The Architecture
Reference + Specification Book

Everything Architects Need to Know Every Day

- Computer standards and 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
The Architecture
Reference + Specification Book
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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 and 3, “Structures and Systems,” and “Standards,” address the major aspects of undertaking an architectural project. Topics include basic measurements and geometry, architectural drawing types and conventions, architectural elements, the human scale, parking, building codes, accessibility, structural and mechanical systems, and building components. Part 4, “Compendium,” brings together 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.
During the design process architects often use a foam board model 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 many uses. The two major classifications—soft wood and hard wood—do not necessarily indicate relative hardness, softness, strength, or durability.

COMMON WOOD TERMS

**Board foot**: Unit of measurement for wood quantities, equivalent to 12" x 12" x 1" (305 x 305 x 25.4).

**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.

Movement in performance: See dimensional stability.

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 are 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.

Stain: Substance used to change the color of wood.

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.

Texture: Describes the size and distribution of wood fibers: coarse, fine, or even.

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

<table>
<thead>
<tr>
<th>Nominal Size(^1) inches</th>
<th>Actual Size, Dry(^2) inches (mm)</th>
<th>Actual Size, Green(^3) inches (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(\frac{3}{4}) (19)</td>
<td>(\frac{25}{32}) (20)</td>
</tr>
<tr>
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<td>1 (25)</td>
<td>1(\frac{1}{32}) (26)</td>
</tr>
<tr>
<td>1(\frac{1}{2})</td>
<td>(1\frac{1}{4}) (32)</td>
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<td>2(\frac{1}{16}) (52)</td>
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<td>3(\frac{3}{16}) (90)</td>
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<td>4(\frac{1}{2})</td>
<td>4 (102)</td>
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<td>7</td>
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<td>8</td>
<td>7(\frac{1}{4}) (184)</td>
<td>7(\frac{1}{2}) (190)</td>
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<td>9</td>
<td>8(\frac{1}{4}) (210)</td>
<td>8(\frac{1}{2}) (216)</td>
</tr>
<tr>
<td>10</td>
<td>9(\frac{1}{4}) (235)</td>
<td>9(\frac{1}{2}) (241)</td>
</tr>
<tr>
<td>11</td>
<td>10(\frac{1}{4}) (260)</td>
<td>10(\frac{1}{2}) (267)</td>
</tr>
<tr>
<td>12</td>
<td>11(\frac{1}{4}) (286)</td>
<td>11(\frac{1}{2}) (292)</td>
</tr>
<tr>
<td>14</td>
<td>13(\frac{1}{4}) (337)</td>
<td>13(\frac{1}{2}) (343)</td>
</tr>
<tr>
<td>16</td>
<td>15(\frac{1}{4}) (387)</td>
<td>15(\frac{1}{2}) (394)</td>
</tr>
</tbody>
</table>

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

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

\(^3\)Green (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 2X6 Stud

2X6 Old Growth
Typically, older growth wood is denser, stronger, and more dimensionally stable. 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.

2X6 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 (Weyerhauser), 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:

\[
\text{thickness} \times \text{face width} \times \text{length} \div 144
\]

**1 x 2**
1 board foot = 1" x 2" x 72"

**2 x 4**
1 board foot = 2" x 4" x 18"

**4 x 8**
1 board foot = 4" x 8" x 4 1/2"

**6 x 12**
1 board foot = 6" x 12" x 2"

**8 x 16**
1 board foot = 8" x 16" x 1 1/8"

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**

<table>
<thead>
<tr>
<th>Quarter*</th>
<th>Rough Dimension</th>
<th>Surfaced 1 Side (S1S)</th>
<th>Surfaced 2 Sides (S2S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot; (10)</td>
<td>1/4&quot; (6)</td>
<td>3/16&quot; (5)</td>
<td></td>
</tr>
<tr>
<td>1/2&quot; (13)</td>
<td>1/2&quot; (10)</td>
<td>3/16&quot; (8)</td>
<td></td>
</tr>
<tr>
<td>5/8&quot; (16)</td>
<td>5/8&quot; (16)</td>
<td>7/16&quot; (11)</td>
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</tr>
<tr>
<td>3/4&quot; (19)</td>
<td>5/8&quot; (16)</td>
<td>9/16&quot; (14)</td>
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<tr>
<td>1&quot; (25)</td>
<td>7/8&quot; (22)</td>
<td>11/16&quot; (21)</td>
<td></td>
</tr>
<tr>
<td>1 1/4&quot; (32)</td>
<td>1 1/8&quot; (29)</td>
<td>1 1/16&quot; (27)</td>
<td></td>
</tr>
<tr>
<td>1 1/2&quot; (38)</td>
<td>1 3/8&quot; (35)</td>
<td>1 1/8&quot; (33)</td>
<td></td>
</tr>
<tr>
<td>2&quot; (51)</td>
<td>1 1/16&quot; (46)</td>
<td>1 3/4&quot; (44)</td>
<td></td>
</tr>
<tr>
<td>3&quot; (76)</td>
<td>2 1/16&quot; (71)</td>
<td>2 3/4&quot; (70)</td>
<td></td>
</tr>
<tr>
<td>4&quot; (102)</td>
<td>3 1/16&quot; (97)</td>
<td>3 3/4&quot; (95)</td>
<td></td>
</tr>
</tbody>
</table>

*Hardwood thickness is often referred to in “quarters:” 3/4 equals 1" (25), 5/4 is 1 1/2" (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.

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**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**

Improved C veneer with splits up to $\frac{1}{8}”$ width and knotholes and borer holes up to $\frac{3}{4}” \times \frac{1}{2}”$. Some broken grain is permitted, and synthetic repairs are allowed.

**D**

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.

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**Typical Plywood Construction**

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.
## Wood Types and Characteristics

<table>
<thead>
<tr>
<th>Type</th>
<th>Species</th>
<th>Hardness</th>
<th>Principal Finish Uses</th>
<th>Color</th>
<th>Paint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash white</td>
<td>Fraxinus Americana</td>
<td>H</td>
<td>trim, cabinetry</td>
<td>Creamy white to light brown</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transp.</td>
<td>excellent</td>
</tr>
<tr>
<td>Birch</td>
<td>Betula alleghaniensis</td>
<td>H</td>
<td>trim, paneling, cabinetry</td>
<td>White to dark red</td>
<td>excellent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transp.</td>
<td>good</td>
</tr>
<tr>
<td>Butternut</td>
<td>Juglans cinerea</td>
<td>M</td>
<td>trim, paneling, cabinetry</td>
<td>Pale brown</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transp.</td>
<td>excellent</td>
</tr>
<tr>
<td>Cedar western red</td>
<td>Thuja plicata</td>
<td>S</td>
<td>trim, exterior &amp; interior paneling</td>
<td>Reddish brown nearly white</td>
<td>n/a</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Wood Type</td>
<td>Scientific Name</td>
<td>Hardness</td>
<td>Principal Finish Uses</td>
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<td>------------------</td>
<td>----------</td>
<td>-----------------------------</td>
<td>------------------------</td>
<td>-------</td>
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<tr>
<td>CHESTNUT</td>
<td>Castanea dentate</td>
<td>M</td>
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<tr>
<td>MAHOGANY Hond.</td>
<td>Sweitenia macrophylla</td>
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<td>Rich golden brown</td>
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<tr>
<td>MAPLE</td>
<td>Acer saccharum</td>
<td>VH</td>
<td>trim, paneling</td>
<td>White to reddish brown</td>
<td>excellent</td>
</tr>
<tr>
<td>OAK English brown</td>
<td>Quercus robur</td>
<td>H</td>
<td>veneered paneling, cabinetry</td>
<td>Leathery brown</td>
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### Wood Types and Characteristics

<table>
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<tr>
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<td></td>
</tr>
<tr>
<td>Principal Finish Uses</td>
<td>trim, paneling, cabinetry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>Reddish tan to brown</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Paint</td>
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<td>Transp.</td>
<td>excellent</td>
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<table>
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<td>H</td>
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<td></td>
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<td>Principal Finish Uses</td>
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<tr>
<td>Color</td>
<td>Grayish tan</td>
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<table>
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<td>H</td>
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<tr>
<td>Principal Finish Uses</td>
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<td></td>
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<tr>
<td>Color</td>
<td>Reddish brown w/brown stripes</td>
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<tr>
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<table>
<thead>
<tr>
<th></th>
<th>Pinus strobes</th>
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<tbody>
<tr>
<td>Hardness</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Principal Finish Uses</td>
<td>trim, frames, paneling, cabinetry</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>Creamy white to pink</td>
<td></td>
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<tr>
<td>Paint</td>
<td>good</td>
<td>Transp.</td>
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</table>
S = soft; M = medium; H = hard; VH = very hard; n/a = not normally used
Finishes: Painted and Transparent

<table>
<thead>
<tr>
<th>Hardness</th>
<th>Principal Finish Uses</th>
<th>Color</th>
<th>Paint</th>
<th>Finish</th>
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<tr>
<td>ROSEWOOD  Dalbergia nigra</td>
<td>VH</td>
<td>veneered paneling, cabinetry</td>
<td>Mixed red/brown/black</td>
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<tr>
<td>TEAK Tectona grandis</td>
<td>H</td>
<td>trim, paneling, cabinetry</td>
<td>Tawny yellow to dark brown</td>
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<td>WALNUT Juglans</td>
<td>H</td>
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<td>Chocolate brown</td>
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<td>ZEBRAWOOD Brachystegaea fleuryana</td>
<td>H</td>
<td>trim, paneling, cabinetry</td>
<td>Gold streaks on dark brown</td>
<td>n/a</td>
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</tbody>
</table>
WOOD JOINERY

Edge Joints

Simple Butt Joint
Back Batten
Tongue and Groove

End Joints

Lap
Shiplap
Fillet

Splice
Squared Splice
Scarf
Half Lap
Finger

Right-Angle Joints (Miters)

Plain
Wood Spline
Quirk
Tongue and Groove
Shoulder
Right-Angle Joints

- Butt Joint
- Right-Angle Joints (Dovetail)
  - Rabbet
  - Dovetail Dado
  - Half Blind
  - Ship
  - Blind

Butt Joint

Right-Angle Joints (Mortise and Tenon)

- Half Blind
- Ship
- Blind

Dado

Right-Angle Joints (Lap)

- Dado
- Middle Lap
- End Lap
- Miter Half Lap

Dado and Rabbet

Dado and Rabbet
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

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 3/8" (10) and 1/2" (13).

### Standard Sizes

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>Joint Thickness in. (mm)</th>
<th>Brick Thickness = T in. (mm)</th>
<th>Brick Height = H in. (mm)</th>
<th>Brick Length = L in. (mm)</th>
<th>Vertical Coursing = (C) in. (mm)</th>
<th>Nominal T in. (mm)</th>
<th>Nominal H in. (mm)</th>
<th>Nominal L in. (mm)</th>
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<tbody>
<tr>
<td>Standard Modular</td>
<td>3/8 (10)</td>
<td>3 7/8 (92)</td>
<td>2 7/4 (57)</td>
<td>7 5/8 (194)</td>
<td>3C = 8 (203)</td>
<td>4 (102)</td>
<td>2 2/3 (68)</td>
<td>8 (203)</td>
</tr>
<tr>
<td></td>
<td>1/2 (13)</td>
<td>3 1/2 (89)</td>
<td>2 1/4 (56)</td>
<td>7 1/2 (191)</td>
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<td>Norman</td>
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<td>3C = 8 (203)</td>
<td>4 (102)</td>
<td>2 2/3 (68)</td>
<td>12 (305)</td>
</tr>
<tr>
<td></td>
<td>1/2 (12.7)</td>
<td>3 1/2 (89)</td>
<td>2 1/4 (56)</td>
<td>11 1/2 (292)</td>
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<td></td>
<td></td>
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<td>Roman</td>
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<td>1 7/8 (41)</td>
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<td>2C = 4 (102)</td>
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<td>2 (51)</td>
<td>12 (305)</td>
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<td></td>
<td>1/2 (12.7)</td>
<td>3 1/2 (89)</td>
<td>1 7/8 (41)</td>
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</tr>
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<td>Engineer Modular</td>
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<td>2 1/8 (57)</td>
<td>7 5/8 (194)</td>
<td>5C = 16 (406)</td>
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<td>3 7/8 (81)</td>
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<td></td>
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<td>3 1/2 (89)</td>
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<td>Economy</td>
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<td>3 7/8 (92)</td>
<td>7 5/8 (194)</td>
<td>1C = 4 (102)</td>
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<td>4 (102)</td>
<td>8 (203)</td>
</tr>
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<td>3 1/2 (89)</td>
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<td>Utility</td>
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<td>3 7/8 (92)</td>
<td>11 7/8 (295)</td>
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<td>3 7/8 (92)</td>
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<tr>
<td>SCR</td>
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<td>3C = 8 (203)</td>
<td>6 (152)</td>
<td>2 2/3 (68)</td>
<td>12 (305)</td>
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### Preferred SI Dimensions for Masonry

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<thead>
<tr>
<th>Nominal Height (H) x Length (L)</th>
<th>Vertical Coursing (C)</th>
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<tbody>
<tr>
<td>50 x 300 mm</td>
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<tr>
<td>67 x 200 mm</td>
<td>[3C = 200]</td>
</tr>
<tr>
<td>67 x 300 mm</td>
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</tr>
<tr>
<td>75 x 200 mm</td>
<td>[4C = 300]</td>
</tr>
<tr>
<td>75 x 300 mm</td>
<td></td>
</tr>
<tr>
<td>80 x 200 mm</td>
<td>[5C = 400]</td>
</tr>
<tr>
<td>80 x 300 mm</td>
<td></td>
</tr>
<tr>
<td>100 x 200 mm</td>
<td>[1C = 100]</td>
</tr>
<tr>
<td>100 x 300 mm</td>
<td></td>
</tr>
<tr>
<td>100 x 400 mm</td>
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</tr>
<tr>
<td>133 x 200 mm</td>
<td>[3C = 400]</td>
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<tr>
<td>133 x 300 mm</td>
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<tr>
<td>133 x 400 mm</td>
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</tr>
<tr>
<td>150 x 300 mm</td>
<td>[2C = 300]</td>
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<tr>
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</tr>
<tr>
<td>200 x 200 mm</td>
<td>[1C = 200]</td>
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<tr>
<td>200 x 300 mm</td>
<td></td>
</tr>
<tr>
<td>200 x 400 mm</td>
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<tr>
<td>300 x 300 mm</td>
<td>[1C = 300]</td>
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#### Acceptable Length Substitutions for Flexibility

<table>
<thead>
<tr>
<th>Length</th>
<th>Substitutions</th>
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<tbody>
<tr>
<td>200 mm</td>
<td>(100 mm)</td>
</tr>
<tr>
<td>300 mm</td>
<td>(100 mm, 150 mm, 200 mm, 250 mm)</td>
</tr>
<tr>
<td>400 mm</td>
<td>(100 mm, 200 mm, 300 mm)</td>
</tr>
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</table>

### 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

<table>
<thead>
<tr>
<th>no. of courses</th>
<th>9'-4&quot; (2.845)</th>
<th>no. of courses</th>
<th>18'-8&quot; (5.690)</th>
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</thead>
<tbody>
<tr>
<td>42</td>
<td>8'-8&quot; (2.642)</td>
<td>84</td>
<td>18'-0&quot; (5.486)</td>
</tr>
<tr>
<td>41</td>
<td>8'-0&quot; (2.438)</td>
<td>83</td>
<td>17'-4&quot; (5.283)</td>
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<tr>
<td>40</td>
<td>7'-4&quot; (2.235)</td>
<td>82</td>
<td>16'-8&quot; (5.080)</td>
</tr>
<tr>
<td>39</td>
<td>6'-8&quot; (2.032)</td>
<td>81</td>
<td>16'-0&quot; (4.877)</td>
</tr>
<tr>
<td>38</td>
<td>6'-0&quot; (1.829)</td>
<td>79</td>
<td>15'-4&quot; (4.674)</td>
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<tr>
<td>37</td>
<td>5'-4&quot; (1.626)</td>
<td>78</td>
<td>14'-8&quot; (4.470)</td>
</tr>
<tr>
<td>36</td>
<td>4'-8&quot; (1.422)</td>
<td>77</td>
<td>14'-0&quot; (4.267)</td>
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<tr>
<td>35</td>
<td>4'-0&quot; (1.219)</td>
<td>76</td>
<td>13'-4&quot; (4.064)</td>
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<tr>
<td>34</td>
<td>3'-4&quot; (1.016)</td>
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<td>12'-8&quot; (3.861)</td>
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<td>33</td>
<td>2'-8&quot; (0.813)</td>
<td>72</td>
<td>12'-0&quot; (3.658)</td>
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<tr>
<td>32</td>
<td>2'-0&quot; (0.610)</td>
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<td>11'-4&quot; (3.454)</td>
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<tr>
<td>31</td>
<td>1'-4&quot; (0.406)</td>
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<td>10'-8&quot; (3.251)</td>
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<tr>
<td>30</td>
<td>8&quot; (0.203)</td>
<td>68</td>
<td>10'-0&quot; (3.048)</td>
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<td>29</td>
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<td>44</td>
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<td>5</td>
<td></td>
<td>43</td>
<td></td>
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</tbody>
</table>
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

- Concave
- V-shaped
- Flush
- Struck
- Weathered
- Raked

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.

