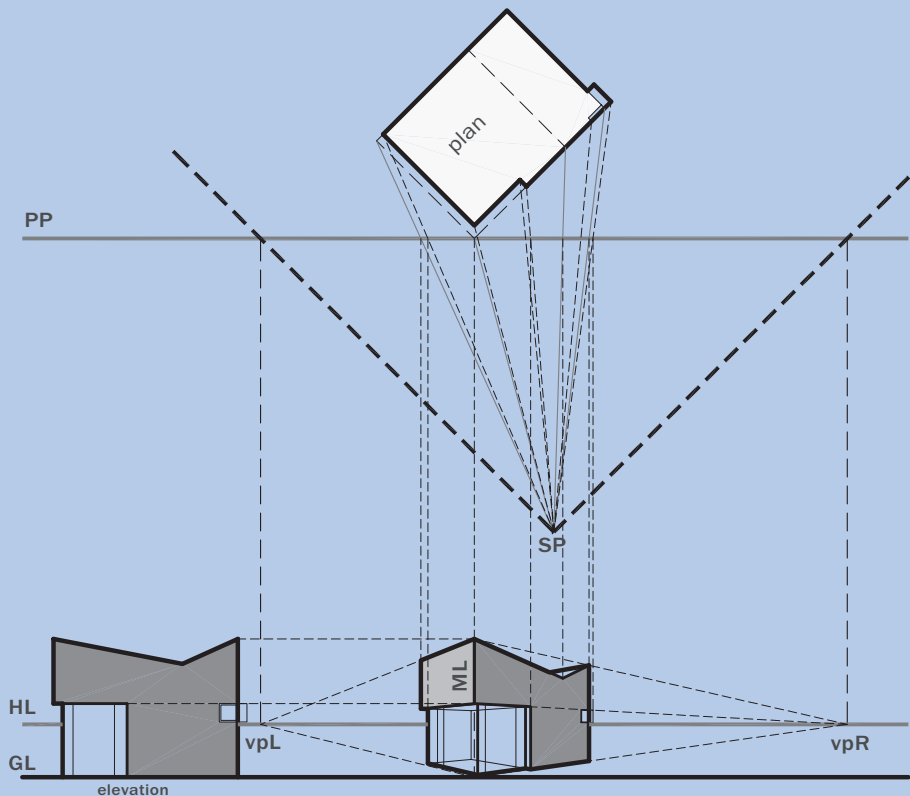
Picture Plane (PP): Flat, two-dimensional surface that records the projected perspective image and aligns perpendicular to the viewer's center of vision. The picture plane is the only true-size plane in the perspective field: Objects behind the picture plane project to its surface smaller than true scale, whereas those between the viewer and the picture plane project to its surface larger than true scale.

Measuring Line (ML): Located on the picture plane, the measuring line is the only true-scale line in a perspective drawing. Most commonly, this is a vertical line from which can be projected the key vertical dimensions of the object.

Horizon Line (HL): Lies at the intersection of the picture plane and a horizontal plane through the eye of the viewer.

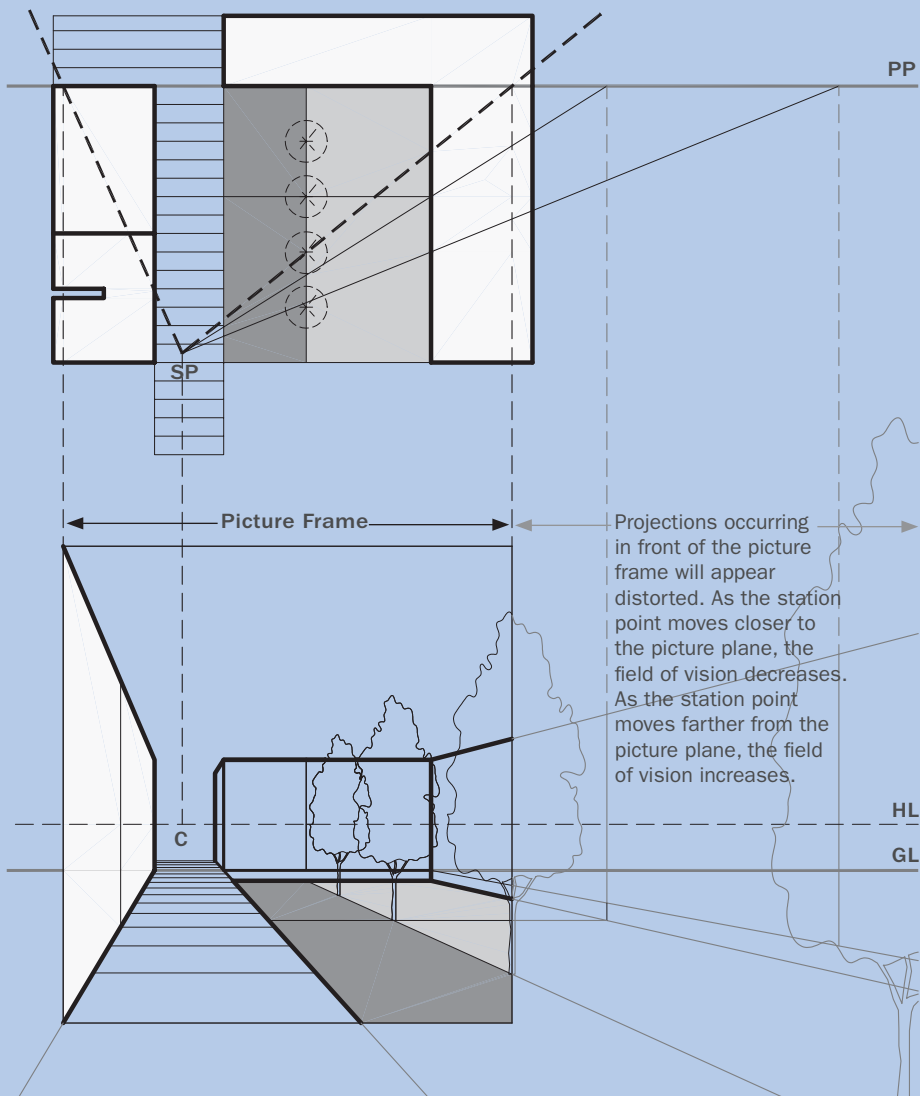
Vanishing Point: Point at which parallel lines appear to meet in perspective. The left (vpL) and right (vpR) vanishing points for an object are determined by the points at which a set of lines originating from the station point and parallel to the object lines intersect the picture plane.

Ground Line (GL): Lies at the intersection of the picture plane and the ground plane.



One-Point Common Method Perspective

One-point perspectives use a single vanishing point, and all edges and planes that are perpendicular to the picture plane vanish toward this point. To locate this point (C), draw a vertical line from the station point to the horizon line. Building edges that are parallel to the picture plane appear as parallel lines in perspective, with no vanishing point.



Chapter 12: Architectural Documents

THE PRACTICE OF ARCHITECTURE

To speak an architectural language is to do many things: It could involve the art of form and style or the more prosaic aspects of contract administration. Architecture and its practice move, sometimes with effort, among realms not only of art, science, and engineering, but also of business, economics, and sociology. All professional groups speak their own language to some extent. To their written and spoken language architects add drawings and symbols, organizing them into accepted standards of presentation and legibility. As with good manners, the point of these standards is not to complicate but to ease communication and interaction.

Most countries have a governing body in architectural practice—in the United States it is the American Institute of Architects (AIA)—which oversees ethics and professional conduct and establishes guidelines for issues ranging from project delivery schedules to contracts and legal documents. The architect who has complete mastery of every aspect of the multiple personalities of architectural practice may be rare. However, all responsible practicing architects are compelled to understand the business of the profession, because the art of architecture depends on the practice of getting it built.

COMMON PROJECT TERMS

Addendum: Written information that clarifies or modifies the bidding documents, often issued during the bidding process.

Alternate: Additional design or material options added to the construction documents and/or specifications to obtain multiple possible cost estimates for a project. “Add-alternates” imply added material and cost; “deduct-alternates” imply removal of certain elements to lower the project cost, as necessary.

ANSI: American National Standards Institute.

As-built drawings: Contract drawings that have been marked up to reflect any changes to a project during construction, differentiating them from the bid documents. Also known as record drawings.

Bid: Offer of a proposal or a price. When a project is “put out to bid,” contractors are asked to submit their estimates as to the time and the cost of a project.

Building permit: Written document issued by the appropriate government authority permitting the construction of a specific project in accordance with the drawings and specifications that the authority has approved.

Certificate of occupancy: Document issued by the appropriate local governmental agency, stating that a building or property meets local standards for occupancy and is in compliance with public health and building codes.

Change order: Written document between and signed by the owner and the contractor authorizing a change in the work, or an adjustment in the contract sum or length of time. Architects and engineers may also sign a change order, but only if authorized (in writing) by the owner to do so.

Charrette: Intensive design process for solving an architectural problem quickly; often undertaken by students of architecture, but also employed by professionals in various stages of the design process. The instructors of the *École des Beaux Arts* in Paris would use a *charrette*, French for “small wooden cart,” for collecting the design work of the students after such a process.

Construction cost: Direct contractor costs for labor, material, equipment, and services, as well as overhead and profit. Excluded from construction cost are fees for architects, engineers, consultants, costs of land, or any other items that, by definition of the contract, are the responsibility of the owner.

Construction management: Organization and direction of the labor force, materials, and equipment to build the project as designed by the architect.

Construction management contract: Written agreement giving responsibility for coordination and accomplishment of overall project planning, design, and construction to a construction management firm or individual, called the construction manager (CM).

Consultant: Professional hired by the owner or architect to provide information and to advise the project in the area of his or her expertise.

Contract administration: Contractual duties and responsibilities of the architect and engineer during a project’s construction.

Contract over- (or under-) run: Difference between the original contract price and the final completed cost, including all change order adjustments.

Contractor: Licensed individual or company that agrees to perform the work as specified, with the appropriate labor, equipment, and materials.

Date of substantial completion: Date certified by the architect when the work is to be completed.

Design-build construction: Arrangement wherein a contractor bids or negotiates to provide design and construction services for the entire project.

Estimating: Calculation of the amount of material, labor, and equipment needed to complete a given project.

Fast-track construction: Method of construction management in which construction work begins before completion of the construction documents, resulting in a continuous design-construction situation.

FF&E: Moveable furniture, fixtures, or equipment that do not require permanent connection to the structure or utilities of a building.

Field order: Written order calling for a clarification or minor change in the construction work and not involving any adjustment to the terms of the contract.

General contractor: Licensed individual or company with prime responsibility for the work.

Indirect cost: Expenses that are not chargeable to a specific project or task, such as overhead.

Inspection list: List prepared by the owner or authorized owner's representative of work items requiring correction or completion by the contractor; generally done at the end of construction. Also called a punch list.

NIBS: National Institute of Building Sciences.

Owner-architect agreement: Written contract between the architect and client for professional architectural services.

Parti: Central idea governing and organizing a work of architecture, from the French *partir* "to depart with the intention of going somewhere."

Program: Desired list of spaces, rooms, and elements, as well as their sizes, for use in designing the building.

Progress schedule: Line diagram showing proposed and actual starting and completion times in a project.

Project cost: All costs for a specific project, including those for land, professionals, construction, furnishings, fixtures, equipment, financing, and any other project-related expenses.

Project directory: Written list of names and addresses of all parties involved in a project, including the owner, architect, engineer, and contractor.

Project manager: Qualified individual or firm authorized by the owner to be responsible for coordinating time, equipment, money, tasks, and people for all or portions of a project.

Project manual: Detailed written specifications describing acceptable construction materials and methods.

Request for Information (RFI): Written request from a contractor to the owner or architect for clarification of the contract documents.

Request for Proposal (RFP): Written request to a contractor, architect, or subcontractor for an estimate or cost proposal.

Schedule: Plan for performing work; also, a chart or table within the drawing set.

Scheme: Chart, diagram, or outline of a system being proposed.

Scope of work: Written range of view or action for a specific project.

Shop drawings: Drawings, diagrams, schedules, and other data specially prepared by the contractor or a subcontractor, sub-subcontractor, manufacturer, supplier, or distributor to illustrate some portion of the work being done. These drawings show the specific way in which the particular contractor or shop intends to furnish, fabricate, assemble, or install its products. The architect is obligated by the owner-architect agreement to review and approve these drawings or to take other appropriate action.

Site: Location of a structure or group of structures.

Soft costs: Expenses in addition to the direct construction cost, including architectural and engineering fees, permits, legal and financing fees, construction interest and operating expenses, leasing and real estate commissions, advertising and promotion, and supervision. Soft costs and construction costs add up to the project cost.

Standards of professional practice: Listing of minimum acceptable ethical principals and practices adopted by qualified and recognized professional organizations to guide their members in the conduct of specific professional practice.

Structural systems: Load-bearing assembly of beams and columns on a foundation.

Subcontractor: Specialized contractor who is subordinate to the prime or main contractor.

Substitution: Proposed replacement or alternate for a material or process of equivalent cost and quality.

Tenant improvements (TIs): Interior improvements of a project after the building envelope is complete.

Time and materials (T&M): Written agreement wherein payment is based on actual costs for labor, equipment, materials, and services rendered, in addition to overhead.

Value engineering (VE): Process of analyzing the cost versus the value of alternative materials, equipment, and systems, usually in the interest of achieving the lowest total cost for a project.

Zoning: Restrictions of areas or regions of land within specific areas based on permitted building size, character, and uses as established by governing urban authorities.

Zoning permit: Document issued by a governing urban authority that permits land to be used for a specific purpose.

COMMON PAPER SIZES

ANSI (American National Standards Institute)

Paper Size	Inches	Millimeters
ANSI-A	8½ × 11	216 × 279
ANSI-B	11 × 17	279 × 432
ANSI-C	17 × 22	432 × 559
ANSI-D	22 × 34	559 × 864
ANSI-E	34 × 44	864 × 1 118

Architectural

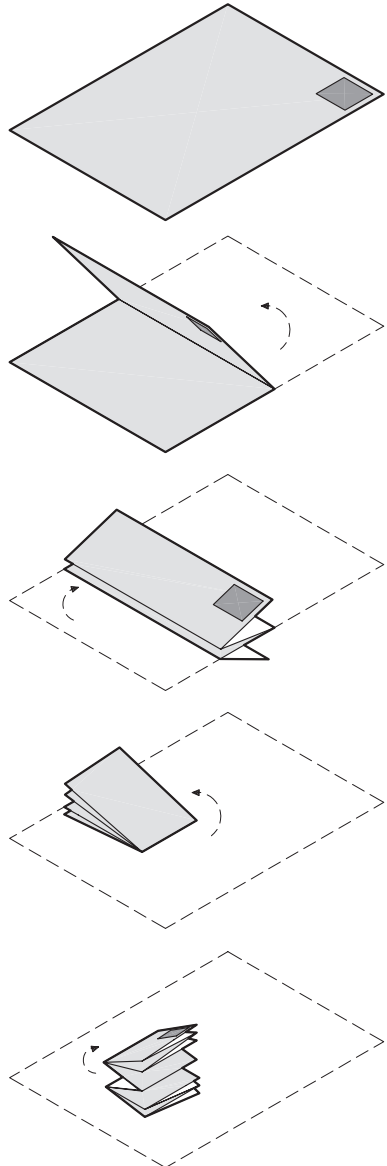
Paper Size	Inches	Millimeters
Arch-A	9 × 12	229 × 305
Arch-B	12 × 18	305 × 457
Arch-C	18 × 24	457 × 610
Arch-D	24 × 36	610 × 914
Arch-E	36 × 48	914 × 1 219

ISO (International Organization for Standardization)—based on one square meter

Paper Size	Inches	Millimeters
4A0	66¼ × 93¾	1 682 × 2 378
2A0	46¾ × 66¼	1 189 × 1 682
A0	33⅞ × 46¾	841 × 1 189
A1	23¾ × 33⅞	594 × 841
A2	16½ × 23¾	420 × 594
A3	11¾ × 16½	297 × 420
A4	8¼ × 11¾	210 × 297
Paper Size	Inches	Millimeters
B0	39¾ × 55⅝	1 000 × 1 414
B1	27⅞ × 39¾	707 × 1 000
B2	19⅝ × 27⅞	500 × 707
B3	13⅞ × 19⅝	353 × 500
B4	9⅞ × 13⅞	250 × 353
Paper Size	Inches	Millimeters
C0	36⅞ × 51	917 × 1 297
C1	25½ × 36⅞	648 × 917
C2	18 × 25½	458 × 648
C3	12¾ × 18	324 × 458
C4	9 × 12½	229 × 324

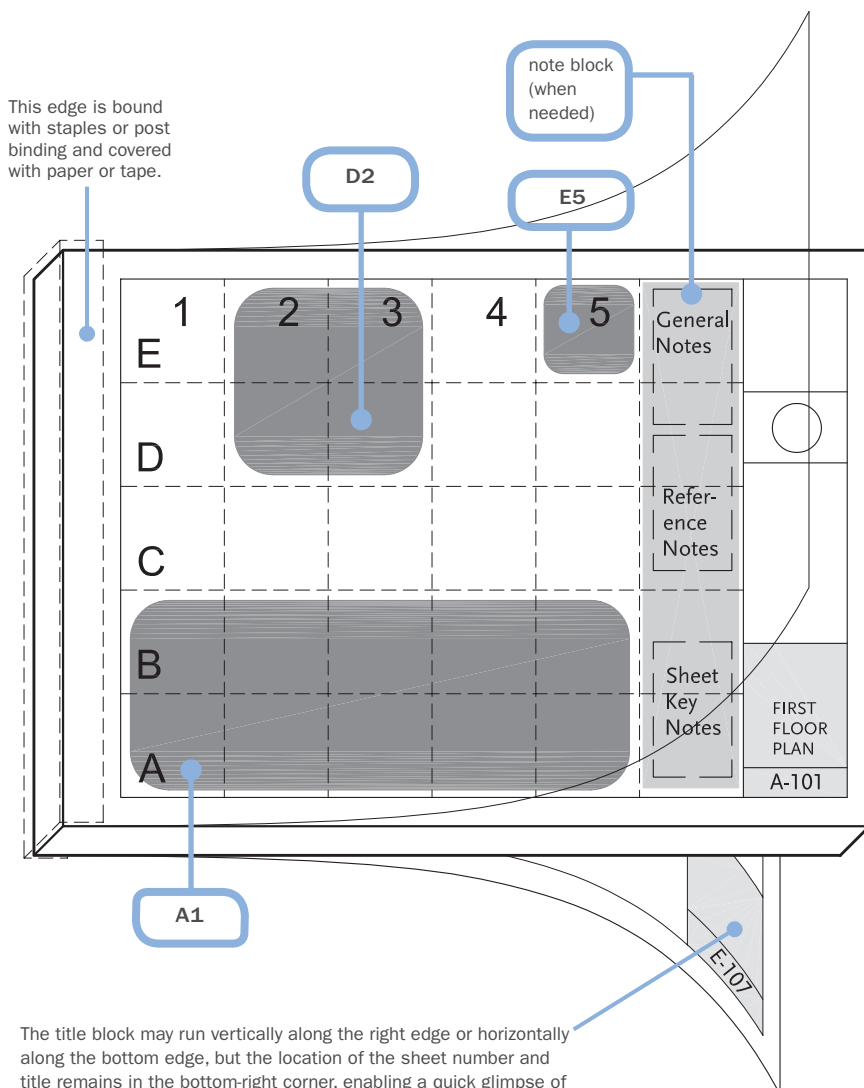
SHEET FOLDING

Individual sheets that must be folded (for reasons of file storage or mailing) should be folded in a logical and consistent manner that allows the title and sheet number information to be visible in the bottom-right corner of the folded sheet. Large numbers of sheets are best bound into sets and rolled for shipping or laid flat for storage.



DRAWING SHEET LAYOUT AND SET ASSEMBLY

In the NIBS Standard sheet layout (in accordance with the National CAD Standard), drawings within a sheet are numbered by coordinate system modules as described below. The graphic or text information modules are known as drawing blocks and their numbers are established by the coordinates for the bottom-left corner of their module. This system enables new drawing blocks to be added to a sheet without having to renumber the existing blocks, saving considerable time once drawings begin to be keyed to other drawings and schedules.

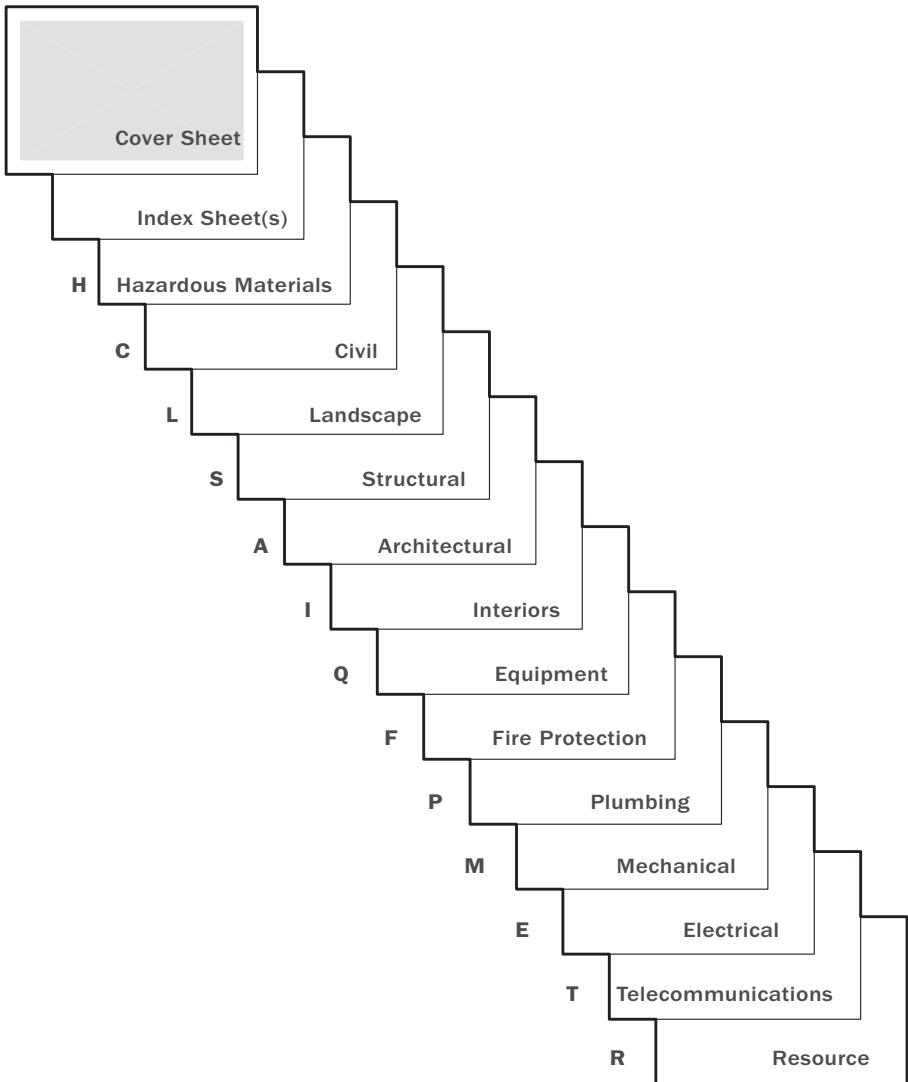


The title block may run vertically along the right edge or horizontally along the bottom edge, but the location of the sheet number and title remains in the bottom-right corner, enabling a quick glimpse of all sheets when flipping through the set.

DRAWING SET ORDER

Typical Order for Disciplines

Standards for the order of disciplines in the drawing set may vary within different offices. The order below is recommended by the Uniform Drawing System (UDS) to minimize confusion among the many trades that will use the set. Note that most projects will not contain all the disciplines listed here, and others might have need for additional, project-specific disciplines.



Typical Order for Sheets within the Architecture Discipline

A-0: General

A-001 Notes and Symbols

A-1: Architectural Floor Plans

A-101 First-Floor Plan

A-102 Second-Floor Plan

A-103 Third-Floor Plan

A-104 First-Floor RCP

A-105 Second-Floor RCP

A-106 Third-Floor RCP

A-107 Roof Plan

A-2: Architectural Elevations

A-201 Exterior Elevations

A-202 Exterior Elevations

A-203 Interior Elevations

A-3: Architectural Sections

A-301 Building Sections

A-302 Building Sections

A-303 Wall Sections

A-4: Large-Scale Views

A-401 Enlarged Toilet Plans

A-402 Enlarged Plans

A-403 Stair and Elevator Plans and Sections

A-5: Architectural Details

A-501 Exterior Details

A-502 Exterior Details

A-503 Interior Details

A-504 Interior Details

A-6: Schedules and Diagrams

A-601 Partition Types

A-602 Room Finish Schedule

A-603 Door and Window Schedules

DRAWING SET ABBREVIATIONS

When all drawings were done by hand, architectural lettering—an art form of its own—could be tedious and time-consuming. As a result, architects and draftspersons abbreviated words. Though many standards were created, they have not always been consistent and historically have led to interpretive errors by contractors. CAD technology makes much shorter work of text production and arrangement and enables less frequent use of abbreviations. If space dictates that abbreviations must be used, omit spaces or periods and capitalize all letters. Though variations still exist, the following is a widely accepted list.

ACT: acoustical ceiling tile
 ADD: additional
 ADJ: adjustable
 AFF: above finish floor
 ALUM: aluminum
 APPX: approximately

BC: brick course
 BD: board
 BIT: bituminous
 BLDG: building
 BLK: block
 BLKG: blocking
 BM: beam
 BOT: bottom
 BUR: built-up roofing

CB: catch basin
 CBD: chalkboard
 CEM: cement
 CI: cast iron
 CIP: cast-in-place
 CJ: control joint
 CLG: ceiling
 CLR: clearance
 CLO: closet
 CMU: concrete masonry unit
 COL: column
 COMP: compressible
 CONC: concrete
 CONST: construction
 CONT: continuous

CPT: carpet
 CRS: courses
 CT: ceramic tile
 CUB: column utility box

DET: detail
 DF: drinking fountain
 DIA: diameter
 DN: down
 DR: door
 DWG: drawing

EA: each
 EJ: expansion joint
 EL: elevation or electrical
 ELEV: elevator
 ENC: enclosure
 EQ: equal
 EQUIP: equipment
 ERD: emergency roof drain
 EWC: electric water cooler
 EXIST: existing
 EXP: expansion
 EXT: exterior

FD: floor drain
 FDN: foundation
 FE: fire extinguisher
 FEC: fire extinguisher cabinet

FFT: finished floor transition
 FHC: fire hose cabinet
 FIN: finish
 FIXT: fixture
 FLR: floor
 FLUOR: fluorescent
 FOC: face of concrete
 FOF: face of finish
 FOM: face of masonry
 FR: fire-rated
 FT: feet
 FTG: footing
 FUB: floor utility box

GA: gauge
 GALV: galvanized
 GC: general contractor
 GL: glass
 GWB: gypsum wallboard
 GYP: gypsum

HC: hollow core or handicap accessible
 HDW: hardware
 HGT: height
 HM: hollow metal
 HORIZ: horizontal
 HP: high point
 HTR: heater
 HVAC: heating, ventilating, and air conditioning

IN: inch
 INCAN: incandescent
 INCL: including
 INS: insulation
 INT: interior

JAN: janitor
 JC: janitor's closet
 JT: joint

LAM: laminated
 LAV: lavatory
 LINO: linoleum
 LP: low point
 LTG: lighting

MAT: material
 MAX: maximum
 MECH: mechanical
 MEMB: member
 MFR: manufacturer
 MIN: minimum
 MISC: miscellaneous
 MO: masonry opening
 MTL: metal

NIC: not in contract
 NO: number
 NTS: not to scale

OC: on center
 OD: outside diameter
 or overflow drain
 OHD: overhead door
 OHG: overhead grille
 OPNG: opening
 OPP: opposite
 OPPH: opposite hand

PC: precast
 PGL: plate glass
 PL: plate
 PLAM: plastic laminate
 PLUM: plumber

PT: paint
 PTD: painted
 PTN: partition
 PVC: polyvinyl chloride

QT: quarry tile
 QTY: quantity

R: radius or riser
 RA: return air
 RD: roof drain
 REG: register
 REV: revision or reverse
 REINF: reinforcing
 REQD: required
 RM: room
 RO: rough opening
 RSL: resilient flooring

SC: solid core
 SECT: section
 SHT: sheet
 SIM: similar
 SPEC: specifications
 SQ: square
 SSSL: stainless steel
 STA: station
 STD: standard
 STL: steel
 STOR: storage
 STRUC: structural
 SUSP: suspended

T: tread
 TBD: tackboard
 TD: trench drain
 TEL: telephone
 THK: thickness
 TO: top of
 TOC: top of concrete
 TOF: top of footing
 TOR: top of rail
 TOS: top of steel
 TOW: top of wall

TRT: treated
 TYP: typical

UNO: unless noted
 otherwise

VCT: vinyl
 composition tile
 VERT: vertical
 VIF: verify in field
 VP: veneer plaster
 VWC: vinyl wall covering

W/: with
 WC: water closet
 WD: wood
 WDW: window
 WF: wide flange
 W/O: without
 WPR: waterproofing
 WUB: wall utility box
 WWF: welded wire fabric

&: and
 <: angle
 ": inch
 ': foot
 @: at
 CL: centerline
 [: channel
 #: number
 Ø: diameter

PROJECT TIMELINE

The information presented here is a generalization of the phases and events within a typical architectural project. It does not attempt to account for all project sizes and client types. The length of each phase is a rough estimation for a medium-sized project, but the time-frames can vary wildly. The expectations and duration of any of these phases are subject to the stipulations of the project's owner-architect agreement.

Marketing

In the competitive environment of architecture, procuring a project can be more time- and labor-intensive than getting it built. Marketing takes many forms, but common modes of obtaining work are:

Competitions: Firms or individuals submit a design for a specified program and site, for which a winner is chosen. Competitions vary in form—they may be paid or unpaid, open or invited—and do not always result in a project being built.

Requests for Qualifications (RFQs): A potential client asks architects to submit their qualifications, sometimes to a specified format.

Requests for Proposal (RFPs): Similar to RFQs, though often firms are specifically asked to supply information about other relevant projects they have completed. Proposals may include a wide variety of information types, including proposed budget and schedule, and sometimes may require a design for the project.

Interviews: A potential client will want to meet the architect, sometimes with his or her prospective consultants. At this meeting, the design team may be asked to present a proposal for the project in question.

Pre-design

Even before beginning the actual design of a project, the architect may be asked to perform the following tasks, alone or in conjunction with other consultants: site selection and evaluation, environmental analysis, community participation, feasibility studies, programming, cost analysis, and conceptual design. It is not unusual for the architect to do many of these services as a (paid or unpaid) marketing effort, in anticipation of being awarded the project.

varies

SD Schematic Design

Major design ideas are proposed and explored, including alternate schemes. Drawings produced in this phase include site plan, plans, elevations, and sections sufficient for cost estimation. SD often requires multiple presentations to the client for review and approval and can encompass the production of perspectives, renderings, and models to describe the design concept.

3 months

DD Design Development

The detailed development of the design (as established in SD) results in a drawing set suitable for a more accurate cost estimate. Coordination with consultants is key in this phase to identify and address potential problems before the design has proceeded too far. Presentations to the client turn more to these issues of coordination and cost control and take into account more specific feedback about the nature of rooms and spaces. The design is documented inside and out, including construction details, interior elevations, schedules, and specifications, all of which will be further refined in the CD phase.

6 months

CD Construction Documents

The “working drawing” phase of the project, in which every aspect of the design is drawn to scale and appropriately specified, is time- and energy-intensive, and project teams usually grow larger to accommodate the work involved. The design of the project must be well established by this point, and most owner-architect agreements stipulate that any requests for major design changes made after DD must be part of an “Additional Services” agreement, to make up for the time it has taken to document the project to date.

The CD set is the official documentation of the project and is distributed to contractors for bids as well as to the building department and other officials for all necessary permits. The architect is responsible for assisting the client in this process.

A CD set contains, at a minimum, a site plan, floor plans, reflected ceiling plans, exterior and interior building elevations, building sections, wall sections depicting construction detailing, interior details, door and window schedules, equipment schedules (if applicable), finishes schedules, and written specifications, as well as the drawings of engineers and other consultants.

9 months

CA Construction Administration

Though the project is under construction, the architect must still maintain control over its outcome, both through regular site visits, in which construction quality is observed for its conformance with the CD set, and by overseeing solutions to unanticipated problems as they arise. The architect must review shop drawings, change orders, and requests for information from the contractor, always acting in the best interest of the client and the budget. At the end of construction, the architect prepares the punch list and assists in obtaining a Certificate of Occupancy.

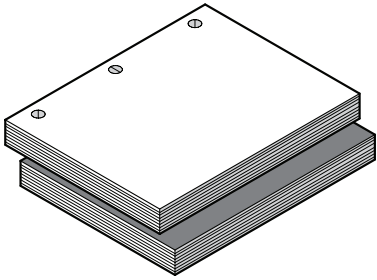
duration of construction

Marketing

Once completed, the project is photographed and documented. The architect may submit it for publication in any number of professional magazines, include it in the firm’s brochure, or post it on the firm’s website. It now serves as a marketing tool for obtaining more projects, and the process continues.

SPECIFICATIONS

Architectural specifications act as written instructions to the contractor and all parties involved in the construction of a building. Specifications are part of the construction document set, usually as a separate project manual. They provide detailed descriptions of the acceptable construction materials for all aspects of a building, from the type and color of paint to the type and method of structural fireproofing. Specification writing is time-consuming and exacting work; it is most often undertaken by specification writers or architects who specialize in the writing of specifications. Certified spec writers list the suffix CCS (Certified Construction Specifier) after their name. A well-written set of specs is imperative to keeping a project safe and on budget and to ensure that the needs of both architect and owner have been met.

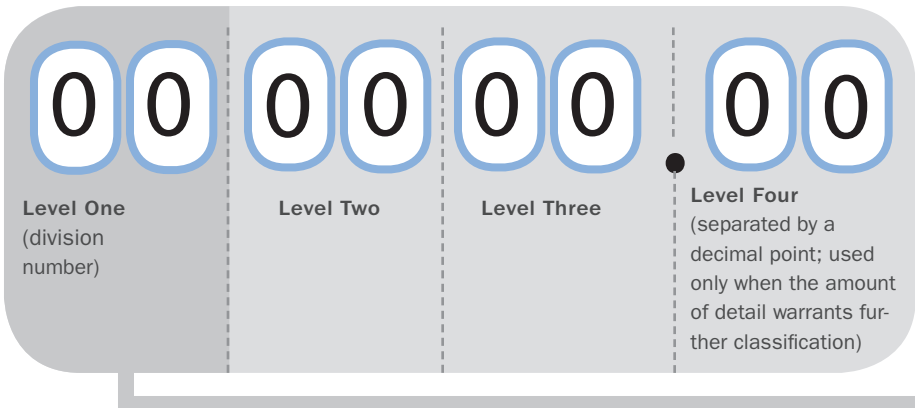


CSI MASTERFORMAT SYSTEM

The Construction Specifications Institute (CSI) was established in 1948 to bring order to the post–World War II building boom. CSI governs standardization of specification writing and formatting, and its Project Resource Manual (formerly the Manual of Practice, or MOP) is the industry reference. Spec writers might avail themselves of prewritten master guide specs that serve as a basis for many projects, or they might begin a set of specs entirely from scratch.

The CSI MasterFormat system has become the standard formatting system for nonresidential building projects in the United States and Canada. It consists of a list of numbers and titles that organize the information contained in the specification project manual.

Division Numbering



CSI MasterFormat Division Titles

Reserved divisions provide space for future development and expansion, and CSI recommends that users not appropriate these divisions for their own use.

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP

00—Procurement and Contracting

SPECIFICATIONS GROUP

General Requirements

01—General Requirements

Facility Construction

02—Existing Conditions
 03—Concrete
 04—Masonry
 05—Metals
 06—Wood, Plastics, and Composites
 07—Thermal and Moisture Protection
 08—Openings
 09—Finishes
 10—Specialties
 11—Equipment
 12—Furnishings
 13—Special Construction
 14—Conveying Equipment
 15—Reserved for future expansion
 16—Reserved for future expansion
 17—Reserved for future expansion
 18—Reserved for future expansion
 19—Reserved for future expansion

Facility Services

20—Reserved
 21—Fire Suppression
 22—Plumbing
 23—Heating, Ventilating, and Air-Conditioning
 24—Reserved
 25—Integrated Automation
 26—Electrical
 27—Communications
 28—Electronic Safety and Security
 29—Reserved for future expansion

Site and Infrastructure

30—Reserved for future expansion
 31—Earthwork
 32—Exterior Improvements
 33—Utilities
 34—Transportation
 35—Waterway and Marine Construction
 36—Reserved
 37—Reserved
 38—Reserved
 39—Reserved

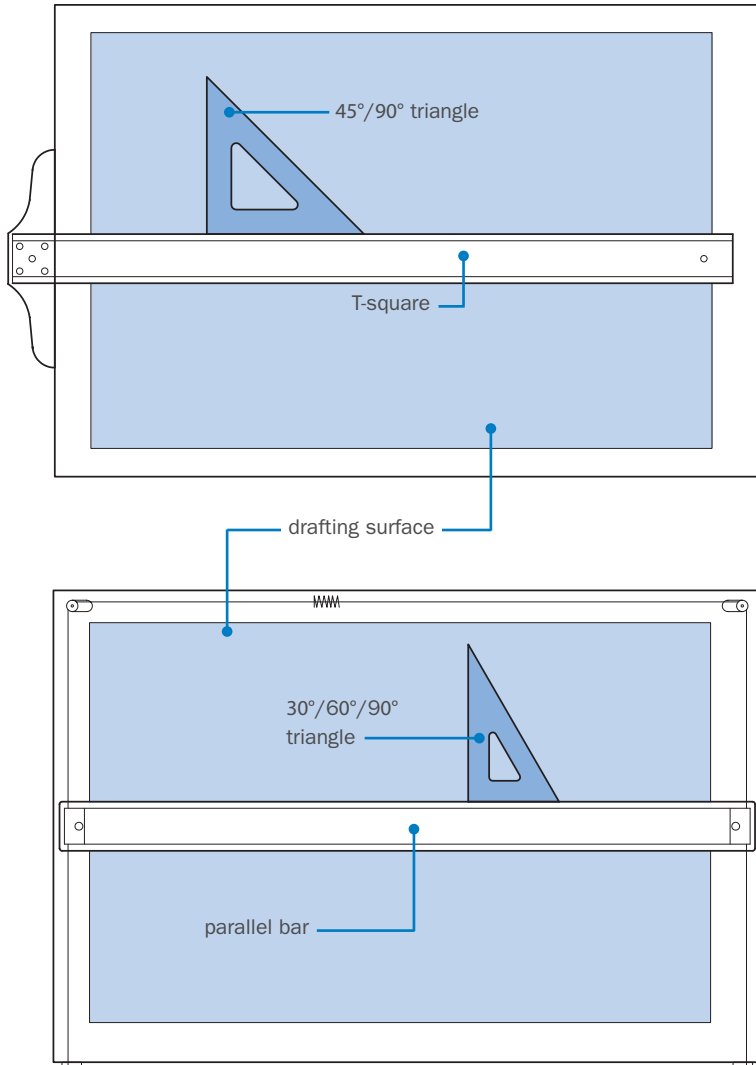
Process Equipment

40—Process Interconnections
 41—Material Processing and Handling Equipment
 42—Process Heating, Cooling, and Drying Equipment
 43—Process Gas and Liquid Handling, Purification and Storage Equipment
 44—Pollution and Waste Control Equipment
 45—Industry-Specific Manufacturing Equipment
 46—Water and Wastewater Equipment
 47—Reserved for future expansion
 48—Electrical Power Generation
 49—Reserved for future expansion

Chapter 13: Hand Drawing

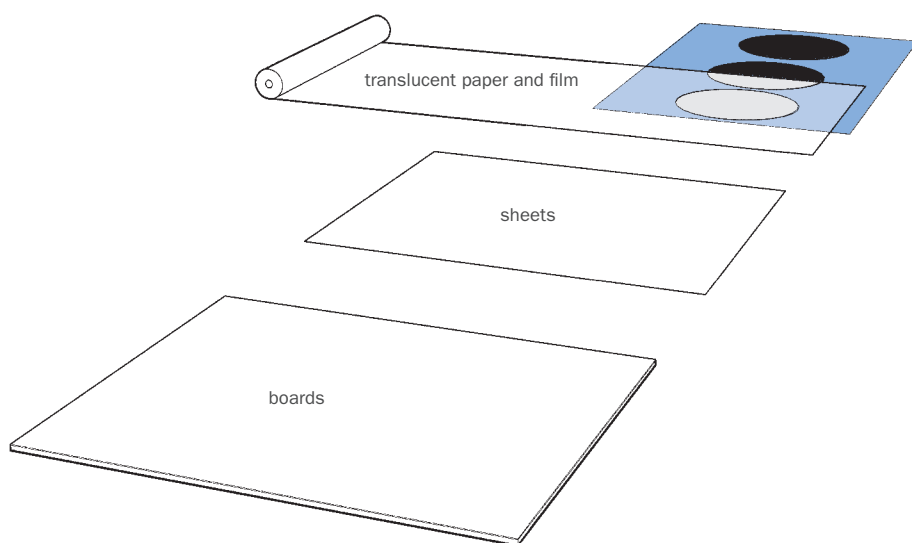
Though rapidly being replaced by computer-aided drafting, hand drafting continues to be used by some practitioners, and its principles can still be applied to computer drawing. The practice of hand drafting employs a number of key instruments.