Colors in various shades shown.
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 x H x L)**

**4” Block**
- 4 x 8 x 16 (102 x 203 x 406)
- 3 5/8 x 7 5/8 x 15 5/8 (92 x 194 x 397)
- 4 x 8 x 8 (102 x 203 x 203) nominal

**6” Block**
- 6 x 8 x 16 (152 x 203 x 406)
- 5 5/8 x 7 5/8 x 15 5/8 (143 x 194 x 397)
- 6 x 8 x 8 (152 x 203 x 203)

**8” Block**
- 8 x 8 x 16 (203 x 203 x 406)
- 7 5/8 x 7 5/8 x 15 5/8 (194 x 194 x 397)
- 8 x 8 x 8 (203 x 203 x 203)

**10” Block**
- 10 x 8 x 16 (254 x 203 x 406)
- 9 5/8 x 7 5/8 x 15 5/8 (244 x 194 x 397)
- 10 x 8 x 8 (254 x 203 x 203)

**12” Block**
- 12 x 8 x 16 (305 x 203 x 406)
- 11 5/8 x 7 5/8 x 15 5/8 (295 x 194 x 397)
- 12 x 8 x 8 (305 x 203 x 203)

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.

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.

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/m$^3$)

**Medium:** Made from concrete weighing 105–25 pcf (1 680–2 000 kg/m$^3$)

**Light:** Made from concrete weighing 105 pcf (1 680 kg/m$^3$) or less
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.

- **Type I:** Normal; for general use
- **Type IA:** Normal, air-entraining
- **Type II:** Moderately sulfate resistant; ideal for use in bridges and pilings; also used when heat build-up is an issue
- **Type IIA:** Moderately sulfate resistant, air-entraining
- **Type III:** Quick hardening with high early strength; used mostly in winter and for rush jobs
- **Type IIIA:** High early strength, air-entraining
- **Type IV:** Slow hardening and low heat producing; used when the amount and rate of heat generation must be minimized
- **Type V:** Highly sulfate resistant; used in high water and soils with high alkali content

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, 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 site-cast 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. Rebar commonly ranges in size from #3 to #18 (diameter in eighths of an inch), and its size, spacing, and number are determined by the sizes and natures of the columns, slabs, and beams.

Casting floor slabs, slabs on grade, plates, walls, columns, beams, and girders all involves the use of formwork, which is often plywood but can also be metal or fiberboard. Standardization of column and beam sizes 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.

Re-bar

#8

#3

Re-bar
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.
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 seawater, 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

<table>
<thead>
<tr>
<th>Series</th>
<th>Alloying Element</th>
<th>Wrought</th>
<th>Series</th>
<th>Alloying Element</th>
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<tr>
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<td>100.0</td>
<td>pure aluminum</td>
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<tr>
<td>6000</td>
<td>magnesium and silicon</td>
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<td></td>
</tr>
<tr>
<td>7000</td>
<td>zinc</td>
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</tr>
<tr>
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</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Series</th>
<th>Alloying Element</th>
</tr>
</thead>
</table>
| 1st digit is series no.; 2nd/3rd are arbitrary identifiers; no. after decimal is casting if 0, ingot if 1 or 2

<table>
<thead>
<tr>
<th>Alloying Element</th>
<th>Cast</th>
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<tbody>
<tr>
<td>pure aluminum</td>
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<tr>
<td>copper</td>
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<td>manganese</td>
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</table>

<table>
<thead>
<tr>
<th>Other elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>tin</td>
</tr>
<tr>
<td>other elements</td>
</tr>
</tbody>
</table>
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, 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, 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.

Gauges and Mil

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

<table>
<thead>
<tr>
<th>Gauge (ga.)</th>
<th>Standard Steel (in. (mm))</th>
<th>Galvanized Steel (in. (mm))</th>
<th>Aluminum (in. (mm))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.2391 (6.073)</td>
<td></td>
<td>0.2294 (5.827)</td>
</tr>
<tr>
<td>4</td>
<td>0.2242 (5.695)</td>
<td></td>
<td>0.2043 (5.189)</td>
</tr>
<tr>
<td>5</td>
<td>0.2092 (5.314)</td>
<td></td>
<td>0.1819 (4.620)</td>
</tr>
<tr>
<td>6</td>
<td>0.1943 (4.935)</td>
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<td>0.1620 (4.115)</td>
</tr>
<tr>
<td>7</td>
<td>0.1793 (4.554)</td>
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<td>0.1443 (3.665)</td>
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<td>0.1644 (4.176)</td>
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<td>0.1285 (3.264)</td>
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<tr>
<td>9</td>
<td>0.1495 (3.797)</td>
<td>0.1532 (3.891)</td>
<td>0.1144 (2.906)</td>
</tr>
<tr>
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<td>0.1019 (2.588)</td>
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<tr>
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<td>0.1196 (3.030)</td>
<td>0.1233 (3.132)</td>
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<td>0.0120 (0.305)</td>
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<td>0.0100 (0.254)</td>
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<td>0.0089 (0.226)</td>
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<tr>
<td>35</td>
<td>0.0075 (0.191)</td>
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<td>0.0056 (0.142)</td>
</tr>
<tr>
<td>36</td>
<td>0.0067 (0.170)</td>
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</table>
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 \( \frac{1}{100}'' \)) + S, T, U, or F designation + flange width (in \( \frac{1}{100}'' \)) + 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 \( \frac{5}{8}'' \) (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: 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.
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 x 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

- **1/4" (6.4)**
  - backing board, some acoustic work
- **5/16" (8)**
  - used for manufactured housing
- **3/8" (9.5)**
  - used in double-layer finishes
- **1/2" (12.7)**
  - used for stud spacings up to 24" (610), most common thickness
- **5/8" (16)**
  - used when additional fire resistance or structural stiffness are required
- **1" (25.4)**
  - coreboard used for shaft walls

### 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

3 5/8”  STC: 40–44: (1 layer 5/8” GWB on either side of 1 5/8” metal studs; face layers of 1/2” GWB)

4 7/8”  STC: 40–44: (1 layer 7/8” type X GWB on either side of 3 5/8” metal studs)

5 1/2”  STC: 45–49: (1 layer 5/8” type X GWB on either side of 3 5/8” metal studs; one face layer 5/8” GWB applied with laminating compound; 3 1/2” glass fiber insulation in cavity)

6 1/4”  STC: 55–59: (2 layers 7/8” type X GWB on either side of 3 5/8” metal studs; one face layer 1/4” GWB applied with laminating compound; 1 1/2” glass fiber insulation in cavity)

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-resistant 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**

**Three-Coat Plaster**

- **metal lath:** expanded metal or mesh (steel)
- **scratch coat:** troweled on roughly and scratched to create a scored surface for the next coat
- **brown coat:** applied over the lath and hardened scratch coat; leveled with a long straightedge
- **finish coat:** very thin (1/16") outer layer that may be smoothed or textured.

Total thickness of all three layers is roughly 5/8" (16) and provides good fire resistance and durability.

**Plaster over Gypsum Lath**

**Two- or Three-Coat Plaster**

- **gypsum lath:** hardened gypsum plaster core with an outer sheet of absorbent paper to adhere to the plaster and water-resistant inner layers to protect the core; comes in 16" x 48" (406 x 1219) boards in 3/8" (10) and 1/2" (13) thicknesses.
- **brown coat**
- **finish coat**

If gypsum is attached to studs, it is rigid enough to require only two coats of plaster; solid plaster walls (plaster on either side of gypsum, with no studs) require three coats. Total thickness of the plaster on one side is 1/2" (13).
**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 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 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.
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.

Ceramic Tile and Quarry Tile

For thick-set installation, tiles are laid on ±1” (25 mm) portland cement mortar. For thin-set installation, tiles are laid on ±1/8” (3 mm) 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).

Resilient Flooring

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

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.

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.
CEILINGS

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.

<table>
<thead>
<tr>
<th>Common Panel Sizes in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 x 12 (305 x 305)</td>
</tr>
<tr>
<td>12 x 24 (305 x 610)</td>
</tr>
<tr>
<td>24 x 24 (610 x 610)</td>
</tr>
<tr>
<td>24 x 48 (610 x 1 219)</td>
</tr>
<tr>
<td>24 x 60 (610 x 1 524)</td>
</tr>
<tr>
<td>20 x 60 (508 x 1 524)</td>
</tr>
<tr>
<td>30 x 60 (762 x 1 524)</td>
</tr>
<tr>
<td>60 x 60 (1 524 x 1 524)</td>
</tr>
<tr>
<td>48 x 48 (1 219 x 1 219)</td>
</tr>
</tbody>
</table>

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.
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 5: 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.

![Beam and Column Diagram]

**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.

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

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**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.

Deep Foundation
Transfers the building’s load at a point well below the substructure.

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

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.

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’ (1829) 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" nominal (102) 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 preservatively 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).
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.
Moment Frame
Rigid framework resists lateral forces

Braced Frame
Internal structure braces light frame

Tube
Exterior walls contribute to structural stability
PRECAST CONCRETE FRAMING

Hollow Core Slab Types

- **Type A**: 8'-0" (2.438)
- **Type B**: 10'-0" (3.048)
- **Type C**: 4'-0" (1.219)
- **Type D**: 5'-0" (1.524)
- **Type E**: 4'-0" (1.219)
- **Type F**: 1'-4" (406)

**Stemmed Deck, Double Tee (DT)**

- **Type A**: 8'-0" (2.438)
- **Type B**: 10'-0" (3.048)

**Stemmed Deck, Single Tee (ST)**

- **Type A**: 8'-0" (2.438)
- **Type B**: 10'-0" (3.048)

**Solid Flat Slab**

- **Stemmed Deck, Double Tee (DT)**

**Hollow Core Slab**

- **Type A**: 8'-0" (2.438)
- **Type B**: 10'-0" (3.048)

**Slab Detail**

- topping
- welded wire fabric
- prestressing strands

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66
**Stemmed Deck DT Framing System**

- **Beam-to-Column Connection**
- **precast column**
- **inverted tee beam**
- **stemmed deck (double tee)**
- **Deck to-Bearing Wall Connection**
- **precast bearing wall**

**Hollow Slab Framing System**

- **Beam-to-Column Connection**
- **hollow core slab**
- **precast column**
- **rectangular beam**
- **precast bearing wall**

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**Structural Systems**
### Structural Steel Shape Designations

<table>
<thead>
<tr>
<th>Shape</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Wide-flange hot-rolled, doubly symmetric wide-flange shapes used as beams and columns</td>
</tr>
<tr>
<td>HP</td>
<td>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</td>
</tr>
<tr>
<td>S</td>
<td>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</td>
</tr>
<tr>
<td>M</td>
<td>Miscellaneous doubly symmetrical shapes that cannot be classified as W or HP shapes</td>
</tr>
<tr>
<td>L</td>
<td>Angle equal leg and unequal leg angles</td>
</tr>
<tr>
<td>C</td>
<td>American Standard channel hot-rolled channels produced in accordance with AASM dimensional standards</td>
</tr>
<tr>
<td>MC</td>
<td>Channel hot-rolled channels from miscellaneous shape</td>
</tr>
<tr>
<td>WT</td>
<td>Structural tee hot-rolled tees cut or split from W shapes</td>
</tr>
<tr>
<td>ST</td>
<td>Structural tee hot-rolled tees cut or split from S shapes</td>
</tr>
<tr>
<td>MT</td>
<td>Structural tee hot-rolled tees cut or split from M shapes</td>
</tr>
<tr>
<td>TU</td>
<td>Tube hollow structural steel members shaped like a square or rectangle; used as beams or columns, or in bracing</td>
</tr>
</tbody>
</table>

*AASM: Association of American Steel Manufacturers*
Steel Shape Examples

Wide-flange
HP12X84
12 = nominal depth (in.);
84 = weight per foot of length (lb.)

American Standard
S8X18.4
8 = nominal depth (in.);
18.4 = weight per foot of length (lb.)

Miscellaneous
M10X8
10 = nominal depth (in.);
8 = weight per foot of length (lb.)

Wide-flange
W8X67
8 = nominal depth (in.);
67 = weight per foot of length (lb.)

Angle
L6X4X7/8
6 and 4 = nominal depths of legs (in.);
7/8 = nominal thickness of legs (in.)

Channel
MC7X22.7
7 = nominal depth (in.);
22.7 = weight per foot of length (lb.)

ST15X3.75

Structural Tees
WT25X95

Structural Systems

Structural Systems
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 Connection: 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.
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**
- **Warren**
- **Fink**
- **Scissors**
- **Pitched Pratt**
- **Flat Pratt**
- **Pitched Howe**
- **Flat Howe**
- **Bowstring**
- **Modified Bowstring**
Chapter 6: 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.

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**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.

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

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

**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.

**Air handling unit (AHU):** Equipment including a fan or blower, heating and/or cooling coils, regulator controls, condensate drain pans, and air filters.

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

![Diagram of fan coil unit system](image-url)

**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

**Horizontal FCU**
Ceiling-hung, may be within soffit or exposed
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 DUCT SYSTEM — Typical residential heating and cooling system

FORCED AIR FURNACE — Typical residential heating and cooling system
SUSTAINABLE DESIGN

The issue of sustainable design shines a brighter and brighter 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.

LEED DESIGN

The LEED (Leadership in Energy and Environmental Design) Green Building Rating System is a voluntary, nationally recognized standard for developing high-performance, sustainable buildings. LEED was developed by the U.S. Green Building Council (USGBC), comprising members from all walks of the building community. LEED’s progressive levels of certification—Certified, Silver, Gold, and Platinum—reflect various levels of building performance and sustainability. Projects wishing for certification must register and submit documentation for review by LEED.

Among LEED’s primary goals is to establish a common standard of measuring sustainability and to promote integrated design practices while raising awareness of the benefits of “green building.” A green building is one that uses energy in an efficient and ecologically aware way and that minimizes negative impact on the health of its users.

DECLARATION OF INTERDEPENDENCE

In 1993 the Union Internationale des Architectes (UIA) and the AIA signed a “Declaration of Interdependence for a Sustainable Future,” which made commitment to environmental and social sustainability a core issue of practice and professional responsibility. In addition to bringing the existing built environment up to established sustainability standards, it also stresses the importance of developing and refining practices, procedures, products, services, and standards to enable implementation of sustainable design, as well as educating all members of the building community, clients, and the general public about the benefits of and need for sustainable approaches to design.

Similarly, a coalition of architects, landscape architects, and engineers formed the Interprofessional Council on Environmental Design (ICED) as a multidisciplinary partnership committed to the common goal of sustainability.
**TERMINOLOGY**

**Adaptive reuse:** Changing a building’s function in response to the changing needs of its users.

**Black water:** Waste water from toilets, kitchen sinks, and dishwashers.

**Brownfields:** Abandoned or underused industrial and commercial sites where environmental contamination hampers redevelopment.

**Chlorofluorocarbons (CFCs):** Chemical compounds used as refrigerants and in aerosol and believed to be responsible for depleting the ozone layer.

**Conservative disassembly:** Counterproposal to destructive demolition of buildings (where most of the building’s material is crushed into waste) that promotes varying levels of salvaging materials from a building before it is demolished.

**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.

**Hydrochlorofluorocarbons (HCFCs):** Alternative to CFCs, with shorter atmospheric lifetimes that deliver less reactive chlorine to the ozone layer, though alternatives to both are still being sought.

**Hydronic heating:** In-floor hot-water heating system where hot water is pumped through a thermal mass floor that absorbs the heat, evenly radiating it over time.

**Life cycle analysis (LCA):** Quantifiable assessment of all stages in the life cycle of a product system (resource extraction, manufacturing, on-site construction, occupancy/maintenance, demolition, and recycling/reuse/disposal) used to determine the impact of the material or system via four phases: initiation, inventory analysis, impact assessment, and improvement assessment.

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

**Photovoltaics:** Solar panels used to harness the sun’s energy into electricity that can be stored in batteries and used to power an electrical system.

**Renewable:** Resource that comes into being through a relatively quick natural process.

**Upstream/downstream:** Cause-and-effect example that what one does upstream affects what happens downstream.

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

**GUIDELINES**

Design for energy efficiency through the use of high levels of insulation and high-performance windows.

Design buildings with renewable energy sources such as passive solar heating, daylighting, and natural cooling, whenever possible.

Design for standard sizes to minimize material waste.

Avoid materials containing CFCs and HCFCs.

Use salvaged or recycled building materials such as heavy timbers, millwork, and plumbing fixtures.

When possible, use locally produced materials to cut down on transportation costs and pollution.

Use materials with low embodied energy. Rules of thumb: lumber, brick, concrete, and fiberglass have relatively low embodied energies, whereas timber, ceramics, and steel are higher, and glass, plastic and aluminum are very high. Often a higher embodied energy level can be justified if it contributes to lower operating energy, such as when large amounts of thermal mass can significantly reduce heating and cooling needs in well-insulated passive solar buildings.

Avoid off-gassing materials with high levels of VOCs.

Reduce energy and water consumption.

Minimize external pollution and environmental impact.

Reduce resource depletion.

Minimize internal pollution and negative effects on health.
Chapter 7: Electrical Systems

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.

LIGHTING TERMINOLOGY

Ambient lighting: General lighting for an entire space.

Ampere (amp): Unit of measuring electrical current, equal to one coulomb per second.

Baffle: Opaque or translucent element that controls the distribution of light at certain angles.

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.

Coefficient of utilization (CU): Ratio of a luminaire’s lumens on a surface to the lamp’s production of lumens.

Color rendering index (CRI): Scale of 1 to 100 determining a light source’s effect on the color appearance of an object, compared to the color appearance under a reference light source. A rating of 1 indicates maximum color shift and 100 indicates no color shift.

Color temperature: Specification of the color appearance of a light source, measured in Kelvins. Color temperatures below 3,200K may be considered warm and those above 4,000K may be considered cool.

Compact fluorescent: Small fluorescent lamp used as an alternative to incandescent light. Known also as twin-tube, PL, CFL, or BIAx.

Daylight compensation: Energy-saving photocell-controlled dimming system that reduces the output of lamps in the presence of daylight.

Diffuser: Translucent piece of plastic or glass that shields a fixture’s light source, scattering and diffusing the transmitted light.

Direct glare: Glare resulting from direct view of light source.

Downlight: Ceiling fixture that can be fully recessed, semirecessed, or ceiling mounted, in which most of the light is directed downward. Variously called a can, high-hat, or recessed downlight.

Electroluminescent: Lighting technology that provides uniform brightness and long lamp life while consuming very little energy, making it ideal for use in exit signs.

Energy: Electric power unit, measured in kilowatt hours (kwh).

Fluorescent: Tube filled with argon, krypton, or another inert gas. An electrical current applied to the gas produces an arc of ultraviolet radiation that causes the phosphors inside the lamp wall to radiate visible light.
Foot-candle (FC): English unit of measuring the light level on a surface, equal to one lumen per square foot.

High-intensity discharge (HID): Mercury vapor, metal halide, high-pressure sodium, and low-pressure sodium light sources.

High output (HO): Lamp or ballast that operates at high currents and produces more light.

IALD: International Association of Lighting Designers.


Illuminance: Luminous flux per unit area on a surface at any given point. Commonly called light level, it is expressed in foot-candles or lux.

Incandescent: Bulb that contains a conductive wire filament through which current flows. This is the most common type of light source.

Lamp: Light-producing component inside a bulb.

Lay-in troffer: Fluorescent fixture that lays into a ceiling grid.

Light-emitting diode (LED): Semiconductor diode that emits light when voltage is applied to it; used in electronic displays such as signage.

Lens: Transparent or translucent element that alters the directional characteristics of light as it passes through.

Lumen: Unit of measuring the total light output of a lamp.

Luminaire: Complete lighting unit (also called a fixture) consisting of lamp(s) and the parts required to distribute the light, hold the lamps, and connect them to a power source.

Luminance: Luminous intensity per unit area of a surface. It is expressed in candelas (metric) or footlamberts (customary).

Lux (LX): Metric unit of illuminance measure. One lux = 0.093 foot-candles; one foot-candle = 10.76 lux.

Nadir: Reference direction directly below (0 degrees) a luminaire.

Opaque: Of material, transmitting no visible light.

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

Reflectance: Ratio of light reflected from a surface to the light incident on the surface. (The reflectance of a dark carpet is 20 percent and that of a clean white wall is 50 to 60 percent.)

Reflector: Element of a luminaire that shrouds the lamps, redirecting some of the light they emit.

Refractor: Element of a luminaire that redirects light output by bending the waves of light.

Room cavity ratio (RCR): Ratio of room dimensions used to determine how light will interact with the room’s surfaces.

T12 lamp: Industry standard designation for a fluorescent lamp that is 12/8” in diameter. T8 and T10 are similarly named.

Translucent: Of material, transmitting some visible light.

Transparent: Of material, transmitting most visible light incident on it.

Troffer: Recessed fluorescent fixture (from trough plus coffer).

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

Underwriters' Laboratories (UL): Independent organization that tests products for public safety.
LIGHT FIXTURES AND TYPES

- recessed fluorescent troffer
- track lighting
- fluorescent fixture in a cove (provides indirect light source)
- table lamp
- floor lamp
Electrical Systems

- semirecessed downlight
- recessed downlight
- recessed wall washer (provides even level of illumination on a wall)
- pendant
- wall sconce
- desk lamp (provides task lighting)
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.

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.

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.

T12
12/8” dia. (1-1/2”)

T8
8/8” dia. (1”)

T5
5/8” dia.

T2
2/8” dia. (1/4”)

Contact pins
Electrode
Mercury
Glass tube (sealed)
Phosphor coating (internal)
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 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 (2-3/8" 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 (1-3/8" 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 (3-3/4" dia.), PAR 38 (4-3/4" dia.), and PAR 64 (8" dia.)
Chapter 8: Plumbing and Fire Protection

Common Bathroom Pipe Layout

- Hot water supply
- Cold water supply
- Tub trap
- Vent stack (through roof)
- Tub supply
- Tub drain
- Shower supply
- Tub
- Drain
- Hot to sink
- Cold to sink
- Waste
PIPES

SUPPLY

**Water Supply:**
white plastic (PVC)
1/2” - 1” dia.

**Water or Gas Supply:**
copper
1/2” - 1” dia.

**Water Supply:**
galvanized iron
1/2” - 1” dia.

**Gas Supply:**
black iron
1/2” - 1” dia.

DRAIN

**Drain and Vent:**
black plastic
1-1/2” + dia.

**Drain and Vent:**
cast iron
1-1/2” + dia.
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-resistant 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.
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### Sprinkler Head Distribution Types

- **Pendant**
  - Hangs from ceiling and sprays water downward.

- **Side Wall**
  - When mounting sprinklers to ceiling is not possible, they may be mounted to walls. Two deflectors spray water out and back toward the wall.

- **Concealed Pendant**
  - Sprinkler head is recessed in ceiling and covered with a decorative cap, which falls off once ambient air temperatures reach a temperature of 20°F prior to sprinkler activation. Water sprays downward in a circular pattern.

- **Upright**
  - Mounted atop supply pipe, upright sprinkler heads are used in locations where ceiling mounting is not possible, or obstructions prevent adequate coverage (such as mechanical or storage rooms).

### Actuation Methods

- **Fusible Link**: two pieces of metal are fused by a heat-sensitive metal alloy, which, when it reaches its melting point, causes the two metals to separate and activate the sprinkler.

- **Glass Bulb**: a glass bulb filled with liquid expands and bursts when it has reached a sufficient temperature, causing the pip cap to fall away and actuate the sprinkler. The color of liquid indicates the temperature range that will cause the liquid to expand.

### Response Temperatures (per National Fire Protection Association 13)

<table>
<thead>
<tr>
<th>classification</th>
<th>sprinkler activation temp.</th>
<th>glass bulb color</th>
<th>fusible link color</th>
</tr>
</thead>
<tbody>
<tr>
<td>ordinary</td>
<td>135°F - 170°F</td>
<td>Orange (135°F) Red (155°F)</td>
<td>Black; no color</td>
</tr>
<tr>
<td>intermediate</td>
<td>175°F - 225°F</td>
<td>Yellow (175°F) Green (200°F)</td>
<td>White</td>
</tr>
<tr>
<td>high</td>
<td>250°F - 300°F</td>
<td>Blue</td>
<td>Blue</td>
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<tr>
<td>extra high</td>
<td>325°F - 375°F</td>
<td>Purple</td>
<td>Red</td>
</tr>
<tr>
<td>very extra high</td>
<td>400°F - 475°F</td>
<td>Black</td>
<td>Green</td>
</tr>
<tr>
<td>ultra high</td>
<td>500°F - 575°F</td>
<td>Black</td>
<td>Orange</td>
</tr>
</tbody>
</table>
Chapter 9: Enclosure Systems

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.
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.

(Images of diagrams showing flashing in different locations)
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)

Steep slope
Low slope
Flat
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.

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 polish.

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

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.

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: 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" 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
WINDOWS AND GLAZING

Caulk: Sealant that fills a void.

Condensation: Process in which water vapor from the air, coming into contact with a cold surface like glass, condenses and forms a foggy effect.

Convection: Transfer of heat by air movement.

Desiccant: Porous crystalline substance used in the air space of insulating glass units to absorb moisture and solvent vapors from the air.

Dew point: Calculated temperature at which water vapor will condense.

Dual-sealed units: Sealed insulating glass units with a primary seal and a secondary outer seal.

Emissivity: Relative ability of a surface to absorb and emit energy in the form of radiation.

Gas-filled units: Insulating glass units with a gas instead of air in the air space, used to decrease the thermal conductivity U value.

Glaze: To fit a window frame with glass.

Grille: Decorative grid installed on or between glass lites, meant to look like a muntin bar, but without actually dividing the glass.

Light (or lite): Unit of glass in a window or door, enclosed by the sash or muntin bars. Sometimes spelled lite to avoid confusion with visible light; also called a pane.

Mullion: Horizontal or vertical member holding together two adjacent lites of glass or sash.

Muntin bar: Strip that separates panes of glass in a sash.

Passive solar gain: Solar heat that is captured naturally as it passes through a material.

R-value: Measure of the overall resistance to heat transmission due only to the difference in air temperature on either side of the material. See U-value.

Radiation: Process by which heat is emitted from a body through open space, as in sunlight.

Sash: Frame that holds glass lites and into which glass products are glazed.

Shading coefficient: Relative measurement of the total amount of solar energy that enters a building space through its glass, as the ratio of the solar heat gain through a specific glass product to the solar heat gain through a lite of 1/8” (3) clear glass. Glass of 1/8” (3) thickness is given a value of 1.0. The lower the shading coefficient number, the lower the amount of solar heat transmitted.

Tempered glass: Specially heat-treated high-strength safety glass.

Thermal performance: Ability of a glass unit to perform as a barrier to the transfer of heat.

Total solar energy: Total solar spectrum composed of UV, visible, and near infrared wavelengths.

U-value: Measure of thermal conductance; the reciprocal of R-value.

Ultraviolet (UV): Type of radiation in wavelengths shorter than those of visible light and longer than those of X rays.

Visible light: Portion of solar energy detected by the human eye as light.
WINDOW TYPES

- Fixed
- Double-hung
- Sliding
- Single-hung
- Casement
- Awning
- Hopper
- Sliding Doors
- Skylight
- French Doors
- Terrace Door
- Roof Window
Window Sizing

A typical chart from a window manufacturer’s catalog depicts stock sizes and types of windows (in feet and inches). Mas Opg (masonry opening) is the opening that must be provided for a brick, block, or stone wall; Rgh Opg (rough opening) is the opening required for typical stud walls; Sash Opg (sash opening) is the size of the window itself; and Glass Size is the size of the glass.