WORK SURFACE



PAPERS AND BOARDS

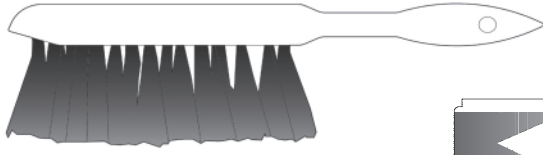
Paper Type	Qualities	Format	Best Uses	Use for Overlay
Tracing paper	white, buff or yellow; inexpensive	Rolls in multiple sizes (12", 18", 24", 36", 48"); pads	sketch overlay; layouts	yes
Vellum	oil-treated to achieve transparency	rolls, sheets, and pads	pencil and technical pen work; overlay work	yes
Mylar (drafting film)	nonabsorbent polyester film (1- and 2-sided)	rolls and sheets	pencil and technical pen work; ideal for archival work	yes
Bond and drawing papers	variety of weights, textures, and colors	rolls and sheets	smooth best for pens; textured best for pencils	no
Illustration board	high-quality white rag affixed to board	large-scale sheet sizes	finished work in watercolor, pencil, chalk, or pen	no
Chip board	variety of plies; mostly gray	large-scale sheet sizes	model making; some dry mounting	no
Foam board	polystyrene foam between paper liners; white/black	large-scale boards; 1/8", 3/16", 1/4", 1/2" thick	model making; dry-mounting sheets	no



DRAFTING SUPPLIES

1. Drafting brush:

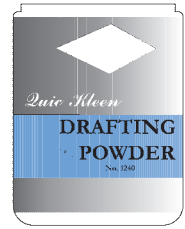
Implement used to brush away erasures and drafting powder.



1

2. Drafting powder:

Finely ground white compound that prevents dust, dirt, and smudges from being ground into the drafting media.



2

3. French curve:

Template used as guide to draw smoothly most desired curvatures.



3

4. X-Acto knife:

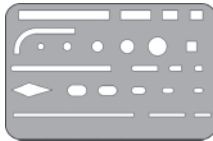
Cutting tool used in model making and in Letratone application.



4

5. Erasing shield:

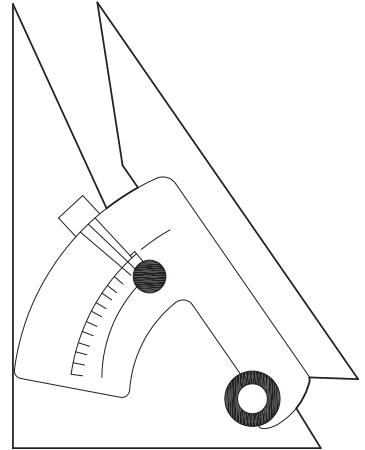
Device used to erase specific lines and areas without affecting others.



5

6. Adjustable triangle:

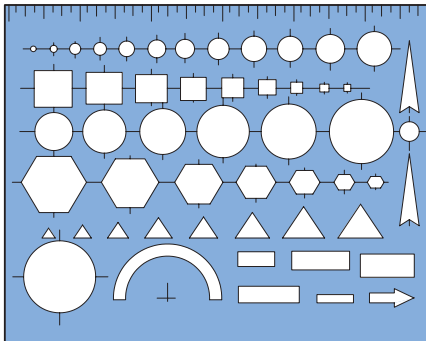
Tool used alone or in combination with other triangles to achieve any angle.



6

7. Template:

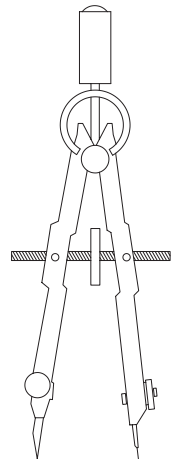
Pattern guides available in a wide variety of types (lettering, toilets, people) and scales.



7

8. Compass:

Hinge-legged instrument that accommodates a pen or pencil to describe precise circles or circular arcs.



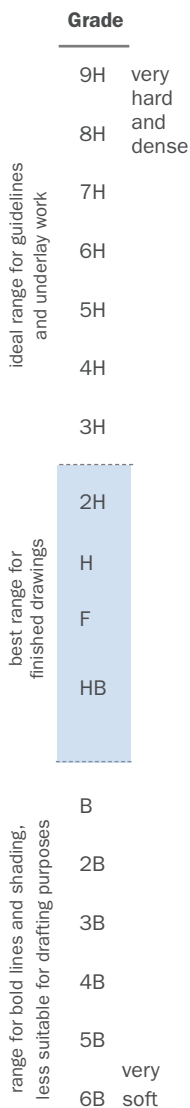
8

PENCILS

Harder leads contain more clay, whereas softer leads contain more graphite. Lead holders employ a push-button that advances the 2 mm lead, which comes in a wide array of hardnesses, colors, and nonphoto blue (does not appear on reproductions).

Leads are sharpened in lead pointers or with simple emery paper or sandpaper blocks.

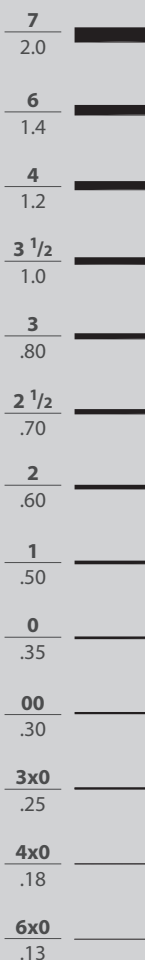
Pencil Hardness Range



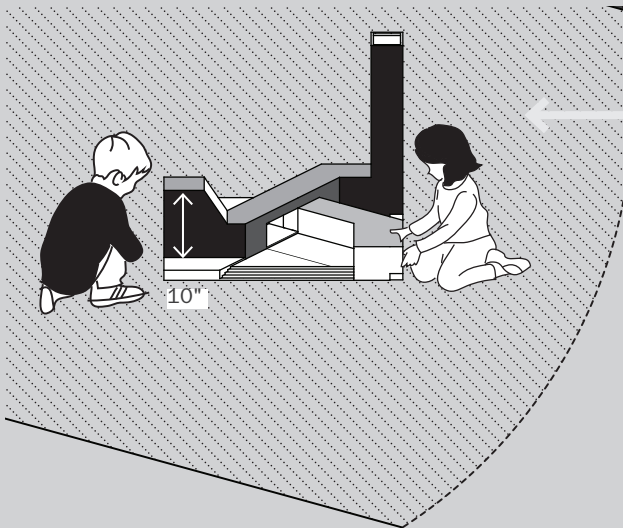
TECHNICAL INK PENS

Technical pens, which use an ink flow-regulating wire with a tubular point (the pen nib), can produce very precise line widths. The ink may come in a prepackaged cartridge or the barrel of the pen may be filled with ink as needed. Ink pens are ideal for vellum and Mylar; they can even be erased from Mylar film with a nonabrasive drafting eraser or electric eraser.

Technical Pen Line Weights



WORKING TO SCALE



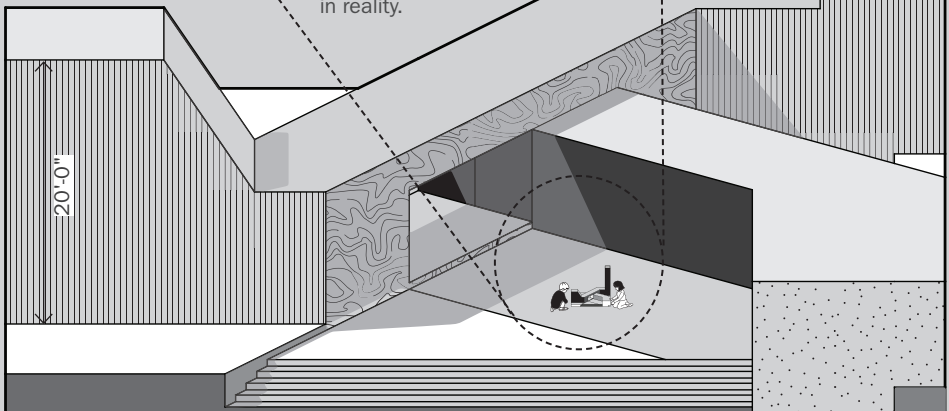
For Example, these children are playing with a model of their own house. The model was made at the scale of $\frac{1}{2}''=1'-0''$.

Therefore, for the children, the 20'-0" wall is only 10" tall. The model is $\frac{1}{24}$ the size of their actual house.

This is also close to the metric scale of 1:25.

With the exception of perspectives and some other three-dimensional representations, most architectural drawings and models are made "to scale."

Simply put, representations too large to be represented at full scale ($1''=1'$) must be reduced to a reasonable working scale (for instance, to fit on a sheet of paper or onto a table). To do so, a standard architect's scale is employed. A representation made at a half-inch scale ($\frac{1}{2}''=1'-0''$) indicates that a distance of a half-inch on the drawing or in the model equals one foot in reality.



The three sides of a triangular architect's scale provide a total of eleven scales (plus full scale), which are written as follows:

$$1/16" = 1'-0"$$

$$3/32" = 1'-0"$$

$$1/8" = 1'-0"$$

$$3/16" = 1'-0"$$

$$1/4" = 1'-0"$$

$$3/8" = 1'-0"$$

$$1/2" = 1'-0"$$

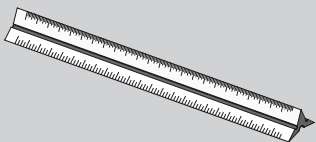
$$3/4" = 1'-0"$$

$$1" = 1'-0"$$

$$1\ 1/2" = 1'-0"$$

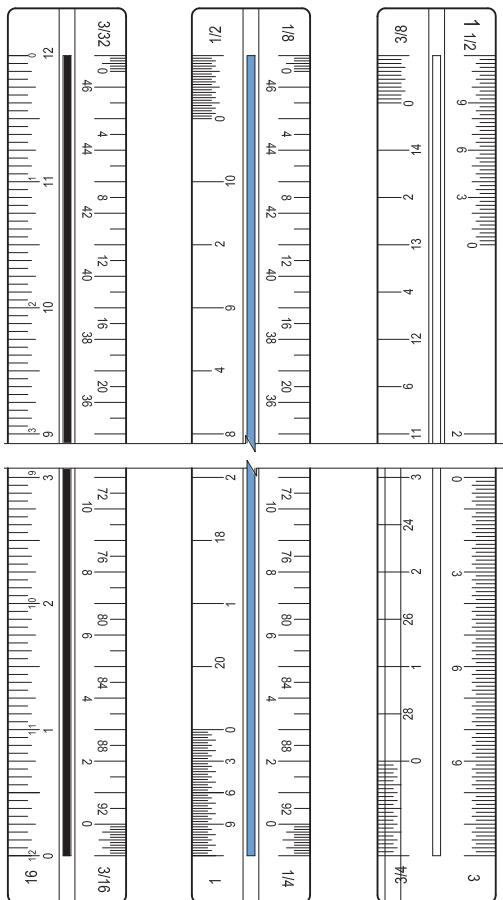
$$3" = 1'-0"$$

Engineer's scales are often used for larger-scale drawings such as site plans; they follow the same principle as architect's scales but with larger increments of ten ($1"=10'$, $1"=50'$, $1"=100'$, and so forth). Scales are also available in metric units.



Customary scales are understood by their relationship to one foot (i.e., $1/4"=1'-0"$). Metric scales operate as ratios (i.e., 1:1 is full scale, 1:50 is 1/50th of full scale, etc.). Though easy to confuse the two systems, it's important to note that $1/4"=1'-0"$ is NOT the same as $1/4$ th of full scale. Instead, its ratio is determined as follows:

$$1/4 \times 1/12 = 1/48, \text{ or } 1:48$$



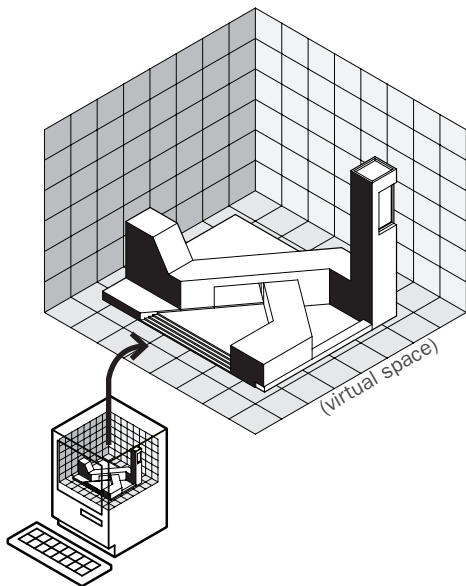
Comparable scales

CUSTOMARY	METRIC
$1/16" = 1'-0"$ (1:192)	1:200
$3/32" = 1'-0"$ (1:128)	1:125
$1/8" = 1'-0"$ (1:96)	1:100
$3/16" = 1'-0"$ (1:64)	
$1/4" = 1'-0"$ (1:48)	1:50
$3/8" = 1'-0"$ (1:32)	
$1/2" = 1'-0"$ (1:24)	1:25
$3/4" = 1'-0"$ (1:16)	
$1" = 1'-0"$ (1:12)	1:10
$1\ 1/2" = 1'-0"$ (1:8)	
$3" = 1'-0"$ (1:4)	1:5

Chapter 14: Digital Production

Building design and construction involves enormous amounts of information in need of organization and dissemination among numerous groups of interested and active parties. The introduction of computers into this process has understandably changed the way in which buildings are conceived, designed, and documented. Truly, many things can now be done faster and with more ease, but computers have given rise to new issues involving management of computer files, quality standards for deliverable materials, and the constant need to stay current with rapidly evolving technologies. The prospect of documenting computer standards and guidelines as static and absolute is therefore neither productive nor possible—the only thing that is certain is that things will change. With this in mind, this chapter focuses on elements common to many types of digital architectural work.

Digital Model: In the virtual space of the computer, this is a “full scale” spatial representation of an object. A digital model can be the basis for numerous forms of output, including orthographic projection drawings, renderings, animations, and fabrication.

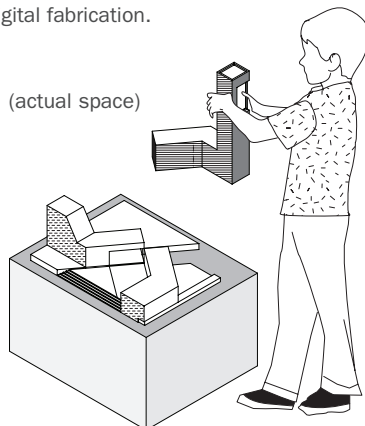


Physical Model: A tangible, three-dimensional replica of a design, usually at a scale much smaller than full size. Such models used to be made exclusively by hand, of materials such as chip board, wood, and foam core. With the increasing dominance of digital production, a physical model is also easily created from a digital model, through methods such as laser cutting and 3D printing.

COMPUTER MODELING

Computers allow for efficient, precise, and easily modifiable architectural output. Within practice, commonly used programs for modeling and drafting deliverable drawing sets include AutoCAD and Revit, though digital modeling and rendering programs are numerous and varied. Often, the more sophisticated the intended product, the more expensive the digital tool.

Digital programs are not limited to the production of static drawings. Many are employed extensively to design complex forms that would simply be impossible otherwise, often with the ability to interface with digital fabrication.



DIGITAL TERMS

Aspect ratio: Ratio of display width to height.

BIM: (Building Information Modeling) Modeling in which a model's three-dimensional information can be shared among multiple users via a database linking models and assemblies.

Block: Grouping of one or more objects combined to form a single object. On creation, blocks are given a name and an insertion point.

CAD: Computer-aided design or computer-aided drafting. Also CADD, for computer-aided design and drafting.

Command line: Text area reserved for keyboard input, messages, and prompts.

Coordinates: X, y, and z location relevant to a model's origin (0,0,0).

Crosshairs: Type of cursor. 

Cursor: Active object on a video display that enables the user to place graphic information or text.



Drawing file: Electronic representation of a building or an object.

Drawing interchange format (DXF): ASCII or binary file format of an AutoCAD drawing, for exporting AutoCAD drawings to other applications or importing those from other applications into AutoCAD.

DWG: File format for saving vector graphics from within AutoCAD.

Entity: Geometric element or piece of data in a digital drawing, such as a line, a point, a circle, a polyline, a symbol, or a piece of text.

External reference: In AutoCAD, a file or drawing that is used as background in another drawing but cannot be edited, except in its original drawing. Examples include building grids and site information. Also called X-Ref.

Polyline: Object made up of one or more connected segments or arcs, treated as a single object.

Raster graphic: Image comprised of a grid of pixels (as bitmap). More pixels create higher resolution and a larger digital file. When scaled up from its original size, a raster image will lose quality and become jagged in appearance, looking pixelated.

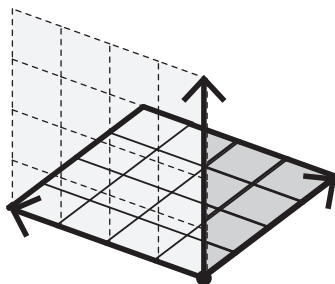


Sheet file: Print- or plot-ready electronic representation of a presentation sheet, containing a view or views of the model, text, symbols, and a title block.

Vector graphic: Graphic composed of paths displayed and stored as geometric primitives (points, lines, curves, and polygons). Made of paths instead of pixels, vectors can remain crisp and sharp even when scaled up or down.



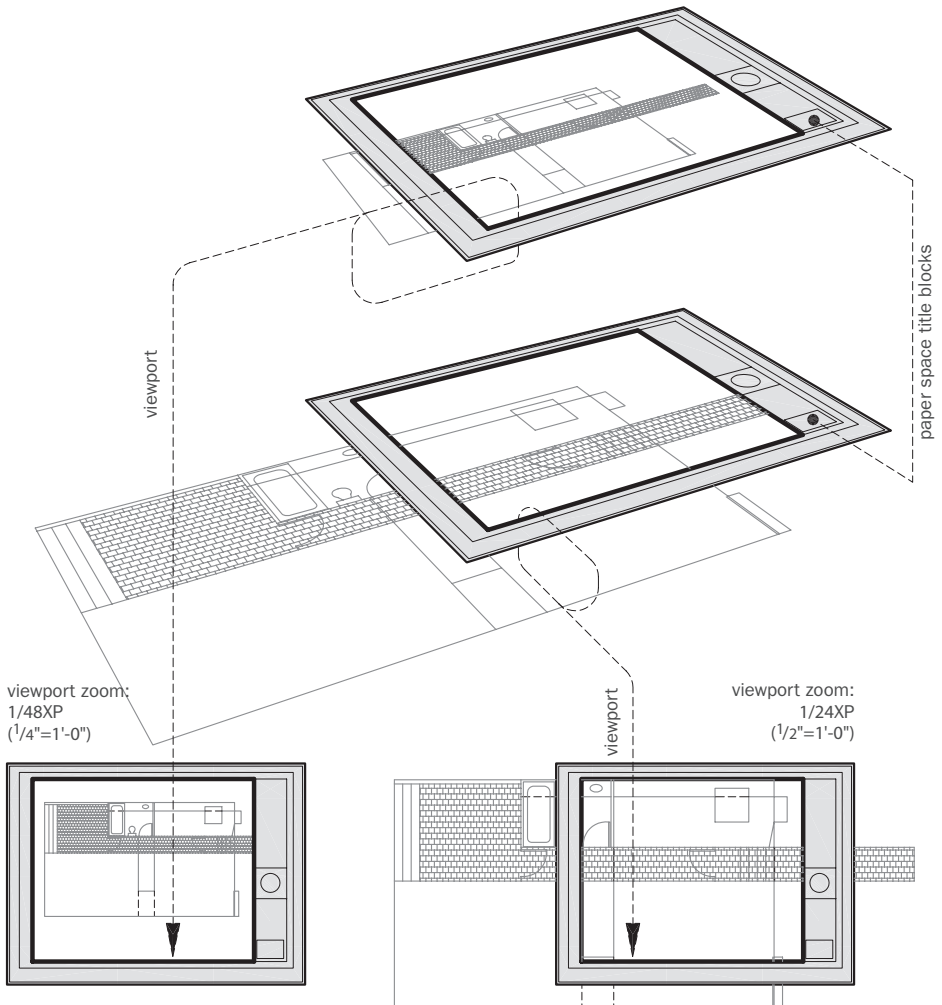
X, y, and z axes: The three directions of the Cartesian coordinate system. x and y establish the two-dimensional plane, and z establishes the third dimension.



MODEL SPACE AND PAPER SPACE SCALES IN AUTOCAD

All AutoCAD models and drawings, from detailed wall sections to expansive site plans, are drawn in model space at full scale (1:1). Paper space is used to set up print- and plot-worthy sheets (often with the use of a title block) that enable the information in model space to be printed to a specific and accurate scale. Such a system allows the architect considerable flexibility when designing and drawing, because one drawing can be used at many different scales and for many different purposes and need not be drawn “to scale.”

A simple way to envision the relationship between model and paper space is to think of the paper space title block as an actual piece of paper, with a hole cut out (the viewport). Through this hole model space is visible. Using XP factors (see following page), the model in the viewport is scaled in relation to the paper space title block.



AutoCAD Text Scale Chart (in inches)

DWG Scale	Scale Factor	XP Factor	Desired Text Height									
			1/16"	3/32"	1/8"	3/16"	1/4"	5/16"	3/8"	1/2"	3/4"	1"
Full	1	1	.0625	.09375	.125	.1875	.25	.3125	.375	.5	.75	1
6"=1'	.5	1/2	.125	.1875	.25	.375	.5	.625	.75	1	1.5	2
3"=1'	.25	1/4	.25	.375	.5	.75	1	1.25	1.5	2	3	4
1 1/2"=1'	.125	1/8	.5	.75	1	1.5	2	2.5	3	4	6	8
1"=1'	.08333	1/12	.75	1.125	1.5	2.25	3	3.75	4.5	6	9	12
3/4"=1'	.0625	1/16	1	1.5	2	3	4	5	6	8	12	16
1/2"=1'	.04167	1/24	1.5	2.25	3	4.5	6	7.5	9	12	18	24
3/8"=1'	.03125	1/32	2	3	4	6	8	10	12	16	24	32
1/4"=1'	.02083	1/48	3	4.5	6	9	12	15	18	24	36	48
3/16"=1'	.015625	1/64	4	6	8	12	16	20	24	32	48	64
1/8"=1'	.01042	1/96	6	9	12	18	24	30	36	48	72	96
1/16"=1'	.005208	1/192	12	18	24	36	48	60	72	96	144	192
1"=10'	.0083	1/120	7.5	11.25	15	22.5	30	37.5	45	60	90	120
1"=20'	.004167	1/240	15	22.5	30	45	60	75	90	120	180	240
1"=30'	.002778	1/360	22.5	33.75	45	67.5	90	112.5	135	180	270	360

Using This Chart

Because all work done in AutoCAD models should be at 1:1, text and labels must be adjusted to appropriate sizes based on the scale at which they will be printed.

For example, if a detail drawing will be printed at 3"=1'-0", and the desired height of the text when printed is 1/8", the text in the model must be set to 0.5". If the same drawing will be printed at 1/4"=1'-0", and that text also needs to be 1/8" high, any text related to the 1/4" scale output would be set to 6" in the model. Many clients, including government agencies, will require a minimum text size for legibility.

Using Paper Space Scales (XP)

The XP scale is the relationship between the desired plotted scale and the sheet of paper on which it will be plotted. With hand drafting, one would typically use an architect's or engineer's scale to assist in correctly making a drawing "to scale." On such a scale, if using 1/4"=1'-0", 1' is shown on the scale as 1/4" in length; 2' is shown as 1/2", and so on. In reality, the scale has already done much of the calculation necessary to draw at the desired scale. To describe this process accurately, one could say that, for the drawing to fit on a certain sheet of paper, the drawing has been made at 1/48th its full scale (if 1/4"=1'-0", 1/4 x 1/12 = X, therefore X = 1/48).

In AutoCAD the process is much the same. To set the scale of a viewport while inside the viewport (ms) in paper space, zoom to 1/48XP (also equal to 0.02083XP). XP literally means "times paper space." This action will zoom the viewport window to 1/4"=1'-0" in relation to the paper space title block, which is printed at 1:1.

CODES AND GUIDELINES **4.**

Codes, laws, and regulations can carry with them a certain off-putting suggestion of bureaucratic obfuscation. To run afoul of them would never be recommended, but attempts to understand them can be frustrating. Certainly, there exist standards that appear senseless or unnecessarily restrictive, but as the world changes and populations expand, the built environment is subject to an increasing number of forces that dictate its use and forms.

As we open doors, turn on lights, and navigate stairs, we all experience firsthand standards within design practice. Ideally, codes and standards allow us to use buildings safely. Constraints brought by code restrictions may also provide an opportunity to let good design solve difficult problems.

As the very real design needs of people with disabilities receive official and widespread acknowledgment and the concept of accessibility becomes more naturally integrated with architecture—for younger designers this is the norm—it can be difficult to imagine how recently it was viewed as an impediment to good design.

Acceptance of the aesthetic possibilities of sustainable design is even more recent. In fact, new standards that accommodate all types of users and a growing recognition of architecture's responsibility to the environment and its future can provide fresh takes on old forms and strong incentives to try new processes.

Chapter 15: Building Codes

The fundamental purpose of building codes is to protect the health, safety, and welfare of all people through the construction of safe buildings and environments. Building practices have long been regulated in various ways, and regulations have existed in America since the early colonies, but it was the 1871 Chicago fire that emphasized the need for effective and enforceable building codes. In the early years since, most building codes in the United States were written and administered by local city, county, or state jurisdictions, eventually producing three major model codes: the National Codes of the Building Officials and Code Administrators International (BOCA), the Uniform Codes of the International Conference of Building Officials (ICBO), and Standard Codes of the Southern Building Code Congress International (SBCCI). With a few exceptions, each of the fifty states has adopted one of these models for its primary building code, in addition to supplemental codes for fire, mechanical, electrical, plumbing, and residential.

INTERNATIONAL BUILDING CODE

The first International Building Code (IBC) was established by the International Code Council in 2000, and with it, the development of the National Codes, Uniform Codes, and Standard Codes was discontinued.

Currently, most U.S. states have adopted or are making efforts to adopt the IBC as their primary building code, though the process continues to differ for each state. The current status of the applicable codes for any given state or local jurisdiction should be verified with local building departments or by visiting the ICC website at www.iccsafe.org. Any code information cited in this book is from the IBC, unless stated otherwise.

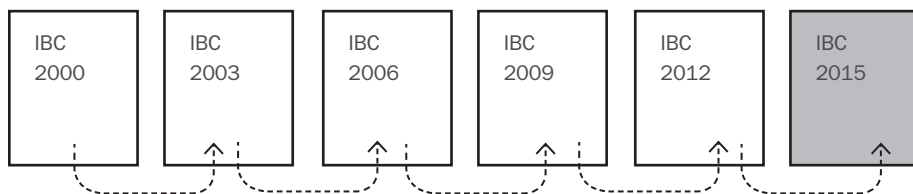
NOTE OF DISCLAIMER

The code information contained in this chapter is for general information only and is here to provide the reader with an introductory overview of the purposes and organization of building codes, and simple “rules of thumb” to follow when beginning design work.

It is not intended to replace any codes discussed, to present interpretations or analyses of said codes, or to address any specific project. It also does not try to address all aspects of any one code in such a small number of pages; rather, the information touches on topics of general interest to most users of this book. All attempts have been made to present information as accurately as possible, with the understanding that code content may change after the book’s publication.

EVOLUTION OF THE IBC

To address a changing world, the IBC codes are evolving through continual review by almost any party that comes in contact with them, including code enforcing officials, various code development committees, and design professionals. Changes occur, for instance, to address new materials, emerging technologies, and shifts in use types. They even occur to clarify interpretations of language and the intent of the codes as written. As a result, the IBC has been designed to be updated every three years. The 2015 edition, for example, exhibits the 2012 code with ICC-approved changes included.



For any project, the applicable codes must be interpreted by the appropriate Authority Having Jurisdiction (AHJ), which could include, among others, local building and fire officials. The use and interpretation of codes can be daunting, and differences of interpretation may occur among designers and building officials. For this reason, it is beneficial to a project to establish contact with the local building department early enough in the design process to address any questions of interpretation.

Even with the help of consultants and the interpretations of others, architects must make every effort to familiarize themselves with pertinent codes, which puts them in a position of greater authority when issues of interpretation do arise. It is never recommended to memorize passages of the code, however, because these will change over time and memory may fail. What is important is to have a thorough working knowledge of the table of contents and to be able to navigate the code with a confident efficiency that, like all aspects of the practice of architecture, comes with experience.

All codes are structured around protection of human life and of property, including both prevention and reaction. Code analysis is performed based on the following sets of data:

- Occupancy Type
- Construction Type
- Building or Floor Area
- Building Height
- Exits and Egress
- Building Separations and Shafts
- Fire Protection
- Fire Extinguishing Systems
- Engineering Requirements

OCCUPANCY TYPE AND USE GROUPS

A building's use and occupancy are primary criteria for determining many aspects of how codes will affect a building, including the height, area, and type of construction allowed. Within each occupancy use group are further subdivisions. It is not unusual for a building to fall under more than one category of occupancy type, which is known as a mixed-use occupancy. It may then be handled either as a "separated use," by providing complete fire separation between occupancies, or as a "nonseparated use," by subjecting each occupancy type to the most stringent requirements for its respective use group.

Occupancy Use Groups

A	Assembly
B	Business
E	Educational
F	Factory and Industrial
H	High Hazard
I	Institutional
M	Mercantile
R	Residential
S	Storage
U	Utility and Miscellaneous

In addition, other building types exist that do not fall into the above categories, and/or contain elements requiring additional code requirements.

Group A: Assembly (50 or more occupants)

A-1: Assembly areas usually with fixed seats, usually for viewing movies or performances (may or may not have a stage).

A-2: Assembly areas involving serving and consumption of food and drink, as in a restaurant or bar. Loose seating and possible patron alcohol impairment are key factors in this group.

A-3: Other assembly groups that don't fit A-1 or A-2. May include houses of worship, art galleries, and libraries.

A-4: Assembly areas for indoor sporting events.

A-5: Assembly areas for outdoor sporting events.

Group B: Business

Most office buildings fall into this category, including their storage areas (unless they exceed the amount of hazardous materials allowable, in which case they become Use Group H).

Also included are educational facilities after grade 12 (colleges and universities), ambulatory care facilities, and research laboratories.

Any assembly area, including a lecture hall, may fall into Group A and should be treated as such.

Group E: Educational

More than 6 people, for classes up to the 12th grade

Daycare facilities for 5 or more children over age 2½ (daycare in a dwelling unit for fewer than 5 people is classified as R-3).

Group F: Factory and Industrial

F-1: Moderate-hazard factory occupancy that has established that the relative hazards of fabrication operations do not put them in Group H (Hazardous) or in category F-2.

F-2: Low-hazard factory industrial occupancy where the materials of manufacture are considered to be noncombustible.

Group H: High Hazard

A range in high-hazard occupancies from H-1 to H-5, addressing the quantities and nature of use of the hazardous materials.

Group I: Institutional

I-1: More than 16 people in a 24-hour residential environment and under supervised conditions. May include group homes, assisted-living facilities, and halfway houses whose residents require custodial care, but are capable of self-preservation.

I-2: More than 5 people in a 24-hour residential environment and under supervised conditions and receiving medical care. May include hospitals and nursing homes whose residents are unable to respond to emergency situations without the aid of staff members.

I-3: More than 5 people in a 24-hour supervised environment under full-time restraint and security. Because of security measures, occupants cannot respond to emergencies without the aid of a staff member. May include prisons, detention centers, and reformatories, which may be further subdivided into five categories based on the amount of freedom of movement of residents inside the facility.

I-4: More than 5 people under supervised conditions or custodial care for less than 24 hours a day. May include adult and child daycare. For facilities with children over age 2½, Group E may apply.

Group M: Mercantile

Department stores, drugstores, markets, gas stations, sales rooms, and retail or wholesale stores.

Group R: Residential

R-1: Residences with sleeping units serving transient occupants. May include hotels and boarding houses.

R-2: Permanent dwellings with more than two units. May include apartments, dormitories, and longer term boarding houses.

R-3: Permanent single-family or duplex residences. May also include care facilities for 5 or fewer people, boarding houses with 10 or fewer occupants, and (nontransient) congregate living facilities with 16 or fewer occupants. Includes many residential occupancies not included in R-1, R-2, R-4, or I.

R-4: Between 5 and 16 occupants of a residential care or assisted-living facility, in which the residents receive custodial care on a 24-hour basis, but are capable of self-preservation. Types include alcohol and drug centers and social rehabilitation facilities.

Group S: Storage

S-1: Moderate-hazard storage occupancy for materials not considered hazardous enough for Group H but that do not qualify as S-2.

S-2: Low-hazard storage occupancy for materials considered to be noncombustible.

Group U: Utility and Miscellaneous

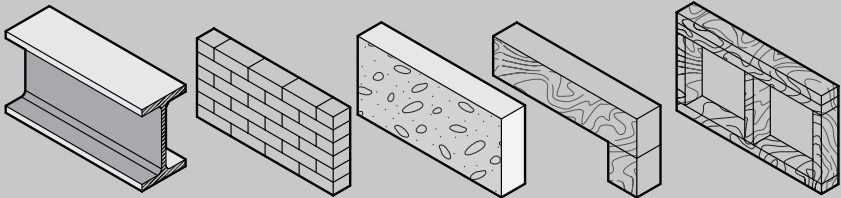
Used for accessory buildings and nonbuildings (such as fences or retaining walls) that are generally not occupied for long periods of time and may serve a secondary function to other occupancies.

CONSTRUCTION TYPES AND FIRE RESISTANCE

Construction types are categorized by their material content and the resistance to fire of the structural system. The IBC assigns five broad categories to all buildings, based on the predominant materials in the building's construction. These categories are I, II, III, IV, and V, with Type I being most fire resistive and Type V being least fire resistive. The five types are divided into A and B categories, reflecting the level of fire-resistance rating for each.

Types of Construction

Noncombustible		Noncombustible/Combustible			Combustible			
IA	IB	IIA	IIB	IIIA	IIIB	IV (Heavy Timber = HT)	VA	VB



Noncombustible materials, which are defined as being materials “of which no part will ignite and burn when subjected to fire,” typically include fire-protected steel, masonry, and concrete.

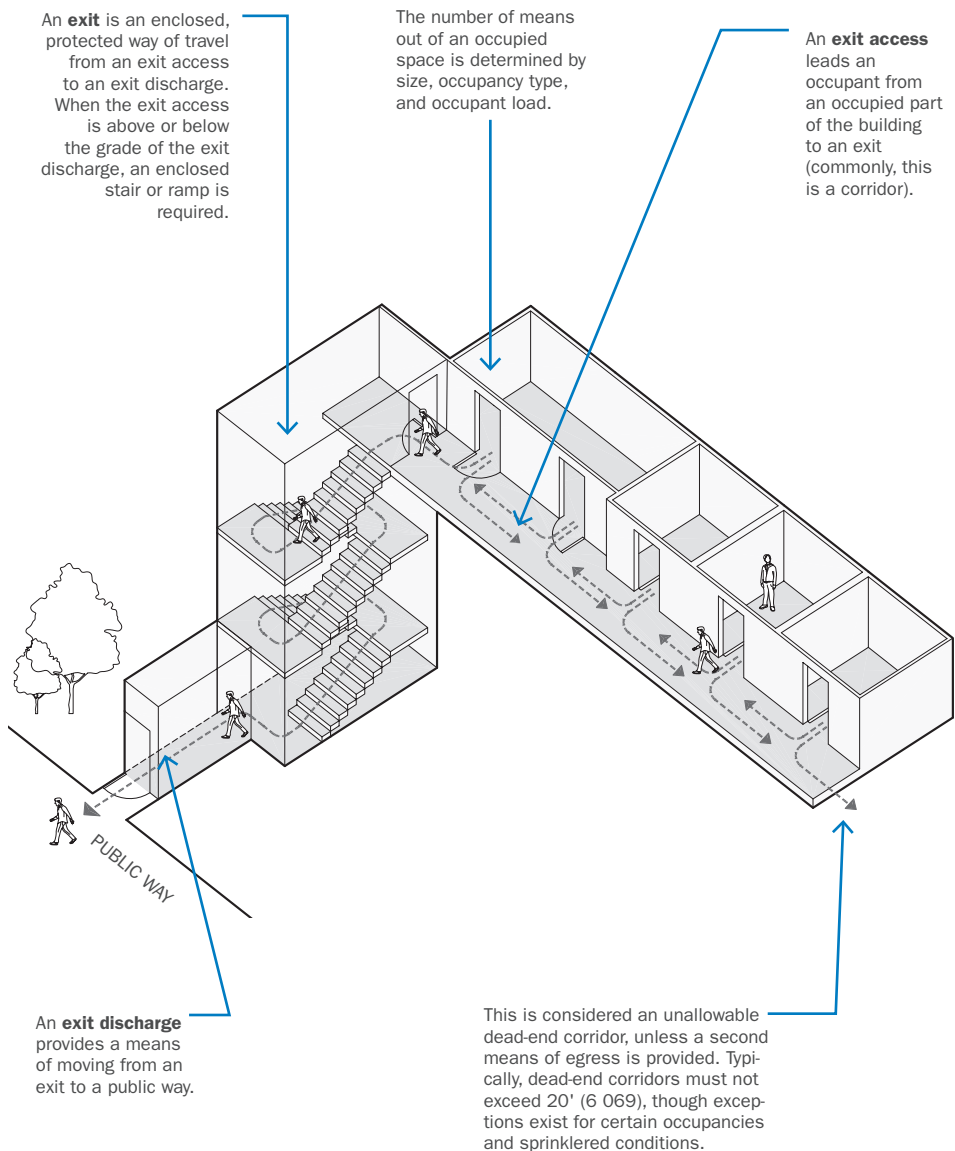
Combustible materials, which may be assumed to be materials that fail to meet noncombustibility requirements, include wood and plastic.

Fire-Resistance Ratings

Fire-resistance ratings are measured in hours or fractions of an hour and reflect the amount of time that a material or assembly of materials will resist fire exposure, as set forth in ASTM E119 (American Society for Testing and Materials Standard for Fire Tests of Building Constructions). When beginning design of a building, the initial code analysis must consider the desired occupancy and the desired height and area to determine the minimum allowable construction type for fire ratings.