Mas Opg 2'-8 1/2"
Rgh Opg 2'-6 3/8"
Sash Opg 2'-4"
Glass Size 24"

3'-6 1/2"
3'-5 3/4"
3'-2"
16"

4'-2 1/2"
4'-1 3/4"
3'-10"
20"

Double-hung Window
**Punched opening**

**Window wall**
Window system ‘rests’ on floor

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

**Curtain wall**
Spandrel panel covers edge of floor
WINDOW CONSIDERATIONS

**casement**
- interior screen
- casement + fixed
- interior screen

**slider**
- exterior screen
- or interior screen

**double hung**
- exterior screen
- fixed
- no screen

**fixed**
- interior screen
- fixed
- tempered
- max. size 72 sf. for single insulated unit (typ.)

*Interior*
- fixed tempered (begins below 24” AFF)

*Hoppers*
- tempered or solid if under 24” AFF (check local codes)

(space above windows ideal for window treatments)

(no wall space for window treatments if windows end at ceiling)
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, which refers to any silicate glass with a composition of at least 5 percent boric oxide, has greater resistance to thermal changes and chemical corrosion.

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.

Glass Thickness

Sheet size, wind, and other loads determine the required glass thickness for any particular window.

<table>
<thead>
<tr>
<th>Nominal Thickness</th>
<th>Actual Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/32&quot; single strength</td>
<td>0.085&quot;–0.101&quot; (2.16–2.57)</td>
</tr>
<tr>
<td>laminate</td>
<td>0.102&quot;–0.114&quot; (2.59–2.90)</td>
</tr>
<tr>
<td>1/8&quot; double strength</td>
<td>0.115&quot;–0.134&quot; (2.92–3.40)</td>
</tr>
<tr>
<td>5/32&quot;</td>
<td>0.149&quot;–0.165&quot; (3.78–4.19)</td>
</tr>
<tr>
<td>3/16&quot;</td>
<td>0.180&quot;–0.199&quot; (4.57–5.05)</td>
</tr>
<tr>
<td>7/32&quot;</td>
<td>0.200&quot;–0.218&quot; (5.08–5.54)</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>0.219&quot;–0.244&quot; (5.56–6.20)</td>
</tr>
<tr>
<td>5/16&quot;</td>
<td>0.292&quot;–0.332&quot; (7.42–8.43)</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>0.355&quot;–0.406&quot; (9.02–10.31)</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>0.469&quot;–0.531&quot; (11.91–13.49)</td>
</tr>
<tr>
<td>5/8&quot;</td>
<td>0.595&quot;–0.656&quot; (15.09–16.66)</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>0.719&quot;–0.781&quot; (18.26–19.84)</td>
</tr>
<tr>
<td>1&quot;</td>
<td>0.969&quot;–1.031&quot; (24.61–26.19)</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>1.125&quot;–1.375&quot; (28.58–34.93)</td>
</tr>
</tbody>
</table>
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. Solar control units may have coatings or inserts. 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.

**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 1/4” (6–7); 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.
GLASS TYPES

**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.

**Reflective Glass:** Ordinary float glass (clear or tinted) is coated with metal or metal oxide to reduce solar heat. The coating also produces a one-way mirror effect, generally with the mirror on the exterior. Shading coefficients depend on the density of the metallic coating and range from about 0.31 to 0.70.

**Body-Tinted Glass:** Chemical elements added to the molten glass mixture produce a variety of colors. The visible light transmitted depends on the color and ranges from about 14 percent for very dark colors to 75 percent for light colors. (Clear glass has about an 85 percent light transmission.) Shading coefficients range from 0.50 to 0.75, meaning that they transmit 50 to 75 percent of the solar energy that would be transmitted by double-strength clear glass.

**Low-E Glass:** Low emissivity is clear float glass with a microscopically thin metal oxide coating that reduces U-value by suppressing radiative heat flow and blocking short wave radiation to impede heat gain. At the same time, it provides for light transmission, low reflection, and reduced heat transfer. Generally, Low-E glass can be cut, laminated, or tempered. It is produced in soft-coat (vacuum or sputter coated) or hard-coat (pyrolitic) versions.

<table>
<thead>
<tr>
<th>Colorant</th>
<th>Glass Colors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium sulfide</td>
<td>yellow</td>
</tr>
<tr>
<td>Carbon and sulfur</td>
<td>brown, amber</td>
</tr>
<tr>
<td>Cerium</td>
<td>yellow</td>
</tr>
<tr>
<td>Chromium</td>
<td>green, pink, yellow</td>
</tr>
<tr>
<td>Cobalt</td>
<td>blue, green, pink</td>
</tr>
<tr>
<td>Copper</td>
<td>blue, green, red</td>
</tr>
<tr>
<td>Iron</td>
<td>blue, brown, green</td>
</tr>
<tr>
<td>Manganese</td>
<td>purple</td>
</tr>
<tr>
<td>Nickel</td>
<td>purple, yellow</td>
</tr>
<tr>
<td>Selenium</td>
<td>pink, red</td>
</tr>
<tr>
<td>Titanium</td>
<td>brown, purple</td>
</tr>
<tr>
<td>Vanadium</td>
<td>blue, gray, green</td>
</tr>
</tbody>
</table>
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. The slower process is also much less expensive. Tempered glass is ideal for floor-to-ceiling glass, glass doors, walls of squash courts, and walls exposed to heavy winds and intense temperatures.

Chemically Strengthened Glass: Glass is covered by a chemical solution that produces a higher mechanical resistance, giving the glass similar properties to thermal-strengthened (tempered) glass.

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

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.

Specialty and Decorative Glasses

Photovoltaic Glass: Solar cells are embedded in special resin between panes of glass. Each cell is electrically connected to the other cells, converting solar energy into an electrical current.

X-ray Protection Glass: Used primarily in medical or other radiology rooms, X-ray glass has high levels of lead oxide that reduce ionizing radiation. X-ray glass can be laminated and used in single- or double-glazed units.

Electrically Heated Glass: Polyvinyl butyral (PVB) films are pressed between two or more sheets of glass. Electrically conductive wires heat the glass, making it useful in areas of high moisture content or with extreme differences between indoor and outdoor temperatures.

Self-cleaning Glass: Float glass is given a photocatalytic coating on the exterior that reacts to ultraviolet rays to break down organic dirt. Hydrophilic properties also cause rain to flow down the glass as a sheet, washing away the dirt.

Enameled/Screen-printed Glass: Special mineral pigments are deposited on one face of the glass surface before tempering or annealing. A variety of colors and patterns may be applied for decorative purposes. Enameled glass can also be used as a solar-ray conductor.

Sand-blasted Glass: A translucent surface is produced by spraying sand at high velocity over the surface of the glass, which may be done in decorative patterns or in varying depths and translucencies, depending on the force and type of sand.

Acid-etched Glass: One side of float glass is acid-etched, giving a smoother finish than achieved by sand-blasting.

Antireflective Glass: Float glass is given a coating that reflects very small amounts of light.
MEASURE AND DRAWING

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 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 ft² for area or 100 ft³ for volume.

### Linear Equivalents

<table>
<thead>
<tr>
<th>Customary Unit of Measure</th>
<th>Relation to Other Customary Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>inch (in. or&quot;)</td>
<td>1/12 ft.</td>
</tr>
<tr>
<td>foot (ft. or')</td>
<td>12 in.</td>
</tr>
<tr>
<td>yard (yd.)</td>
<td>36 in.</td>
</tr>
<tr>
<td>rod (rd.), pole, or perch</td>
<td>16 1/2 ft.</td>
</tr>
<tr>
<td>chain</td>
<td>4 rd.</td>
</tr>
<tr>
<td>furlong</td>
<td>22 yd. or 40 rd. or 10 chains or 1/8 mi.</td>
</tr>
<tr>
<td>mile (mi.), statute</td>
<td>5,280 ft. or 1,760 yd. or 8 furlongs</td>
</tr>
<tr>
<td>mile (mi.), nautical</td>
<td>2,025 yd.</td>
</tr>
</tbody>
</table>

### Area Equivalents

<table>
<thead>
<tr>
<th>Customary Unit of Measure</th>
<th>Relation to Other Customary Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>square inch (sq. in.)</td>
<td>0.007 (1/144) sq. ft.</td>
</tr>
<tr>
<td>square foot (sq. ft.)</td>
<td>144 sq. ft.</td>
</tr>
<tr>
<td>square yard (sq. yd.)</td>
<td>1,296 sq. in.</td>
</tr>
<tr>
<td>square pole</td>
<td>30 1/4 sq. yd.</td>
</tr>
<tr>
<td>acre</td>
<td>43,560 sq. ft. or 40 rd. (1 furlong) x 4 rd. (1 chain)</td>
</tr>
<tr>
<td>square mile (sq. mi.)</td>
<td>640 acres</td>
</tr>
</tbody>
</table>
### Fraction to Decimal Equivalents

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Decimal</th>
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<tbody>
<tr>
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<td>0.03125</td>
</tr>
<tr>
<td>1/16</td>
<td>0.0625</td>
</tr>
<tr>
<td>1/8</td>
<td>0.125</td>
</tr>
<tr>
<td>5/32</td>
<td>0.1563</td>
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<tr>
<td>1/4</td>
<td>0.250</td>
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<tr>
<td>9/32</td>
<td>0.2813</td>
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<tr>
<td>5/16</td>
<td>0.3125</td>
</tr>
<tr>
<td>11/32</td>
<td>0.3438</td>
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<tr>
<td>3/8</td>
<td>0.375</td>
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<td>13/32</td>
<td>0.4063</td>
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<tr>
<td>7/16</td>
<td>0.4375</td>
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<tr>
<td>15/32</td>
<td>0.4688</td>
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<tr>
<td>1/2</td>
<td>0.500</td>
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<tr>
<td>17/32</td>
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<td>9/16</td>
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<td>5/8</td>
<td>0.625</td>
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<td>11/16</td>
<td>0.6875</td>
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<td>1/4</td>
<td>0.750</td>
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<td>0.7813</td>
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<td>0.8125</td>
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<td>27/32</td>
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<td>7/8</td>
<td>0.875</td>
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<td>29/32</td>
<td>0.9063</td>
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<tr>
<td>15/16</td>
<td>0.9375</td>
</tr>
<tr>
<td>31/32</td>
<td>0.9688</td>
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<tr>
<td>1/1</td>
<td>1.000</td>
</tr>
</tbody>
</table>

### METRIC CONVERSION

#### Conversion Factors for Length

<table>
<thead>
<tr>
<th>Customary</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in.</td>
<td>25.4 mm</td>
</tr>
<tr>
<td>1 ft.</td>
<td>0.3048 m or 304.8 mm</td>
</tr>
<tr>
<td>1 yd.</td>
<td>0.9144 m</td>
</tr>
<tr>
<td>1 mi.</td>
<td>1.609344 km</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customary</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 sq. in.</td>
<td>645.16 mm²</td>
</tr>
<tr>
<td>1 sq. ft.</td>
<td>0.092903 m²</td>
</tr>
<tr>
<td>1 sq. yd.</td>
<td>0.836127 m²</td>
</tr>
<tr>
<td>1 acre</td>
<td>0.404686 ha or 4 046.86 m²</td>
</tr>
<tr>
<td>1 sq. mi.</td>
<td>2.59000 km²</td>
</tr>
</tbody>
</table>

#### Conversion Factors for Area

<table>
<thead>
<tr>
<th>Metric</th>
<th>Customary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 micrometer (µm)</td>
<td>0.0000394 in. or 0.03937 mils</td>
</tr>
<tr>
<td>1 mm</td>
<td>0.0393701 in.</td>
</tr>
<tr>
<td>1 m</td>
<td>3.28084 ft. or 1.09361 yd.</td>
</tr>
<tr>
<td>1 km</td>
<td>0.621371 mi.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Customary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm²</td>
<td>0.001550 sq. in.</td>
</tr>
<tr>
<td>1 m²</td>
<td>10.7639 sq. ft. or 1.19599 sq. yd.</td>
</tr>
<tr>
<td>1 ha</td>
<td>2.47105 acres</td>
</tr>
<tr>
<td>1 km²</td>
<td>0.386102 sq. mi.</td>
</tr>
</tbody>
</table>
**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

<table>
<thead>
<tr>
<th>Millimeters (mm)</th>
<th>Centimeters (cm)</th>
<th>Decimeters (dm)</th>
<th>Meters (m)</th>
<th>Decameters (dam)</th>
<th>Hectometers (hm)</th>
<th>Kilometers (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.01</td>
<td>0.001</td>
<td>0.0001</td>
<td>0.00001</td>
<td>0.000001</td>
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<tr>
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<td>0.01</td>
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<td>0.1</td>
<td>0.01</td>
<td>0.001</td>
<td>0.0001</td>
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<tr>
<td>1 000</td>
<td>100</td>
<td>10</td>
<td>1</td>
<td>0.1</td>
<td>0.01</td>
<td>0.001</td>
</tr>
<tr>
<td>10 000</td>
<td>1 000</td>
<td>100</td>
<td>10</td>
<td>1</td>
<td>0.1</td>
<td>0.01</td>
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<td>10 000</td>
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<td>100</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

### Area Metric Equivalents

<table>
<thead>
<tr>
<th>Square Millimeters (mm²)</th>
<th>Square Centimeters (cm²)</th>
<th>Square Decimeters (dm²)</th>
<th>Square Meters (m²)</th>
<th>Ares</th>
<th>Hectares (ha)</th>
<th>Square Kilometers (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.01</td>
<td>0.001</td>
<td>0.0001</td>
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<td>0.00001</td>
<td>0.000001</td>
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<tr>
<td>1 000</td>
<td>100</td>
<td>1</td>
<td>0.01</td>
<td>0</td>
<td>0.00001</td>
<td>0.000001</td>
</tr>
<tr>
<td>10 000</td>
<td>1 000</td>
<td>100</td>
<td>1</td>
<td>0</td>
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<td>10 000</td>
<td>1 000</td>
<td>100</td>
<td>1</td>
<td>0.01</td>
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</table>
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**

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<thead>
<tr>
<th>Physical Quantity</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
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<td>Area</td>
<td>square meter</td>
<td>m²</td>
</tr>
<tr>
<td>Volume</td>
<td>cubic meter</td>
<td>m³</td>
</tr>
<tr>
<td>Density</td>
<td>kilogram per cubic meter</td>
<td>kg/m³</td>
</tr>
<tr>
<td>Velocity</td>
<td>meter per second</td>
<td>m/s</td>
</tr>
<tr>
<td>Angular velocity</td>
<td>radian per second</td>
<td>rad/s</td>
</tr>
<tr>
<td>Acceleration</td>
<td>meter per second squared</td>
<td>m/s²</td>
</tr>
<tr>
<td>Angular acceleration</td>
<td>radian per second squared</td>
<td>rad/s²</td>
</tr>
<tr>
<td>Volume rate of flow</td>
<td>cubic meter per second</td>
<td>m³/s</td>
</tr>
<tr>
<td>Moment of inertia</td>
<td>kilogram meter squared</td>
<td>kg m²</td>
</tr>
<tr>
<td>Moment of force</td>
<td>newton meter</td>
<td>N m</td>
</tr>
<tr>
<td>Intensity of heat flow</td>
<td>watt per square meter</td>
<td>W/m²</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>watt per meter kelvin</td>
<td>W/m K</td>
</tr>
<tr>
<td>Luminance</td>
<td>candela per square meter</td>
<td>cd/m²</td>
</tr>
</tbody>
</table>

**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 x 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 (1:1)

Feet and Meters Scale

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<th>Millimeters</th>
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<tr>
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<tr>
<td>2</td>
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<tr>
<td>2.5</td>
<td>762 mm</td>
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<tr>
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<td>11</td>
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<tr>
<td>12</td>
<td>0.60 mm</td>
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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).