EGRESS

Means of Egress Diagram



EGRESS

MEANS OF EGRESS

IBC 202 defines a means of egress as “a continuous and unobstructed path of vertical and horizontal egress travel from any occupied portion of a building or structure to a public way.” It consists of the exit access, the exit, and the exit discharge. Simply put, means of egress provide conditions for getting all occupants to a safe place (usually an outdoor public way) in the event of fire or other emergency.

Number of Means of Egress

Per IBC 1006, occupancies (per story) that require more than one means of egress are (other restrictions may apply relative to the level above or below grade):

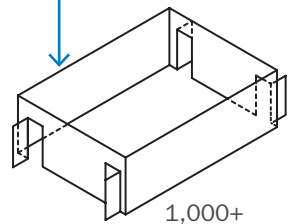
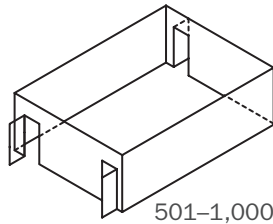
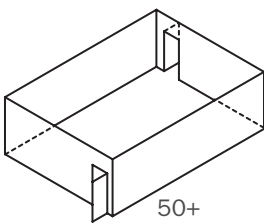
A, B, E, F, M, and U, with occupant loads 50 and over

H-2, H-3, with occupant loads over 3

H-4, H-5, I, and R-1, R-2, R-4 with occupant loads over 10

S with occupant loads 30 and over

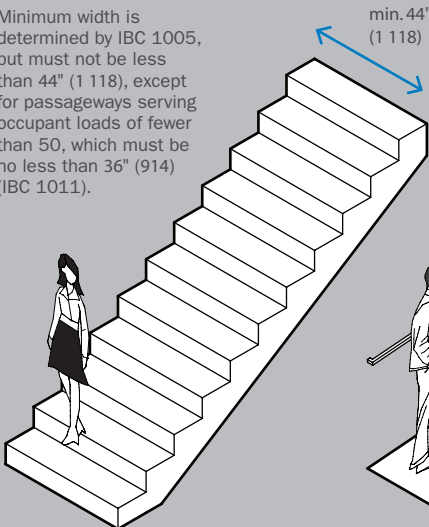
Any occupancy between 501 and 1,000 requires three exits, and occupancies over 1,000 require four.



MEANS OF EGRESS SIZING

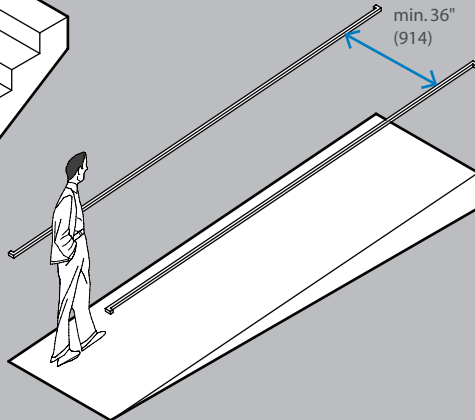
Egress Stairs

Minimum width is determined by IBC 1005, but must not be less than 44" (1 118), except for passageways serving occupant loads of fewer than 50, which must be no less than 36" (914) (IBC 1011).



Ramps

Ramps in an egress system should have a width no less than the corridors that serve them, and no less than 36" (914) between handrails (IBC 1012).



Required Egress Widths

Sizes are determined by coordinating IBC 1004 (Floor Area per Occupant) with IBC 1005 (Means of Egress Sizing), and comparing to the minimum allowable sizing, taking the higher option.

Egress Doors

In areas with an egress load of more than 50 occupants, or any Group H occupancy, exit access doors should swing in the direction of travel (IBC 1010). If they swing into a required egress path, they may not reduce the required width by more than one half while swinging open, and once opened 180°, the door may not project into the required width more than 7" (178).

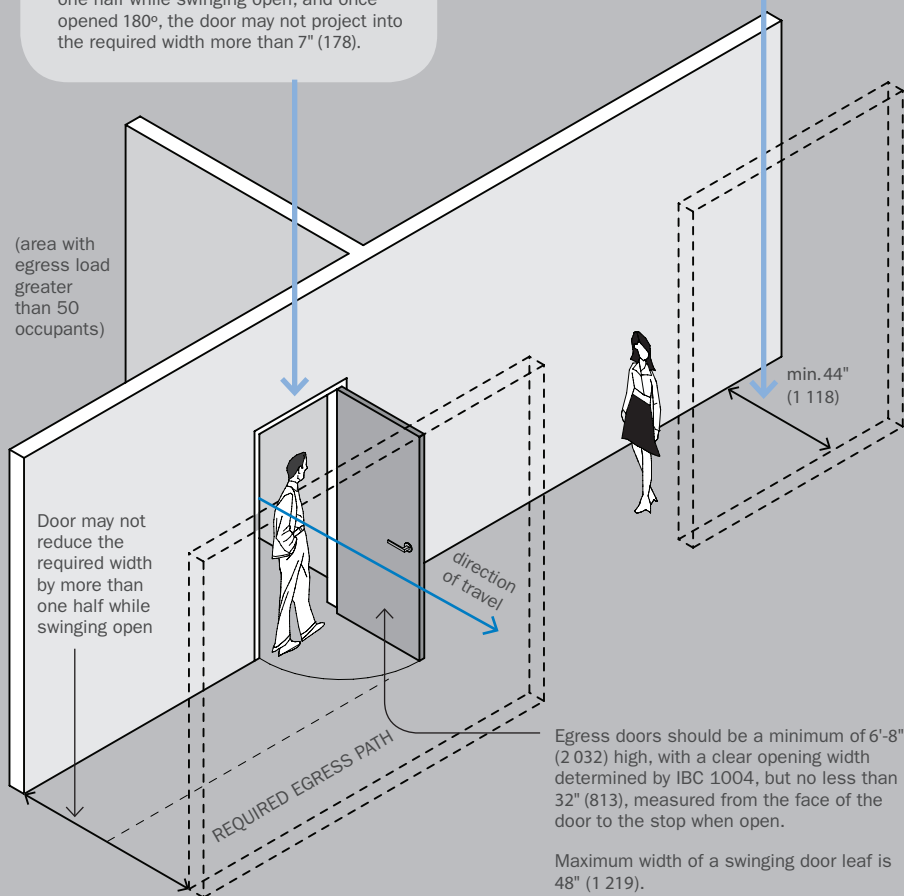
Exit Passageways

Minimum passageway width is determined by IBC 1005, but must not be less than 44" (1 118), except for (IBC 1020):

Within a dwelling unit or in an occupancy of less than 50: 36" (914)

Group E with 100+ occupant load: 72" (1 829)

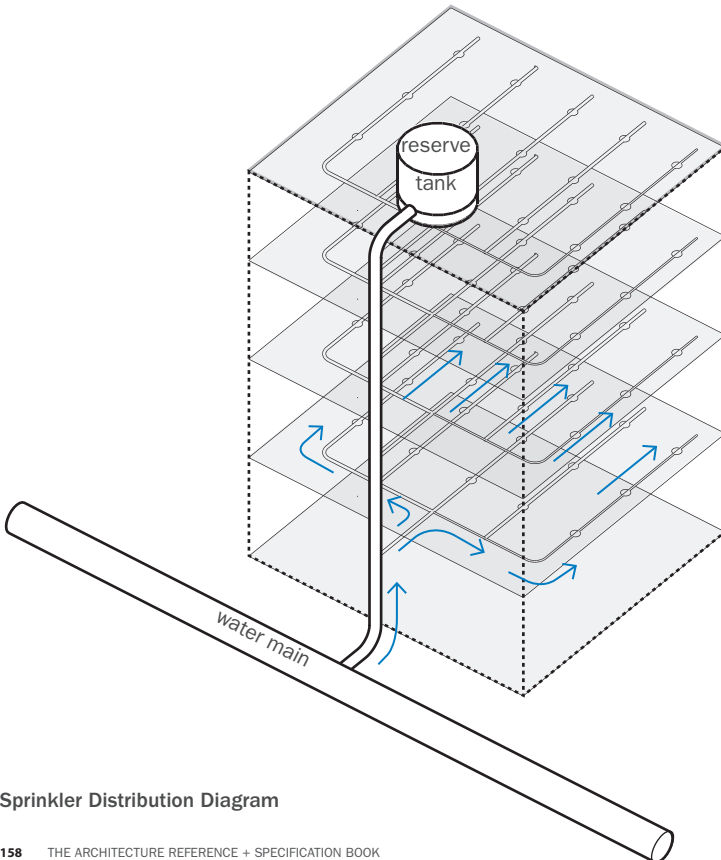
Group 1-2 areas with required bed movement: 96" (2 438)



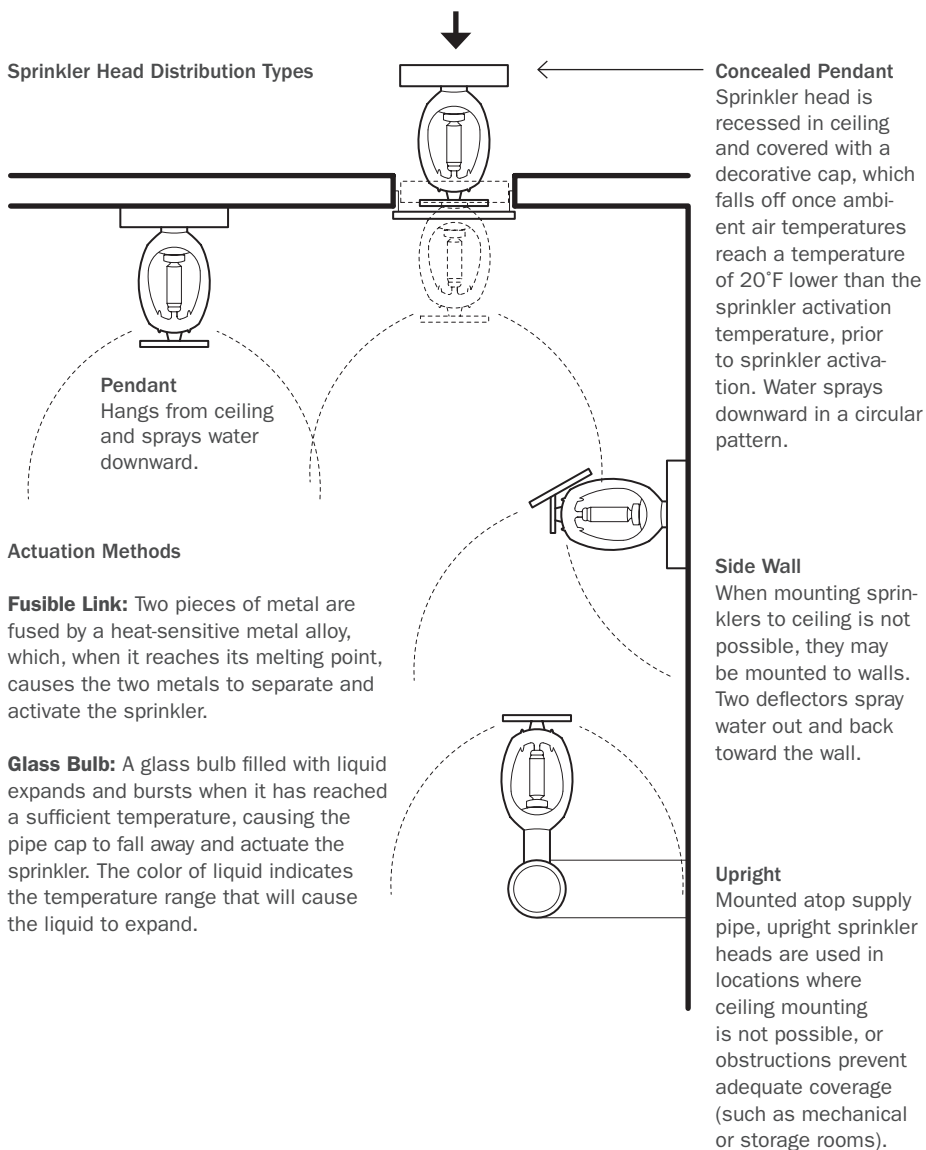
FIRE PROTECTION SYSTEMS

Limitations on building area and height may be lessened when fire-protection systems such as automatic sprinklers are in place. Active fire-protection systems are defined by IBC 202 as “approved devices, equipment and systems or combinations of systems used to detect a fire, activate an alarm, extinguish or control a fire, control or manage smoke and products of a fire, or any combination thereof.” They are meant to work in conjunction with the building’s passive systems (fire-resistive construction) to provide necessary protection for the occupants of any building type. Higher levels of stringency in one system might mean lessened requirements in the other, though neither should be compromised for the sake of cost or convenience.

The IBC requires active systems for buildings above certain sizes and occupant loads, regardless of the type of construction. IBC Section 903 establishes these requirements based on use groups and fire areas (“the aggregate floor area enclosed and bounded by fire walls, fire barriers, exterior walls, or fire-resistance-rated horizontal assemblies of a building”). Alternative fire-extinguishing systems may be used when necessary, in compliance with IBC 904. Examples of reasons to use alternative systems might include libraries and museums or telecommunications facilities, whose contents would sustain water damage from standard water sprinkler systems. Until recently, Halon 1301 gas was widely preferred as a fire-suppression option; however, it has proven to be harmful to the ozone layer and is being replaced by other options.



Sprinkler Distribution Diagram



Chapter 16: ADA and Accessibility

The Americans with Disabilities Act (ADA) was passed by Congress in 1990 to protect and honor the civil rights of people with disabilities, including conditions affecting mobility, sight, hearing, stamina, speech, and learning disorders. Modeled on earlier landmark laws prohibiting discrimination based on race and gender, the ADA provides equal access for all people to housing, public accommodations, employment, government services, transportation, and telecommunications. Similar to building codes, accessibility guidelines and standards are continually subject to improvement and revision, and in 2010 the Department of Justice adopted a revised set of standards, published as the 2010 Standards for Accessible Design. Included among the revisions are accommodation for children, and ambulatory (in addition to wheelchair) accessibility.

KEY TERMS AS DEFINED BY ADA

Access aisle: Accessible pedestrian space between elements such as parking spaces, seating, or desks that provides clearances appropriate for use of the elements.

Accessible: Of a site, building, facility, or portion thereof, in compliance with ADA guidelines.

Accessible element: Element (telephone, controls, and the like) specified by ADA guidelines as in compliance.

Accessible route: Continuous unobstructed path connecting all accessible elements and spaces of a building or facility. Interior accessible routes may include corridors, floors, ramps, elevators, lifts, and clear floor space at fixtures. Exterior accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, and lifts.

Accessible space: Space that complies with ADA guidelines.

Adaptability: Ability of certain building spaces and elements, such as kitchen counters, sinks, and grab bars, to be added or altered so as to accommodate the needs of individuals with or without disabilities or with different types or degrees of disability.

Addition: Expansion, extension, or increase in the gross floor area of a building or facility.

Administrative authority: Governmental agency that adopts or enforces regulations and guidelines for the design, construction, or alteration of buildings and facilities.

Area of rescue assistance: Area that has direct access to an exit, where people who cannot use stairs may remain temporarily in safety to await further instructions or assistance during emergency evacuation.

Assembly area: Room or space accommodating a group of individuals for recreational, educational, political, social, or amusement purposes, or for the consumption of food and drink.

Automatic door: Door equipped with a power-operated mechanism and controls that open and close the door automatically on receipt of a momentary actuating signal. The switch that begins the automatic cycle may be a photoelectric device, floor mat, or manual switch. See power-assisted door.

Building: Any structure used and intended for supporting or sheltering any use or occupancy.

Circulation path: Exterior or interior way of passage from one place to another for pedestrians, including, but not limited to, walks, hallways, courtyards, stairways, and stair landings.

Clear: Unobstructed.

Clear floor space: Minimum unobstructed floor or ground space required to accommodate a single, stationary wheelchair and occupant.

Common use: Describes interior and exterior rooms, spaces, or elements that are made available for the use of a restricted group of people (for example, the occupants of a homeless shelter, the occupants of an office building, or the guests of such occupants).

Cross slope: Slope that is perpendicular to the direction of travel.

Curb ramp: Short ramp cutting through a curb or built up to it.

Detectable warning: Standardized surface feature built in or applied to a walking surface or other elements to warn visually impaired people of hazards on a circulation path.

Egress, means of: Continuous and unobstructed way of exit travel from any point in a building or facility to a public way. A means of egress comprises vertical and horizontal travel and may include intervening room spaces, doorways, hallways, corridors, passageways, balconies, ramps, stairs, enclosures, lobbies, horizontal exits, courts, and yards. An accessible means of egress is one that complies with ADA guidelines and does not include stairs, steps, or escalators. Areas of rescue assistance or evacuation elevators may be included as part of accessible means of egress.

Elements: Architectural or mechanical component of a building, facility, space, or site (for example, a telephone, curb ramp, door, drinking fountain, seating, or water closet).

Entrance: Any access point to a building or portion of a building or facility used for the purpose of entering. An entrance includes the approach walk, the vertical access leading to the entrance platform, the entrance platform itself, vestibules if provided, the entry door(s) or gate(s), and the hardware of the entry door(s) or gate(s).

Marked crossing: Crosswalk or other identified path intended for pedestrian use in crossing a vehicular way.

Operable part: Part of a piece of equipment or appliance used to insert or withdraw objects, or to activate, deactivate, or adjust the equipment or appliance (for example, a coin slot, push button, or handle).

Power-assisted door: Door used for human passage with a mechanism that helps to open the door, or relieves the opening resistance of a door, on the activation of a switch or a continued force applied to the door itself.

Public use: Describes interior or exterior rooms or spaces that are made available to the general public. Public use may be provided at a building or facility that is privately or publicly owned.

Ramp: Walking surface that has a running slope greater than 1:20.

Running slope: Slope that is parallel to the direction of travel.

Signage: Displayed verbal, symbolic, tactile, and pictorial information.

Space: Definable area (for example, a room, toilet room, hall, assembly area, entrance, storage room, alcove, courtyard, or lobby).

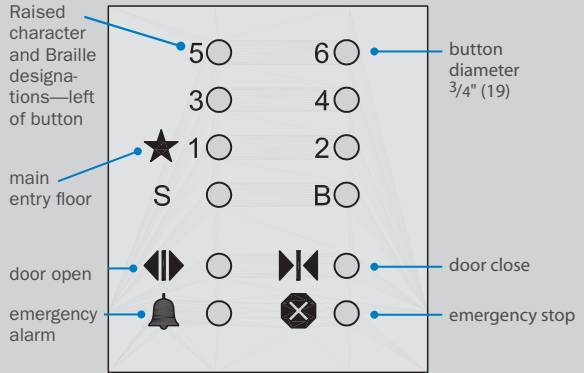
Tactile: Of an object, perceptible using the sense of touch.

Text telephone: Machinery or equipment that employs interactive graphic (that is, typed) communications through the transmission of coded signals across the standard telephone network. Text telephones can include devices known as TDDs (telecommunication display devices or telecommunication devices for deaf persons) or computers.

Walk: Exterior pathway with a prepared surface intended for pedestrian use, including general pedestrian areas such as plazas and courts.

SIGNAGE

Elevator Control Panel



Emergency controls should be grouped at the bottom, with centerlines no less than 35" (889) AFF.

Raised and Tactile Characters

Characters should be raised 1/32" (0.8) and in uppercase with sans serif font. Characters shall not be italic, oblique, decorative or unusual.

Characters must be accompanied by Grade 2 Braille.

Raised characters must be a minimum of 5/8" (16) and maximum of 2" (51) high based on an uppercase I.

Braille shall be positioned below the corresponding text, and shall be separated by 3/8" (10) minimum from any other tactile characters or raised borders.

Tactile characters on signs shall be located 48" (1 220) min. AFF, measured from the baseline of the lowest character, and 60" (1 525) max. AFF, measured from the baseline of the highest tactile character.

Visual Characters

Characters and background must be egg-shell, matte, or another nonglare finish and must contrast with background (either light on dark or dark on light).

Characters may be uppercase or lowercase, or a combination of both, and shall not be italic, oblique, decorative or unusual.

Minimum character height shall be determined by the horizontal viewing distance (per 2010 Standard 703).

Pictograms

Text descriptors (if any) must be placed directly below pictogram field.

Pictograms can be any size within a minimum field of 6" (153) in height.



ACCESSIBLE MEANS OF EGRESS

Any space that is considered to be accessible must have at least one accessible means of egress.

Elevators that comply with ASME A17.1, Safety Code for Elevators and Escalators, may be allowed as part of an accessible egress route. Primarily, they must be equipped with standby power and emergency operation and signaling devices, and most must be accessed from an area of refuge.

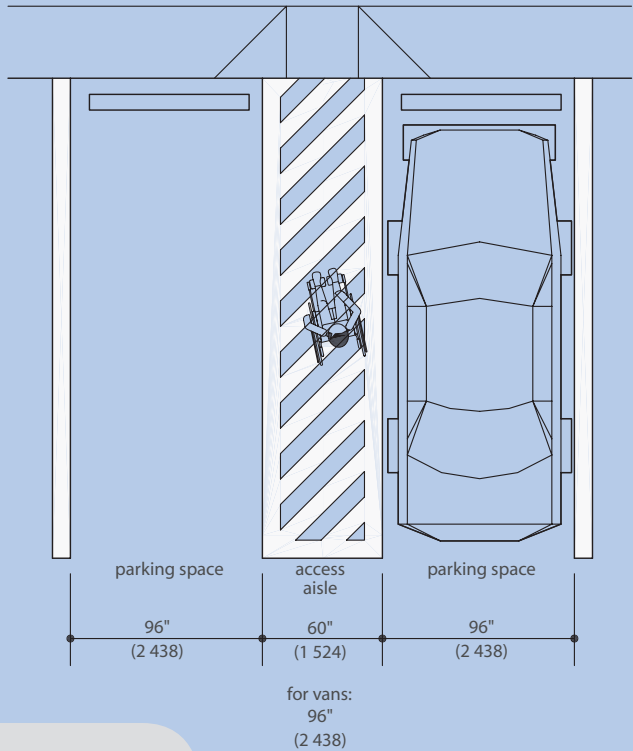
Areas of refuge, where those unable to use stairways remain temporarily in an evacuation, should be in an egress stairway or have direct access to one, or to an elevator with emergency power. Two-way communications systems should be provided in the area of refuge, connecting it to a central control point.

One 30" x 48" (762 x 1 219) wheelchair space must be provided for every 200 occupants of the space served. Generally these spaces are alcoves within an enclosed stair, because they must not reduce the egress width.

Except in sprinklered buildings, accessible egress stairways should be a minimum of 48" (1 219) wide clear between handrails. This provides a space wide enough for two people to carry a disabled person down or up to safety.

ACCESSIBLE PARKING SPACES

The length of accessible parking spaces must be in accordance with local building codes. Accessible spaces should be marked by high-contrast painted lines or other high-contrast delineation. Access aisles should be a part of an accessible route to the building or facility entrance. Two accessible parking spaces may share a common access aisle. Access aisles should be marked clearly by means of diagonal stripes.



Number of Accessible Spaces Required

1–25	1
26–50	2
51–75	3
76–100	4
101–150	5
151–200	6
201–300	7
301–400	8
401–500	9
501–1,000	2% of total
1,001 and over	20 plus 1 for each 100 over 1,000

Surface slopes should not exceed 1:50 (2%) in any direction on accessible parking spaces and access aisles.

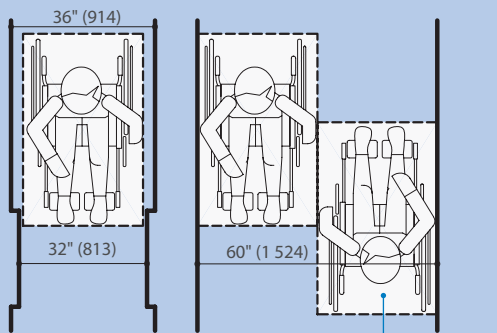
Accessible parking spaces serving a particular building should be located on the shortest accessible route of travel from the adjacent parking to an accessible entrance.

In buildings with multiple accessible entrances with adjacent parking, accessible parking spaces should be dispersed and located closest to the accessible entrances.

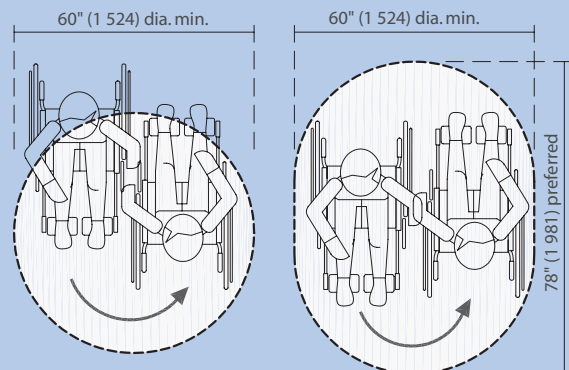
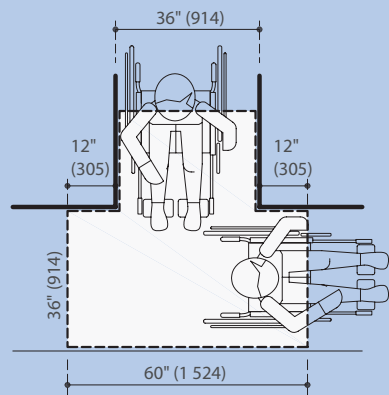
WHEELCHAIR SPACE ALLOWANCES

Clear floor or ground space is defined as the minimum clear area required to accommodate a single, stationary wheelchair and occupant. This applies to both forward and parallel approaches to an element or object. Clear floor space may be part of the knee space required under objects such as sinks and counters.

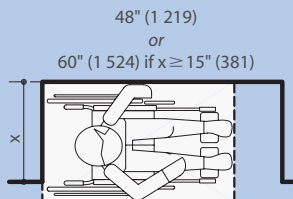
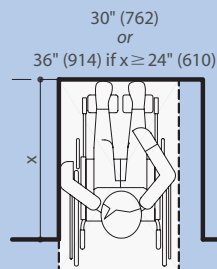
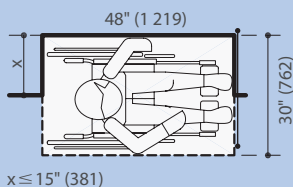
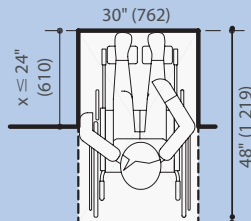
Wheelchair Passage Widths



30" x 48"
(762 x 1 219)
clear floor
space, typical

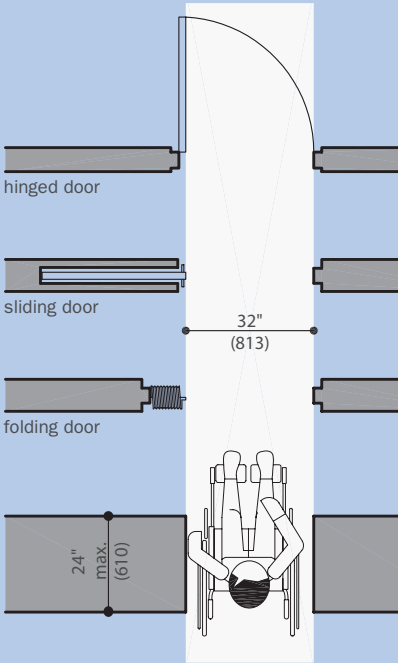


Clear Floor Space at Alcoves

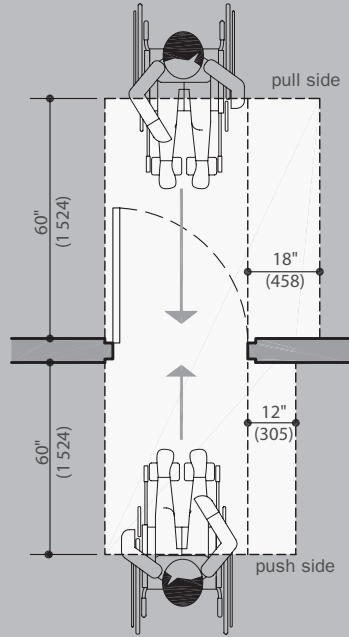


DOORS

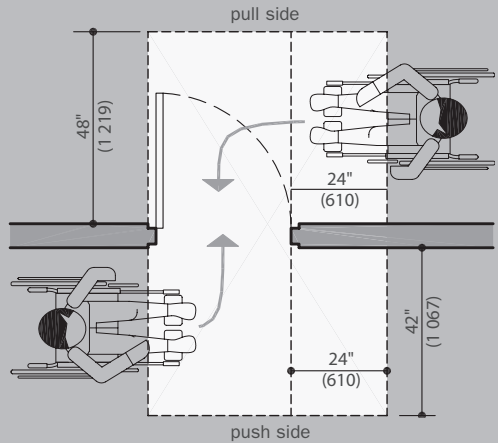
Clear Doorway Width and Depth



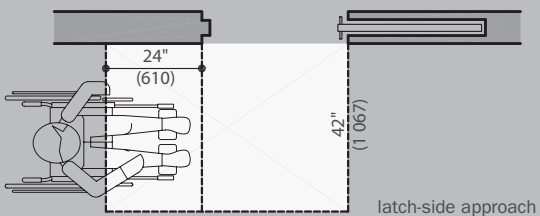
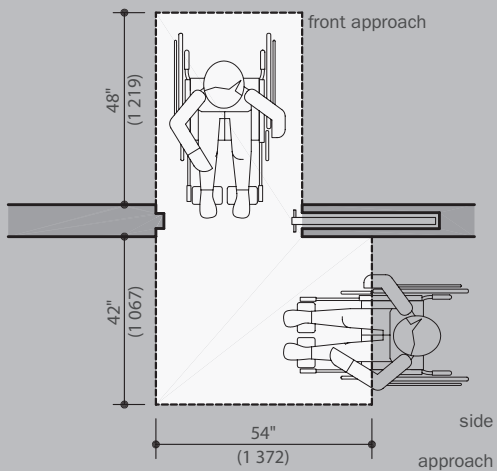
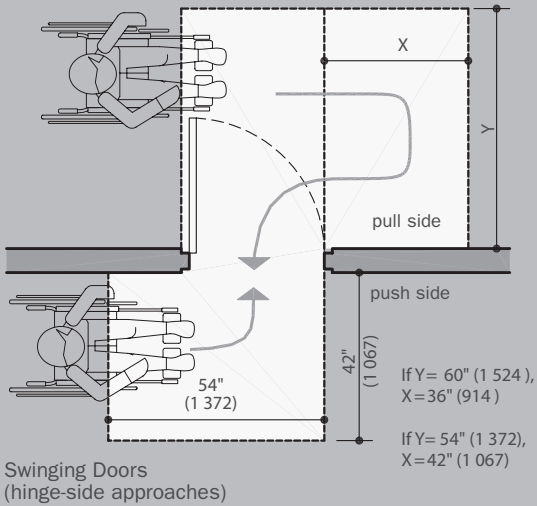
Maneuvering Clearances at Doors



Swinging Doors
(front approaches)

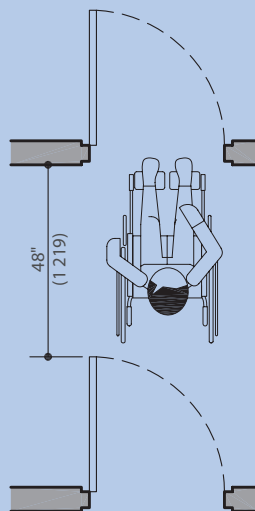
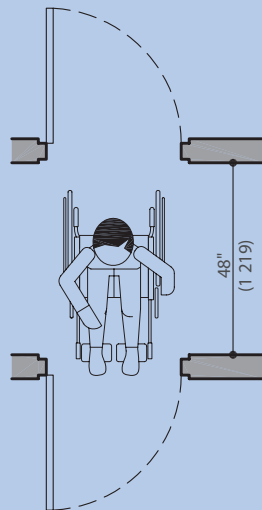


Swinging Doors
(latch-side approaches)



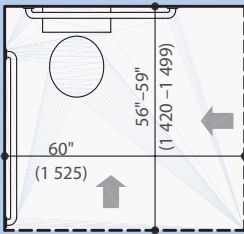
Sliding and Folding Doors

Two Hinged Doors
in a Series

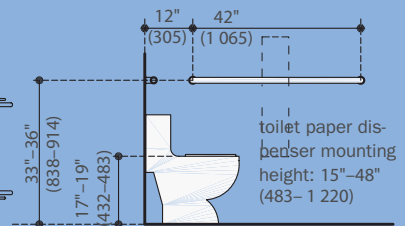
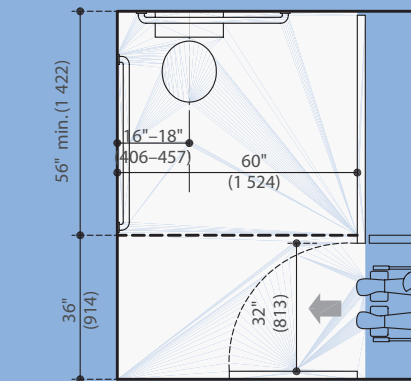
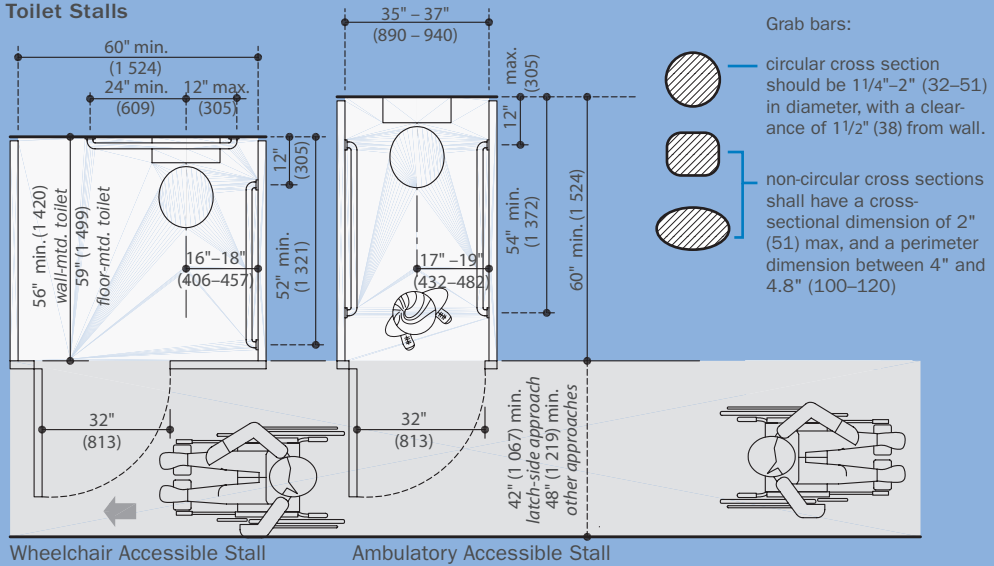


TOILETS AND BATHROOMS

Clear Floor Space at Water Closets - Adult



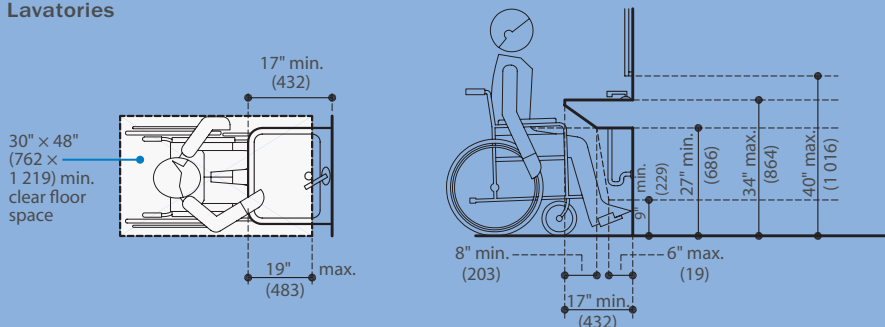
Toilet Stalls



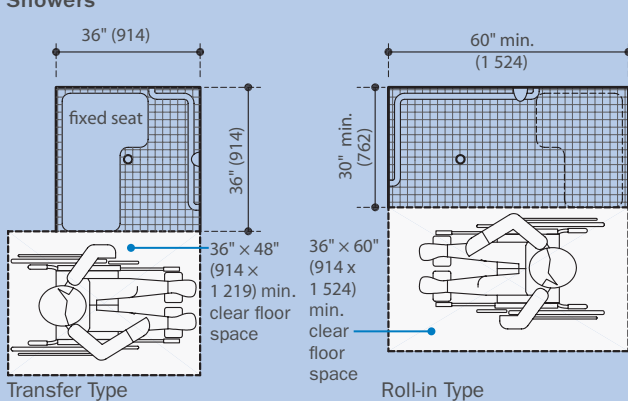
End-of-Row Wheelchair Accessible Stall

Side-wall Elevation

Lavatories



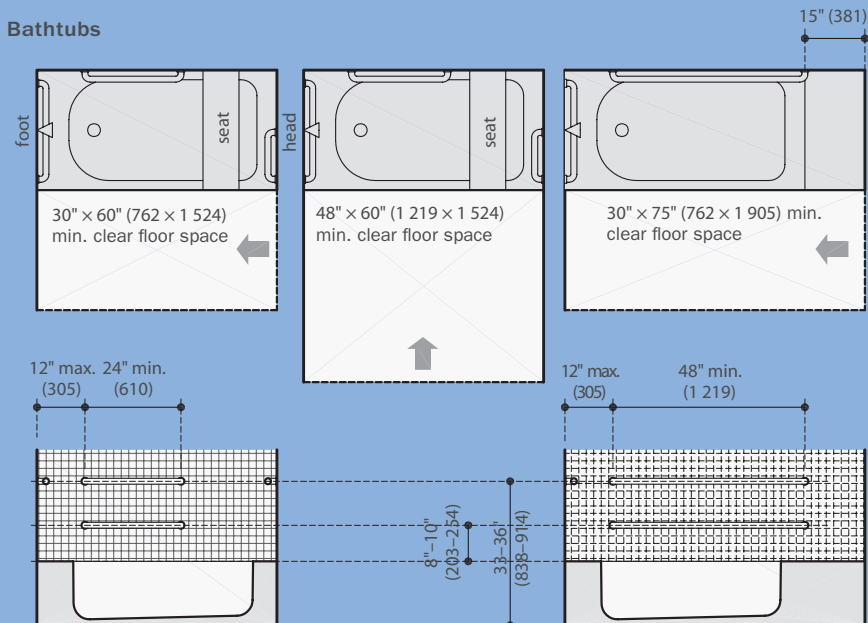
Showers



A seat must be provided in shower stalls 36" x 36" (914 x 914), mounted 17"–19" (432–83) from the bathroom floor and extending from the back wall to a point within 3" (76) of the compartment entry.

Fixed seats in 30" x 60" (762 x 1 524) shower stalls should be of a folding type mounted on the wall adjacent to the controls.

Bathtubs

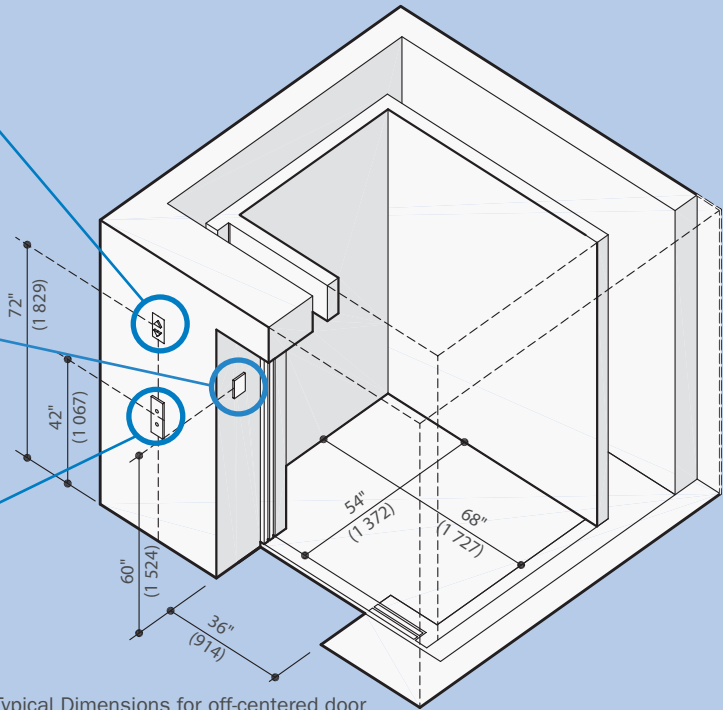


ELEVATORS

Hall lantern fixtures at each hoistway entrance must indicate visibly and audibly which car is answering a call.

Door jambs should have raised and Braille floor designation markings.

Call buttons must be a minimum $\frac{3}{4}$ " (19) in the smallest direction.



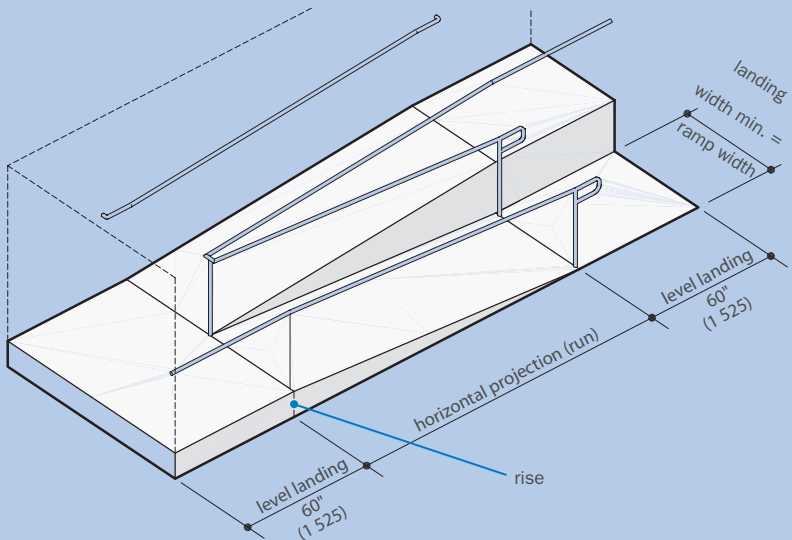
Typical Dimensions for off-centered door

RAMPS

The rise for any ramp run before landing shall be 30" (762) max.

The minimum clear width of a ramp should be 36" (914), inside handrails. If a ramp has a rise greater than 6" (150) then it should have handrails on both sides.

Maximum slope is 1:12.



STAIRS

Nosings

Risers should be sloped, or the underside of nosings should have an angle not less than 60° from the horizontal.



flush riser

11" (280) min. tread depth



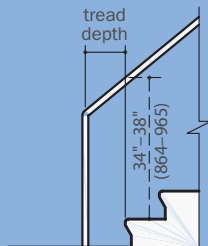
angled nosing

7" (178) max. riser height

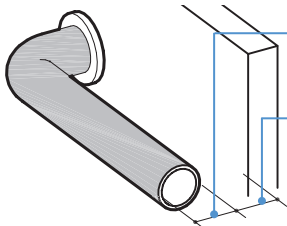


rounded nosing

Handrail Extension (min.) at Bottom of Run



Handrails



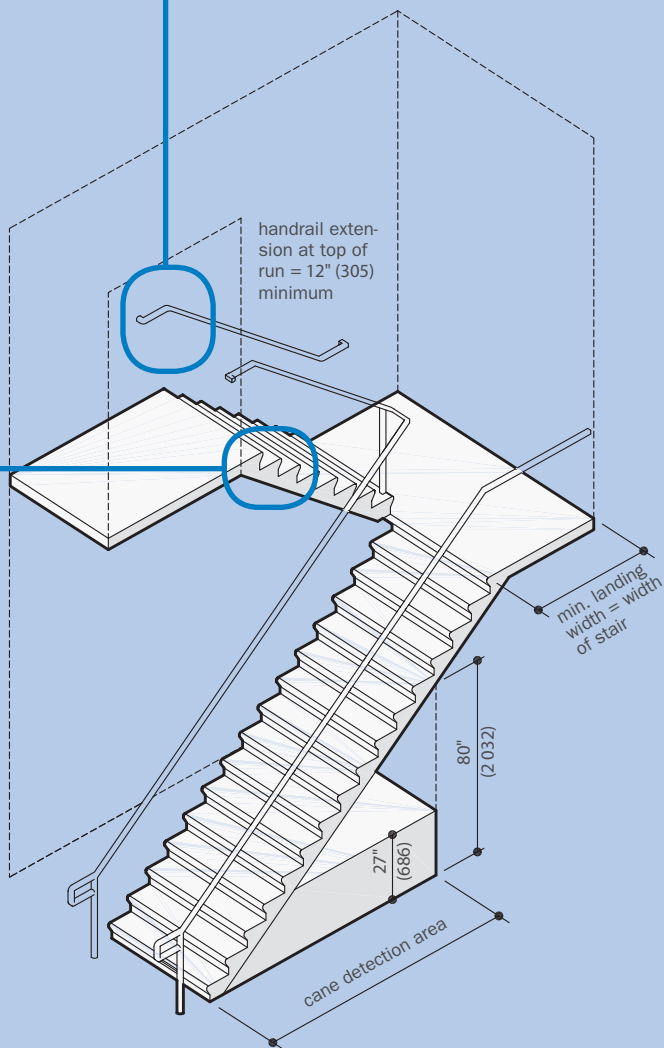
1 1/4" - 2"
(32-51) dia.

1 1/2" (38) min.
from wall

at wall: handrail returns to wall

at switchback: handrail is continuous

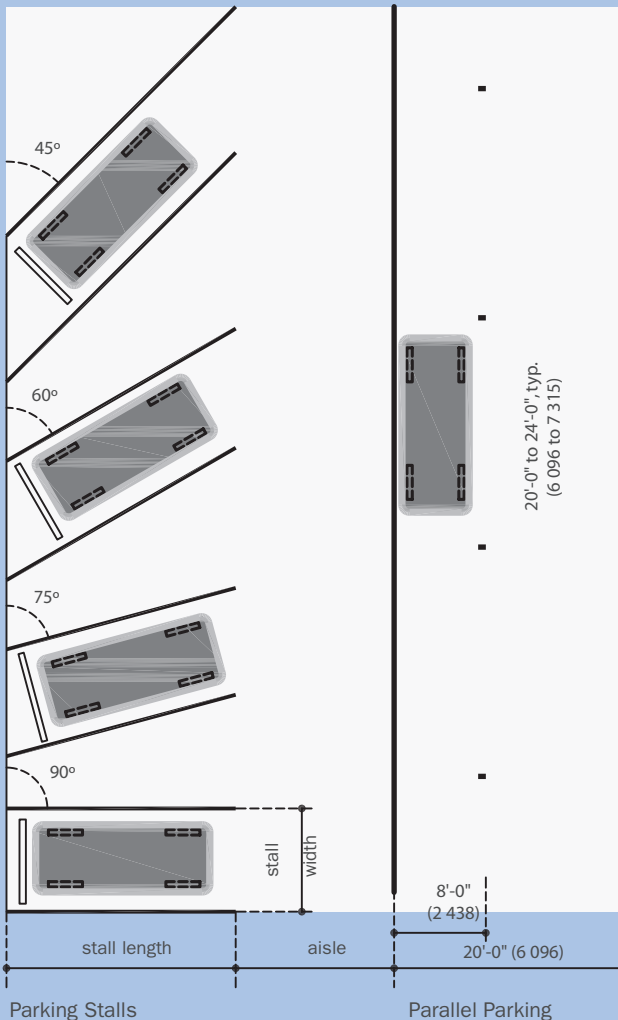
where no wall: handrail returns smoothly to the floor



Chapter 17: Parking

Almost everywhere, parking is often a person's first and last interface with a building and should be designed with this in mind. Primarily, parking should be safe, efficient, well-marked, and able to accommodate users of all kinds. Because vehicle sizes fluctuate, parking areas must be flexible enough to respond to future scenarios.

PARKING LOTS



General Guidelines

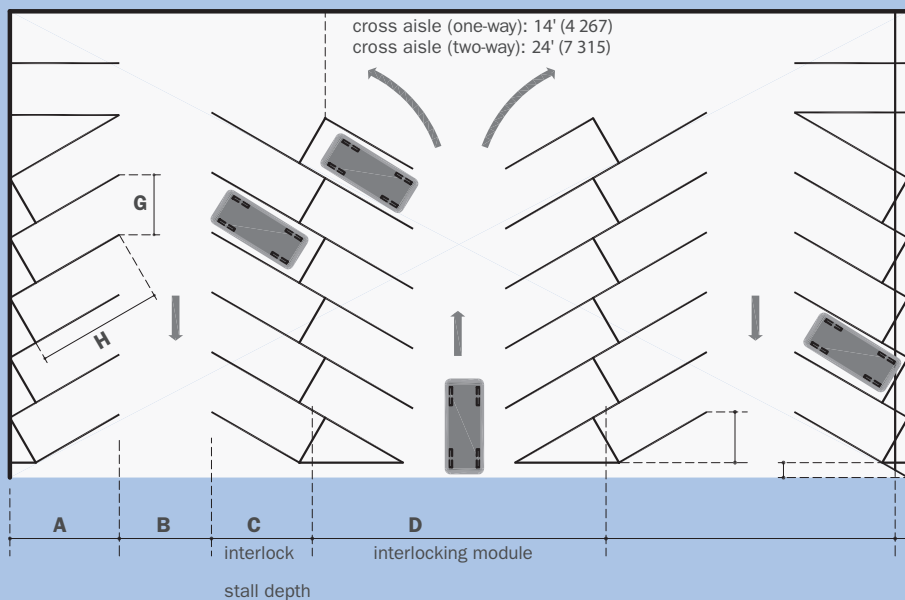
Pavement striping should be 4" (102) wide, in white or yellow paint.

Parking area surfaces should have a minimum slope of 2 percent (a $\frac{1}{4}$ " per foot or 6 mm per 305 mm) for drainage purposes.

Lots are laid out with modules. One complete module includes one access aisle and the parking it serves on either side.

The most common angle for parking is the 60° stall, which provides for ease of entering and exiting spaces while still allowing for an efficiently sized module. Stalls of 45° reduce the total number of parking spaces for a given area but do not require a wide access aisle. They are the only acceptable angle for a herringbone parking lot pattern. Stalls of 90° provide the most parking spaces for a given area, though they are unsuitable for in-and-out traffic, due to the higher degree of difficulty entering and exiting the stalls. They are ideal for all-day parking, such as for employees.

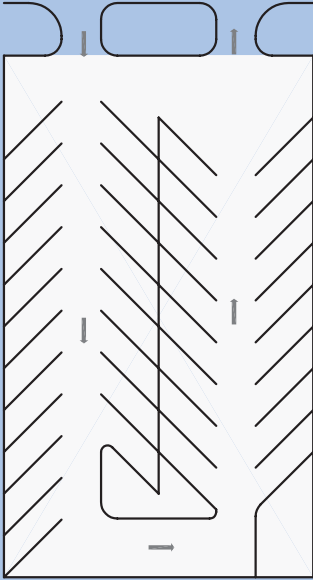
COMMON PARKING STALL LAYOUTS



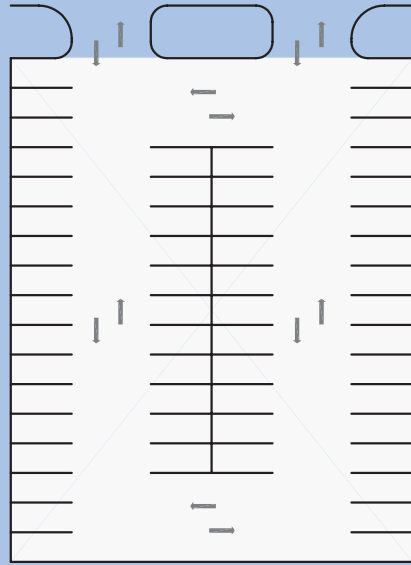
	A	B	C	D
45°	17.5' (5 334)	12.0' (3 658)	15.3' (4 663)	42.6' (12 984)
60°	19.0' (5 791)	16.0' (4 877)	17.5' (5 334)	51.0' (15 549)
75°	19.5' (5 944)	23.0' (7 010)	18.8' (5 730)	61.0' (18 593)
90°	18.5' (5 639)	26.0' (7 925)	18.5' (5 639)	63.0' (19 202)

Recommended parking layouts and stall dimensions vary and are most often determined by local or state zoning provisions (which should *always* be consulted). Commonly accepted minimum stall sizes are 9' (2 743) × 18.5'–19.5' (5 639–944), though sizes and layouts should best accommodate their situation; for instance, stalls at hardware or grocery stores should be wide enough to accommodate easy loading and unloading of large packages, and may be up to 10' (3 048) wide. Compact car spaces may be as small as 7'-6" × 15' (2 286 × 4 572) and should be well marked and logically grouped.

Parking Lot Flows



One-way Angled



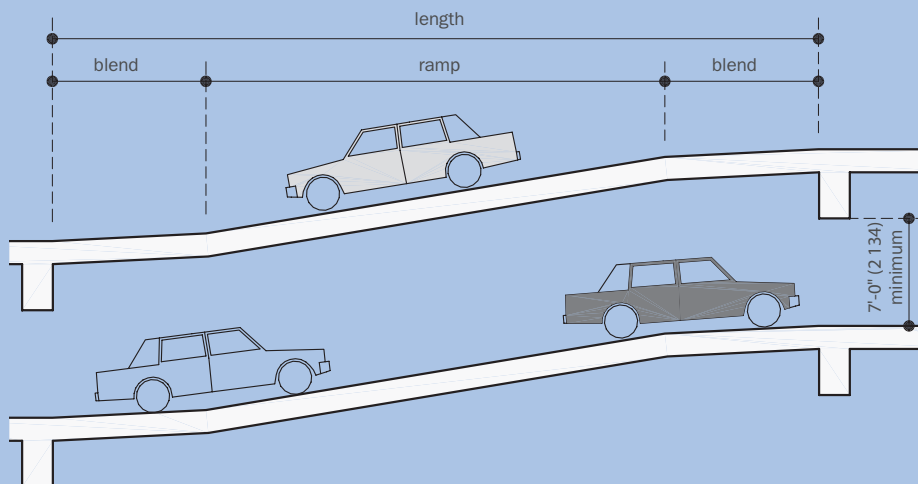
Two-way 90 Degrees

Common Parking Space Allocations

Hospital	1.2 per bed
Auditorium/theater/stadium	0.3 per seat
Restaurant	0.3 per seat
Industrial	0.6 per employee
Church	0.3 per seat
Retail	4.0 per 1000' gross floor area
Office	3.3 per 1000' gross floor area
Shopping center	5.5 per 1000' gross leasable area
Hotels/motel	1.0 per room/0.5 per employee
Senior high schools	0.2 per student/1.0 per staff member
Elementary schools	1.0 per classroom

PARKING GARAGES

Ramp Design



Straight Ramps

Length	< 65'-0" (19 812)	> 65'-0" (19 812)
Blend length	10'-0" (3 048)	8'-0" (2 438)
Blend slope	8%	6%
Ramp slope	16%	12%

Helical Ramps

width = 15'-0" (4 572)
for counterclockwise travel

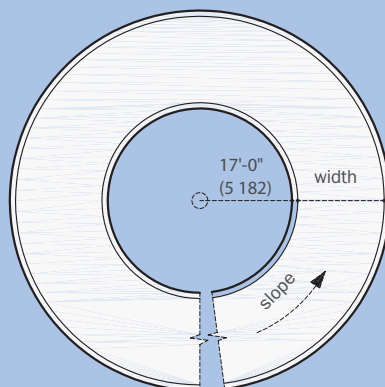
width = 20'-0" (6 096)
for clockwise travel

slope = 12% maximum
(4% in transverse direction)

General Considerations

Parking garage stalls should be well-marked and use clear signage to direct drivers, especially in one-way traffic situations.

Express helical exit ramps are recommended to avoid congestion inside garage.



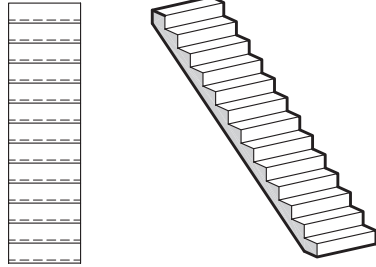
Chapter 18: Stairs

Stairs are a primary method of vertical circulation in most private residences and even in public places where elevators or escalators are present. In elevated buildings, building codes will require a minimum number of enclosed exit stairs. Stair construction is typically of wood, metal, or concrete, or a combination of all three.

STAIR TYPES

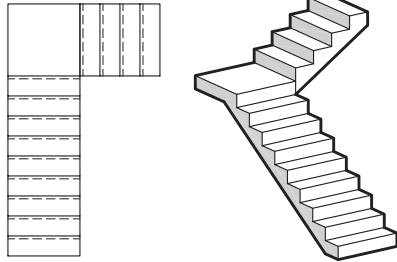
Straight Run Stair

Fire codes generally restrict the total rise of a straight stair to 12'-0" (3 658) before an intermediate landing is required. Landing depth should equal the stair width.



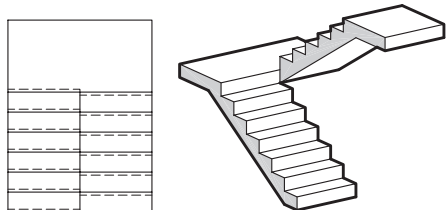
L-shaped Stair with Landing

L-shaped stairs may contain long or short legs, with a landing at any change in direction.



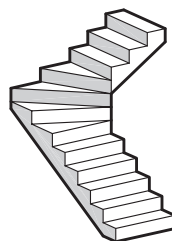
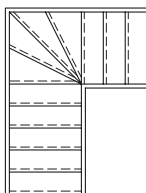
U-shaped Stair with Landing

U-shaped stairs, which switch back as they ascend, are useful in tight floor plans and as one component in a stacking multilevel circulation system (such as an egress stair core).



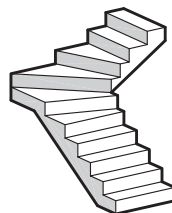
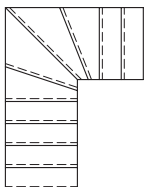
L-shaped Stair with Winders

Winders may help to compress the area needed for a stair by adding angled treads where a landing might go in a typical L-shaped stair. Most winders do not comply with local codes.



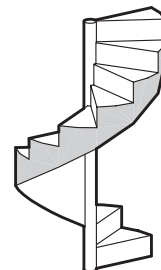
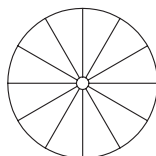
L-shaped Stair with Offset Winders

Offset winder treads are more generous in proportion and, therefore, may comply with applicable codes.



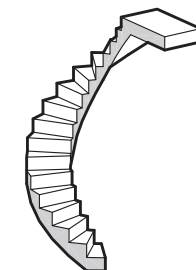
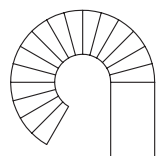
Spiral Stair

Spiral stairs occupy a minimum amount of plan space and are often used in private residences. Most spiral stairs are not acceptable as egress stairs, except in residences and in spaces of five or fewer occupants in 250 sq. ft. (23 m²) or less.

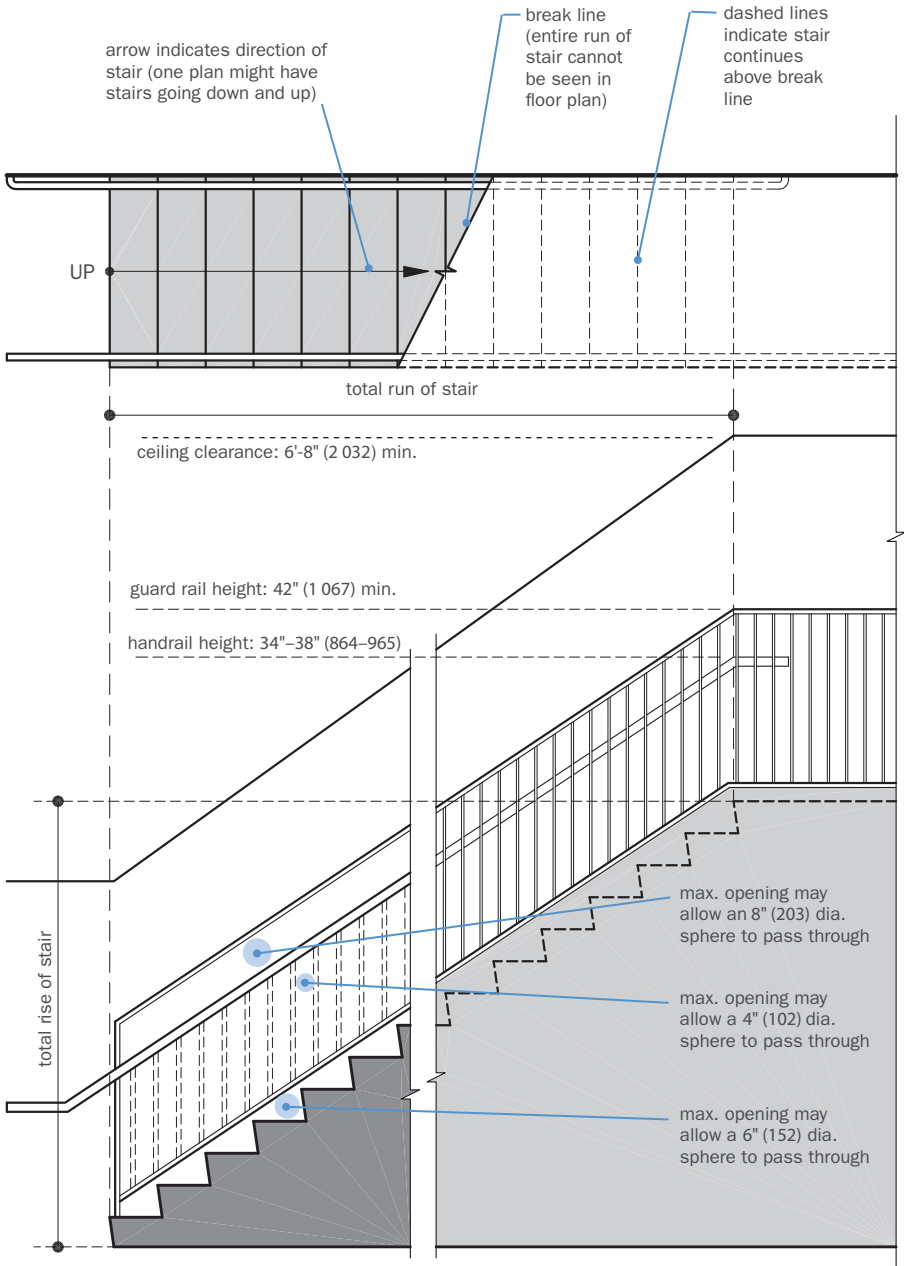


Curved Stair

Curved stairs follow the same layout principles of spiral stairs, though with a sufficient open center diameter, the treads may be dimensioned to legal code standards for egress.

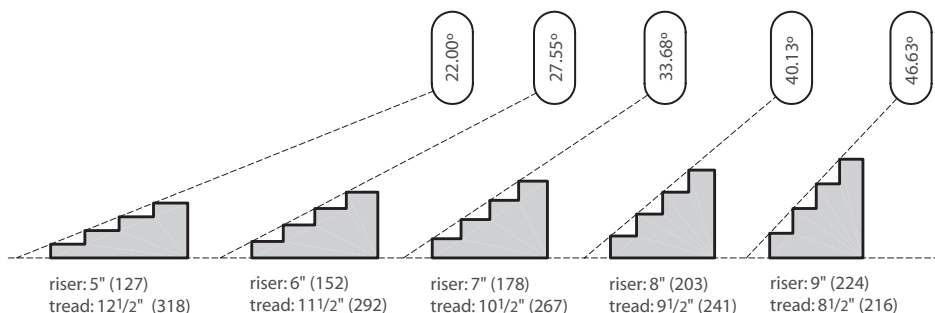


STAIR COMPONENTS



Plan and Elevation of Stair

TREADS AND RISERS



Riser and Tread Dimensions

Angle	Riser inches (mm)	Tread inches (mm)
22.00°	5 (127)	12 $\frac{1}{2}$ (318)
23.23°	5 $\frac{1}{4}$ (133)	12 $\frac{1}{4}$ (311)
24.63°	5 $\frac{1}{2}$ (140)	12 (305)
26.00°	5 $\frac{3}{4}$ (146)	11 $\frac{3}{4}$ (299)
27.55°	6 (152)	11 $\frac{1}{2}$ (292)
29.05°	6 $\frac{1}{4}$ (159)	11 $\frac{1}{4}$ (286)
30.58°	6 $\frac{1}{2}$ (165)	11 (279)
32.13°	6 $\frac{3}{4}$ (172)	10 $\frac{3}{4}$ (273)
33.68°	7 (178)	10 $\frac{1}{2}$ (267)
35.26°	7 $\frac{1}{4}$ (184)	10 $\frac{1}{4}$ (260)
36.87°	7 $\frac{1}{2}$ (191)	10 (254)
38.48°	7 $\frac{3}{4}$ (197)	9 $\frac{3}{4}$ (248)
40.13°	8 (203)	9 $\frac{1}{2}$ (241)
41.73°	8 $\frac{1}{4}$ (210)	9 $\frac{1}{4}$ (235)
43.36°	8 $\frac{1}{2}$ (216)	9 (229)
45.00°	8 $\frac{3}{4}$ (222)	8 $\frac{3}{4}$ (222)
46.63°	9 (229)	8 $\frac{1}{2}$ (216)
48.27°	9 $\frac{1}{4}$ (235)	8 $\frac{1}{4}$ (210)
49.90°	9 $\frac{1}{2}$ (241)	8 (203)

Blue band indicates preferred proportions for comfort and safety.

General Guidelines

The following are rules of thumb for calculating limits; always check appropriate local codes:

riser \times run = 72"–75" (1 829–905)

riser + run = 17"–17 $\frac{1}{2}$ " (432–445)

2(riser) + run = 24"–25" (610–635)

exterior stairs: 2(riser) + run = 26" (660)

Nonresidential:

minimum width = 44" (1 120)

maximum riser = 7 $\frac{1}{2}$ " (191)

minimum tread = 11" (279)

Residential:

minimum width = 36" (915)

maximum riser = 8 $\frac{1}{4}$ " (210)

minimum tread = 9" (229)

Chapter 19: Doors

Interior and exterior doors may be of many combinations of wood, metal, and glass, and mounted in wood or metal frames. Interior doors may require various levels of fire ratings; exterior doors must be well constructed and tightly weather-stripped to avoid excessive leakage of air and moisture.

Widths

2'-0"	2'-4"	2'-6"	2'-8"	2'-10"	3'-0"	3'-4"	3'-6"	3'-8"	3'-10"	4'-0"
(610)	(711)	(762)	(813)	(864)	(914)	(1 016)	(1 067)	(1 118)	(1 168)	(1 219)

Preferred SI Dimensions

single widths:
700 mm, 800 mm,
900 mm, 1 000 mm

double widths:
1 200 mm, 1 500 mm,
1 800 mm

heights:
2 100 mm, 2 200 mm,
2 400 mm

Thicknesses

1³/₈" (35)

1³/₄" (44)

2¹/₄" (54)

Heights

6'-8" (2 032)

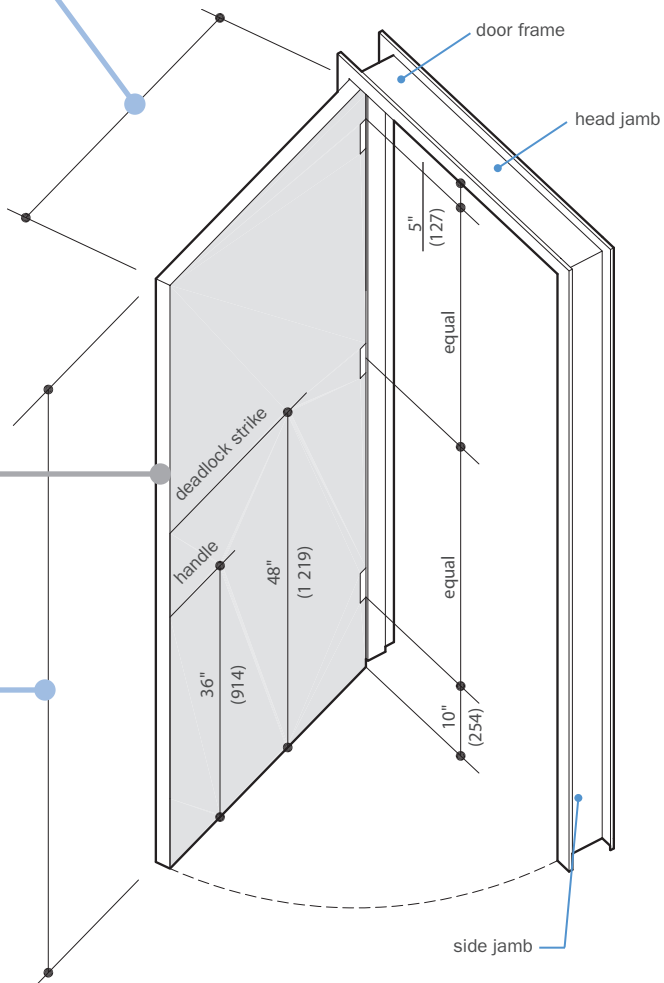
7'-0" (2 134)

7'-2" (2 184)

7'-10"* (2 388)

8'-0"* (2 438)

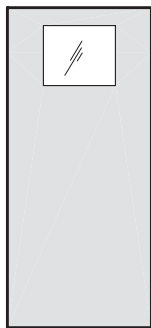
*1³/₄" thick
doors only



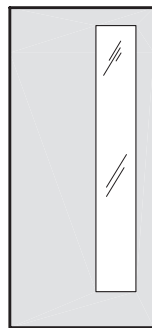
DOOR TYPES



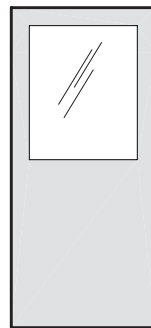
Flush



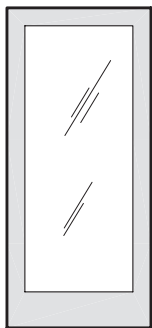
Vision Panel



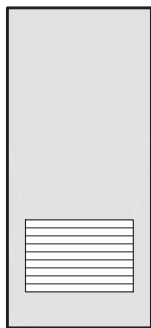
Narrow Lite



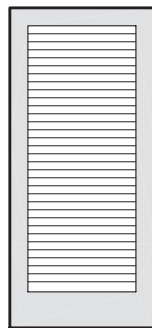
Glass



Glass



Louvered



Louvered



Glass and Louvered

Fire Doors

U.L. Label	Rating	Glazing Permitted: 1/4" (6.4) Wire Glass
A	3 hour	no glazing permitted
B	1 1/2 hour	100 sq. in. (64 516 mm ²) per leaf
C	3/4 hour	1 296 sq. in. (836 179 mm ²) per light; 54" (1 372) max. dimension
D	1 1/2 hour	no glazing permitted
E	3/4 hour	720 sq. in. (464 544 mm ²) per light; 54" (1 372) max. dimension

Max. door size: 4' × 10' (1 219 × 3 048); door frame and hardware must have same rating as door; door must be self-latching and equipped with closers; louvers with fusible links are permitted for B and C label doors; no louver and glass light combinations are allowed.

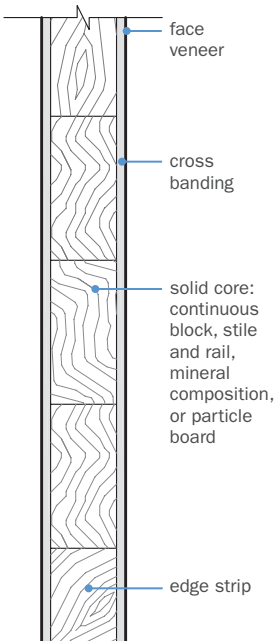
WOOD DOORS

Flush Solid Core

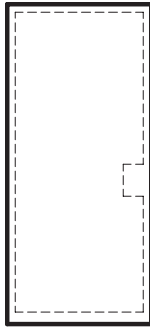
Used primarily for exterior conditions and wherever increased fire resistance, sound insulation, and dimensional stability are required.



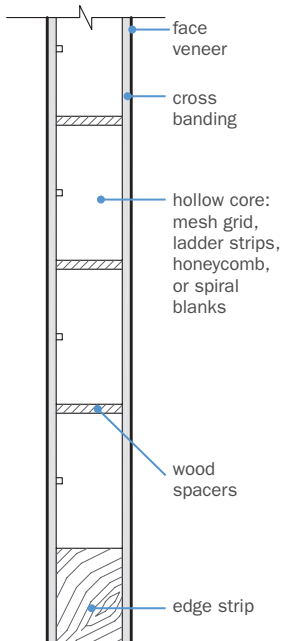
Door Elevation
Detail Section

**Flush Hollow Core**

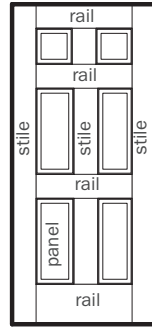
Lightweight and inexpensive, used primarily for interior applications, though may be used on the exterior if bonded with a waterproof adhesive. Low sound and heat insulation value.



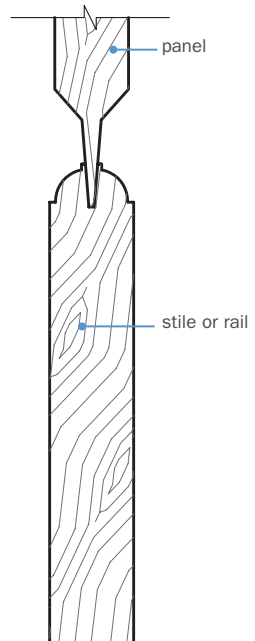
Door Elevation
Detail Section

**Panel**

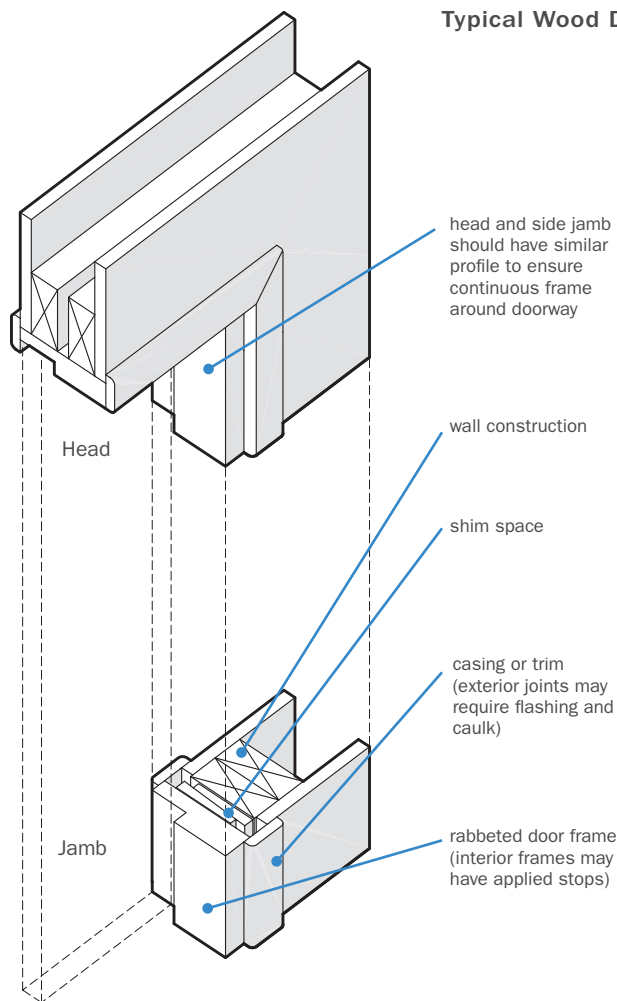
Supporting framework of rails and stiles may hold panels of wood, glass, or louvers. Makeup of doors minimizes dimensional changes brought on by fluctuating moisture content of the wood.



Door Elevation
Detail Section



Typical Wood Door Framing



In the interest of speed and economy, many wood doors have been prehung (hinged and fitted to their frames at the mill). When they arrive on site, the carpenter may tilt the frame into the rough opening, carefully plumbing the frame and shimming as necessary before nailing the frame in place.

In the prehung method, shims help assure that the door and frame will fit cleanly in the rough opening provided. The resulting gap between the frame and the wall finish is generally covered with a casing. Detailing of this condition may take many forms, depending on the desired result, though a common approach is shown at left.

Wood Face Veneer Types

Standard: $\frac{1}{32}$ "– $\frac{1}{16}$ " (0.08–1.6), bonded to hardwood; crossband of $\frac{1}{16}$ "– $\frac{1}{10}$ " (1.6–2.5). Economical and widely used; for all types of cores. Difficult to refinish or repair face damage.

Sawn veneers: $\frac{1}{8}$ " (3.2), bonded to crossband. Easily refinished and repaired.

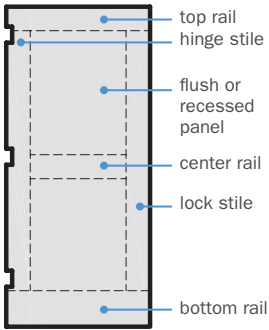
Sawn veneers: $\frac{1}{4}$ " (6.4), no crossband on stile and rail. Face depth allows for decorative grooves.

Wood Grades

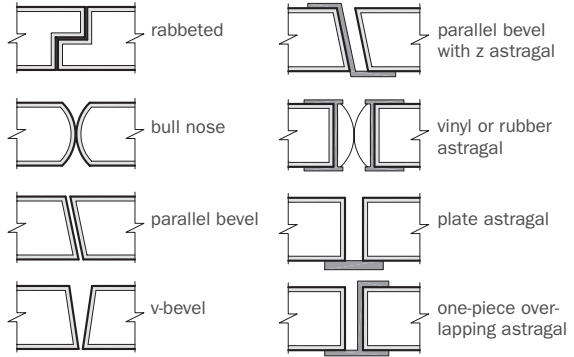
Premium: For natural, clear, or stained finishes

Standard: For opaque (painted) finishes

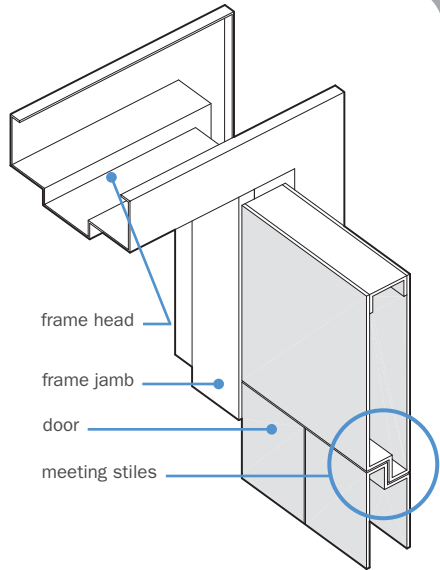
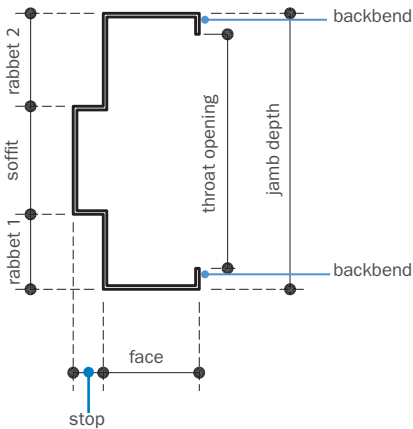
HOLLOW METAL DOORS



Meeting Stiles



Standard Double Rabbet Frame

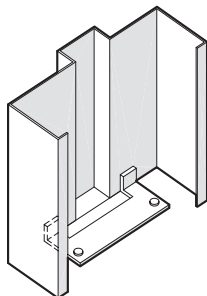


Jamb	4 3/4"	5 1/2"	5 3/4"	6 3/4"	7 3/4"	8 3/4"	12 3/4"
Depth	(121)	(140)	(146)	(171)	(197)	(222)	(324)
Rabbet 1	1 9/16" (40) standard for 1 3/8" (35) door						
Rabbet 2	1 15/16" (49) standard for 1 3/4" (44) door						
Backband	1/2"	3/4"	1/2"	1/2"	1/2"	1/2"	1/2"
	(13)	(19)	(13)	(13)	(13)	(13)	(13)
Throat	3 3/4"	4"	4 3/4"	5 3/4"	6 3/4"	7 3/4"	11 3/4"
	(95)	(102)	(121)	(146)	(171)	(197)	(298)

Hollow Metal Door Gauges

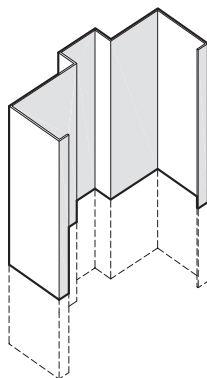
GRADE	GAUGE
Residential	20 and lighter
Commercial	16 and 18
Institutional	12 and 14
High Security	steel plate

FRAME ANCHORS



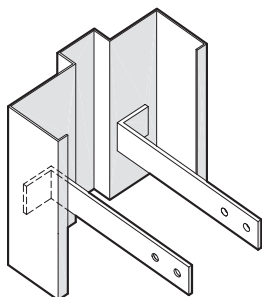
Standard Floor Knee

Jambs are attached to the floor with powder-driven fasteners.