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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:

\[
\text{Gradient} = \frac{\text{Horizontal Distance (H)}}{\text{Vertical Distance (V)}}
\]

Calculating % Grade:

\[
\% \text{ Grade} = 100 \times \text{Tangent (Slope)} \quad \text{or} \quad 100 \times \frac{V}{H}
\]
### PLANE FIGURE FORMULAS

#### Rectangle
- Area: \( \text{area} = ab \)
- Perimeter: \( \text{perimeter} = 2(a+b) \)
- \( a^2 + b^2 = c^2 \)

#### Equilateral Triangle (all sides equal)
- Area: \( \text{area} = \frac{a^2 \sqrt{3}}{4} = 0.433 a^2 \)
- Perimeter: \( \text{perimeter} = 3a \)
- \( h = \frac{a}{2} \sqrt{3} = 0.866a \)

#### Parallelogram
- Area: \( \text{area} = ah = ab \sin \theta \)
- Perimeter: \( \text{perimeter} = 2(a+b) \)

#### Triangle
- Area: \( \text{area} = \frac{bh}{2} \)
- Perimeter: \( \text{perimeter} = \text{sum of length of all sides} \)

#### Trapezoid
- Area: \( \text{area} = \frac{(a+b)h}{2} \)
- Perimeter: \( \text{perimeter} = \text{sum of length of all sides} \)

#### Trapezium (irregular quadrilateral)
- Area: \( \text{area} = \frac{(h+h_1)g + eh + fh_1}{2} \)
- Perimeter: \( \text{perimeter} = \text{sum of length of all sides} \)

#### Quadrilateral
- Area: \( \text{area} = \frac{d_1d_2 \sin \theta}{2} \)
- (Divide figure into two triangles and add their areas together.)
**VOLUMES**

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

\[ \text{volume} = \text{area of base} \times \text{altitude} \]

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)**

\[ \text{volume} = \text{area of base} \times \frac{1}{3} \text{altitude} \]

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

---

**Regular Polygons**

(all sides equal)

- **Polygon**: Prism or Cylinder (right or oblique, regular or irregular)
- **Volume**: \[ \text{area} = \frac{n\, r^2}{2} = n\, \tan \theta = \frac{nR^2}{2} \sin 2\theta \]
- **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 \(a^2\)
**CIRCLE**

- **a** = arc
- **r** = radius
- **d** = diameter
- **c** = chord
- **m** = distance
- **Θ** = degrees
- **π** = 3.14159

**Circumference**

\[\text{circumference} = 2\pi r = \pi d = 3.14159 d\]

**Area**

\[\text{area} = \pi r^2 = \frac{\pi d^2}{4} = 0.785d^2\]

**Length of arc**

\[a = \frac{\pi}{180} r = 0.017453 \Theta r\]

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

\[c = 2r \sin \frac{1}{2} \Theta\]

\[m = r \pm \sqrt{r^2 - c^2}\]

- Use + if arc ≥ 180°
- Use – if arc < 180°

**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**

\[\text{area ACDA} = \frac{r^2}{2} \times \left( \frac{\pi \Theta - \sin \Theta}{180} \right)\]

- **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) =
\[\pi [1.5 (x + y) - \sqrt{x^2 + y^2}]\]

(Assume point G is the center point of the ellipse, with x,y coordinates of 0,0, and point B coordinates of B_x and B_y)

area ABFEA =
\[(B_x x B_y) + ab \sin^{-1} (B_x/a)\]

DOUBLE-CURVED SOLIDS

Sphere

volume = \[\frac{4 \pi R^3}{3}\]
surface = \[4 \pi R^2\]

Segment of Sphere

volume = \[\frac{\pi b^2 (3R-b)}{3}\]
(surface - cone)

Sector of Sphere

volume = \[\frac{2\pi R^2 b}{3}\]
(surface = \[\pi R(4b + C)/2\]
(sector + cone)

Ellipsoid

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**
- **partition type**
- **wall or detail section**
- **north arrow**
- **detail section (nondirectional)**
- **enlarged detail reference**
- **elevation target**
- **first floor elevation**
- **exterior elevation**
- **interior elevation**
- **room name and room number**
- **ceiling height**
- **window number**
- **door number**
- **column grid and bubbles**
- **centerline**
- **drawing label**
- **graphic scale**
- **break line**
- **revision cloud and number**
- **spot elevation**
- **align note**

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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.

**West Elevation**

1/4"=1'-0"

**East Elevation**

1/4"=1'-0"
**Architectural Drawing Types**

**North Elevation (Partial)**

1/4" = 1' - 0"

**Match Line**

**10\" Channel Glass**

**5'x5' Precast Conc. Panels**

**5'x4' Precast Conc. Panels**

**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.
**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.

**Details**

Details are drawn at scales such as $1\frac{1}{2}'' = 1'-0''$, $3'' = 1'-0''$, $6'' = 1'-0''$, and sometimes even at full scale, and are keyed from and to numerous other drawings.
THREE-DIMENSIONAL DRAWINGS

Paraline Drawings

Paraline drawings are projected pictorial representations of the three-dimensional qualities of an object. These drawings can be classified as orthographic projections, with a rotated plan view and a tilted side view. They are also commonly referred to as axonometric or axiometric drawings. Unlike in perspective drawings, the projection lines in a paraline drawing remain parallel instead of converging to a point on the horizon.

Oblique

In an oblique drawing, one face (either plan or elevation) is drawn directly on the picture plane. Projected lines are drawn at a 30- or 45-degree angle to the picture plane. The length of the projecting lines is determined as shown in the diagrams opposite.

Dimetric

A dimetric drawing is similar to an oblique drawing, except that the object is rotated so that only one corner touches the picture plane.

Isometric

An isometric drawing is a special type of dimetric drawing, where all axes of the object are simultaneously rotated away from the picture plane and kept at the same angle (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 two exposed sides are not at equal angles to the picture plane.
Isometric (30° Dimetric)

30° Oblique

45° Oblique

15° Dimetric

45° Dimetric

Isometric (30° Dimetric)

30°

30°

45°

45°

Trimetric

30°

30°

60°

30°
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)**: Based on one square meter

<table>
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**Architectural ISO (International Organization for Standardization)**

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**ISO (International Organization for Standardization)**: Based on one square meter

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### 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.

This edge is bound with staples or post binding and covered with paper or tape.

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

<table>
<thead>
<tr>
<th>A-0: General</th>
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<tbody>
<tr>
<td>A-001 Notes and Symbols</td>
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<tr>
<td>A-1: Architectural Floor Plans</td>
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<tr>
<td>A-101 First-Floor Plan</td>
</tr>
<tr>
<td>A-102 Second-Floor Plan</td>
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<td>A-103 Third-Floor Plan</td>
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<td>A-104 First-Floor RCP</td>
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<td>A-107 Roof Plan</td>
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<td>A-2: Architectural Elevations</td>
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<td>A-201 Exterior Elevations</td>
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<td>A-203 Interior Elevations</td>
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<td>A-3: Architectural Sections</td>
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<tr>
<td>A-301 Building Sections</td>
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<td>A-302 Building Sections</td>
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<td>A-303 Wall Sections</td>
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<td>A-4: Large-Scale Views</td>
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<td>A-401 Enlarged Toilet Plans</td>
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<td>A-402 Enlarged Plans</td>
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<td>A-403 Stair and Elevator Plans and Sections</td>
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<td>A-5: Architectural Details</td>
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<td>A-504 Interior Details</td>
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<tr>
<td>A-6: Schedules and Diagrams</td>
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<td>A-601 Partition Types</td>
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<td>A-602 Room Finish Schedule</td>
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Architectural Documents

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# 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.

<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tr>
<td>ACT</td>
<td>acoustical ceiling tile</td>
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<tr>
<td>ADD</td>
<td>additional</td>
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<td>adjustable</td>
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<tr>
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<td>APPX</td>
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<td>board</td>
</tr>
<tr>
<td>BIT</td>
<td>bituminous</td>
</tr>
<tr>
<td>BLDG</td>
<td>building</td>
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<tr>
<td>BLK</td>
<td>block</td>
</tr>
<tr>
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</tr>
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<tr>
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</tr>
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<td>brick course</td>
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<td>CBD</td>
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<td>cast iron</td>
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<td>cast-in-place</td>
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<tr>
<td>CJ</td>
<td>control joint</td>
</tr>
<tr>
<td>CMU</td>
<td>concrete masonry unit</td>
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<tr>
<td>CEM</td>
<td>cement</td>
</tr>
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<td>compressible</td>
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<tr>
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<td>CONT</td>
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<td>detail</td>
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<td>diameter</td>
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<td>door</td>
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<td>each</td>
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</tr>
<tr>
<td>EJ</td>
<td>expansion joint</td>
</tr>
<tr>
<td>EL</td>
<td>elevation or electrical</td>
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<tr>
<td>ELEV</td>
<td>elevator</td>
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<tr>
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<td>equal</td>
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<tr>
<td>EQUIP</td>
<td>equipment</td>
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<tr>
<td>ERD</td>
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<td>electric water cooler</td>
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<td>existing</td>
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<td>expansion</td>
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<td>FHC</td>
<td>fire hose cabinet</td>
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<td>GYP</td>
<td>gypsum</td>
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<tr>
<td>HC</td>
<td>hollow core or handicap accessible</td>
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<tr>
<td>HDW</td>
<td>hardware</td>
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<tr>
<td>HM</td>
<td>hollow metal</td>
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<td>horizontal</td>
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<tr>
<td>HP</td>
<td>high point</td>
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<tr>
<td>HGT</td>
<td>height</td>
</tr>
<tr>
<td>HTR</td>
<td>heater</td>
</tr>
<tr>
<td>HVAC</td>
<td>heating, ventilating, and air conditioning</td>
</tr>
</tbody>
</table>
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 normal, medium-sized project, but the timeframes 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.

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.

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.
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.

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.

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 keep 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

<table>
<thead>
<tr>
<th>Level One (division number)</th>
<th>Level Two</th>
<th>Level Three</th>
<th>Level Four (separated by a decimal point; used only when the amount of detail warrants further classification)</th>
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</thead>
<tbody>
<tr>
<td>0000000000</td>
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MasterSpec Sample Section Pro Forma

<table>
<thead>
<tr>
<th>PART 1 - GENERAL</th>
<th>SECTION NUMBER</th>
<th>SECTION TITLE</th>
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<tbody>
<tr>
<td>1.01</td>
<td></td>
<td>Summary</td>
</tr>
<tr>
<td>1.02</td>
<td></td>
<td>Price and Payment Procedures</td>
</tr>
<tr>
<td>1.03</td>
<td></td>
<td>References</td>
</tr>
<tr>
<td>1.04</td>
<td></td>
<td>Administrative Requirements</td>
</tr>
<tr>
<td>1.05</td>
<td></td>
<td>Submittals</td>
</tr>
<tr>
<td>1.06</td>
<td></td>
<td>Quality Assurance</td>
</tr>
<tr>
<td>1.07</td>
<td></td>
<td>Delivery, Storage, and Handling</td>
</tr>
<tr>
<td>1.08</td>
<td></td>
<td>Warranty</td>
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<table>
<thead>
<tr>
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<th>SECTION TITLE</th>
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<td>2.01</td>
<td></td>
<td>Manufacturig</td>
</tr>
<tr>
<td>2.02</td>
<td></td>
<td>Manufacturers and Products</td>
</tr>
<tr>
<td>2.03</td>
<td></td>
<td>Materials</td>
</tr>
<tr>
<td>2.04</td>
<td></td>
<td>Finishes</td>
</tr>
<tr>
<td>2.05</td>
<td></td>
<td>Accessories</td>
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<table>
<thead>
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<th>SECTION TITLE</th>
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<td>Examination</td>
</tr>
<tr>
<td>3.02</td>
<td></td>
<td>Preparation</td>
</tr>
<tr>
<td>3.03</td>
<td></td>
<td>Erection</td>
</tr>
<tr>
<td>3.04</td>
<td></td>
<td>Field Quality Control</td>
</tr>
<tr>
<td>3.05</td>
<td></td>
<td>Adjusting</td>
</tr>
<tr>
<td>3.06</td>
<td></td>
<td>Cleaning</td>
</tr>
</tbody>
</table>
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 Integration
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

Architectural Documents
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

- 45°/90° triangle
- T-square
- drafting surface
- 30°/60°/90° triangle
- parallel bar
# PAPERS AND BOARDS

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

1. **Drafting brush:**
   Implement used to brush away erasures and drafting powder.

2. **Drafting powder:**
   Finely ground white compound that prevents dust, dirt, and smudges from being ground into the drafting media.

3. **French curve:**
   Template used as guide to draw smoothly most desired curvatures.

4. **X-Acto knife:**
   Cutting tool used in model making and in Letratone application.

5. **Erasing shield:**
   Device used to erase specific lines and areas without affecting others.

6. **Adjustable triangle:**
   Tool used alone or in combination with other triangles to achieve any angle.

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

8. **Compass:**
   Hinge-legged instrument that accommodates a pen or pencil to describe precise circles or circular arcs.
With the exception of perspectives and some other three-dimensional representations, most architectural drawings are made "to scale." Simply put, a floor plan or elevation, too large to be represented at full scale (1"=1"), must be reduced to fit on a sheet of paper. To do so, a standard architect's scale is employed. A representation made at a quarter-inch scale (1/4"=1'-0"), for instance, indicates that a distance of a quarter-inch on the drawing equals one foot in reality.