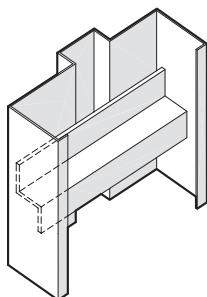
Extended Frame with Base Anchor

Floor-topping concrete is poured around the door frame.



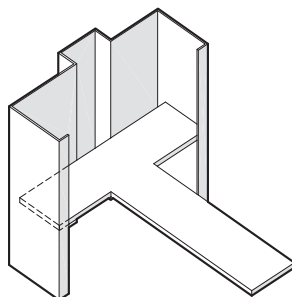
Wood Stud Anchor

Jambs are anchored to wood studs by nailing through holes in jamb inserts.



Steel Channel Anchor

Jambs are anchored to steel studs; sheet metal zees are welded to jambs, and receive screws driven through studs.

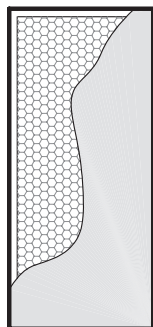


Masonry T Anchor

Jambs are anchored to masonry walls: loose sheet metal tees are inserted into the frame and built into the mortar joints.

OTHER CORES

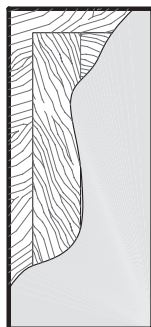
treated fibrous material formed into honeycomb



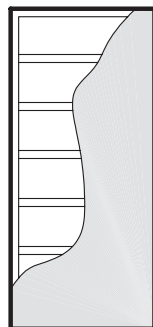
anhydrous mineral, foam, or fiber core



kiln-dried structural wood core



z-member or channel stiffeners (vertical, horizontal, or gridded)



PROPORTION AND FORM 5.

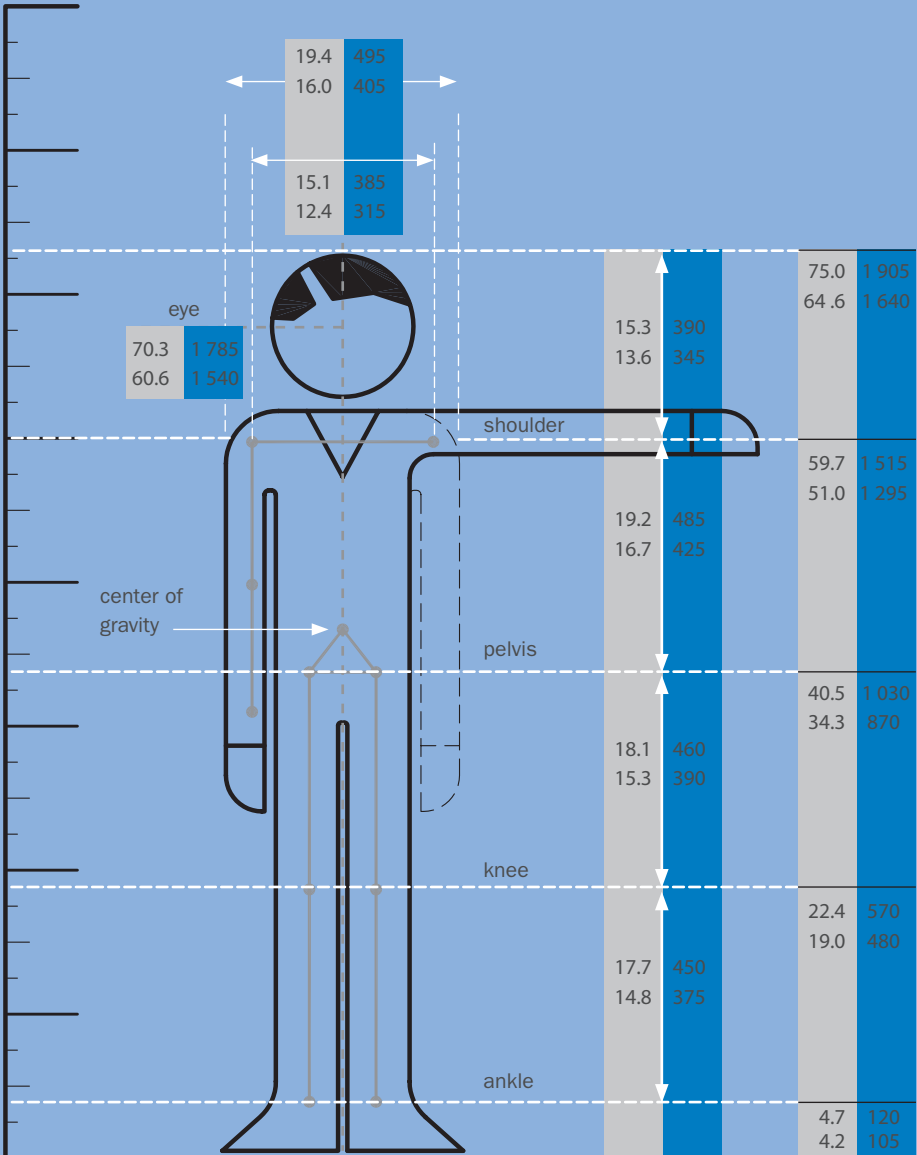
Since most architecture, even that designed for a large-scale use (such as an airplane hangar or an elephant barn), requires some human interface, our own bodies serve as useful reference points for inhabiting space. Similarly, no matter how complicated structures may be, most are reducible to the point, line, or plane that evolved into the more complex combinations of forms and spaces that constitute a design.

Throughout history, architects have devised and employed ordering and proportioning systems for architecture based on the logics of harmonics, arithmetic, geometry, and the human body, often producing a visual and physical order that is apparent to the observer even if the organizing logic is not known or understood.

Daily life brings us into contact with endless numbers of systems of arrangement and order, much of it centered on how our bodies and our cars (extensions of our bodies) use and navigate our immediate surroundings and share them with others. The standards presented here describe the basic clearances demanded of an assortment of programs that architects regularly encounter. They do not propose specific designs, but give a better understanding of how different bodies occupy different spaces.

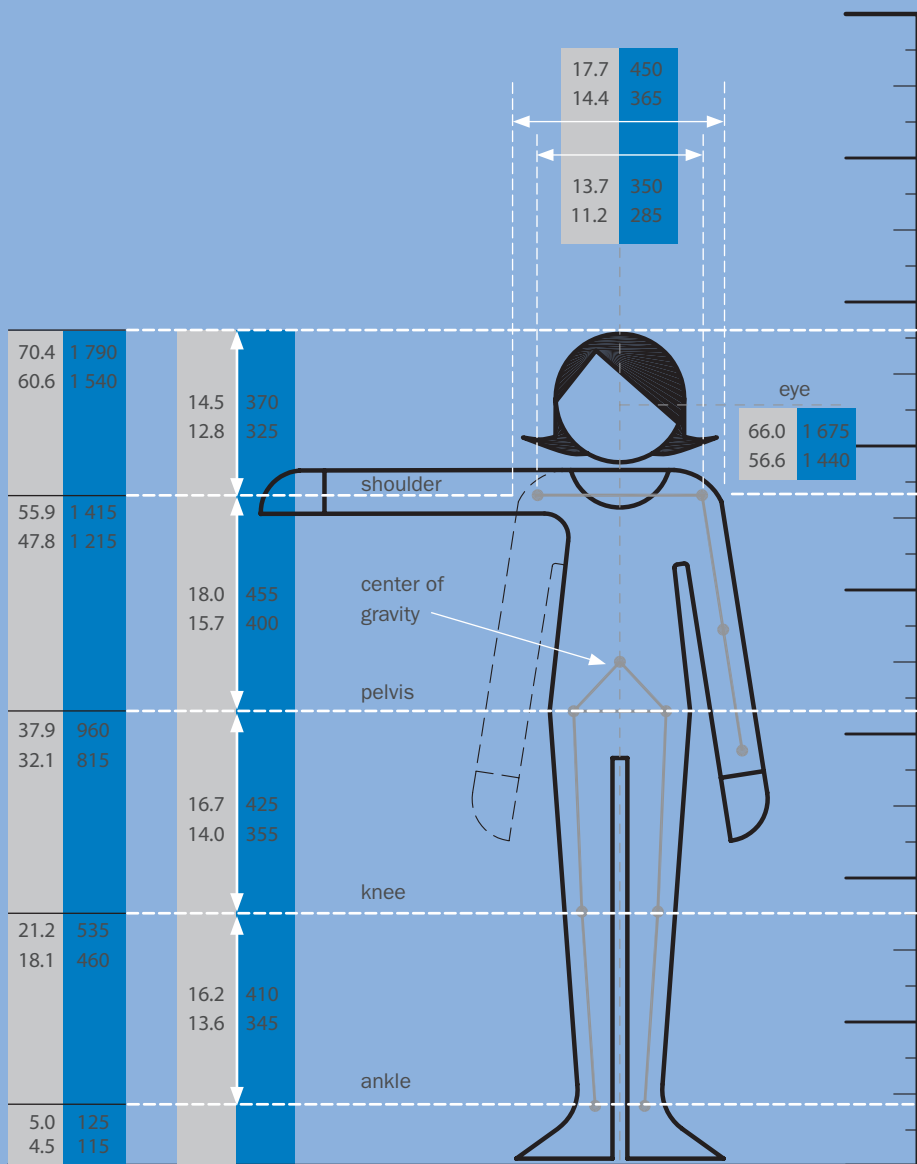
Chapter 20: The Human Scale

The scale of the human body informs almost every aspect of architectural design. The dimensions in this chapter represent an average range (the lower number denotes the 2.5th percentile, while the upper number denotes the 97.5th percentile).



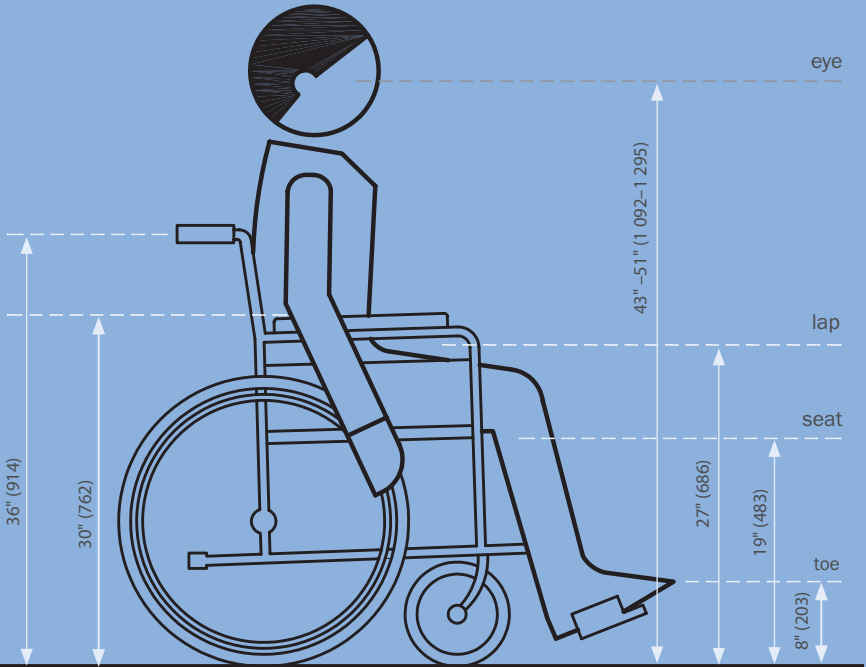
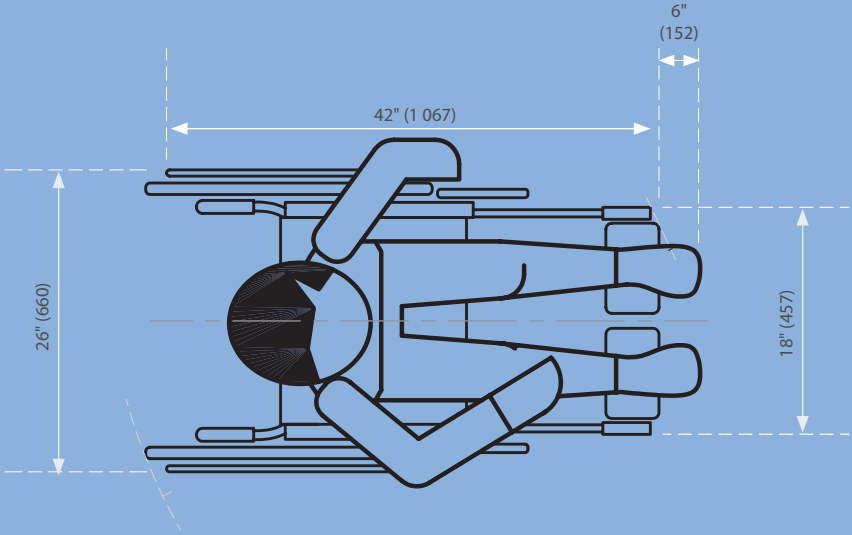
Adult Male Figure

On the drawings below, the gray bars indicate inches and the blue bars indicate millimeters.



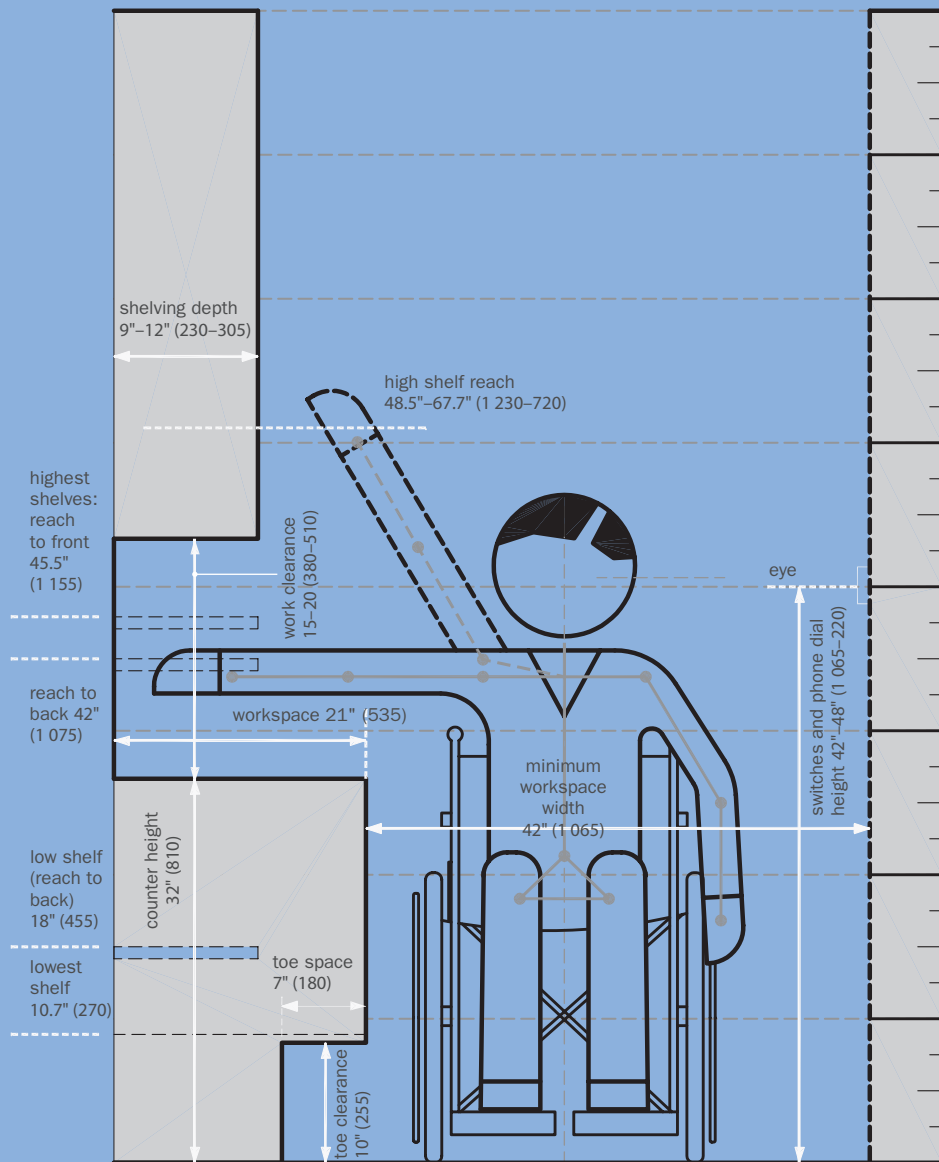
Adult Female Figure

ACCESSIBLE DESIGN DIMENSIONS



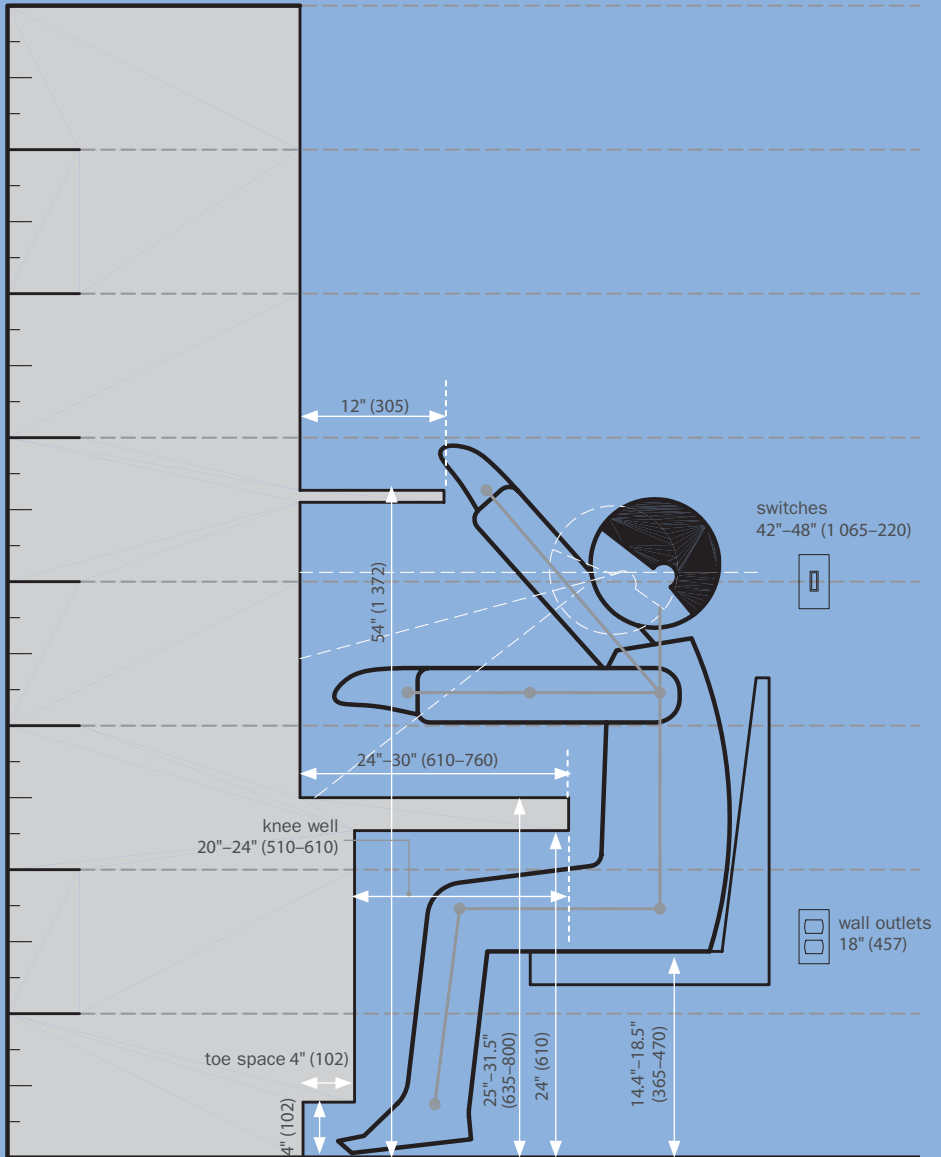
Overall Dimensions for Adult Wheelchairs

Architects must equally be familiar with the dimensions of those with special needs, specifically the constraints posed by wheelchair use. Design to accommodate wheelchairs and other special needs is increasingly the rule rather than the exception, particularly as the concept of universal design gains more prominence. Universal design suggests making all elements and spaces accessible to and usable by all people to the greatest extent possible—a goal that, through thoughtful planning and design, need not add to the cost of production.

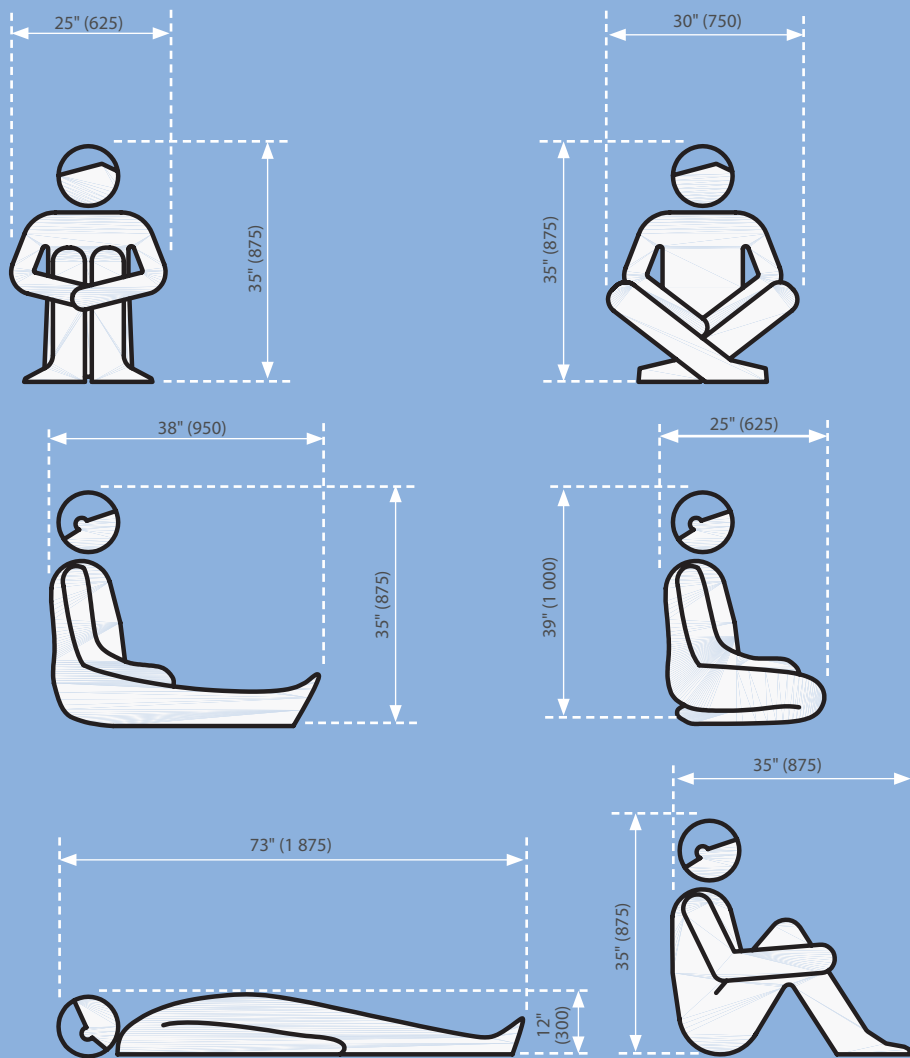


Side Approach Work Station Clearances

SEATED DIMENSIONS



Work Station Clearances

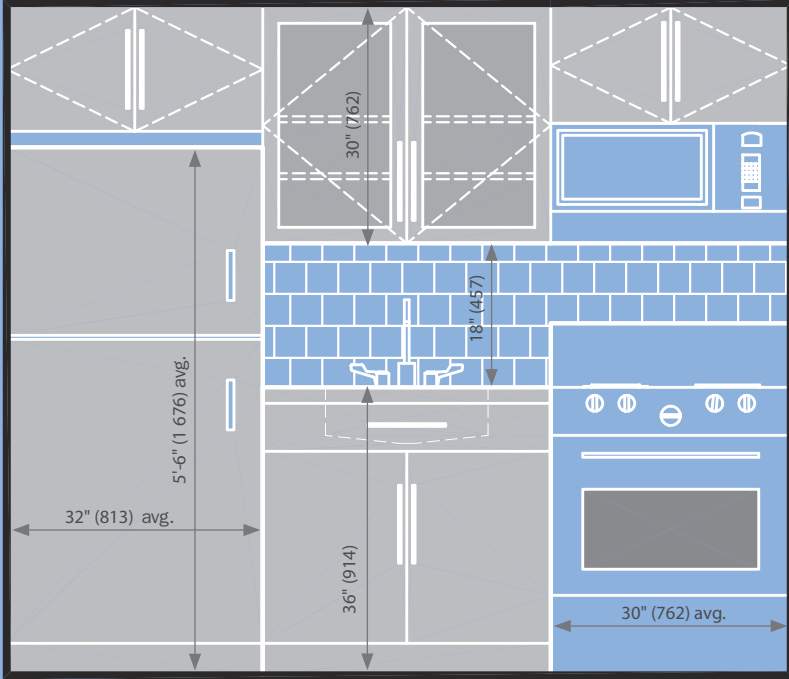


Lounging Position General Space Considerations

Chapter 21: Interior Spaces

KITCHENS

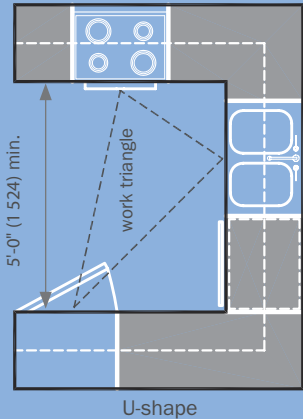
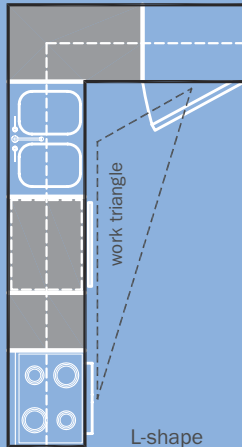
Typical Dimensions



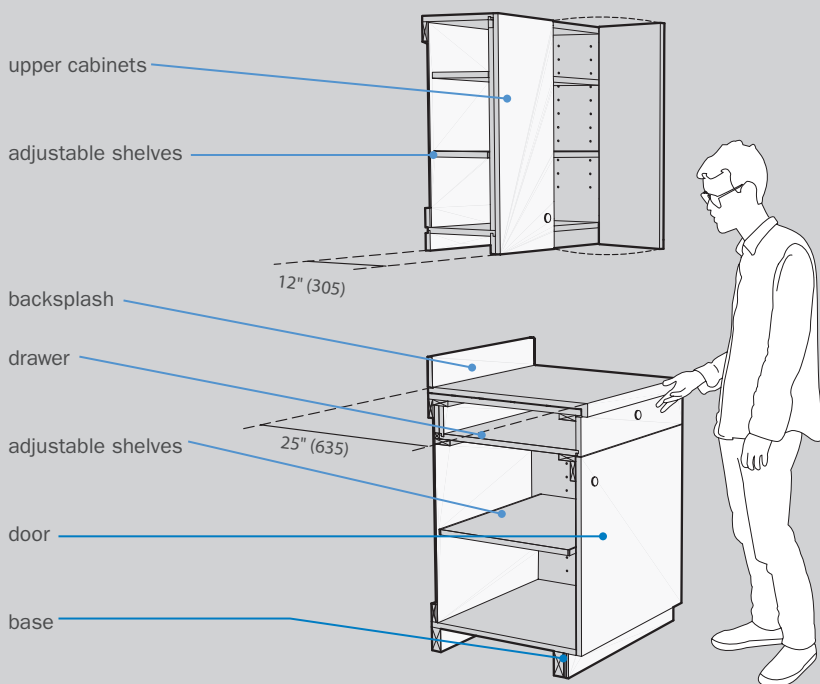
Typical Layout Types

Storage guidelines:
 minimum 18 sq. ft.
 (1.67 m²) basic storage,
 plus 6 sq. ft. (0.56 m²)
 per person served.

The total distance of all
 three sides of the work
 triangle should average
 between 12 lineal feet
 (3660) and 22 lineal feet
 (6705).

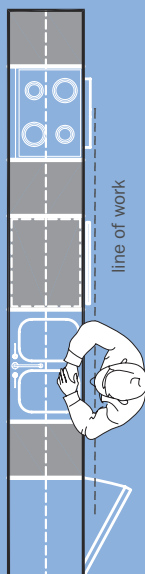


Cabinetry Components

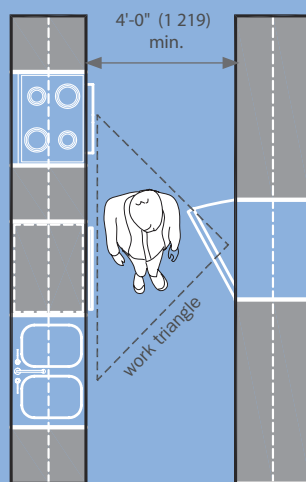


Appliances

Many appliances have become modular in width, and fit within a 3" system (ex. 9", 12", 15", 18", 21", 24"... 48")



Single Wall



Parallel Walls

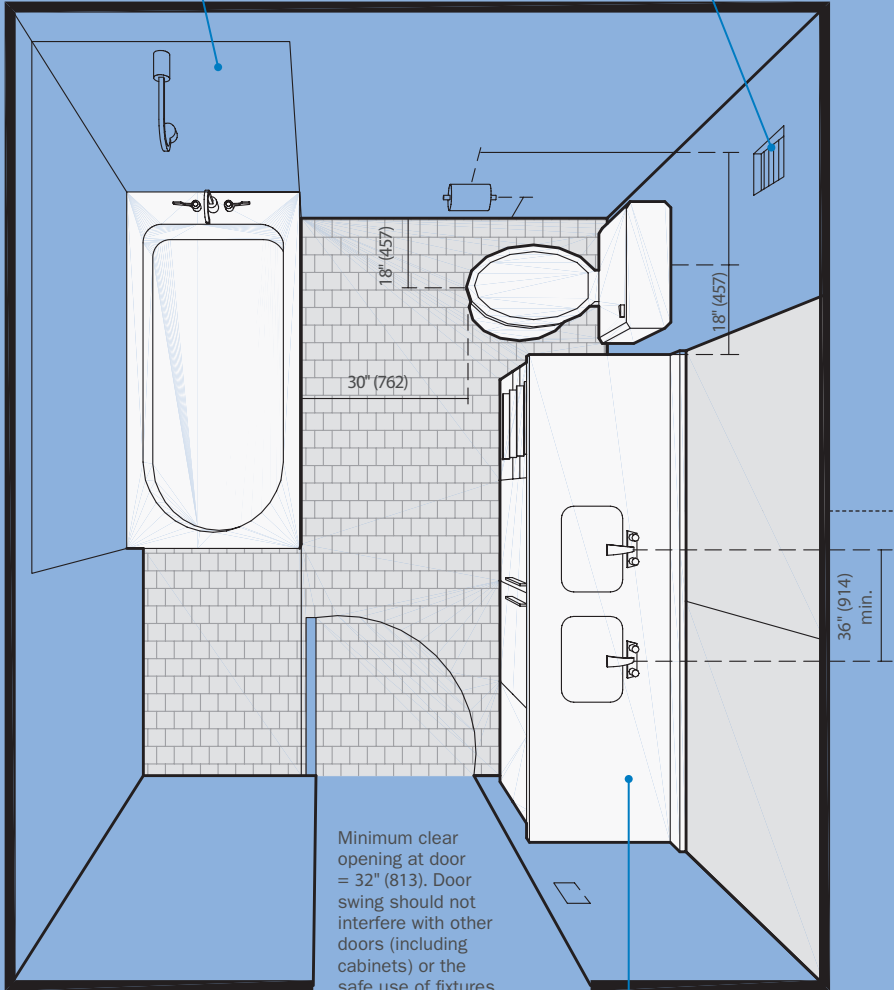
BATHROOMS

General Guidelines
 (Subject to Local Codes)

Wall area above a tub or shower pan should be covered in a waterproof material to a height of not less than 72" (1 829) AFF.

Minimum ceiling height = 6'-8" (2 032)

Minimum ventilation should be a window of at least 3 sq. ft. (0.28 m²), of which 50 percent is operable, or a mechanical ventilation system of at least 50 cu. ft. per minute (cfm) ducted to the outside.



Minimum clear opening at door = 32" (813). Door swing should not interfere with other doors (including cabinets) or the safe use of fixtures and cabinets.

Vanity height = 32"–43" (813–1 092), as it suits the user

Glazing

Tempered glass or an approved equal should be used in the following conditions: shower doors or other glass in tub or shower enclosures; tub or shower surrounds with glass windows or walls that are less than 60" (1 524) above any standing surface; and any glazing such as windows or doors whose bottom edge is less than 18" (458) AFF.

Floors

Bathroom floors and tub and shower floors should have slip-resistant surfaces.

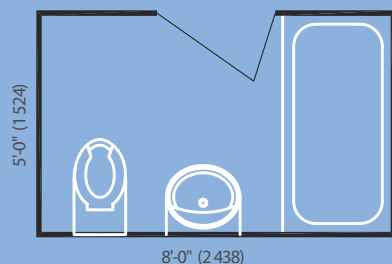
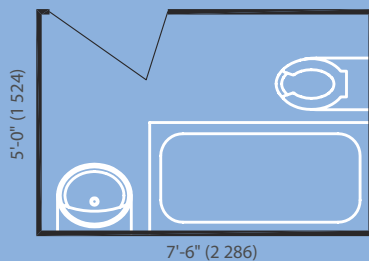
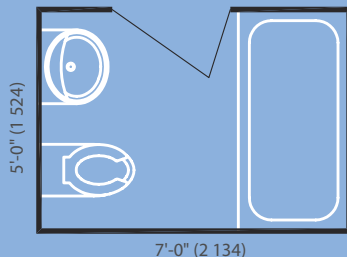
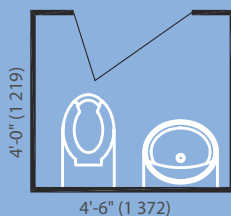
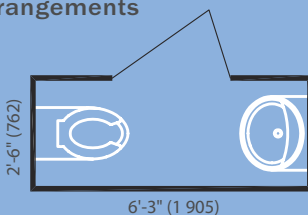
Electrical Outlets

All electrical receptacles should be protected by GFCI (ground-fault circuit interrupter) protectors, and at least one GFCI receptacle should be installed within 36" (914) of the outside edge of the lavatory. No receptacles of any kind should be installed in a shower or bathtub space, nor should switches be installed in wet locations in tub and shower spaces (unless installed as part of a UL-listed tub or shower assembly).

Lighting

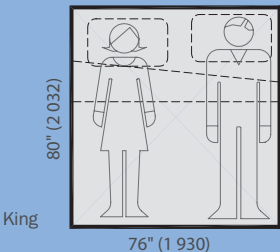
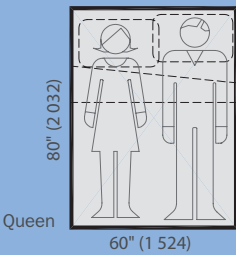
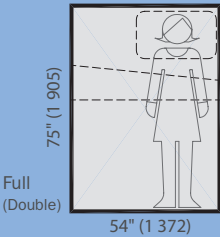
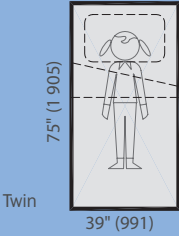
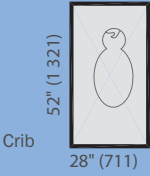
In addition to general lighting, task lighting should be installed at each functional area of the bathroom, and at least one light must be provided that is controlled by a wall switch located at the entry. Any light fixture installed at a tub or shower must be marked as suitable for damp/wet locations.

Typical Arrangements



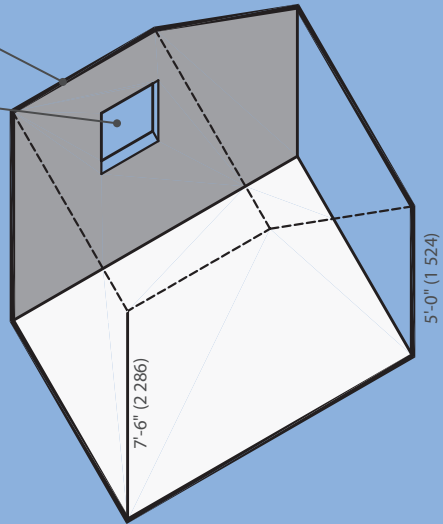
HABITABLE ROOMS

Beds (mattress sizes)



Ceiling height should not be less than 7'-6" (2 286) for at least 50 percent of the required area; 50 percent may be sloped to a minimum height of 5' (1 524).

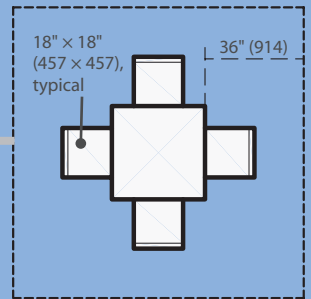
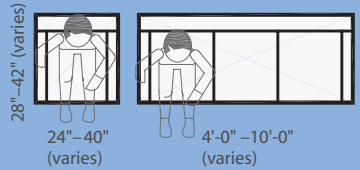
In most residential projects, sleeping rooms should have at least one means of egress to the exterior, which can be in the form of an operable window of not less than 3.3 sq. ft. (0.307 m²), and with a minimum clear opening of 20" x 24" (508 x 610), with a sill height no higher than 44" (1 118).



Seating

Table Size (in.)	Maximum Seats
24 x 48	4
30 x 48	4 (2 wch.)
30 x 60	6 (4 wch.)
36 x 72	6 (6 wch.)
36 x 84	8 (6 wch.)
30 x 30	2
36 x 36	4
42 x 42	4 (2 wch.)
48 x 48	8 (2 wch.)
54 x 54	8 (4 wch.)
30 dia.	2
36 dia.	4
42 dia.	4-5
48 dia.	6 (2 wch.)
54 dia.	6 (4 wch.)

wch. = wheelchair



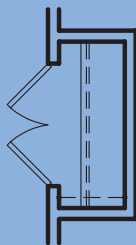
in.	24	30	36	42	48	54	60	72	84
mm	610	762	914	1067	1219	1372	1524	1829	2134

Each dwelling should have at least one room not less than 120 sq. ft. (11.15 m²).

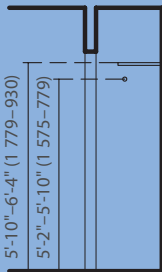
Habitable rooms (except bathrooms and kitchens) should have an area greater than or equal to 70 sq. ft. (6.51 m²), with no less than 7'-0" (2 134) in any direction.

Kitchens may be a minimum of 50 sq. ft. (4.65 m²).

Closets



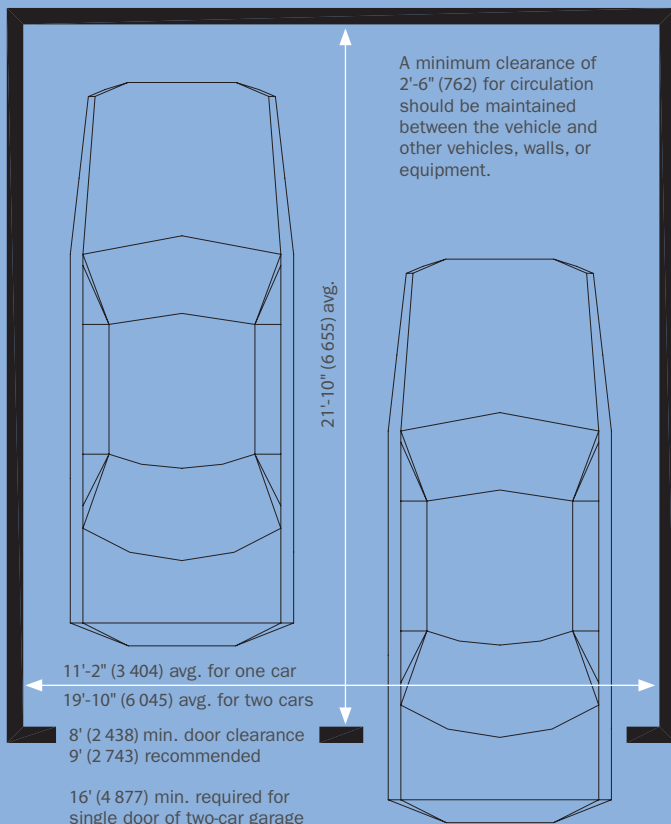
22"-30" (559-762)
clear inside depth



48"-72" (1 219-829)
of hanging space
per person

12" (305) = 6 suits,
12 shirts, 8 dresses,
or 6 pairs of pants

Garages

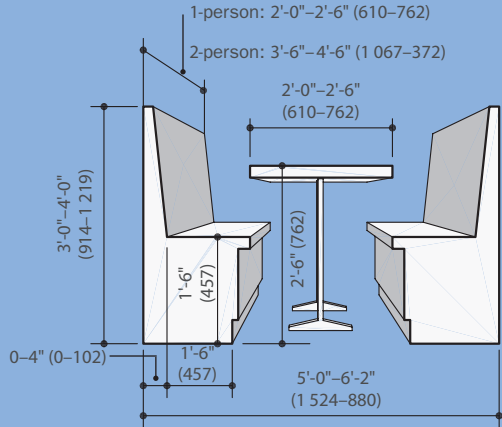


EATING

Seating Types

Booths

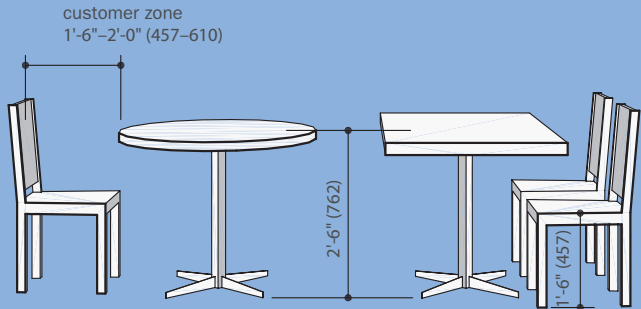
Booth tables may be 2" (51) shorter than bench seats, and with rounded corners to facilitate getting in and out of the booth.



Tables

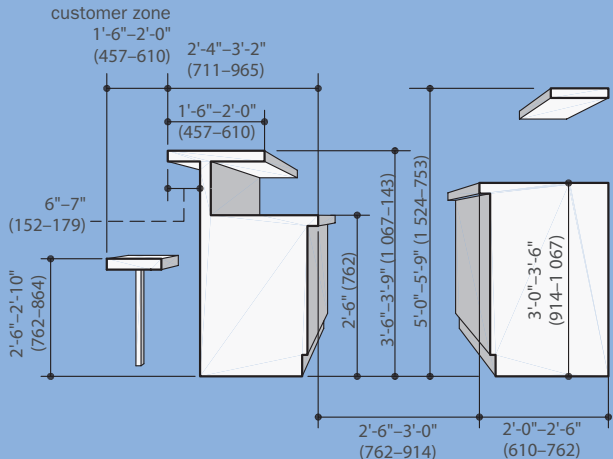
Chair seat dimensions average 1'-2"-1'-6" (356-457).

Tables with widespread bases (shown here) are more practical for sitting down and getting up than four-legged tables.



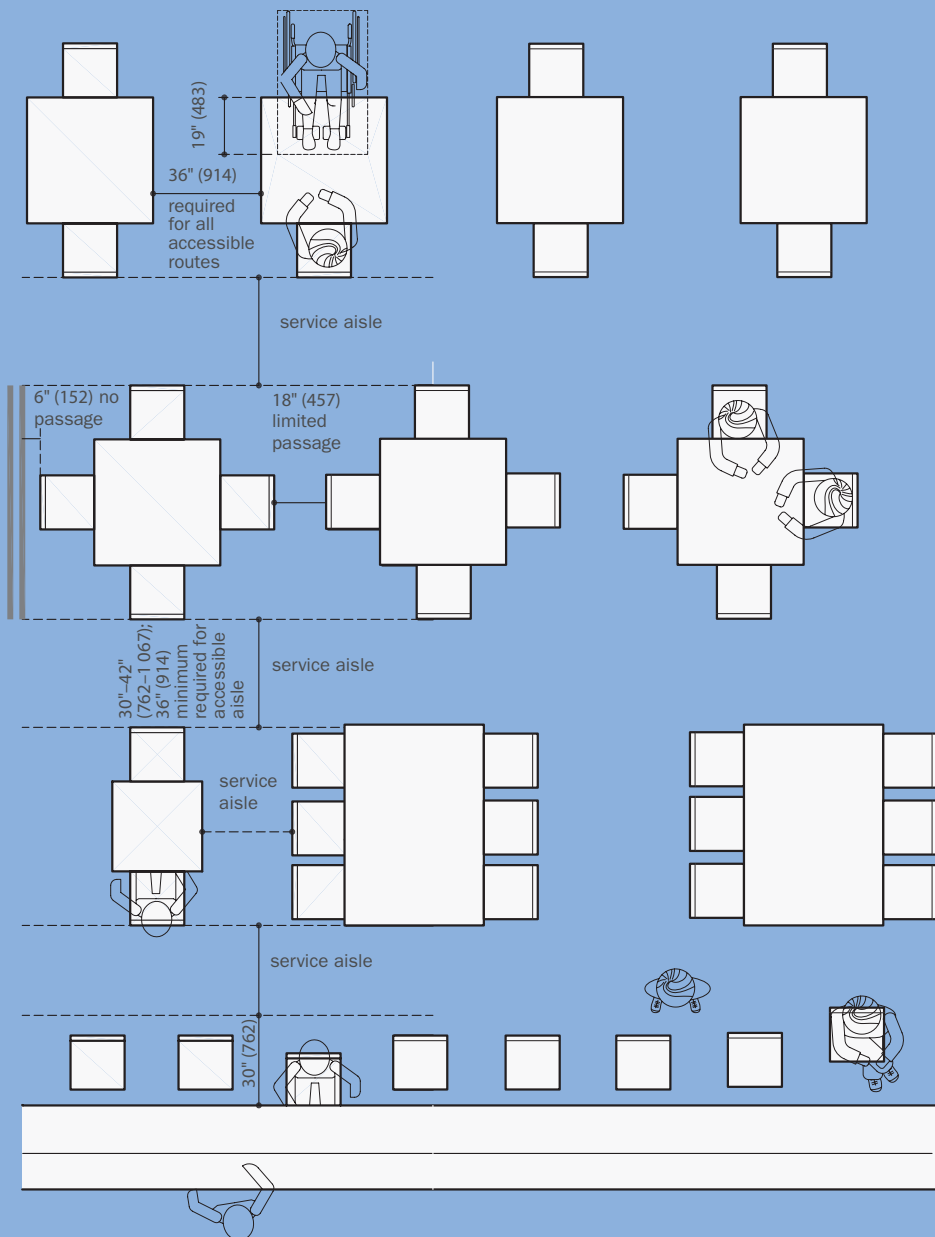
Bars and Counters

Counter stools should average ten per server.



Seating Clearances

Clear floor area for wheelchairs is 30" x 48" (762 x 1219), of which 19" (483) may be used for required under-table knee space. At least 5 percent (but not less than 1) of tables must be accessible.



PUBLIC SEATING

Accessible spaces of 36" × 60" (914 × 1 524) should be open, on level ground, and provided as follows:

Total Seating	Wheelchair Spaces
4–25	1
26–50	2
51–300	4
301–500	6
500+	6 (+1 per each additional 100 seats)

Also, 1 percent of all fixed seats (but not less than one) must have removable or folding armrests on the aisle side and must be identified with appropriate signage.

Typical Chair Widths

Chair widths typically run 18"–24" (457–610); the ideal width is 21" (533).

Plumb Line Clearance

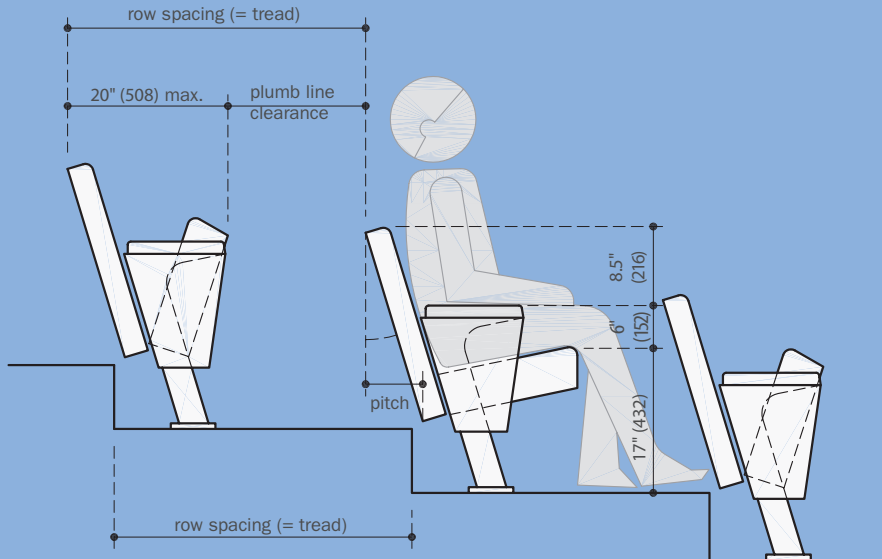
The distance between an unoccupied chair in the up position and the back of the chair in front of it. Local codes should be consulted for minimum clearances.

Row Spacing

Row spacing, like tread, runs 32"–40" (813–1 016) and higher.

Closer spacing may cause uncomfortable conditions for the seated person, as well as difficulty for anyone trying to pass in front of a seated person. Conversely, whereas wider spacing of rows provides more comfort while sitting and passing in front of seated persons, too wide a spacing may make the audience feel overly spread out. In addition, the wider spacing may encourage some people to try to squeeze through when exiting, causing a jam that could be dangerous in the event of an emergency.

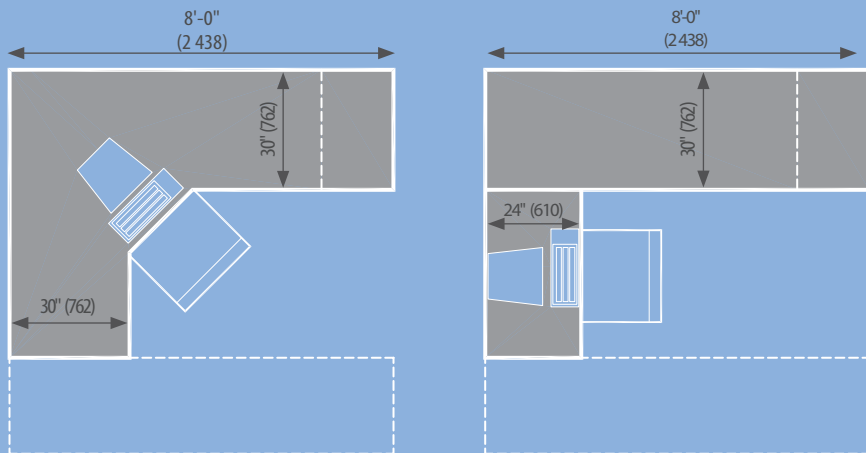
An ideal spacing that accounts for all of these factors is 36" (914).



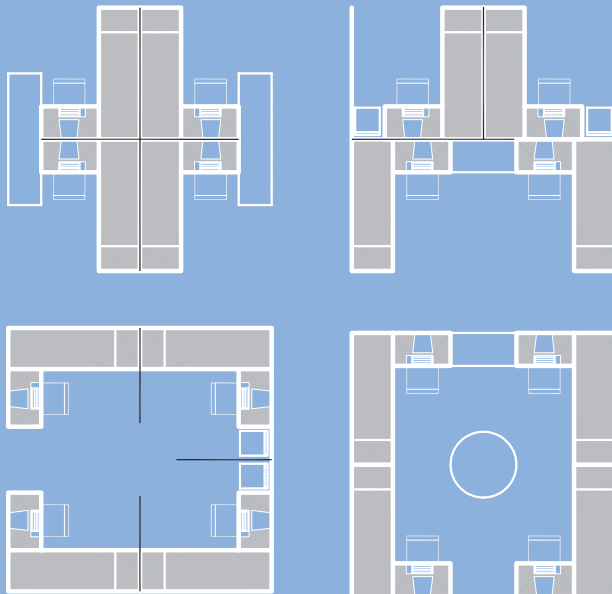
OFFICE WORKSPACES

Flexible Workspaces

Many companies produce flexible office furniture and workspace modules, in a wide variety of styles and finishes. These diagrams are for general layout purposes only and to illustrate a range of possibilities for office privacy, interaction, and space allocation.



Various arrangements of four 8' x 8' (2 438 x 2 438) workspaces, allowing for a wide range of levels of interaction.



The primary advantage of flexible office furniture is precisely its ability to adjust to changing staff levels, changing personnel type, and even shifts in the nature of work being performed in the space.

CONTEXT 6.

The art of architecture is not easily quantified or defined. It is certainly more than the sum of the systems and materials that give it shape, though architecture would not exist without the standardized procedures that erect its forms. The preceding chapters have provided the rudimentary tools for making buildings. It is in how architects use these tools to transform limitations into possibilities that allow them to navigate challenging situations and ultimately produce a better built environment.

The breadth of practical information about basic systems and concepts that this book has so far touched on is also a way of describing the world of architecture to all its users. What follows is a broad overview of how these basic systems have become a history of our overlapping cultures.

We live in the built world: whether it is well designed or poorly designed, it is the space and surface of our existence. By inhabiting architecture and moving around it, we have knowledge of it. To enhance our understanding, this book ends with a beginning: an introduction to a range of resources within the enormous, endless scope of architectural information and discussion.

3500
BCE(increments of
250 years) →3250
BCE3000
BCE

Chapter 22: Timeline

The history of architecture is a history of civilization. Buildings are artifacts intrinsically linked to the epoch and society of their creation, clearly exposing the varied conditions of how they came to be. To understand a piece of architecture is to gain insight into countless aspects of a place and a moment in time—geography, weather, social hierarchies, religious practices, and industrialization. And because architecture is rarely portable, it is virtually impossible to disengage a building from its origins.

The fluidity of history can make for unwieldy attempts to classify periods succinctly, and architectural styles and movements reflect this difficulty: though some styles may have come into sudden existence as the result of a specific event, most evolve slowly and taper off gradually. The distillation of any history presents obvious limitations; therefore, many dates shown here are approximations, serving the overall purpose of this timeline, which is to illustrate relationships among movements.

Bronze Age (ca. 3200–1050 BCE)

Mesopotamian
(ca. 4500–539 BCE)

Egyptian
(ca. 3500–30 BCE)

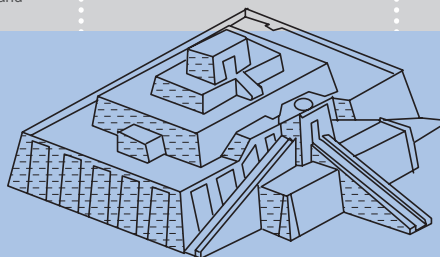
BCE (Before Common Era) = BC
CE (Common Era) = AD
b. = before; c. = century; ca. = circa

2750
BCE

Imhotep

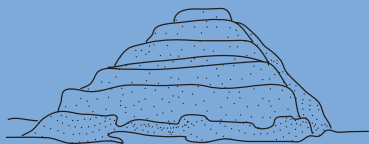
2500
BCE

Stonehenge
(ca. 2900–1400 BCE)
Salisbury Plain, England

2250
BCE

Ziggurat at Ur
(ca. 2100 BCE)
Mesopotamia

- Stepped Pyramid of Zoser
(c. 2700 BCE) Egypt
Imhotep



- Great Sphinx of Giza
(ca. 2500 BCE) Egypt

- Great Pyramids of Giza
(2570–2500 BCE) Egypt



- Mentuhotep Mortuary Temple
(2061–2010 BCE)
Deir el-Bahari, Egypt

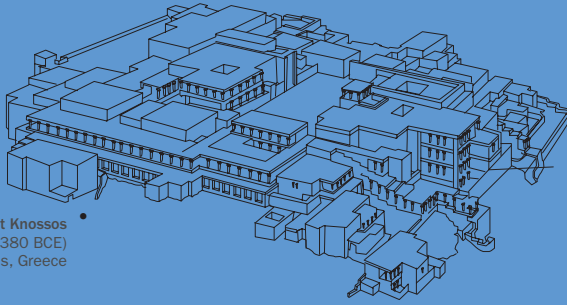
1750
BCE(increments of
250 years) →1500
BCE1250
BCE

Amenhotep III
ca. 1411 BCE

Bronze Age (ca. 3200–1050 BCE)

Greek

(ca. 2000–31 BCE)



Palace at Knossos
(1700–1380 BCE)
Knossos, Greece

Mesopotamian

(ca. 4500–539 BCE)

Egyptian

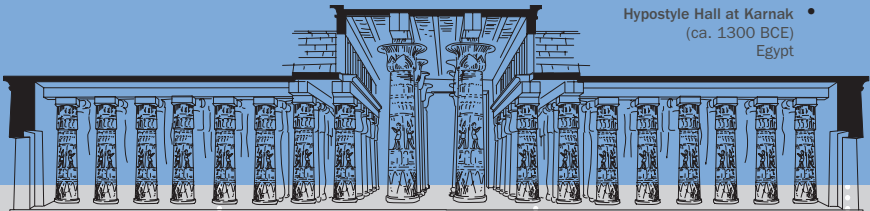
(ca. 3500–30 BCE)

Great Temple of Ramses II

(ca. 1285–1225 BCE)
Abu Simbel, Egypt

Hypostyle Hall at Karnak

(ca. 1300 BCE)
Egypt



1000
BCE750
BCE500
BCE

Homer's
The Iliad and *The Odyssey*
ca. 750 BCE



Plato



Parthenon (448–432 BCE) •
Athens, Greece

Stoa of Attalus •
(150 BCE)
Athens, Greece

Temple of Paestum •
(ca. 530-460 BCE) Paestum, Italy

Temple of Apollo
(310 BCE) Paeonis
and Daphnis, Turkey

Classical Orders

DORIC



Temple of Hera •
(460 BCE) Paestum, Italy

IONIC



CORINTHIAN



Etruscan (ca. 8th c.-4th c. BCE)

• Citadel of Sargon II
(742–706 BCE)
Khorsabad

Roman
(510 BCE–476 CE)

Library at Alexandria •
(c. 3rd BCE)
Egypt

(increments of 100 years) →

100

200



Augustus
emperor:
27 BCE–14 CE



Vitruvius' *De Architectura*
c. 15 BCE

Greek

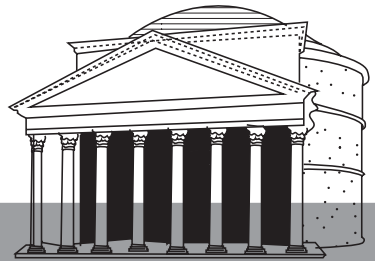
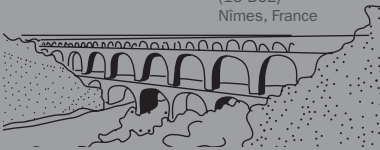
(ca. 2000–31 BCE)

- Stoa of Attalus (150 BCE)
Athens, Greece

Roman

(510 BCE–479 CE)

- Pont du Gard Aqueduct (15 BCE)
Nîmes, France



- Pantheon (118–128 CE)
Rome, Italy
- Baths of Caracalla (215 CE)
Rome, Italy
- Colosseum (72–80 CE)
Rome, Italy

Egyptian

(ca. 3500–30 BCE)



300

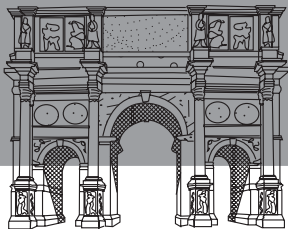


Constantine the Great

400

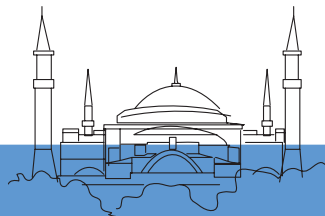


- Arch of Constantine (312–15 CE)
Rome, Italy



500

MIDDLE AGES



- Hagia Sophia (537)
Istanbul
(Constantinople),
Turkey
- San Vitale (526)
Ravenna, Italy

Byzantine
(324–12th c.)

Romanesque
(500–1200 CE)

- S. Apollinaire Nuovo
(ca. 490)
Ravenna, Italy



700

(increments of
100 years) →

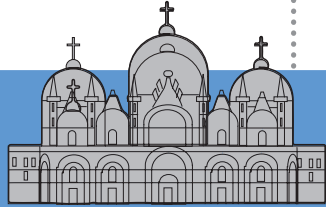
800

900

MIDDLE AGES (ca. 500–1500 CE)

Byzantine

(324–12th c.)



- Basilica of San Marco
(830)
Venice, Italy

Romanesque

(500–1200 CE)

- Dome of the Rock
(687–89 CE)
Jerusalem



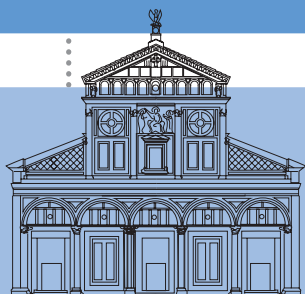
- El Castillo
(850 CE)
Chichen Itza,
Yucatan, Mexico

1000

1100

1200

- Angkor Wat
(b. ca. 1120)
Cambodia



- Worms Cathedral (1110–81)
Worms, Germany
- Basilica of San Miniato al Monte
(1062–c.1200)
Florence, Italy
- Pisa Cathedral (1063–1092)
and Baptistery (1153)
Pisa, Italy



- Notre-Dame Cathedral
(1163–1250)
Paris, France
- Strasbourg Cathedral
(begun 1277)
Alsace, France
- Chartres Cathedral
(1194–1220)
Chartres, France

Gothic

(ca. 1140–1500)

- Salisbury Cathedral
(1220–1260)
Salisbury, England
- Amiens Cathedral
(1220–1247)
Amiens, France

1350

(increments of
50 years) →

1400

1450

MIDDLE AGES (ca. 500–1500 CE)



• Duomo de S. Maria del Fiore
(1377–1436)
Florence, Italy
Filippo Brunelleschi



Renaissance
(1350–1600)



• Palazzo Rucelai
(1455–1470)
Florence, Italy
Leon Battista Alberti

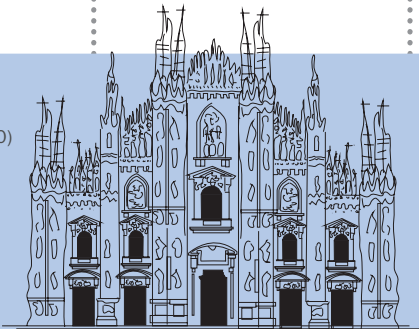
• Façade of S. Maria Novella (1458)
Florence, Italy
Leon Battista Alberti



Leonardo da Vinci
1452–1519



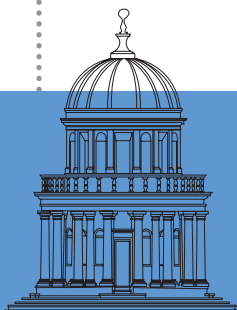
Gothic
(ca. 1140–1500)



• King's College Chapel
(1446–1515)
Cambridge, England

• Milan Cathedral
(1387–1572)
Milan, Italy

1500



- **Tempietto of S. Pietro in Montorio (1502)**
Rome, Italy
Donato Bramante

- **Laurentian Library (1524)**
San Lorenzo, Italy
Michelangelo

- **S. Giorgio Maggiore (1566)**
Venice, Italy
Andrea Palladio

- **Hall of Supreme Harmony (15th c.)**
Forbidden City, Beijing, China

- **Palais de Justice (1493–1508)**
Rouen, France

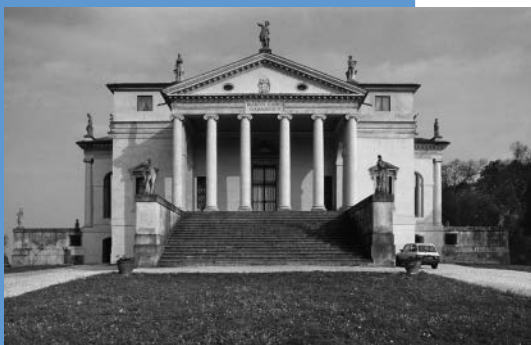
1550



Galileo Galilei
1564–1642



- **Villa La Rotonda (1557)**
Vicenza, Italy
Andrea Palladio



1600

- **Taj Mahal (1630–1653)**
Agra, India
Emperor
Shah Jahan

- **Façade of S. Susanna (1603)**
Rome, Italy
Carlo Maderno

Baroque
(1600–1700)

1700

(increments of
20 years) →

1720

1740



- S. Carlo alle Quattro Fontane
(b. 1634) Rome, Italy
Francesco Borromini

Baroque (1600–1700)

- Colonnade Piazza of St. Peter's
(1656) Rome, Italy
Gianlorenzo Bernini
- Karlskirche (b. 1656)
Vienna, Austria
Johann Fischer van Erlach

Rococo (1700–1780)

- Spanish Steps
(1723–1725)
Rome, Italy
Francesco de Sanctis

Georgian (1714–1830)

- Chiswick House
(1725–1729)
London, England
Lord Burlington

1760



1780

- **Salt Works (1780)**
Chaux, France
Claude-Nicolas Ledoux

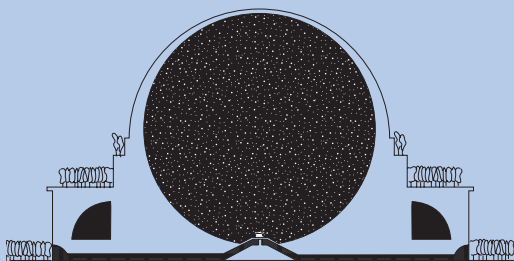


1800

Neoclassicism (1750–1880)

- **Monticello (1771–1782)**
Charlottesville, Va., USA
Thomas Jefferson
- **Panthéon (1764–1790)**
Paris, France
Jacques Germain Soufflot

- **Cenotaph for Isaac Newton (1784)**
(unbuilt)
Étienne-Louis Boullée



- **Bank of England (1788)**
London, England
John Soane

1840

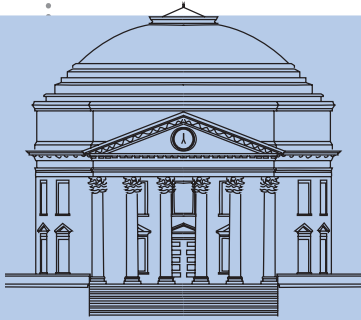
(increments of
20 years) →

1860

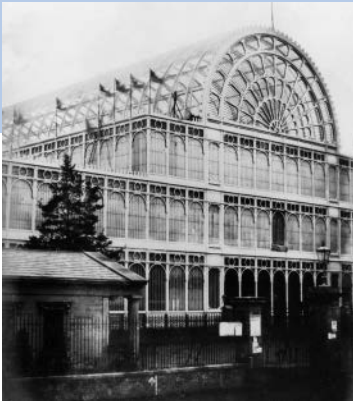
1880



Neoclassicism (1750–1880s)



- **Schauspielhaus** (1819–1821)
Berlin, Germany
Karl Friedrich Schinkel



• **Crystal Palace** (1851)
London, England
Joseph Paxton

- **University of Virginia** (1826)
Charlottesville, Va., USA
Thomas Jefferson

- **Marshall Field Wholesale Store**
(1885–1887) Chicago, Ill., USA
H. H. Richardson



- **Boston Public Library** (1887–1895)
Boston, Mass., USA
McKim, Mead & White

- **Bibliothèque Nationale**
(1858–1868)
Paris, France
Henri Labrouste

- **Houses of Parliament**
(1836–1868)
London, England
Charles Barry

- **Tassel House** (1893)
Brussels, Belgium
Victor Horta

- **Red House** (1859–
1860)
Bexleyheath, England
Philip Speakman Webb

1900

1920

1940



German Pavilion (Barcelona Pavilion)
(1928; demolished 1930, rebuilt 1959)
Barcelona, Spain
Ludwig Mies van der Rohe

• Casa Milà (1906–1910)
Barcelona, Spain
Antoni Gaudí

Modernism (1900–1945)

• Goldman & Salatsch Store
(1910)
Vienna, Austria
Adolf Loos

• Ward Willits House (1902)
Highland Park, Ill., USA
Frank Lloyd Wright

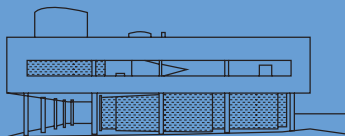


Einstein Tower (1921)
Potsdam, Germany
Erich Mendelsohn



• Eames House (1945)
Pacific Palisades, Calif., USA
Charles & Ray Eames

• Villa Savoye (1929)
Poissy, France
Le Corbusier



International Style Exhibition,
MoMA
(1929) New York, N.Y., USA



• Bauhaus (1925)
Dessau, Germany
Walter Gropius



• Fallingwater (1937)
Mill Run, Pa., USA
Frank Lloyd Wright

Art
Nouveau
(1880–1902)

• Empire State Building (1930)
New York, N.Y., USA
Shreve, Lamb & Harmon

Art Deco
(1920s–1940s)

Exposition Internationale des Arts
Décoratifs et Industriels Modernes
(1925) Paris, France

Arts & Crafts
(1860–1925)

1960

(increments of
10 years) →

1970

1980

Late Modernism

(1945–1975)

- **Glass House** (1949)
New Canaan, Conn., USA
Philip Johnson

- **Palazzetto dello Sport** (1960)
Rome, Italy
Pier Luigi Nervi
- **Kimbell Art Museum** (1967–1972)
Fort Worth, Tex., USA
Louis I. Kahn

- **TWA Terminal** (1962)
New York, N.Y., USA
Eero Saarinen

- **House III** (1969–1970)
Lakeville, Conn., USA
Peter Eisenman

- **Carpenter Center** (1964)
Cambridge, Mass., USA
Le Corbusier

- **Parc de la Villette** (1982–1985)
Paris, France
Bernard Tschumi

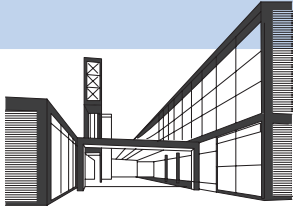
Deconstructivist Architecture, MoMA
(1988) New York, N.Y., USA

Deconstructivism

(1980–1988)

- **Centre Pompidou** (1976)
Paris, France
Renzo Piano & Richard Rogers

- **Hunstanton School** (1954)
Norfolk, England
Alison & Peter Smithson



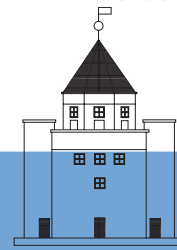
Brutalism

(1950s–1970s)

Postmodernism

(1960s–1990s)

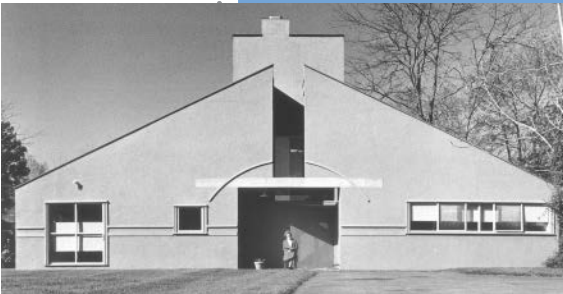
- **Vanna Venturi House** (1964)
Chestnut Hill, Pa., USA
Robert Venturi



- **Teatro del Mondo** (1979)
Venice, Italy
Aldo Rossi

- **AT&T Building** (1978)
New York, N.Y., USA
Philip Johnson & John Burgee

- **Portland Building** (1982)
Portland, Ore., USA
Michael Graves



1990



• Wexner Center
for the Arts (1989)
Columbus, Ohio, USA
Peter Eisenman

• Vitra Fire Station (1990)
Weil am Rhein, Germany
Zaha Hadid

2000

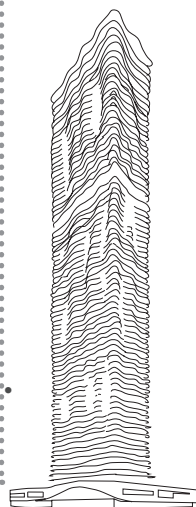


• Seattle Public Library (2004)
Seattle, Wash., USA
Rem Koolhaas (OMA)



2010

• Aqua Tower (2010)
Chicago, Il., USA
Studio Gang

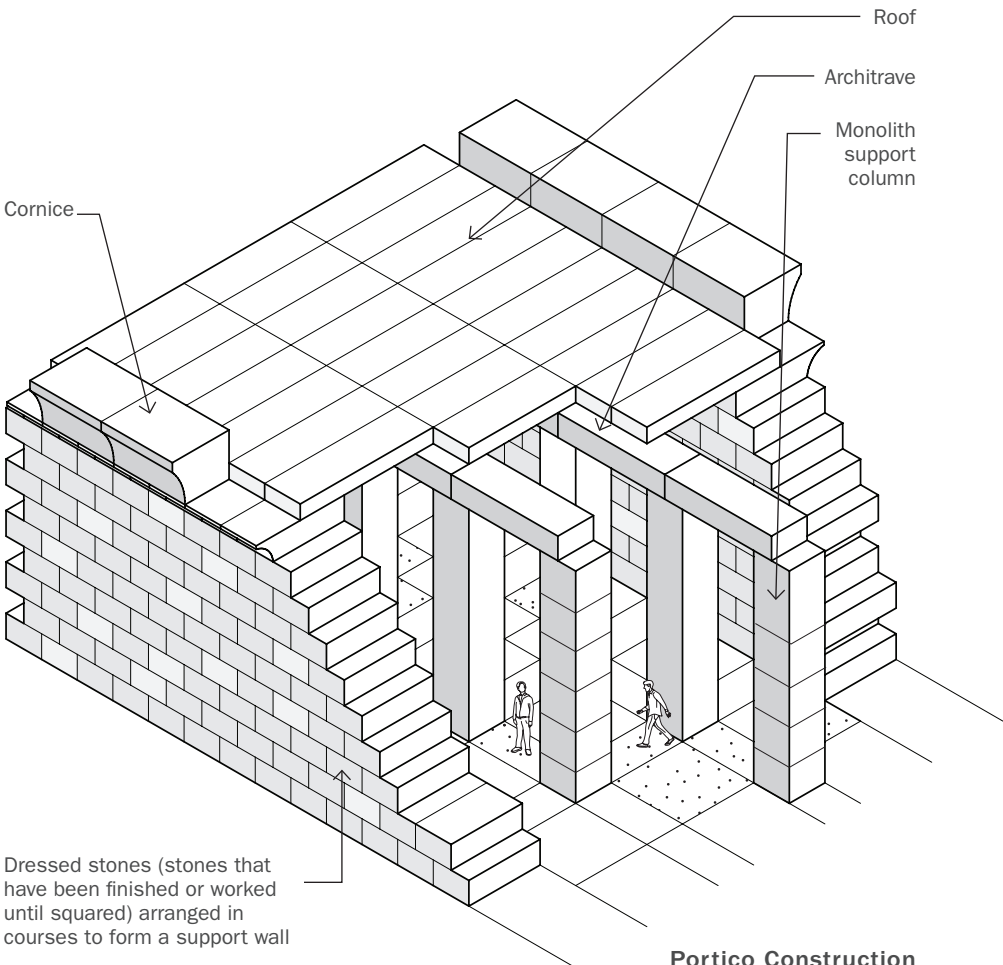


Chapter 23: Architectural Elements and Ideas

ANCIENT EGYPT

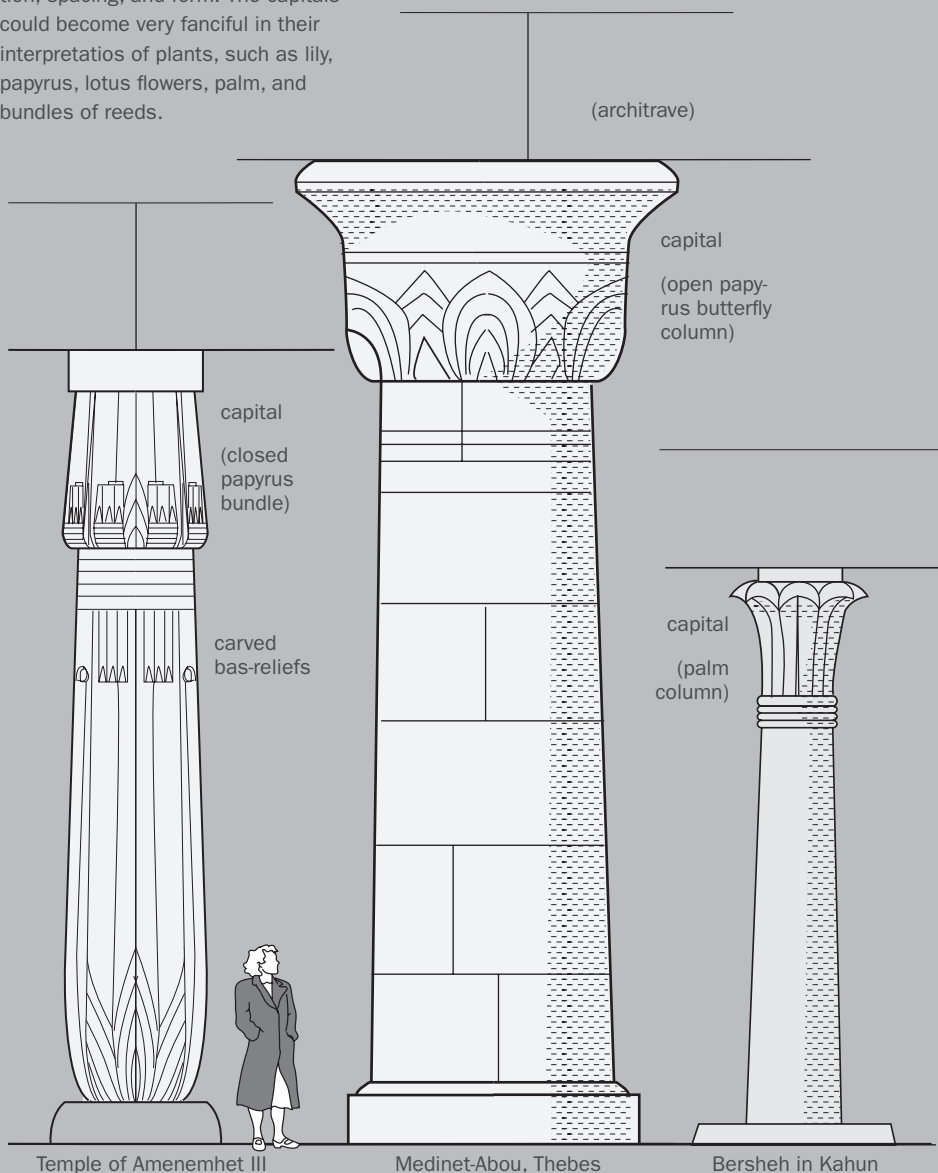
For over 3,000 years, ancient Egyptian civilization prospered, producing significant and monumental built forms that not only still stand, but from which contemporary building practices were born. Egypt introduced the use of columns and capitals, dressed stones, and pure geometric forms.