The three sides of a triangular architect's scale provide a total of eleven scales, 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.
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

<table>
<thead>
<tr>
<th>Grade</th>
<th>Weight and Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>9H</td>
<td>very hard and dense</td>
</tr>
<tr>
<td>8H</td>
<td>ideal range for guidelines and underlay work</td>
</tr>
<tr>
<td>7H</td>
<td>ideal range for guidelines and underlay work</td>
</tr>
<tr>
<td>6H</td>
<td>ideal range for guidelines and underlay work</td>
</tr>
<tr>
<td>5H</td>
<td>ideal range for guidelines and underlay work</td>
</tr>
<tr>
<td>4H</td>
<td>ideal range for guidelines and underlay work</td>
</tr>
<tr>
<td>3H</td>
<td>ideal range for guidelines and underlay work</td>
</tr>
<tr>
<td>2H</td>
<td>medium-hard</td>
</tr>
<tr>
<td>H</td>
<td>medium</td>
</tr>
<tr>
<td>F</td>
<td>medium, general purpose</td>
</tr>
<tr>
<td>HB</td>
<td>medium-soft, bold line work</td>
</tr>
<tr>
<td>B</td>
<td>best range for finished drawings</td>
</tr>
<tr>
<td>2B</td>
<td>range for bold lines and shading, less suitable for drafting purposes</td>
</tr>
<tr>
<td>3B</td>
<td>range for bold lines and shading, less suitable for drafting purposes</td>
</tr>
<tr>
<td>4B</td>
<td>range for bold lines and shading, less suitable for drafting purposes</td>
</tr>
<tr>
<td>5B</td>
<td>range for bold lines and shading, less suitable for drafting purposes</td>
</tr>
<tr>
<td>6B</td>
<td>very soft</td>
</tr>
</tbody>
</table>
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. Depending on the pen type, the ink may come in a prepackaged cartridge or the barrel of the pen may be filled with ink as needed. The finer the pen nib, the more fragile and prone to clogging it is. All nibs require cleaning and maintenance to keep them in working order. Ink should be waterproof, nonfading, and opaque. Ink pens can be used on most paper types and 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

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<th>Size</th>
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<td>7</td>
<td>2.0</td>
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<tr>
<td>6</td>
<td>1.4</td>
</tr>
<tr>
<td>4</td>
<td>1.2</td>
</tr>
<tr>
<td>3 1/2</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>0.80</td>
</tr>
<tr>
<td>2 1/2</td>
<td>0.70</td>
</tr>
<tr>
<td>2</td>
<td>0.60</td>
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<tr>
<td>1</td>
<td>0.50</td>
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<td>0.25</td>
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<tr>
<td>4x0</td>
<td>0.18</td>
</tr>
<tr>
<td>6x0</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Technical pen body

Pen nib
Chapter 14: Computer Standards and Guidelines

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 guidelines affecting AutoCAD, at this printing still the de facto industry standard for construction document production.

COMPUTER PROGRAMS

Architectural production can be divided into two major groups: contract document deliverables and general presentation materials.

Deliverables are usually understood as the construction document set composed of the basic two-dimensional drawing types (plan, section, elevation, details, and schedules) that describe the building sufficiently for the contractors to build it.

The computer programs used to produce a standard set of deliverables are primarily drafting programs. In essence, they provide efficient, precise, and easily modifiable mechanical drawings. AutoCAD remains the drafting program of choice for most architects and engineers. Though it does have three-dimensional capabilities and can also accommodate rendering plug-ins, for high-quality presentation drawings, AutoCAD is still most valued for its precision as a versatile drafting program.

Presentation materials can include standard plan, section, and elevation drawings as well as physical three-dimensional models, computer renderings, and animations. Computer modeling and rendering programs are numerous and varied, depending on the desired output. Predictably, the more sophisticated the intended product, the more expensive the tool.

Modeling programs are not limited to production output. Many are employed extensively to design complex forms that would simply be impossible otherwise. Increasingly, architecture is taking advantage of programs developed for use in other fields, such as the automotive industry, aerospace engineering, video game development, and animated film production.
AUTOCAD TERMS

Aspect ratio: Ratio of display width to height.

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 object.

Drawing web format (DWF): Compressed file format that is created from a DWG file, ideal for publishing and viewing on the Web.

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

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.

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

Explode: Disassemble complex objects such as blocks and polylines.

External reference: 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.

Layer: Entity used for classification in a CAD drawing, whose properties allow for manipulation and flexibility of information in the drawing.

Model: In AutoCAD, a two- or three-dimensional representation of an object; or a three-dimensional replica of a design, whether physical or digital.

Model space: One of two primary spaces in which AutoCAD entities exist. Model space is a three-dimensional coordinate space in which both two-dimensional and three-dimensional drafting and design are done at full (1:1) scale.

Paper space: Other primary AutoCAD space. Used for creating a finished printable or plottable layout; usually contains a title block.

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

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.

User coordinate system (UCS): System that defines the orientation of x, y, and z in three-dimensional space.

UCS icons: Keys that indicate the direction of x, y, and z planes, as well as whether the user is in paper space or model space.

Viewport: Bounded area that displays some portion of the model space of a drawing.

Window: Drawing area, including the command line and surrounding menues.
AUTOCAD WINDOWS

Active Model Space

Model may be edited in model space.

Tilemode = 1 (on)

All drawing done in model space should be at 1:1.

UCS icon

Active Paper Space

Title block or other non-model space information may be edited in the paper space viewport.

Tilemode = 0 (off). When tilemode is off, viewports are objects that can be moved and resized.

UCS icon

Paper Space with Active Model Space Viewport

To enter the viewport, type ms at command line; note the model space icon.

Tilemode = 0 (off)

Paper space scales (XP) may be set by zooming while in this mode. Editing of the model is possible though not encouraged.
EXTERNAL REFERENCES

External reference (X-Ref) drawings contain architectural information common to multiple sheet files. Typically, these drawings are floor plans that can serve many purposes; each has its own sheet file. For example, the same plan model can be used for floor plans, reflected ceiling plans, and large-scale plans.

The following diagram describes the interaction between X-Ref drawings and sheet files.
MODEL SPACE AND PAPER SPACE SCALES

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)

<table>
<thead>
<tr>
<th>DWG Scale</th>
<th>Desired Text Height</th>
<th>XP Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>1/16” 1/32” 1/8” 3/16” 1/4” 5/16” 3/8” 1/2” 3/4” 1”</td>
<td>1 1 .0625 .09375 .125 .1875 .25 .3125 .375 .5</td>
</tr>
<tr>
<td>6”=1’</td>
<td>1/12” .125 .1875 .25 .375 .5</td>
<td>.0625 .09375 .125</td>
</tr>
<tr>
<td>3”=1’</td>
<td>1/8” .125 .1875 .25 .375 .5</td>
<td>.0625 .09375 .125</td>
</tr>
<tr>
<td>11/2”=1’</td>
<td>1/4” .125 .1875 .25 .375 .5</td>
<td>.0625 .09375 .125</td>
</tr>
<tr>
<td>1”=1’</td>
<td>1/8” 1.125 1.5</td>
<td>.08333 1/12</td>
</tr>
<tr>
<td>3/4”=1’</td>
<td>1/16” 1.5</td>
<td>.0625 1/16</td>
</tr>
<tr>
<td>1/2”=1’</td>
<td>1/24” 1.5</td>
<td>.04167 1/24</td>
</tr>
<tr>
<td>3/8”=1’</td>
<td>1/32” 1.5</td>
<td>.03125 1/32</td>
</tr>
<tr>
<td>1/4”=1’</td>
<td>1/48” 1.5</td>
<td>.02083 1/48</td>
</tr>
<tr>
<td>3/16”=1’</td>
<td>1/64” 1.5</td>
<td>.015625 1/64</td>
</tr>
<tr>
<td>1/8”=1’</td>
<td>1/96” 1.5</td>
<td>.01042 1/96</td>
</tr>
<tr>
<td>1/16”=1’</td>
<td>1/120” 1.5</td>
<td>.005208 1/120</td>
</tr>
<tr>
<td>1”=10’</td>
<td>1/180” 1.5</td>
<td>.00083 1/180</td>
</tr>
<tr>
<td>1”=20’</td>
<td>1/240” 1.5</td>
<td>.004167 1/240</td>
</tr>
<tr>
<td>1”=30’</td>
<td>1/360” 1.5</td>
<td>.002778 1/360</td>
</tr>
</tbody>
</table>

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’ are 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”=12", 1/4 x 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.
AUTOCAD FILE-NAMING CONVENTIONS

File types have a direct bearing on the format of the file and the manner in which it should be named. File types include models, details, sheets, schedules, text, databases, symbols, borders, and title blocks. The file- and layer-naming system discussed here follows the AIA CAD Guidelines, as established by the U.S. National CAD Standard.

Model Files
A building model file is an electronic representation of the building. Models may be two- or three-dimensional and are created at a true 1:1 scale. All geometry in a model file contains a three-dimensional coordinate (x, y, z). In two-dimensional drawings, the z coordinate is 0.

Sheet Files
The electronic sheet file contains one or more views of one or more model files, as well as text, symbols, and, often, a border or title block. The title block generally contains graphic and text information common to all other sheets in a project or section.

Level 1 Discipline Designators
Both file names and layer names are classified by discipline. The discipline code is a two-character field in which the second character is either a hyphen or a modifier defined by the user.

A  Architectural
B  Geotechnical
C  Civil
D  Process
E  Electrical
F  Fire Protection
G  General
H  Hazardous Materials
I  Interiors
L  Landscape
M  Mechanical
O  Operations
P  Plumbing
Q  Equipment
R  Resource
S  Structural
T  Telecommunications
V  Survey/Mapping
W  Distributed Energy
X  Other Disciplines
Z  Contractor/Shop Drawings
Standard Model File Identification

Model File Types
- FP: Floor Plans
- SP: Site Plans
- DP: Demolition Plans
- QP: Equipment Plans
- XP: Existing Plans
- EL: Elevations
- SC: Sections
- DT: Details
- SH: Schedules
- 3D: Three-Dimensional Drawings
- DG: Diagrams

A - A A U U U U U
- Discipline designator (same as for sheet file naming)
- Hyphen (serves as a placeholder and makes name more readable)

A - A A U U U U U
- Model file type
- Defined by user (optional alphanumeric modifiers)

Examples: A-FP-01 (Architectural Floor Plan, Level 1)
           P-DP-010 (Plumbing Demolition Plan, Level 1)

Standard Sheet Identification

Sheet Type Designators
0: General
1: Plans
2: Elevations
3: Sections
4: Large-scale Views
5: Details
6: Schedules and Diagrams
7: User Defined
8: User Defined
9: Three-Dimensional Drawings

A A - N N N - U U U
- Discipline designator (discipline character plus optional modifier character)

A A - N N N - U U U
- Sheet type designator
- Sheet sequence numbers
- Defined by user (optional alphanumeric modifiers)

Examples: A-103 (Architectural Plan, Level 3)
           AD206 (Architectural Demolition Elevation, Level 6)
STANDARDS

3.
PROPORTION AND FORM

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 15: 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).
On the drawings below, the gray bars indicate inches and the blue bars indicate millimeters.
ACCESSIBLE DESIGN DIMENSIONS

Overall Dimensions for Adult Wheelchairs

- **Seat**: 36" (914)
- **Lap**: 30" (762)
- **Eye**: 8" (203)
- **Toe**: 6" (152)
- **Overall Dimensions for Adult Wheelchairs**: 42" (1,067)
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.
SEATED DIMENSIONS

Work Station Clearances

- 12" (305)
- 14.4"–18.5" (365–470)
- 25"–31.5" (635–800)
- 24"–30" (610–760)
- 54" (1372)
- 20"–24" (510–610)
- 12" (305)
- 42"–48" (1065–220)
- 18" (457)
- 42"–48" (1065–220)
- 24" (610)
- 14.4"–18.5" (365–470)
- 4" (102)

Toe space 4" (102)
Knee well 20"–24" (510–610)
Wall outlets 18" (457)
The Human Scale

MATERIALS, STRUCTURES, AND STANDARDS

Switches
42"–48" (1065–220)

Wall outlets
18" (457)

Lounging Position General Space Considerations

The Human Scale

- 25" (625)
- 30" (750)
- 35" (875)
- 38" (950)
- 25" (625)
- 35" (875)
- 35" (875)
- 35" (875)
- 35" (875)
- 39" (1000)
- 35" (875)
- 73" (1875)

Dimensions for lounging positions.
Proportions of Materials

Wood

Masonry

8" (203) 12" (305)

6" (152)

4" (102)

6" (152)

8" (203)

10" (254)

12" (305)
Proportions of Materials

- Gypsum Wall Board
- Plywood

Dimensions:
- 48" (1.220)
- 96" (2.440)
- 60" (1.524)
Chapter 16: Residential 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 (3 660) and 22 lineal feet (6 705).
Cabinetry Components

- upper cabinets
- adjustable shelves
- backsplash
- drawer
- adjustable shelves
- door
- base

Appliances

Many appliances have become modular in width, and fit within a 3" system (ex. 9", 12", 15", 18", 21", 24"...48")
BATHROOMS

General Guidelines
(Subject to Local Codes)

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.

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.

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.

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.
HABITABLE ROOMS

Beds (mattress sizes)

<table>
<thead>
<tr>
<th>Size</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crib</td>
<td>28&quot; (711)</td>
</tr>
<tr>
<td>Twin</td>
<td>39&quot; (991)</td>
</tr>
<tr>
<td>Full (Double)</td>
<td>54&quot; (1 372)</td>
</tr>
<tr>
<td>Queen</td>
<td>60&quot; (1 524)</td>
</tr>
<tr>
<td>King</td>
<td>76&quot; (1 930)</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Table Size (in.)</th>
<th>Maximum Seats</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 x 48</td>
<td>4</td>
</tr>
<tr>
<td>30 x 48</td>
<td>4</td>
</tr>
<tr>
<td>30 x 60</td>
<td>6 (4 wch.)</td>
</tr>
<tr>
<td>36 x 72</td>
<td>6 (6 wch.)</td>
</tr>
<tr>
<td>36 x 84</td>
<td>8 (6 wch.)</td>
</tr>
<tr>
<td>30 x 30</td>
<td>2</td>
</tr>
<tr>
<td>36 x 36</td>
<td>4</td>
</tr>
<tr>
<td>42 x 42</td>
<td>4 (2 wch.)</td>
</tr>
<tr>
<td>48 x 48</td>
<td>8 (2 wch.)</td>
</tr>
<tr>
<td>54 x 54</td>
<td>8 (4 wch.)</td>
</tr>
<tr>
<td>36 dia.</td>
<td>4</td>
</tr>
<tr>
<td>42 dia.</td>
<td>6</td>
</tr>
<tr>
<td>48 dia.</td>
<td>6 (2 wch.)</td>
</tr>
<tr>
<td>54 dia.</td>
<td>6 (4 wch.)</td>
</tr>
</tbody>
</table>

wch. = wheelchair

Table Size (in.) 28"–42" (varies)

Maximum Seats 24"–40" (varies) 4'-0"–10'-0" (varies)
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" (1,219–1,829) of hanging space per person
- 12" (305) = 6 suits, 12 shirts, 8 dresses, or 6 pairs of pants

Garages

- A minimum clearance of 2'-6" (762) for circulation should be maintained between the vehicle and other vehicles, walls, or equipment.
- 11'-2" (3.404) avg. for one car
- 19'-10" (6.045) avg. for two cars
- 8'(2.438) min. door clearance
- 9'(2.743) recommended
- 16'(4.877) min. required for single door of two-car garage

- 5'-10"–6'-4" (1.779–930)
- 5'-2"–5'-10" (1.575–779)
- 2'-6" (762) for circulation
- 11'-2" (3.404) avg. for one car
- 19'-10" (6.045) avg. for two cars
- 8'(2.438) min. door clearance
- 9'(2.743) recommended
- 16'(4.877) min. required for single door of two-car garage

- 11'-2" (3.404) avg. for one car
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- 8'(2.438) min. door clearance
- 9'(2.743) recommended
- 16'(4.877) min. required for single door of two-car garage
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 1,219), 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.

Seating Clearances

3'-0”–3'-6”
(914–1,067)
required for all accessible routes

service aisle

36” (914)
required for accessible aisle

18” (457)
limited passage

6” (152)
no passage

30” (762)
bar

Residential Spaces

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PUBLIC SEATING

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).