Egyptians built with stones such as limestone, granite, and sandstone, as well as bricks (both fired and not) and even wood carpentry assemblages. Compact construction was a primitive form of concrete, and combined clay with chopped straw in a manner that allowed it to be poured into forms. This was, however, inferior in strength and durability to stone.



COLUMNS

Egyptian column designs were highly varied in height, diameter, ornamentation, spacing, and form. The capitals could become very fanciful in their interpretation of plants, such as lily, papyrus, lotus flowers, palm, and bundles of reeds.



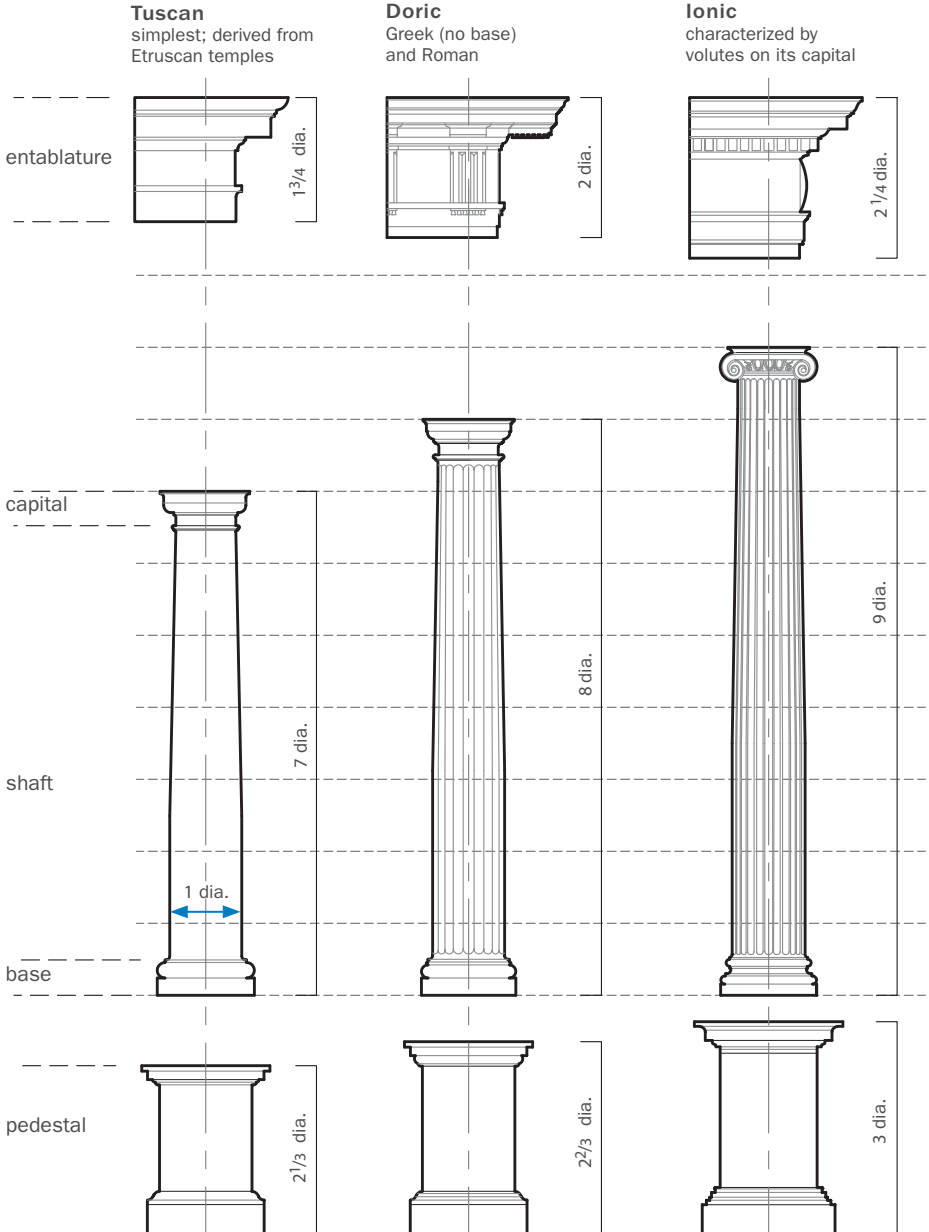
Temple of Amenemhet III

Medinet-Abou, Thebes

Bersheh in Kahun

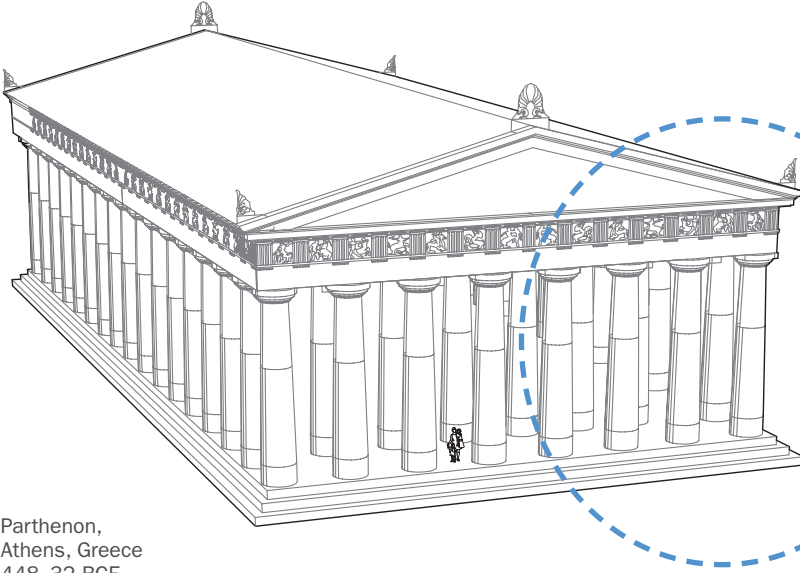
CLASSICAL ORDERS

Elements of the classical orders are distinguished by their unique proportioning system based on the shaft diameter of the columns, from which pedestal, shaft, and entablature heights are derived. Using a common shaft diameter, the five orders are shown here in their proportional relationship to each other.

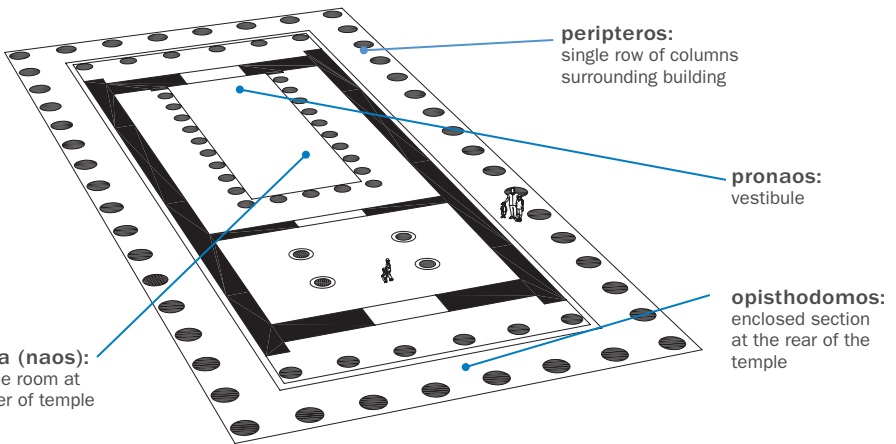


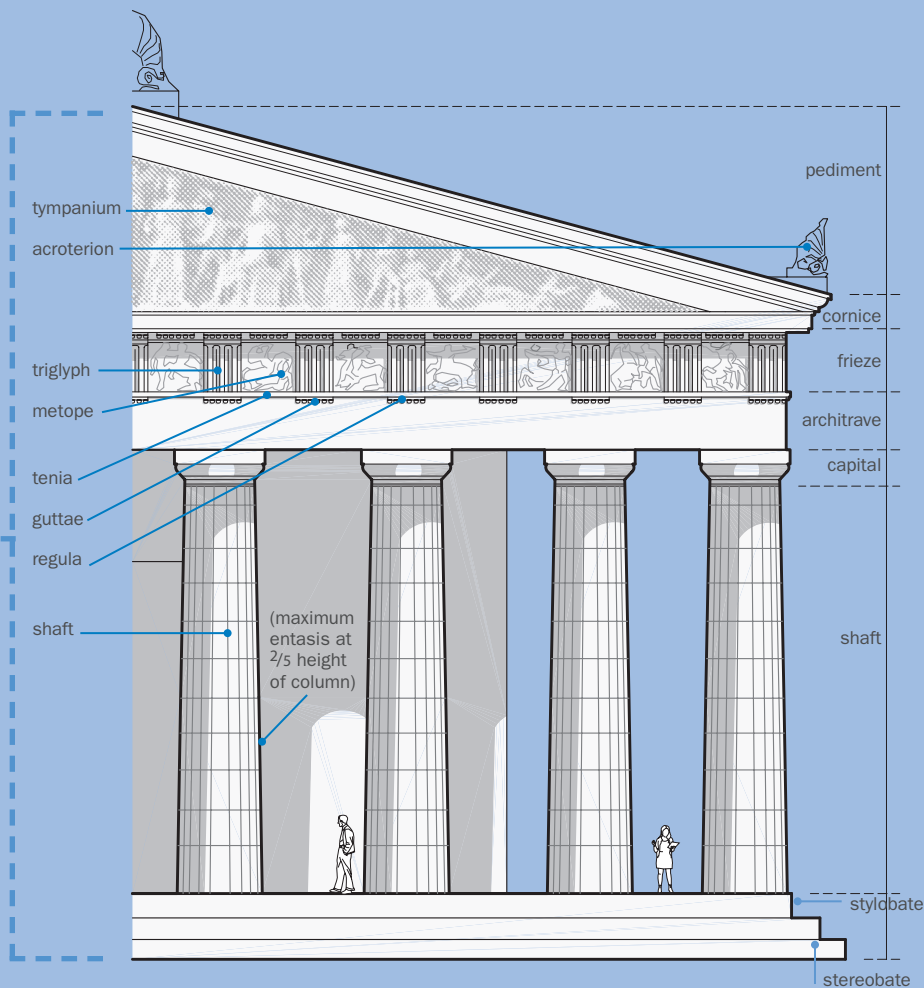
ANCIENT GREECE

Classical architecture typically refers to the styles of both ancient Greece and Rome, which are based around the fixed columnar proportions and ornamentation of the classical orders. Both Greek and Roman classicism have been the bases of revivals throughout history, and the ideals behind their form and proportion continue to have resonance today.



Parthenon,
Athens, Greece
448–32 BCE



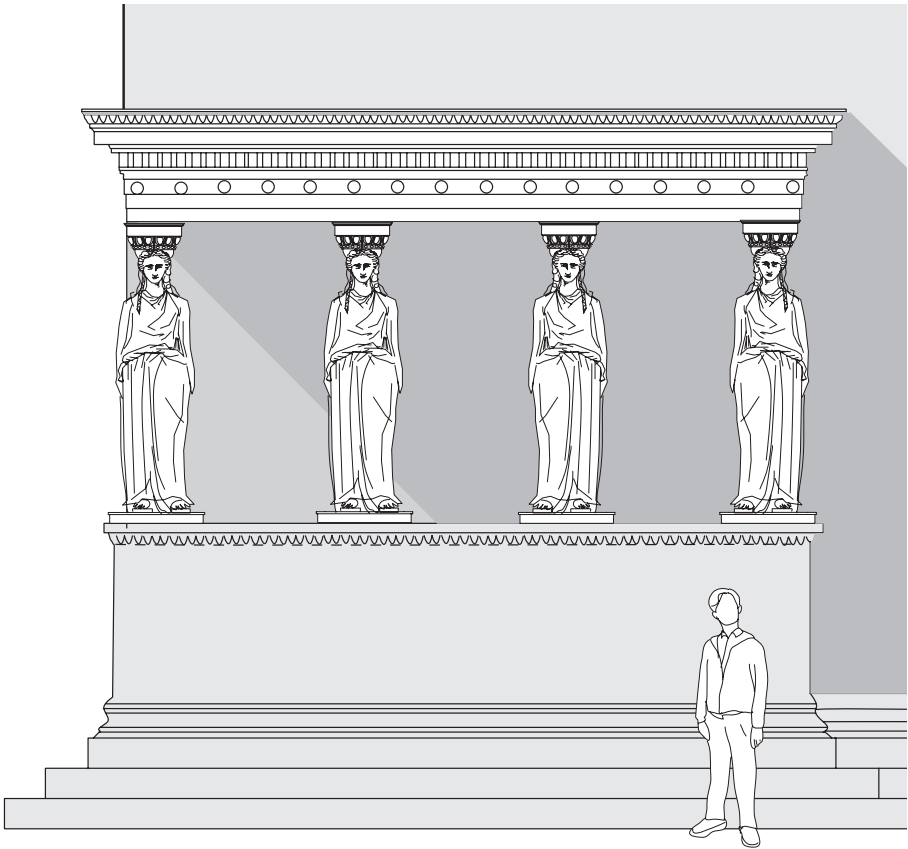


Entasis: Slight convex curvature of classical columns, used to counteract the optical illusion of concavity produced by straight lines. Other adjustments, such as reclining the columns slightly away from the vertical and making the end columns larger and closer together, also produce a more pleasing visual effect.

ANCIENT GREECE

A caryatid was a sculpted (from marble) female figure used as a column to support an entablature. Other forms include atlantes or telamones (male caryatids), canephorae (females with baskets on their heads), herms (three-quarter-height figures), and terms (pedestals that taper upward, terminating in a sculptured human or animal).

Ornately carved braids provided extra strength to the maiden's neck, making the figure's head a strong capital.



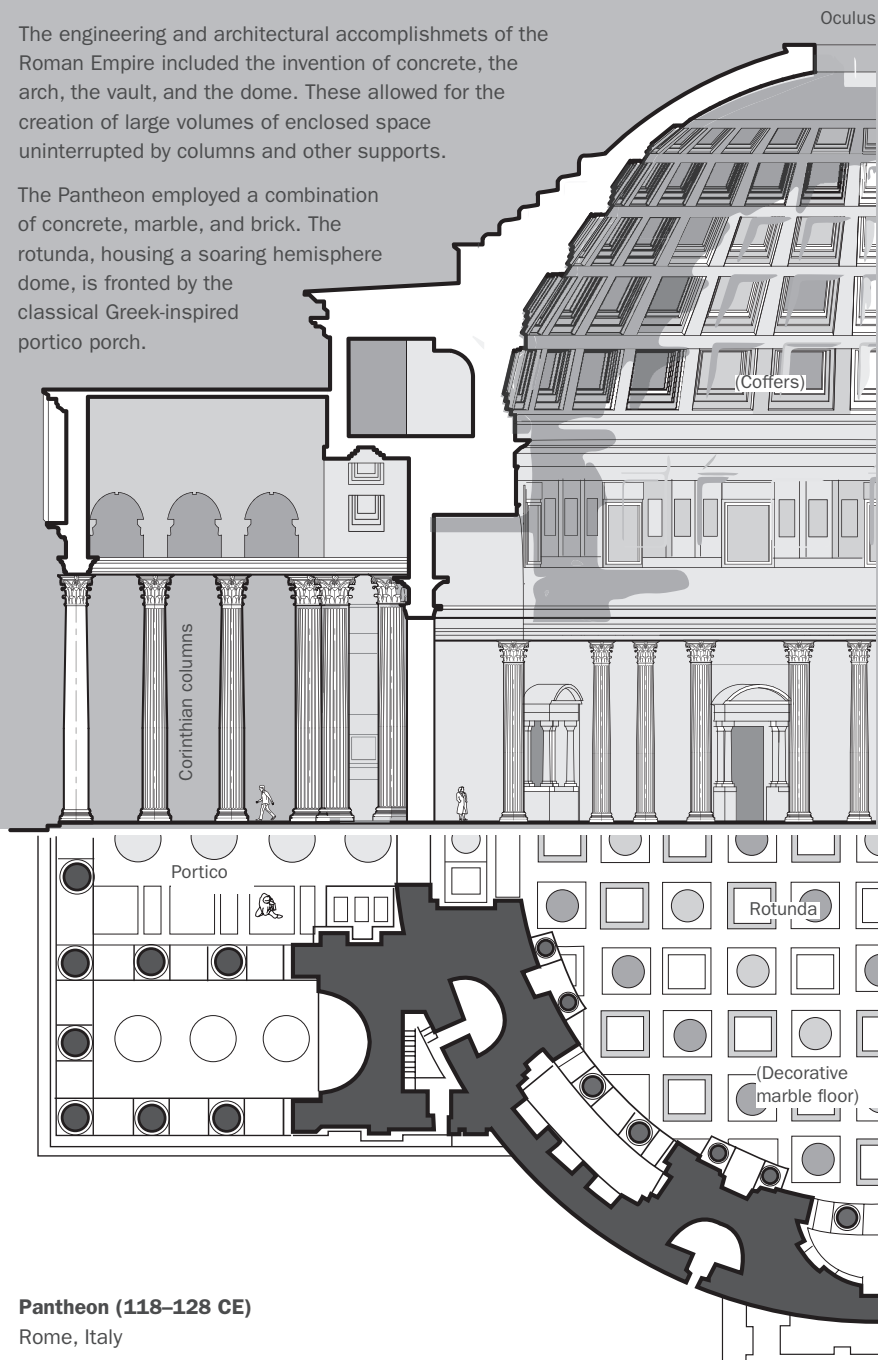
Erechtheion, Athens (421 BCE)

Porch of the Maidens

ANCIENT ROME

The engineering and architectural accomplishments of the Roman Empire included the invention of concrete, the arch, the vault, and the dome. These allowed for the creation of large volumes of enclosed space uninterrupted by columns and other supports.

The Pantheon employed a combination of concrete, marble, and brick. The rotunda, housing a soaring hemisphere dome, is fronted by the classical Greek-inspired portico porch.

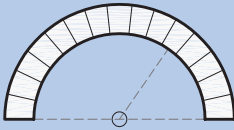
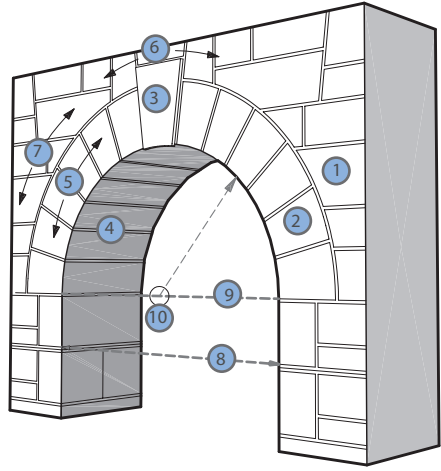


Pantheon (118–128 CE)

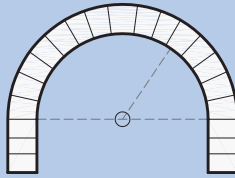
Rome, Italy

ARCHES

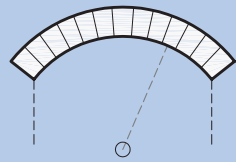
- 1 abutment
- 2 voussoirs
- 3 keystone
- 4 intrados (soffit)
- 5 extrados
- 6 crown
- 7 haunch
- 8 span
- 9 springing line
- 10 center



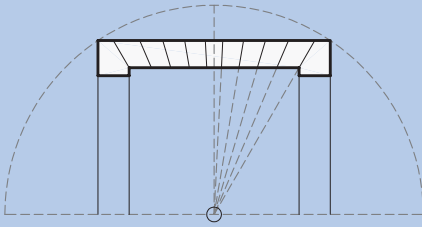
Semicircular



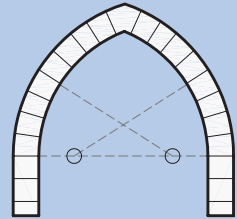
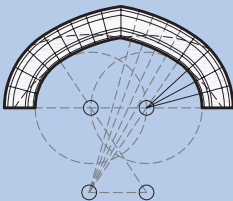
Semicircular Stilted



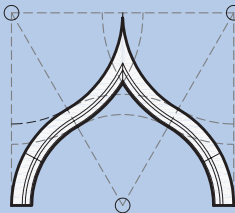
Segmental



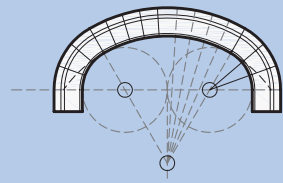
Jack

Pointed Saracenic
(Gothic)

Tudor (Four-Centered)

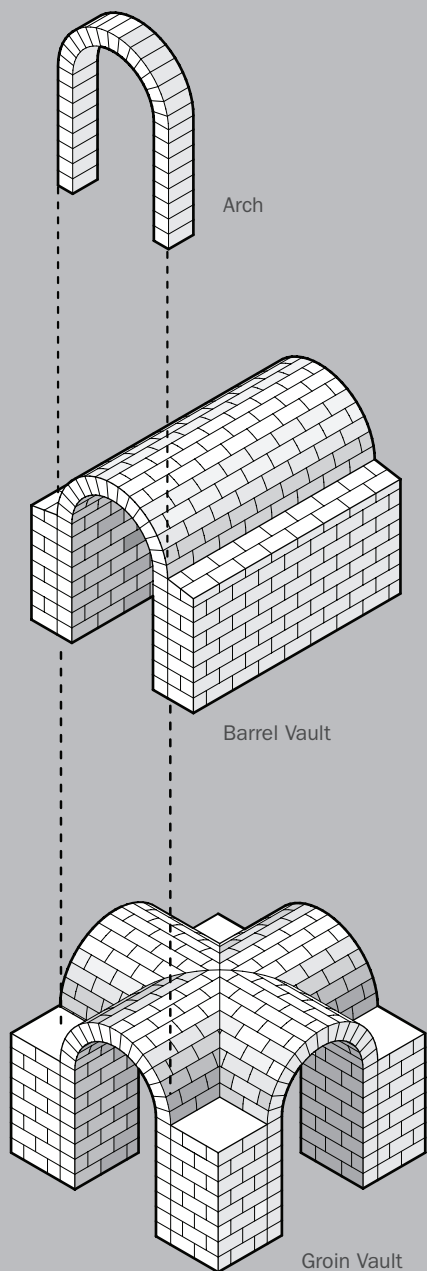


Ogee



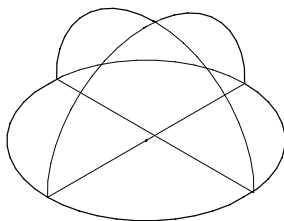
Three-Centered

VAULTS

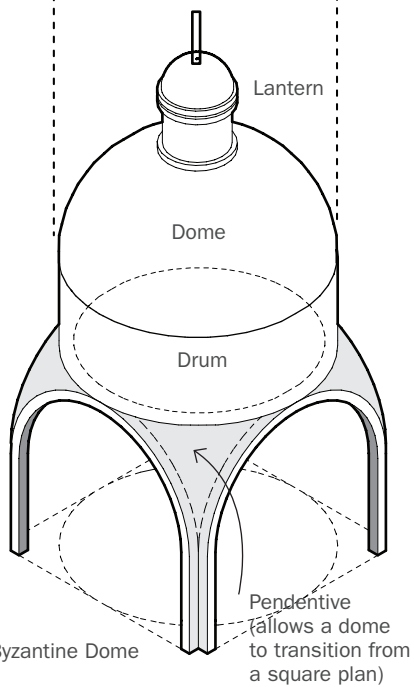
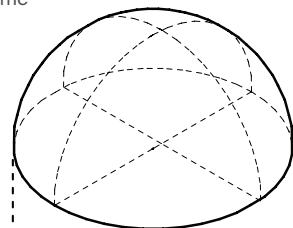


DOMES

Rotated Arch

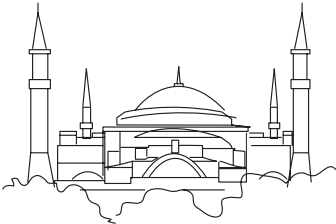


Dome



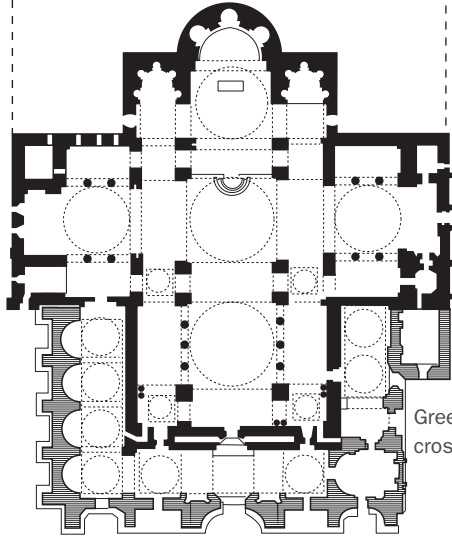
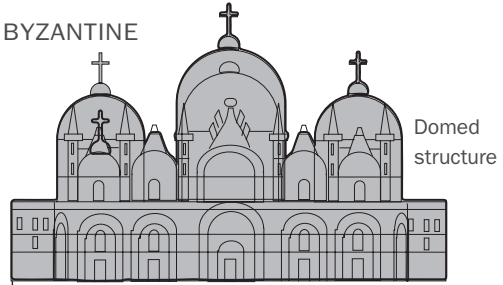
THE MIDDLE AGES

The Middle Ages in Europe (roughly 500 to 1500 CE) fell between the Roman Empire and the coming enlightenment of the Renaissance. In this period, Byzantine architecture flourished in Constantinople in the east. The domed basilica of the Hagia Sophia (532 CE) was a marvel of engineering that appeared to “float” through the use of pendentives. Ultimately, Byzantine influence extended back to central Europe.



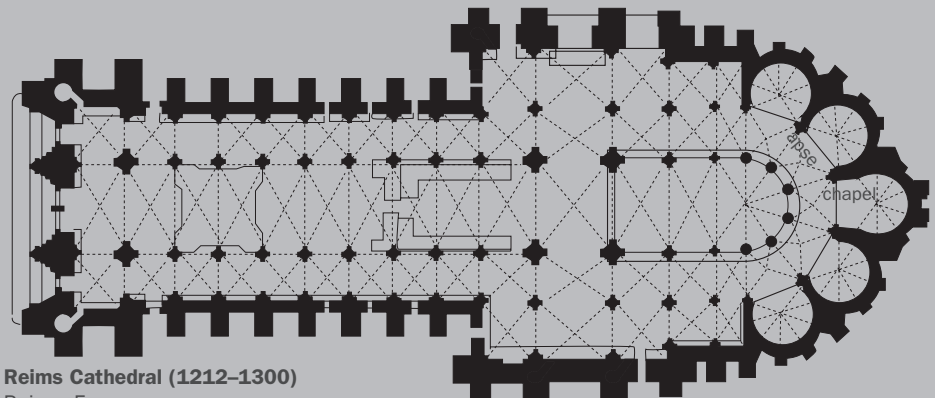
The innovations of the Hagia Sophia reached northern Europe through returning Crusaders, who brought new technologies and insights with them. These enabled the development of the pointed arch, the flying buttress, and the rib vault. All were used in service of new ways to open up tall, light-filled spaces for gathering and worship, in the form of the Gothic cathedral.

BYZANTINE



Basilica of San Marco (830 CE)

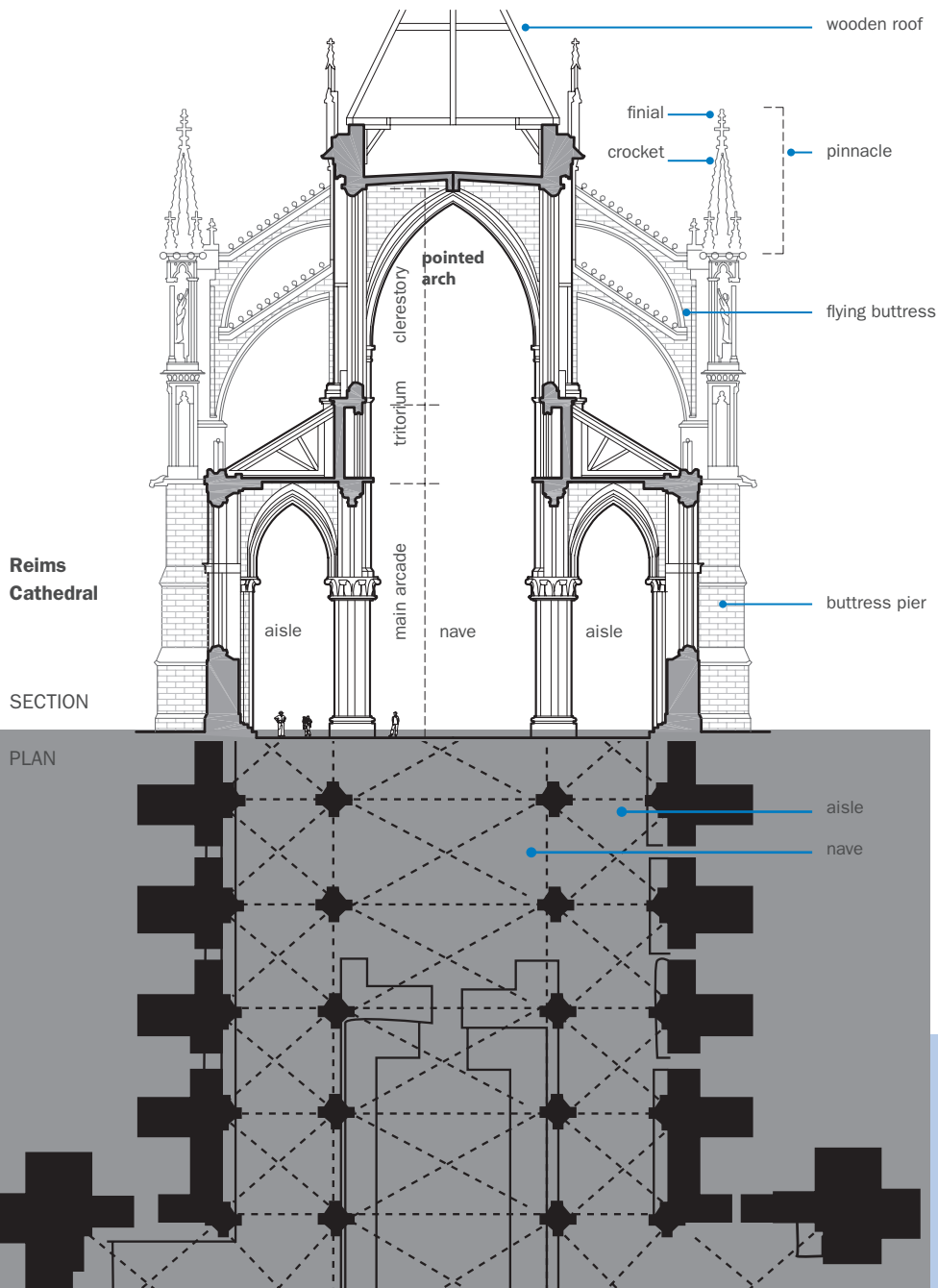
Venice, Italy

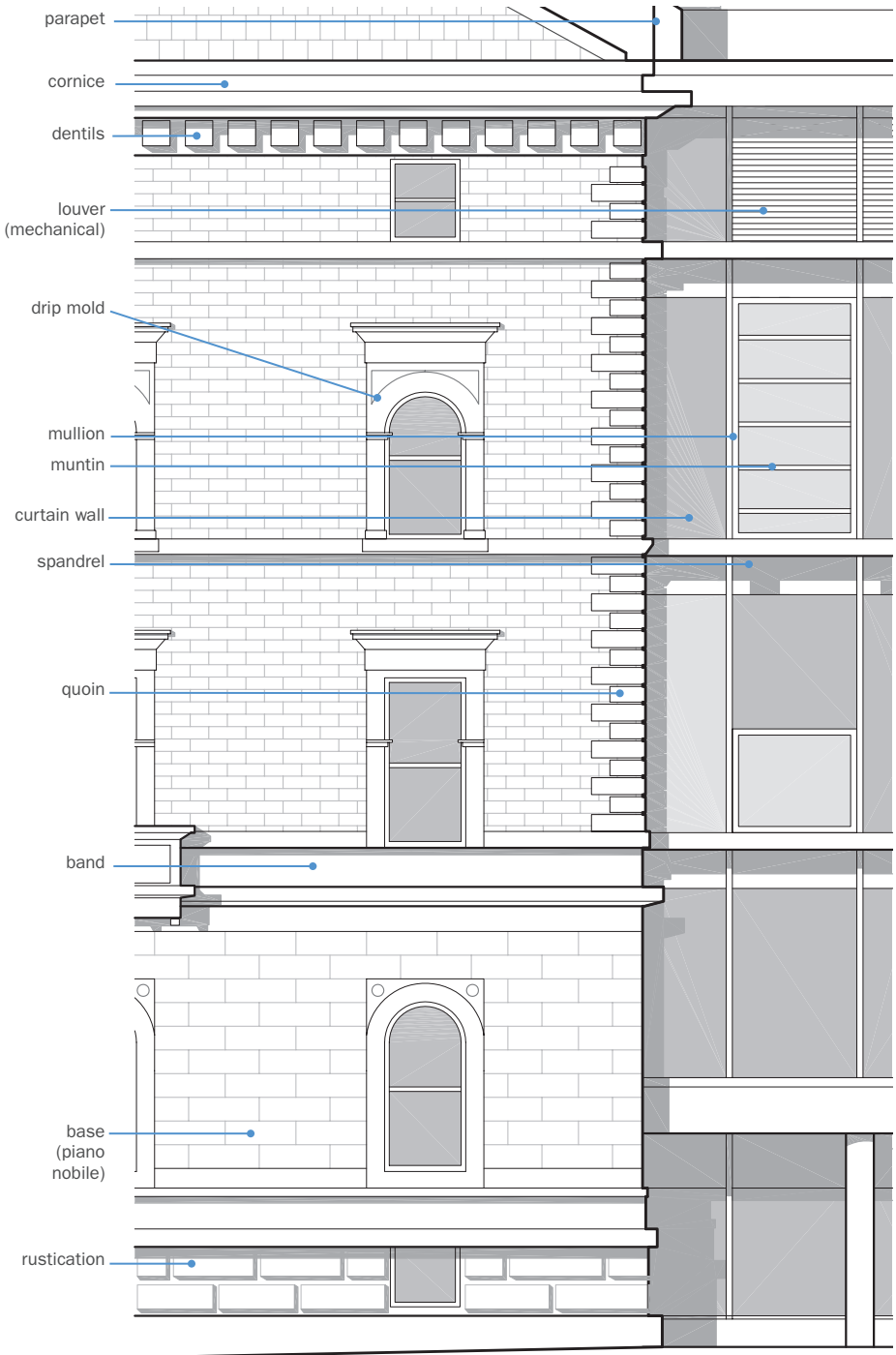


Reims Cathedral (1212–1300)

Reims, France

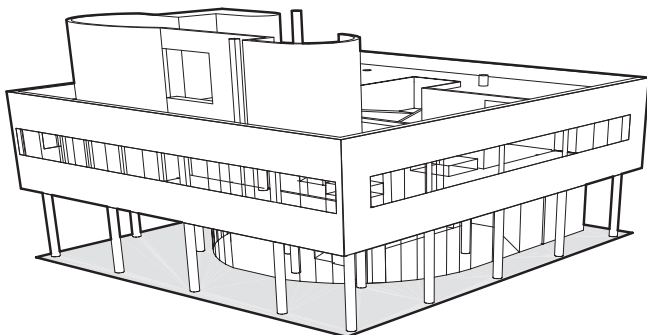
GOTHIC



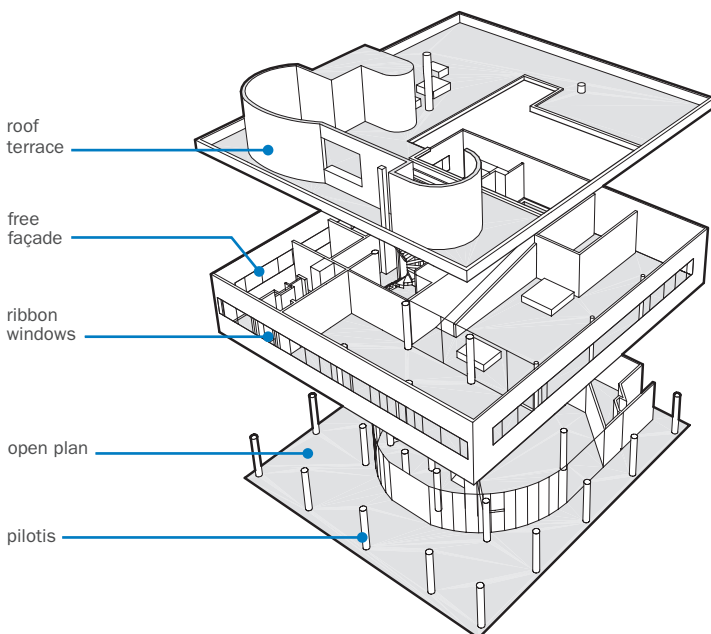


MODERNISM

Architectural modernism opposed following the forms and styles of the past in favor of embracing contemporary technology and opportunities. Industrialization and innovative methods of using iron, steel, and concrete for structural systems opened up new and flexible ways to design buildings that no longer depended on heavy masonry bearing walls. Swiss architect Le Corbusier (1887–1965) developed the Domino House system (1914), in which he separated building structure from enclosure, freeing up both plan and façade.



Le Corbusier's five points are supports (pilotis), roof gardens, free plans, horizontal windows, and free design of the façade. His 1929 Villa Savoye (which he dubbed a "machine for living") in Poissy, France, illustrates all five points clearly.



CANONICAL ARCHITECTURAL PUBLICATIONS

MARCUS VITRUVIUS POLLIO (c. 80–15 BCE)

De Architectura (in English, *Ten Books on Architecture*)

Vitruvius was an architect, engineer, and writer, who wrote his *Ten Books* around 15 BCE and dedicated them to Emperor Augustus. The books provide explanation and insight into the architecture, engineering, and city planning of classical antiquity, though it was not until the Renaissance that they were rediscovered and ultimately published in 1486. Vitruvius proposed *firmitas*, *utilitas*, and *venustas* as three elements forming the basis for architecture:

- firmness (structural stability and integrity)
- commodity (efficient and functional spatial arrangement)
- delight (pleasing proportion and beauty)

Book 1: *Education of the architect; principals of architecture; city planning*

Book 2: *Materials for building; origin of the dwelling house*

Book 3: *Symmetry and proportion; temples; architectural orders*

Book 4: *Temples; origins of the three orders (continuation of Book 3)*

Book 5: *Civic buildings (Forum, Basilica, Senate); theater design*

Book 6: *Domestic buildings*

Book 7: *Stucco; plasterwork; colors*

Book 8: *Water; aqueducts and cisterns*

Book 9: *Zodiac; planets; astrology*

Book 10: *Machines and instruments*



LEON BATTISTA ALBERTI (1404–1472)

De Re Aedificatoria (*On the Art of Building*)

Written between 1443 and 1452, this became the first printed book on architecture with its publication in 1485 (followed by the publication of Vitruvius's *Ten Books* finally in 1486).