Accessible spaces of 36” x 60” (914 x 1,524) should be open, on level ground, and provided as follows:

<table>
<thead>
<tr>
<th>Total Seating</th>
<th>Wheelchair Spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>4–25</td>
<td>1</td>
</tr>
<tr>
<td>26–50</td>
<td>2</td>
</tr>
<tr>
<td>51–300</td>
<td>4</td>
</tr>
<tr>
<td>301–500</td>
<td>6</td>
</tr>
<tr>
<td>500+</td>
<td>6 (+1 per each additional 100 seats)</td>
</tr>
</tbody>
</table>

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.

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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.
Chapter 17: 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.

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PRIMARY SHAPES

Square
Triangle
Circle

PLATONIC SOLIDS

Cube
Pyramid
Cone
Cylinder
Sphere

182  THE ARCHITECTURE REFERENCE + SPECIFICATION BOOK
POLYHEDRA

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.

RULED SURFACES

A ruled surface, which is the surface generated by connecting line segments between corresponding points, can take many forms.

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**

\[
\frac{AC}{CB} = \frac{AB}{AC} \quad \text{(a unique characteristic)}
\]

If \( AB = 1 \), let \( AC = x \)

\[
x = \frac{\sqrt{5} + 1}{2} = 0.61803398 \ldots \text{ (infinite)}.
\]

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…). The higher the numbers, the more accurate the answer will be (for example: 377/610 = 0.6180327…).

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 18: Architectural Elements

CLASSICAL ELEMENTS

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 B.C.E.
**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.

**Caryatid:** Sculpted 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).
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.

- **Tuscan**
  - simplest; derived from Etruscan temples

- **Doric**
  - Greek (no base) and Roman

- ** Ionic**
  - characterized by volutes on its capital

---

**Entablature**
- 1 3/4 dia.

**Capital**
- 2 dia.

**Shaft**
- 2 1/4 dia.

**Base**
- 3 dia.

**Pedestal**
- 2 1/3 dia.
**Corinthian**
Greek and Roman, fluted or not; characterized by acanthus leaves on its capital.

**Composite**
Roman combination of Ionic and Corinthian orders.

- **Corinthian Capital**: Shown with dimensions 2 1/2 dia. x 10 dia.
- **Composite Capital**: Shown with dimensions 3 1/3 dia. x 10 dia.

**Terms**:
- **Entablature**: The structure of a roof, including the architrave, frieze, and cornice.
- **Entablature Details**: Shows the relationship between the entablature, architrave, frieze, and cornice.
- **Base**: The lower part of a column, often consisting of several parts.
- **Plinth**: The stone slab that forms the base of a column or pedestal.
- **Dado**: The lower part of an entablature that supports the architrave.
- **Die**: The upper part of a column, often decorative or ornate.
- **Pedestal**: A raised base for a column or statue.
GOTHIC ELEMENTS

Rheims Cathedral, France
1212–1300

Typical Plan
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
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.
MARCUS VITRUVIUS POLLIO (c. 80 BCE - c. 15 BCE) was a Roman architect, engineer, and writer, whose De Architectura (in English, Ten Books on Architecture) was written around 15 BCE and dedicated 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 re-discovered 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; principles 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 (1401-1472)

*De Re Aedificatoria* (On the Art of Building), written between 1443-1452, 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’s highly illustrated treatise includes 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

With the first of the books published in 1537, Serlio’s books 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.
STANDARDS
CODES AND GUIDELINES

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 19: 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

In 1997 the International Code Council (ICC) enlisted representatives from BOCA, ICBO, and SBCCI (the three founding arms of the ICC) to create a comprehensive and internationally available model construction code that would combine the considerable scope of the existing model codes. The first International Building Code (IBC) was established 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. Some have adopted the IBC but have not yet made it effective, others have adopted it on a statewide level, and still others have let their local city and county governments decide. The same has been true for the supplemental codes. 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. 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.
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 2012 edition, for example, exhibits the 2009 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.

Numerous publications offer explanations and interpretations of many aspects of code use, though they should always be used in conjunction with the code itself, and not as a substitute. In addition, licensed code consultants can provide further clarification of codes or offer a general review of projects, especially large and complex ones, with an eye to code compliance.

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.

OTHER CODES

Within any one jurisdiction, a complex variety of codes may still be in use, even if the IBC has been adopted as the primary code. Local building departments must always be consulted for a complete breakdown of what codes are to be addressed for any given project. In addition, federal laws such as the Americans with Disabilities Act and the Federal Fair Housing Act must be followed.

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 which 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), outpatient clinics and doctors’ offices, 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 five or more children over age 2 1/2 (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 mental hospitals, 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 care facilities for adults and children under the age of two, who are unable to respond to emergency situations without assistance from a staff member.

Group M: Mercantile

Department stores, drug stores, 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 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 incidental 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. This occupancy is seldom used and is not to be used for any building that is difficult to categorize.
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.

Noncombustible materials, which are defined as being materials “of which no part will ignite and burn when subjected to fire,” typically include masonry and steel. Combustible materials, which may be assumed to be materials that fail to meet noncombustibility requirements, include wood and plastic.

<table>
<thead>
<tr>
<th>Types of Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncombustible</td>
</tr>
<tr>
<td>IA IIB</td>
</tr>
<tr>
<td>All building elements as listed in IBC Table 601 (structural frame, interior and exterior bearing walls, interior and exterior nonbearing walls, floor construction, and roof construction) are of noncombustible materials.</td>
</tr>
<tr>
<td>Noncombustible/Combustible</td>
</tr>
<tr>
<td>IIA IIB</td>
</tr>
<tr>
<td>All building elements as listed in IBC Table 601 (structural frame, interior and exterior bearing walls, interior and exterior nonbearing walls, floor construction, and roof construction) are of noncombustible materials. Type IIB construction is not required to be fire-resistance rated.</td>
</tr>
<tr>
<td>Combustible</td>
</tr>
<tr>
<td>IV (Heavy Timber = HT)</td>
</tr>
<tr>
<td>Exterior walls must be of noncombustible materials and interior building elements may be of any material permitted by the code. Fire retardant–treated wood framing may be allowed in exterior wall assemblies of less than 2-hour rating, as long as they comply with IBC Section 2303.2.</td>
</tr>
<tr>
<td>VA VB</td>
</tr>
<tr>
<td>All building elements as defined by IBC Table 601 are of any materials permitted by the code.</td>
</tr>
</tbody>
</table>

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.
Means of Egress Diagram

An **exit** is an enclosed, protected way of travel from an exit access to an exit discharge. When the exit access is above or below the grade of the exit discharge, an enclosed stair or ramp is required.

The number of means out of an occupied space are determined by size, occupancy type, and occupant load.

An **exit access** leads an occupant from an occupied part of the building to an exit (commonly, this is a corridor).

An **exit discharge** provides a means of moving from an exit to a public way.

This is considered an unallowable dead-end corridor, unless a second means of egress is provided. Typically, dead-end corridors must not exceed 20’ (6 069), though exceptions exist for certain occupancies and sprinklered conditions.

**PUBLIC WAY**

Building Codes
MEANS OF EGRESS

ICB 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 Table 1015.1, occupancy spaces that require more than one means of egress are:

- A, B, E, F, M, and U, with occupant loads 50 and over
- H-1, H-2, H-3, with occupant loads over 3
- H-4, H-5, I-1, I-2, I-3, I-4, and R, 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.

### Required Egress Widths

Sizes are determined by coordinating IBC Table 1004.1 (summarized on the following page) with the requirements below, taking whichever number is higher.

### Egress Doors

In areas with an egress load of more than fifty occupants, or any Group H occupancy, exit access doors should swing in the direction of travel. 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).

Egress doors should be a minimum of 6’-8” (2032) high, with a clear opening width determined by IBC 1008.1, but no less than 32” (813), measured from the face of the door to the stop when open.

Maximum width of a swinging door leaf is 48” (1219).

### Exit Passageways

Minimum passageway width is determined by IBC 1005.1 but must not be less than 44” (1118), except for the following conditions:

- Within a dwelling unit or in an occupancy of less than fifty: 36” (914)
- Group E with a hundred or more capacity: 72” (1829)
- Group I-2 areas with required bed movement: 96” (2438)

### Egress Stairs

Minimum width is determined by IBC 1005.1 but must not be less than 44” (1118), except for passageways serving occupant loads of less than fifty, which must be no less than 36” (914).

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.
Determining Occupancy Loads

The table at right may be used to establish occupant loads per area sizes, from which egress widths per occupant are calculated. Alternatively, occupant loads are determined by the actual number, if larger, of occupants for whom the space is designed or, in addition, for whom the space will serve as a means of egress.

### Required Egress Widths in Inches Per Occupant

<table>
<thead>
<tr>
<th>Type of Occupancy</th>
<th>Floor Area per Occupant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly with fixed seats</td>
<td>Occupant load for areas with fixed seats and aisles is determined by the number of seats, with one person for every 18&quot; (457) of seating length; or one person for every 24&quot; (610) in seating booths.</td>
</tr>
<tr>
<td>Assembly without fixed seats</td>
<td>chairs (concentrated): 7 sq. ft. (0.65 m²) net standing space: 5 sq. ft. (0.46 m²) net tables and chairs (unconcentrated): 15 sq. ft. (1.39 m²) net</td>
</tr>
<tr>
<td>Business areas</td>
<td>100 sq. ft. (9.29 m²) gross</td>
</tr>
<tr>
<td>Dormitories</td>
<td>50 sq. ft. (4.65 m²) gross</td>
</tr>
<tr>
<td>Educational—classrooms</td>
<td>20 sq. ft. (1.86 m²) net</td>
</tr>
<tr>
<td>Educational—shop and vocational areas</td>
<td>50 sq. ft. (4.65 m²) net</td>
</tr>
<tr>
<td>Commercial kitchens</td>
<td>200 sq. ft. (18.58 m²) gross</td>
</tr>
<tr>
<td>Library reading room</td>
<td>50 sq. ft. (4.65 m²) net</td>
</tr>
<tr>
<td>Library stacks</td>
<td>100 sq. ft. (9.29 m²) gross</td>
</tr>
<tr>
<td>Mercantile—basement or grade floor</td>
<td>30 sq. ft. (2.79 m²) gross</td>
</tr>
<tr>
<td>Mercantile—floors other than basement or grade floor</td>
<td>60 sq. ft. (5.57 m²) gross</td>
</tr>
<tr>
<td>Mercantile—storage, stock, and shipping</td>
<td>300 sq. ft. (27.87 m²) gross</td>
</tr>
<tr>
<td>Parking garage</td>
<td>200 sq. ft. (18.58 m²) gross</td>
</tr>
<tr>
<td>Residential</td>
<td>200 sq. ft. (18.58 m²) gross</td>
</tr>
</tbody>
</table>

Net area is generally considered to be the actual occupied area and does not include unoccupied areas such as corridors, walls, stairways, or toilets. Gross area includes floor area within the inside perimeter of the exterior walls, as well as corridors, stairways, closets, interior partitions, columns, and other fixed features.
Chapter 20: 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**

Raised character and Braille designations - left of button

<table>
<thead>
<tr>
<th>Character</th>
<th>Button Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3/4&quot; (19)</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>

*Main entry floor* |

*Door open* |

*Emergency alarm* |

*Door close* |

*Emergency stop* |

Emergency controls should be grouped at the bottom, with centerlines no less than 35” (889) AFF.

**Raised and Tactile Characters**

Characters should be raised $\frac{1}{32}$” (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 $\frac{5}{8}$” (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 eggshell, 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 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 1219) wheelchair space must be provided for every two hundred 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” (1219) 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.

**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.

**Number of Accessible Spaces Required**

<table>
<thead>
<tr>
<th>Number of Spaces</th>
<th>Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–25</td>
<td>1</td>
</tr>
<tr>
<td>26–50</td>
<td>2</td>
</tr>
<tr>
<td>51–75</td>
<td>3</td>
</tr>
<tr>
<td>76–100</td>
<td>4</td>
</tr>
<tr>
<td>101–150</td>
<td>5</td>
</tr>
<tr>
<td>151–200</td>
<td>6</td>
</tr>
<tr>
<td>201–300</td>
<td>7</td>
</tr>
<tr>
<td>301–400</td>
<td>8</td>
</tr>
<tr>
<td>401–500</td>
<td>9</td>
</tr>
<tr>
<td>501–1,000</td>
<td>2% of total</td>
</tr>
<tr>
<td>1,001 and over</td>
<td>20 plus 1 for each 100 over 1,000</td>
</tr>
</tbody>
</table>
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**

<table>
<thead>
<tr>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>32&quot; (813)</td>
<td>single wheelchair</td>
</tr>
<tr>
<td>36&quot; (914)</td>
<td>two wheelchairs</td>
</tr>
<tr>
<td>48&quot; (1219)</td>
<td>clear floor space, typical</td>
</tr>
</tbody>
</table>

**Clear Floor Space at Alcoves**

<table>
<thead>
<tr>
<th>Width</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30&quot; (762)</td>
<td>single wheelchair</td>
</tr>
<tr>
<td>36&quot; (914)</td>
<td>2 wheelchairs</td>
</tr>
<tr>
<td>48&quot; (1219)</td>
<td>clear floor space, preferred</td>
</tr>
<tr>
<td>60&quot; (1524)</td>
<td>min.</td>
</tr>
<tr>
<td>78&quot; (1981)</td>
<td>preferred</td>
</tr>
</tbody>
</table>
DOORS

Clear Doorway Width and Depth

Maneuvering Clearances at Doors

hinged door

sliding door

folding door

Swinging Doors
(front approaches)

Swinging Doors
(latch-side approaches)

Clear Doorway Width and Depth

- hinged door
- sliding door
- folding door

Maneuvering Clearances at Doors

- pull side
- push side

Swinging Doors
(front approaches)

Swinging Doors
(latch-side approaches)

Dimensions:
- 32" (813)
- 24" max.
- 18" (458)
- 12" (305)
- 60" (1524)
- 48" (1219)
- 42" (1067)
- 24" (610)
Two Hinged Doors in a Series

Swinging Doors (hinge-side approaches)

- Pull side
- Push side

If Y = 60" (1524),
X = 36" (914)

If Y = 54" (1372),
X = 42" (1067)

Sliding and Folding Doors

- Front approach
- Side approach
- Latch-side approach

If Y = 60" (1524),
X = 36" (914)

If Y = 54" (1372),
X = 42" (1067)
TOILETS AND BATHROOMS

Clear Floor Space at Water Closets - Adult

Wheelchair Accessible Stall

Grab bars:
- circular cross section should be 1 1/4" - 2" (32 - 51) in diameter, with a clearance of 1 1/2" (38) from wall.
- non-circular cross sections shall have a cross-sectional dimension of 2" (51) max, and a perimeter dimension between 4" and 4.8" (100 - 120)

Wheelchair Accessible Stall Ambulatory Accessible Stall

End-of-Row Wheelchair Accessible Stall

Side-wall Elevation

Toilet Stalls

Grab bars:
- circular cross section should be 1 1/4" - 2" (32 - 51) in diameter, with a clearance of 1 1/2" (38) from wall.
- non-circular cross sections shall have a cross-sectional dimension of 2" (51) max, and a perimeter dimension between 4" and 4.8" (100 - 120)

Wheelchair Accessible Stall Ambulatory Accessible Stall

Grab bars:
- circular cross section should be 1 1/4" - 2" (32 - 51) in diameter, with a clearance of 1 1/2" (38) from wall.
- non-circular cross sections shall have a cross-sectional dimension of 2" (51) max, and a perimeter dimension between 4" and 4.8" (100 - 120)

Wheelchair Accessible Stall Ambulatory Accessible Stall

Grab bars:
- circular cross section should be 1 1/4" - 2" (32 - 51) in diameter, with a clearance of 1 1/2" (38) from wall.
- non-circular cross sections shall have a cross-sectional dimension of 2" (51) max, and a perimeter dimension between 4" and 4.8" (100 - 120)
**Lavatories**

30" x 48" (762 x 1219) min. clear floor space

17" min. (432)

19" max. (483)

**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 1524) shower stalls should be of a folding type mounted on the wall adjacent to the controls.