1. *Lineaments*
2. *Materials*
3. *Construction*
4. *Public Works*
5. *Works of Individuals*
6. *Ornament*
7. *Ornament to Sacred Buildings*
8. *Ornament to Public Secular Buildings*
9. *Ornament to Private Buildings*
10. *Restoration of Buildings*



ANDREA PALLADIO (1508–1580)

I quattro libri dell'architettura
(*The Four Books of Architecture*)

A Renaissance architect, Palladio wrote a highly illustrated treatise that included his own designs and the ancient Roman inspirations for his and other work of the Renaissance.

Book 1: Building materials and techniques; the orders of architecture

Book 2: Private houses

Book 3: Streets, bridges, piazzas

Book 4: Reproductions of ancient Roman temple designs



LE CORBUSIER (1887–1965)

Oeuvre Complète
(*Complete Works in Eight Volumes*)

Published regularly throughout the prolific working life (and beyond) of Swiss architect Le Corbusier, the *Oeuvre Complète* comprises over 1700 pages. Contained within is a comprehensive collection of his sketches, drawings, projects both built and unbuilt, texts and manifestos, paintings, and sculptures.

Volume 1: 1910–1929

Volume 2: 1929–1934

Volume 3: 1934–1938

Volume 4: 1938–1946

Volume 5: 1946–1952

Volume 6: 1952–1957

Volume 7: 1957–1965

Volume 8: 1965–1969 (last works)



SEBASTIANO SERLIO (1475–1554)

I sette libri dell'architettura (*Seven Books of Architecture*) also known as:
Tutte l'opere d'architettura et prospetiva (*All the Works on Architecture and Perspective*)

1. *On Geometry*
2. *On Perspective*
3. *On Antiquities*
4. *On the Five Styles of Buildings*
5. *On Temples*
6. *On Habitations*
7. *On Situations*



The first of Serlio's books was published in 1537; they were highly illustrated and written in Italian in order to appeal to architects and builders of the day—in contrast to Alberti's books, which were written in Latin and did not focus on illustration. Many of Serlio's books were published long after his death.

Chapter 24: Form and Organization

PRIMARY ELEMENTS

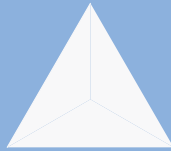
The primary elements of form are points, lines, planes, and volumes, each growing from the other. A point is a position in space and the prime generator of form. A line is a point extended; its properties are length, position, and direction. A plane is a line extended; its properties are width and length, shape, surface, orientation, and position. A volume is a plane extended; its properties are length, width, and depth, form and space, surface, orientation, and position.



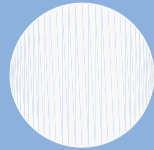
PRIMARY SHAPES



Square

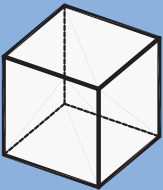


Triangle

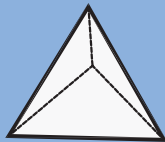


Circle

PLATONIC SOLIDS



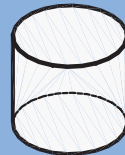
Cube



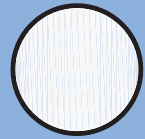
Pyramid



Cone

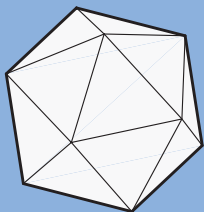


Cylinder

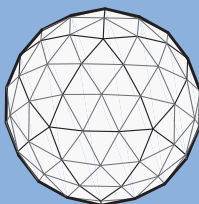


Sphere

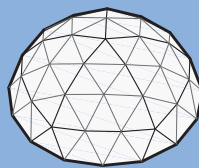
POLYHEDRA



Icosahedron (20-Sided Solid)



Geodesic Sphere



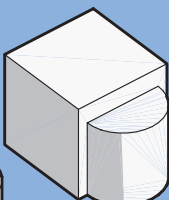
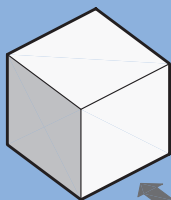
Geodesic Dome

A geometric polyhedron is a three-dimensional solid made up of a collection of polygons, usually joined at the edges.

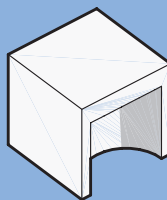
Geodesic spheres and domes are designed by filling each face of a solid, such as an icosahedron, with a regular pattern of triangles, bulged out so that their vertices are not coplanar but are in the surface of the sphere instead. As a structural concept, the subpattern of triangles form geodesics that distribute stresses across the structure.

BOOLEAN OPERATIONS

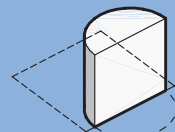
Joining together or subtracting of one solid from one or more sets of solids.



Union



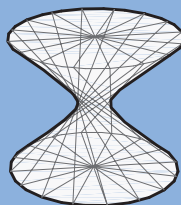
Extraction



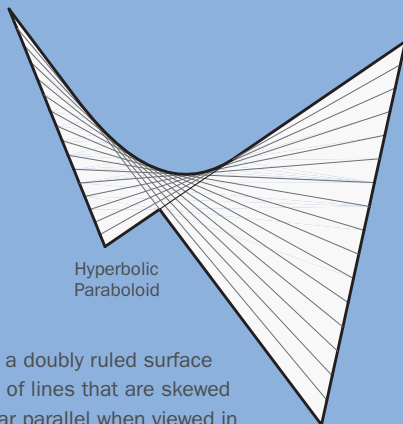
Intersection

RULED SURFACES

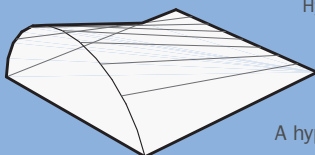
A ruled surface, which is the surface generated by connecting line segments between corresponding points, can take many forms.



Hyperboloid of Revolution



Hyperbolic Paraboloid



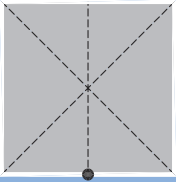
Conoid

A hyperbolic paraboloid is a doubly ruled surface generated by two meshes of lines that are skewed from each other but appear parallel when viewed in plan. The saddle point is found at its center.

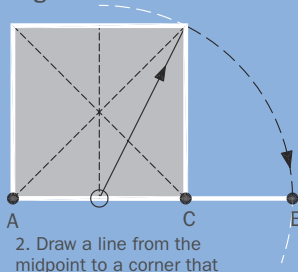
THE GOLDEN SECTION

The properties of proportion of the golden section have been employed by architects, artists, mathematicians, and musicians since the ancient Greeks recognized its proportional ordering in the human body. Even today many believe it to contain mystical qualities, whose unique mathematical and geometrical relationships create a harmonic condition that is nature's aesthetically "perfect" balance between symmetry and asymmetry.

Constructing a Golden Rectangle

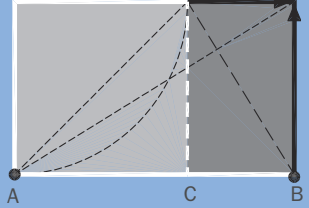


1. Create a square and locate the midpoint of one side.



2. Draw a line from the midpoint to a corner that does not share a line with the midpoint.

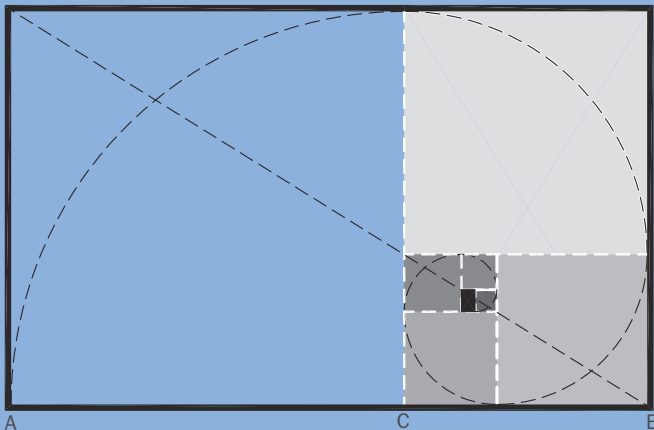
3. This is the radius of a circle with its center at the midpoint; the point where the circle and the line AC intersect becomes point B.



4. Line AB is the long leg of the golden rectangle.

5. A golden rectangle has been added to the original square, and together they also form a larger golden rectangle.

6. The process can be repeated infinitely, creating proportionally larger or smaller series of squares and rectangles.



In mathematics, the golden section is the ratio of the two divisions of a line such that the smaller is to the larger as the larger is to the sum of the two. In addition to its many uses in the arts and music, there are practical uses for the mathematical integrity of the golden section in its proportions as related to structure.

Calculating the Golden Mean

$AC/CB = AB/AC$ (a unique characteristic)
If $AB = 1$, let $AC = x$

$$x = \frac{\sqrt{5}-1}{2} = 0.61803398 \dots (\text{infinite}).$$

Therefore: the ratio of AC to AB is approximately 61.8%; the inverse (1/61.8) is 1.61803398 . . .

THE FIBONACCI SEQUENCE

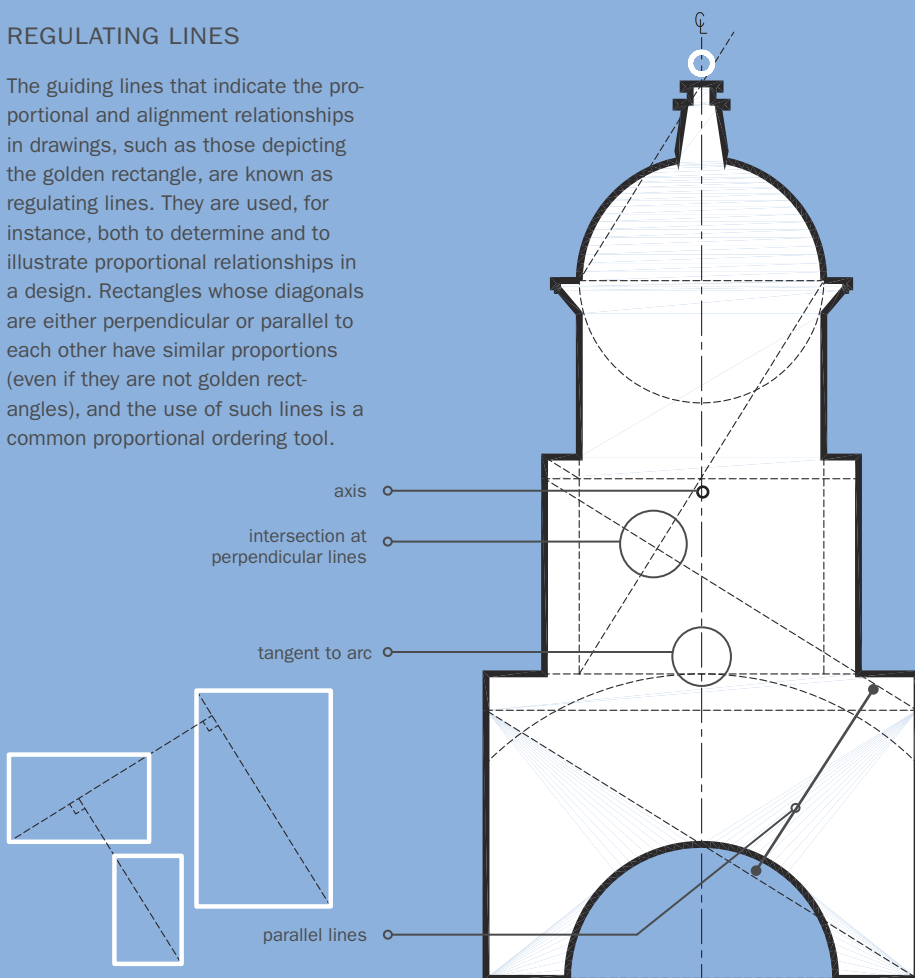
The Fibonacci Sequence is a recursive series of numbers, where each number in the sequence is the sum of the two numbers preceding it. A simple sequence beginning with 0 follows:

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55 ...

Any two adjacent numbers in the sequence may be divided, the lower number by the higher number (for example, $34/55$), to achieve a very close approximation of the golden section (in this case, $0.6181818 \dots$). The higher the numbers, the more accurate the answer will be (for example: $377/610 = 0.6180327 \dots$).

REGULATING LINES

The guiding lines that indicate the proportional and alignment relationships in drawings, such as those depicting the golden rectangle, are known as regulating lines. They are used, for instance, both to determine and to illustrate proportional relationships in a design. Rectangles whose diagonals are either perpendicular or parallel to each other have similar proportions (even if they are not golden rectangles), and the use of such lines is a common proportional ordering tool.



Chapter 25: Glossary

2 × 4: A standard American lumber size equal to 1½" × 3½" (38 × 89). A roughly equivalent standard SI size would be 40 × 90 or 50 × 100.

AASM: Association of American Steel Manufacturers

AGCA: Associated General Contractors of America

AIA: American Institute of Architects

AISC: American Institute of Steel Construction.

AISI: American Iron and Steel Institute

ANSI: American National Standards Institute

APA: American Plywood Association

ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers

ASTM: American Society for Testing and Materials

CSI: Construction Specifications Institute

IESNA: Illumination Engineering Society of North America

ICC: International Code Council

ICED: International Council on Environmental Design

ISO: International Organization for Standardization

LEED: Leadership in Energy & Environmental Design

NIBS: National Institute of Building Sciences

NFPA: National Fire Protection Association

RAIC: Royal Architecture Institute of Canada

RIBA: Royal Institute of British Architects

UIA: Union Internationale des Architectes

UL: Underwriters' Laboratory

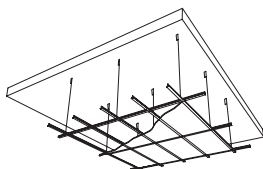
A

Aalto, Alvar: (1898–1976) Finnish architect and designer; notable buildings include the Municipal Library in Viipuri, Finland, Paimio Sanatorium, and Baker House at MIT.

Access flooring: Removable finish floor panels raised above the floor structure to allow installation of wiring and ductwork below.

Accessible: Capable of being reached by all persons, regardless of levels of disability.

Acoustical ceiling: System of fibrous removable tiles in the ceiling that absorb sound.



ADA: Americans with Disabilities Act.

Adaptive reuse: Changing a building's function in response to the changing needs of its users.

AFF: Above finish floor.

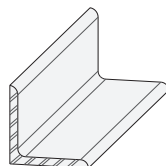
Aggregate: Particles such as sand, gravel, and stone used in concrete and plaster.

Alberti, Leon Battista: (1404–1472) Italian architect, artist, and Renaissance humanist polymath; notable work includes the facade of the Santa Maria Novella in Florence, Italy, and numerous treatises on art and architecture, with scientific study of perspective.

Alloy: Substance made of two or more metals or a metal and another substance.

Anchor bolt: Concrete-embedded bolt that fastens a building frame to masonry or concrete.

Angle: L-shaped steel or aluminum structural section.



Annealed: Metal cooled under controlled conditions.

Arcade: Series of arches on columns or piers.

Arch: Structural device that supports vertical loads by translating them into axial forces.

Area: Quantity expressing the size of a figure in a plane or surface.

Atelier: Workshop or studio.

Atrium: Open-roofed entrance court of a Roman dwelling; also, a many-storied court in a building, usually skylit.

Axial: Force, load, tension, or compression in a direction parallel to the long axis of a structural member.

B

Ballast: In roofing, a heavy material such as crushed stone installed over a roof membrane to minimize wind uplift; in lighting, a device that provides starting voltage for a fluorescent or high-intensity discharge lamp, then regulates the current during operation.

Balloon frame: Wood-frame construction in which vertical studs run from the sill to the eave instead of resting on intermediate floors.

Baluster: Vertical member used to support a stair railing or a railing in a continuous banister.

Balustrade: Railing system, usually around a balcony, that consists of balusters and a top rail.

Band/banding: Continuous horizontal division on a wall created by different materials, colors, or textures.

Bar: Small rolled steel shape.



Bar joist: Truss type used for floor and roof support, with steel members on top and bottom and heavy wire or rod web lacing.

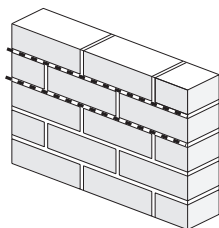
Base plate: Steel plate between a column and foundation that distributes the column's load to the foundation.

Bay: Rectangular area of a building defined at its four corners by adjacent columns; projecting portion of a façade.

Beam: Horizontal linear element that spans an opening and is supported at both ends by walls or columns.

Bearing wall: Wall that supports floors or roofs.

Bed joint: Horizontal layer of mortar between units in a masonry wall.



Bending moment: Force acting on a structure, causing it to curve.

Blocking: Pieces of wood placed between joists, studs, or rafters to stabilize the structure or provide a nailing surface for finishes.

Blueprint: Photographic print on specially coated paper; ideal for making precise and undistorted copies of large-scale drawings. Blueprint technology is rapidly being superseded by computer plotters and printers.

Board foot: Unit of measuring lumber volume (nominally: 144 cu. in.).

Bond beam: Top course of a masonry wall, filled with concrete and reinforcing steel, and used to support roof loads.

Bramante, Donato: (1444–1514) Italian Renaissance architect; notable buildings include St. Peter's Basilica and the Tempietto, both in Rome.

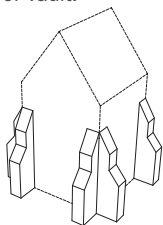
Brise-soleil: Shading screen attached to the exterior of a building.

Brunelleschi, Filippo: (1377–1446) Italian Renaissance architect and engineer; notable buildings include the Dome of the Cathedral of Florence and the Basilica of Santo Spirito in Florence.

Building code: Legal restrictions meant to enforce safety and health in the built environment.

Built-up roof: Roof membrane composed of asphalt-saturated felt layers laminated together and bonded with bitumen or pitch.

Buttress: Masonry or concrete reinforcement applied to a wall to resist diagonal forces from an arch or vault.



C

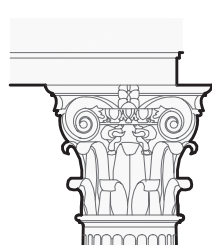
CAD: Computer-aided drafting.

Caisson: Long cylindrical foundation element formed by drilling deep into firm clay and pouring concrete into the hole.

Canopy: Projection over doors or windows.

Cantilever: Beam or slab extending beyond its last point of support.

Capital: Uppermost element of a column.



Cavity wall: Masonry wall with a continuous airspace between wythes.

Cement: Dry powder that combines chemically with water and bonds aggregate particles together to form concrete. Also known as portland cement.

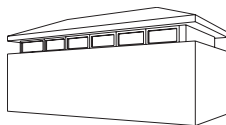
Change order: Written document between the owner and contractor of a project authorizing a change in the project.

Chase wall: Cavity wall containing electrical runs or plumbing pipes in its cavity.

Chord: Structural member of a truss.

Clear floor space: Minimum unobstructed floor or ground space required to accommodate a single, stationary wheelchair and occupant.

Clerestory: Windows placed high in a wall, usually above lower roof levels. Also called clearstory.



Coefficient of expansion: Fractional change in length, area, or volume of an object per unit change in temperature at a given constant pressure.

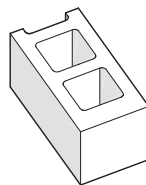
Cold rolling: Rolling of metal at room temperature and stretching its crystals to harden the metal.

Colonnade: Linear series of columns carrying an entablature or arches.

Column: Upright structural member.

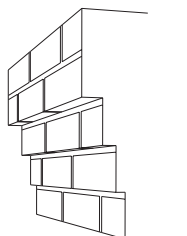
Concrete: Mix of cement, aggregates, and water that forms a structural material.

Concrete masonry unit (CMU): Solid or hollow block of cured concrete.



Coping: Protective cap or cover on top of a wall to throw off water.

Corbel: Series of spanning stones or bricks in which each successive course projects over the course below it; also, a projecting masonry or concrete bracket.



Cornice: Projecting molding at the top of a building; also, the uppermost element of an entablature.

Course: Horizontal layer of one-unit-high masonry units.

Cricket: Component used to divert water away from roof curbs, platforms, chimneys, walls, or other roof forms.

Cripple stud: Short wood framing member in walls interrupted by a header or sill.

Cupola: Domed roof structure rising from a building.

Curtain wall: Non-load-bearing exterior wall system supported on the building's frame.

D

Deck: Horizontal surface spanning across joists or beams.

Deflection: Under an applied load, the amount of bending movement of any part of a structural member perpendicular to that member's axis.

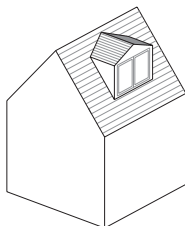
Deliverables: Set of items such as construction documents provided by the architect to the client, and as agreed on in the owner-architect agreement.

Detail: Drawing that provides very specific information about the materials and construction of a component of a project and that is keyed into larger-scale drawings.

Dimensional stability: Ability of a section of wood to resist changes in volume at fluctuating moisture levels.

Dome: Bowl-shaped volume created by rotating an arch about its vertical axis.

Dormer: Protrusion in a sloping roof, usually containing a window.



Duct: Hollow conduit for circulating and directing air.

DWG: Computer drawing file.

E

Eave: Edge of a roof plane, usually projecting over the exterior wall.

Egress: Means of exiting safely.

Eisenman, Peter: (1932–) American architect; notable buildings include House VI, Wexner Center for the Arts, and the University of Phoenix Stadium.

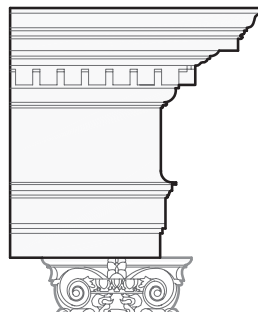
Elevation: Architectural drawing of a view of the vertical planes of the building, showing their relationship to each other.

Encroachment: Portion of a building that extends illegally beyond the property owned and onto another property.

Energy efficiency: Reducing energy requirements without reducing the end result.

Engaged column: Non-free-standing column attached to a wall.

Entablature: Uppermost part of a classical order, comprised of architrave, frieze, and cornice and supported on a colonnade.



Expansion joint: Surface divider joint allowing for surface expansion.

F

Façade: Face or elevation of a building.

Fascia: Exposed vertical face of an eave.

Fenestration: Windows and window arrangements on a façade.

Finial: Ornament at the top of a spire or roof.

Fire-resistance rating: Determination of the amount of time (in fractions of an hour) that an assembly or material will resist fire.

Flashing: Continuous sheet of thin metal, plastic, or other waterproof material used to divert water and prevent it from passing through a joint into a wall or roof.

Float glass: Common plate glass made by floating the material on a bed of molten metal, producing a smooth, flat surface.

Footing: Widened base of a foundation that spreads a building's loads across the soil.

Foundation: Lowest portion of a building that transfers the building's structural loads into the earth.

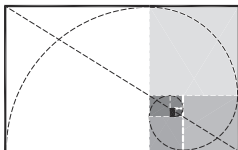
G

Galvanic action: Corrosion resulting from an electrical current between two unlike metals.

Girder: Large horizontal beam that supports other beams.

Girt: Horizontal beam that supports wall cladding between columns.

Golden section: Unique proportional ratio of two divisions of a line such that the smaller of the two is to the larger as the larger is to the sum of the two.



Grab bar: Bar attached parallel to a wall to provide a handgrip for steadying oneself.

Grade: Classification of size or quality; the surface of the ground; the act of moving earth to make the ground level.

Gropius, Walter: (1883–1969) German architect and founder of the Bauhaus. Notable buildings include the Bauhaus School and the Pan Am Building in New York.

Guardrail: Protective railing to prevent falling into stairwells or other openings.

Gusset plate: Flat steel plate to which truss chords are connected at a truss joint.

Gypsum wallboard (GWB): Interior facing board with a gypsum core between paper facing. Also called drywall and plasterboard.

H

Hadid, Zaha: (1950–) Iraqi-British architect; notable buildings include Vitra Fire Station in Weil-am-Rhein, Germany, the London Aquatics Centre for the 2012 Olympics, and the Broad Art Museum in Lansing, Michigan.

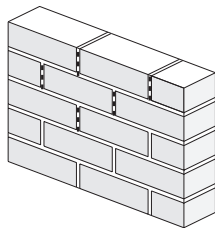
Half-timbered: Timber wall with the spaces between filled with masonry.

Handrail: Railing running parallel to the rise of a stairway or ramp, providing a continuous gripping surface.

Hard metric: Conversion of component sizes to fall within a rational metric module, not a strict translation of other units into their exact metric equivalents.

Hardwood: Wood from deciduous trees.

Head joint: Vertical layer of mortar between units in a masonry wall.



Header: Lintel; in steel, a beam that spans between girders; also, masonry unit laid across two wythes, exposing its end in the face of the wall.

Heavy timber: Structural lumber having a minimum width and thickness of 5" (127).

Hot-rolled steel: Steel formed and shaped by being heated and passed through rollers.

HSLA: High-strength low-alloy grade of steel.

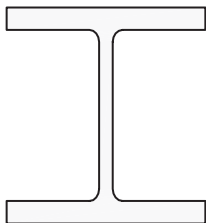
HUD: Housing and Urban Development.

HVAC: Heating, Ventilating, and Air-Conditioning.

I

IBC: International Building Code.

I-beam: Obsolete term for American Standard steel section that is I- or H-shaped.



Insulation: Any material that slows or retards the flow or transfer of heat.

J

Jamb: Vertical frame of a window or door.

Johnson, Philip: (1906–2005) American architect; notable work includes the Glass House in New Canaan, Connecticut, the AT&T Building in New York, and the Four Seasons Restaurant in New York.

Joists: Light, closely spaced beams supporting floors or flat roofs.

K

Kahn, Albert: (1869–1942) German-American architect; notable buildings include Hill Auditorium at the University of Michigan, the Packard Automotive Plant in Detroit, and the Detroit Athletic Club.

Kahn, Louis: (1901–1974) American architect; notable buildings include the Philips Exeter Academy Library in New Hampshire; the Salk Institute in La Jolla, California; and the Kimbell Art Museum in Fort Worth, Texas.

Keystone: Central wedge-shaped stone at the top of an arch.

Koolhaas, Rem: (1944–) Dutch architect; notable buildings include the Kunsthall in Rotterdam, the Seattle Central Library, and the CCTV Headquarters in Beijing.

L

Laminate: Material produced through bonding together layers of other materials.

Le Corbusier: (1887–1965) Swiss architect notable for the Villa Savoye (1929), the Unite d'Habitation, and the chapel at Ronchamp.

Ledoux, Claude Nicolas: (1736–1806) French neoclassical architect; notable designs include the Royal Saltworks at Arc-et-Senan, and the Theatre of Besancon.

Lintel: Beam over a door or window that carries the load of the wall above.

Lite: Pane of glass; also “light,” though often spelled differently to avoid confusion with visible light.

Loads: Forces acting on a structure. Dead loads are fixed and static elements such as the building's own skin, structure, and equipment; live loads are the changing weight on a building and include people, snow, vehicles, and furniture.

Longitudinal: Lengthwise.

Loos, Adolf: (1870–1933) Austro-Hungarian architect; notable buildings include the Kärntner Bar in Vienna, the Villa Müller in Prague, and Maison Tzara in Paris.

Louvers: Opening with horizontal slats that permit passage of air, but not rain, sunlight, or view.

M

Masonry: Brickwork, blockwork, and stonework; also, the trade of a mason.

Metrication: Act of changing from the use of customary units to metric units.

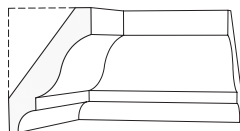
Mezzanine: Intermediate level between a floor and ceiling that occupies a partial area of the floor space.

Mild steel: Steel with a low carbon content.

Millwork: Interior wood finish components of a building, including cabinetry, windows, doors, moldings, and stairs.

Model: Physical representation (usually at a reduced scale) of a building or building component; in computer drafting and modeling, it is the digital two- or three-dimensional representation of a design.

Molding: Strip of wood, plaster, or other material with an ornamental profile.



Mortar: Material composed of portland cement, hydrated lime, fine aggregate (sand), and water, used to adhere together and cushion masonry units.

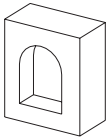
Mullion: Horizontal or vertical bar or divider in the frames of windows, doors, or other openings, and that holds and supports panels, glass, sashes, or sections of a curtain wall.

Muntin: Secondary system of horizontal or vertical divider bars between small lites of glass or panels in a sash.

Mylar: Polyester film that, when coated, can be used as drafting sheets.

N

Niche: Recess in a wall, usually for holding a sculpture.



Nominal: Approximate rounded dimensions given to materials for ease of reference.

O

Occupancy: Category of the use of a building for determining specific code requirements.

Ogee: Profile section with a reverse-curve face (that is, concave above and convex below).

Overhang: Projection beyond the face of a wall below.

P

Palladio, Andrea: (1508–1580 Italian architect; notable work includes numerous villas in the Veneto region of Italy, the Teatro Olimpico in Vicenza, and his treatise *The Four Books of Architecture*.

Parametric: Having one or more variables (parameters) that can be altered to achieve different results. In parametric modeling, a database tracks changes to all elements of a design simultaneously.

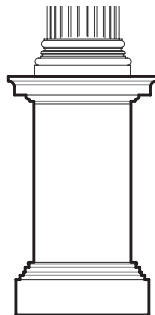
Parapet: Low wall projecting from the edge of a platform, usually on a roof.

Parti: Central idea governing and organizing a work of architecture.

Partition: Interior non-load-bearing wall.

Passive solar: Technology of heating and cooling a building naturally, through the use of energy-efficient materials and proper site placement.

Pedestal: In classical architecture, a base supporting a column or statue.



Pediment: Triangular space that forms the gable end of a low-pitched roof, often filled with relief sculpture.



Pendentive: Curved, triangular support that results from transforming a square bay into a dome.

Penthouse: Enclosed space above the level of the main roof used for mechanical equipment; an above-roof apartment.

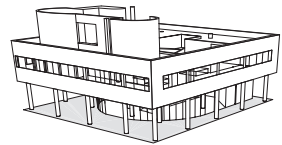
Peristyle: Colonnaded courtyard.

Pier: Caisson foundation; also, a structural element that supports an arch.

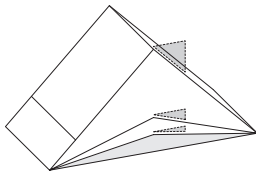
Pilaster: Pier engaged in a wall.

Pillar: Columnar support that is not a classical column.

Pilotis: Columns or pillars that lift a building from the ground.



Pitch: Slope of a roof or other inclined surface, usually expressed as inches of rise per foot of run (X:12, when x is a number between 1 and 12).



Plan: Architectural drawing of a view of the horizontal planes of the building, showing their relationship to each other, and acting as a horizontal section.

Plenum: Space between a suspended ceiling and the structure above, used for mechanical ductwork, piping, and wiring.

Pointing: Process of applying mortar to the outside surface of a mortar joint after laying the masonry, as a means of finishing the joint or making repairs to an existing joint.

Portico: Entrance porch.

Precast concrete: Concrete that is cast and cured in a location other than its final position.

Prefabricated building: Buildings consisting of components such as walls, floors, and roofs that are

built off-site (often in a factory), then shipped to the site for assembly.

Purlin: Beams spanning across the slope of a roof that support the roof decking.

Q

Quoin: Corner stones in a wall made distinct from the surrounding wall by being larger, of a different texture, or having deeper joints to make the stones protrude.

R

Rabbet: Notch in wood for joining pieces or recessed parts in a typical door frame.

Rafter: Roof framing member that runs in the direction of slope.

Reflected ceiling plan: Upside-down plan drawing that documents the ceiling plane.

Retaining wall: Site wall built for resisting lateral displacement of soil, water, or other material.

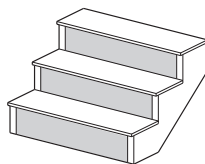
RFP (Request for Proposal): Official invitation for architects to submit qualifications and proposals to perform a project.

Rib: Fold or bend in a sheet of deck.

Ridge: Horizontal line created at the connection of two sloping roof surfaces.

Rise: Vertical difference in elevation, as in the rise of a stair.

Riser: Vertical face between two treads of a stair; also, vertical run of plumbing, ductwork, or wiring.

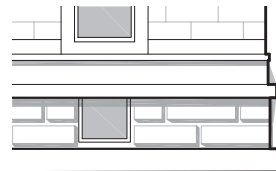


Room cavity ratio: Ratio of room dimensions used to determine how light will interact with the room's surfaces.

Rotunda: Space that is circular in plan and covered by a dome.

Run: Horizontal dimension of a stair, ramp, or other slope.

Rustication: Masonry pattern consisting of large blocks with deep joints.



R-value: Measure of the capacity of a material to resist the transfer of heat.

S

Saarinen, Eero: (1910–1961) Finnish-American architect and son of Eliel Saarinen. Notable buildings include the Miller House in Columbus, Indiana; the Gateway Arch in St. Louis; and the TWA Terminal at JFK Airport.

Saarinen, Eiel: (1873–1950) Finnish architect and father of Eero Saarinen. Notable buildings include the Kleinhans Music Hall in Buffalo, New York, and the Cranbrook Educational Community in Bloomfield Hills, Michigan.

Schedule: Chart or table in a set of architectural drawings, including data about materials, finishes, equipment, windows, doors, and signage; also, plan for performing work.

Schinkel, Karl Friedrich: (1781–1841) Prussian architect, city planner and painter; notable buildings include the Altes Museum, the Neues Schauspielhaus, and the Neue Wache, all in Berlin.

Scope of work: Written range of view or action for a specific project.

Section: Architectural drawing of a view of a vertical cut through the building's components, acting as a vertical plan.

Shaft: Trunk of a column between base and capital; also, enclosed vertical clear opening in a building for the passage of elevators, stairs, ductwork, plumbing, or wiring.

Sheetrock: Brand name for gypsum wallboard, often incorrectly used to describe any gypsum board or drywall.

SI: *Système International d'Unités* (metric system).

Sitecast: Concrete that is poured and cured in its final position; also called cast-in-place or poured-in-place.

Slab on grade: Concrete slab that rests directly on the ground

Soane, Sir John: (1753–1837) English architect; notable buildings include the Bank of England and Sir John Soane's Museum.

Soffit: Finished underside of a lintel, arch, or overhang.

Soft metric: Precise conversion between customary and metric units.

Softwood: Lumber from coniferous (evergreen) trees.

Spall: Splitting off from a surface, in concrete or masonry, as a result of weathering.

Span: Distance between supports.

Spandrel: Exterior panels of a wall between vision areas of windows that conceal structural floors; the triangular space between the curve of an arch and the rectangular outline enclosing it.

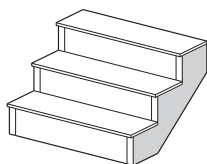
Specifications: Written instructions about the materials and means of construction for a building, and included as part of the construction document set.

STC: Sound Transmission Class, a number rating of airborne sound transmission loss as measured in an acoustical laboratory under carefully controlled test conditions.

Stile: Framing member in a door.

Stud: Vertical structural member used in light-frame wall construction and made of dimension wood or metal.

Stringer: In a stair, the sloping wood or steel member that supports the treads.



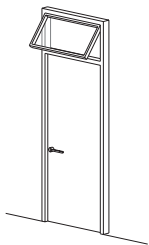
Strut channel: Standardized metal framing system used for light structural support of electrical wiring, mechanical ductwork, and plumbing. Commonly referred to by many of its manufacture trade names, including Unistrut, Flex-Strut and G-Strut

Sustainable design: Environmentally aware design using systems that meet present needs without compromising the needs of future generations.

T

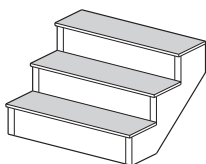
Thermal performance: Ability of a glass unit to perform as a barrier to the transfer of heat.

Transom: Opening above a door or window that may be filled with a glazed or solid operable panel.



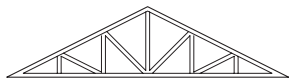
Transverse: Crosswise.

Tread: Horizontal surface between two risers of a stair.



Trompe-l'oeil: Two-dimensional painting or decoration made to look three-dimensional; literally, “trick the eye.”

Truss: Structural element made up of a triangular arrangement of members that transforms the nonaxial forces acting on it into a set of axial forces on the truss members.



U

Undressed lumber: Lumber that is not planed.

V

Valley: Trough formed at the intersection of two sloping roofs.

Value engineering:

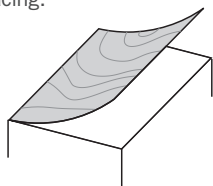
Analyzing the materials and processes in a project in an effort to achieve the desired function at the lowest overall cost.

van der Rohe, Ludwig Mies:

(1886–1969) German architect; notable buildings include the New National Gallery in Berlin, the Seagram Building in New York (with Philip Johnson), and Crown Hall and other buildings at the Illinois Institute of Technology.

Vault: Arched form.

Veneer: Thin layer, sheet, or facing.



Vernacular: Structures built with indigenous materials, methods, and traditions.

Vitruvius: (c. 80–15 BCE) Roman architect, engineer, and writer; most notable for his treatise *De Architectura* (*On Architecture*).

W

Waler: Horizontal support beam used in concrete formwork.

Winder: L-shaped staircase that used wedge-shaped treads to turn a 90-degree corner.

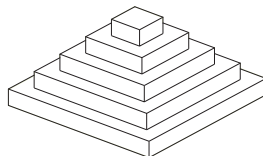
Wright, Frank Lloyd:

(1867–1959) American architect; notable buildings include Fallingwater, the Johnson Wax Building, and the Solomon R. Guggenheim Museum.

Wythe: One-unit-thick vertical layer of masonry.

Z

Ziggurat: Stepped-back pyramid temple.



Chapter 26: Resources

The contents of this book offer a quick-reference reflection of numerous sources of information on architectural design and construction—the tip of a formidable iceberg. Any reader wishing to find out more on a specific topic is advised to consult the listing of sources that follow, which is itself an abridged acknowledgment of a wealth of available information. Many of these sources can be found in a well-stocked architecture firm's in-office library, in the libraries of most schools of architecture, and even in some local libraries. Websites have quickly established themselves as excellent resources for (usually) free information on many subjects, and are especially invaluable for exploring the offerings of product manufacturers or trade-related information. It should be noted, however, that Web-based content and addresses are always subject to change.

Architecture and Design Professions

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Architecture (monthly, USA); www.architectmagazine.com

Architectural Record (monthly, USA); www.archrecord.construction.com

Architectural Review (monthly, UK); www.architectural-review.com

Arquitectura Viva (bimonthly, Spain); www.arquitecturaviva.com

a+u (Architecture and Urbanism) (monthly, Japan); www.japan-architect.co.jp

Casabella (monthly, Italy)

Detail (bimonthly, Germany); www.detail.de

El Croquis (five times yearly, Spain); www.elcroquis.es

JA (Japan Architect) (quarterly, Japan); www.japanarchitect.co.jp

Lotus International (quarterly, Italy); www.editorialelotus.it

Metropolis Magazine (monthly, USA); www.metropolismag.com

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Seventy-plus volumes contain more than 12,000 standards available in print, CD-ROM, and online formats.

www.ansi.org (American National Standards Institute)

www.nist.gov (National Institute of Standards and Technology)

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Christian Müller; Birkhäuser, 2000

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Thomas Herzog et al.; Birkhäuser, 2004

Detail Praxis: Timber Construction—Details, Products, Case Studies

Theodor Hughs et al.; Birkhäuser, 2004

AITC Timber Construction Manual, 5th ed.

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www.awinet.org (Architectural Wood Institute)

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Narendra Taly; McGraw-Hill Professional, 2000

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Roger L Brockenbrough and Frederick S. Merritt; McGraw-Hill Professional, 1999

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William McDonough and Michael Braungart; North Point Press, 2002

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Dedication

For Walter, Matthew, and John

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About the Author

Julia McMorrough is Associate Professor of Practice in Architecture at the Taubman College of Architecture and Urban Planning at the University of Michigan, and partner in studioAPT (Architecture Project Theory). While working professionally in architecture firms in Kansas City, New York, Boston, and Columbus, Ohio, she was the lead designer on a range of projects throughout the country, including libraries, academic buildings, and housing.

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