**Bathtubs**

30" x 60" (762 x 1524) min. clear floor space

48" x 60" (1219 x 1524) min. clear floor space

30" x 75" (762 x 1905) min. clear floor space
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 3/4" (19) in the smallest direction.

Typical Dimensions for off-centered door

RAMPS

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.

The rise for any ramp run before landing shall be 30" (762) max.
STAIRS

Nosings
Risers should be sloped, or the underside of nosings should have an angle not less than 60° from the horizontal.

Handrails
at wall: handrail returns to wall
at switchback: handrail is continuous
where no wall: handrail returns smoothly to the floor

Handrail Extension (min.) at Bottom of Run

flush riser
11" (280) min. tread depth
angled nosing
7" (178) max. riser height
rounded nosing

designation area
cane detection area

tread depth

1 1/4" – 2" (32 – 51) dia.
1 1/2" (38) min. from wall

min. landing width = width of stair

72" – 96" (1 830 – 2 440)
Chapter 21: 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

- **45º**
- **60º**
- **75º**
- **90º**

**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 quarter-inch 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 60º stall, which provides for ease of entering and exiting spaces while still allowing for an efficiently sized module. Stalls of 45º 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 90º 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.
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 quarter-inch 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 60º stall, which provides for ease of entering and exiting spaces while still allowing for an efficiently sized module. Stalls of 45º 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 90º 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.

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) x 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" (2 286) x 15' (4 572) and should be well marked and logically grouped.
## Parking Lot Flows

- **One-way Angled**
- **Two-way 90 Degrees**

## Common Parking Space Allocations

<table>
<thead>
<tr>
<th>Category</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital</td>
<td>1.2 per bed</td>
</tr>
<tr>
<td>Auditorium/theater/stadium</td>
<td>0.3 per seat</td>
</tr>
<tr>
<td>Restaurant</td>
<td>0.3 per seat</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.6 per employee</td>
</tr>
<tr>
<td>Church</td>
<td>0.3 per seat</td>
</tr>
<tr>
<td>Retail</td>
<td>4.0 per 1000’ gross floor area</td>
</tr>
<tr>
<td>Office</td>
<td>3.3 per 1000’ gross floor area</td>
</tr>
<tr>
<td>Shopping center</td>
<td>5.5 per 1000’ gross leasable area</td>
</tr>
<tr>
<td>Hotels/motel</td>
<td>1.0 per room/0.5 per employee</td>
</tr>
<tr>
<td>Senior high schools</td>
<td>0.2 per student/1.0 per staff member</td>
</tr>
<tr>
<td>Elementary schools</td>
<td>1.0 per classroom</td>
</tr>
</tbody>
</table>

## Typical Car Length Classifications

<table>
<thead>
<tr>
<th>Class</th>
<th>Pre-1975</th>
<th>Post-1975</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcompact</td>
<td>&lt;100” (2.540)</td>
<td>&lt;100” (2.540)</td>
</tr>
<tr>
<td>Compact</td>
<td>101”–111” (2.565–819)</td>
<td>100”–111” (2.540–845)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>112”–118” (2.845–997)</td>
<td>Large</td>
</tr>
<tr>
<td>Standard</td>
<td>&gt;119” (3.025)</td>
<td>&gt;112” (2.845)</td>
</tr>
</tbody>
</table>
PARKING GARAGES

Ramp Design

Straight Ramps

<table>
<thead>
<tr>
<th>Length</th>
<th>&lt; 65'-0&quot; (19 812)</th>
<th>&gt; 65'-0&quot; (19 812)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blend length</td>
<td>10'-0&quot; (3 048)</td>
<td>8'-0&quot; (2 438)</td>
</tr>
<tr>
<td>Blend slope</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>Ramp slope</td>
<td>16%</td>
<td>12%</td>
</tr>
</tbody>
</table>

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 22: 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 elevatored 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

- Arrow indicates direction of stair (one plan might have stairs going down and up)
- Break line (entire run of stair cannot be seen in floor plan)
- Dashed lines indicate stair continues above break line
- Ceiling clearance: 6'-8" (2,032) min.
- Guard rail height: 42" (1,067) min.
- Handrail height: 34–38" (864–965)
- Max. opening may allow an 8" (203) dia. sphere to pass through
- Max. opening may allow a 4" (102) dia. sphere to pass through
- Max. opening may allow a 6" (152) dia. sphere to pass through

Plan and Elevation of Stair
TREADS AND RISERS

Riser and Tread Dimensions

<table>
<thead>
<tr>
<th>Angle</th>
<th>Riser (inches)</th>
<th>Tread (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.00°</td>
<td>5 (127)</td>
<td>12 1/2 (318)</td>
</tr>
<tr>
<td>23.23°</td>
<td>5 1/4 (133)</td>
<td>12 1/4 (311)</td>
</tr>
<tr>
<td>24.63°</td>
<td>5 1/2 (140)</td>
<td>12 (305)</td>
</tr>
<tr>
<td>26.00°</td>
<td>5 3/4 (146)</td>
<td>11 3/4 (299)</td>
</tr>
<tr>
<td>27.55°</td>
<td>6 (152)</td>
<td>11 1/2 (292)</td>
</tr>
<tr>
<td>29.05°</td>
<td>6 1/4 (159)</td>
<td>11 1/4 (286)</td>
</tr>
<tr>
<td>30.58°</td>
<td>6 1/2 (165)</td>
<td>11 (279)</td>
</tr>
<tr>
<td>32.13°</td>
<td>6 3/4 (172)</td>
<td>10 3/4 (273)</td>
</tr>
<tr>
<td>33.68°</td>
<td>7 (178)</td>
<td>10 1/2 (267)</td>
</tr>
<tr>
<td>35.26°</td>
<td>7 1/4 (184)</td>
<td>10 1/4 (260)</td>
</tr>
<tr>
<td>36.87°</td>
<td>7 1/2 (191)</td>
<td>10 (254)</td>
</tr>
<tr>
<td>38.48°</td>
<td>7 3/4 (197)</td>
<td>9 3/4 (248)</td>
</tr>
<tr>
<td>40.13°</td>
<td>8 (203)</td>
<td>9 1/2 (241)</td>
</tr>
<tr>
<td>41.73°</td>
<td>8 1/4 (210)</td>
<td>9 1/4 (235)</td>
</tr>
<tr>
<td>43.36°</td>
<td>8 1/2 (216)</td>
<td>9 (229)</td>
</tr>
<tr>
<td>45.00°</td>
<td>8 3/4 (222)</td>
<td>8 3/4 (222)</td>
</tr>
<tr>
<td>46.63°</td>
<td>9 (229)</td>
<td>8 1/2 (216)</td>
</tr>
<tr>
<td>48.27°</td>
<td>9 1/4 (235)</td>
<td>8 1/4 (210)</td>
</tr>
<tr>
<td>49.90°</td>
<td>9 1/2 (241)</td>
<td>8 (203)</td>
</tr>
</tbody>
</table>

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 x run = 72"–75" (1 829–905)
- riser + run = 17"–17 1/2" (432–45)
- 2(riser) + run = 24"–25" (610–35)

For exterior stairs:
- 2(riser) + run = 26" (660)

Nonresidential:
- minimum width = 44" (1 120)
- maximum riser = 7 1/2" (191)
- minimum tread = 11" (279)

Residential:
- minimum width = 36" (915)
- maximum riser = 8 1/4" (210)
- minimum tread = 9" (229)
Chapter 23: 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.

**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**

- 1 3/8" (35)
- 1 3/4" (44)
- 2 1/4" (54)

**Heights**

- 6'-8" (2 032)
- 7'-0" (2 134)
- 7'-2" (2 184)
- 7'-10"* (2 388)
- 8'-0"* (2 438)

*1 3/4" thick doors only

---

**Widths**

- 2'-0" (610)
- 2'-4" (711)
- 2'-6" (762)
- 2'-8" (813)
- 2'-10" (864)
- 3'-0" (914)
- 3'-4" (1 016)
- 3'-6" (1 118)
- 3'-8" (1 168)
- 4'-0" (1 219)
Max. door size: 4’ x 10’ (1 219 x 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.

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.

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

face
veneer

cross banding

solid core: continuous block, stile and rail, mineral composition, or particle board

edge strip

Door Elevation
Detail Section

face
veneer

cross banding

hollow core: mesh grid, ladder strips, honeycomb, or spiral blanks

wood spacers

door elevation

Door Elevation
Detail Section

panel

stile or rail
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.

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>$\frac{1}{32}'' - \frac{1}{16}''$ (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.</td>
</tr>
<tr>
<td><strong>Sawn veneers</strong></td>
<td>$\frac{1}{8}''$ (3.2), bonded to crossband. Easily refinished and repaired.</td>
</tr>
<tr>
<td><strong>Sawn veneers</strong></td>
<td>$\frac{1}{4}''$ (6.4), no crossband on stile and rail. Face depth allows for decorative grooves.</td>
</tr>
</tbody>
</table>

### Wood Grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Premium</strong></td>
<td>For natural, clear, or stained finishes</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>For opaque (painted) finishes</td>
</tr>
</tbody>
</table>

**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.
HOLLOW METAL DOORS

Meeting Stiles
- Top rail hinge stile
- Flush or recessed panel
- Center rail
- Lock stile
- Bottom rail

- Rabbeted
- Parallel bevel
- Parallel bevel with Z astragal
- Bull nose
- Vinyl or rubber astragal
- V-bevel
- Plate astragal
- One-piece overlapping astragal

Standard Double Rabbet Frame

<table>
<thead>
<tr>
<th>Jamb Depth</th>
<th>4 3/4&quot; (121)</th>
<th>5 1/2&quot; (140)</th>
<th>5 3/4&quot; (146)</th>
<th>6 3/4&quot; (171)</th>
<th>7 3/4&quot; (197)</th>
<th>8 3/4&quot; (222)</th>
<th>12 3/4&quot; (324)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rabbet 1</td>
<td>1 3/16&quot; (40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rabbet 2</td>
<td>1 11/16&quot; (49)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backbend</td>
<td>1/2&quot; (13)</td>
<td>1/2&quot; (13)</td>
<td>1/2&quot; (13)</td>
<td>1/2&quot; (13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throat</td>
<td>3 3/4&quot; (95)</td>
<td>4&quot; (102)</td>
<td>4 3/4&quot; (121)</td>
<td>5 3/4&quot; (146)</td>
<td>6 3/4&quot; (171)</td>
<td>7 3/4&quot; (197)</td>
<td>11 3/4&quot; (298)</td>
</tr>
</tbody>
</table>

Jamb Depth:
- 4 3/4"
- 5 1/2"
- 5 3/4"
- 6 3/4"
- 7 3/4"
- 8 3/4"
- 12 3/4"

Rabbet 1:
- 1 3/16" (40) standard for 1 3/8" (35) door

Rabbet 2:
- 1 11/16" (49) standard for 1 3/4" (44) door

Backbend:
- 1/2" (13)
- 3/4" (19)
- 1/2" (13)
- 1/2" (13)
- 1/2" (13)
- 1/2" (13)

Throat:
- 3 3/4" (95)
- 4" (102)
- 4 3/4" (121)
- 5 3/4" (146)
- 6 3/4" (171)
- 7 3/4" (197)
- 11 3/4" (298)
Hollow Metal Door Gauges

<table>
<thead>
<tr>
<th>GRADE</th>
<th>GAUGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>20 and lighter</td>
</tr>
<tr>
<td>Commercial</td>
<td>16 and 18</td>
</tr>
<tr>
<td>Institutional</td>
<td>12 and 14</td>
</tr>
<tr>
<td>High Security</td>
<td>steel plate</td>
</tr>
</tbody>
</table>

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 zebs 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)
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.
Chapter 24: 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.

b.c.e. (Before Common Era) = b.c.
c.e. (Common Era) = a.d.
b. = before; c. = century; ca. = circa
<table>
<thead>
<tr>
<th>Time Period</th>
<th>Region</th>
<th>Landmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 B.C.E.</td>
<td>Egyptian</td>
<td>Ziggurat at Ur</td>
</tr>
<tr>
<td>1000 B.C.E.</td>
<td>Egyptian</td>
<td>Mentuhotep Mortuary Temple</td>
</tr>
<tr>
<td>0 B.C.E.</td>
<td>Egyptian</td>
<td>Great Temple of Ramses II</td>
</tr>
<tr>
<td>2000-31 B.C.E.</td>
<td>Greek</td>
<td>Temple of Hera</td>
</tr>
<tr>
<td>2000-1380 B.C.E.</td>
<td>Greek</td>
<td>Palace at Knossos</td>
</tr>
<tr>
<td>1700-530-460 B.C.E.</td>
<td>Greek</td>
<td>Parthenon</td>
</tr>
<tr>
<td>448-432 B.C.E.</td>
<td>Greek</td>
<td>Stoa of Attalus</td>
</tr>
<tr>
<td>72-80 C.E.</td>
<td>Roman</td>
<td>Colosseum</td>
</tr>
<tr>
<td>72-80 C.E.</td>
<td>Roman</td>
<td>Pont du Gard Aqueduct</td>
</tr>
<tr>
<td>1300-1225 B.C.E.</td>
<td>Egyptian</td>
<td>Hypostyle Hall at Karnak</td>
</tr>
<tr>
<td>850 C.E.</td>
<td>Byzantine</td>
<td>Arch of Constantine</td>
</tr>
<tr>
<td>324-15th c.</td>
<td>Byzantine</td>
<td>Temple of Apollo 310 B.C.E.</td>
</tr>
<tr>
<td>324-15th c.</td>
<td>Byzantine</td>
<td>Bath of Caracalla</td>
</tr>
<tr>
<td>510 B.C.E.–476 C.E.</td>
<td>Roman</td>
<td>Pantheon</td>
</tr>
<tr>
<td>500–1200 C.E.</td>
<td>Romanesque</td>
<td>El Castillo</td>
</tr>
<tr>
<td>687–89 C.E.</td>
<td>Romanesque</td>
<td>Great Temple of Ramses II</td>
</tr>
<tr>
<td>324–15th c.</td>
<td>Byzantine</td>
<td>Great Temple of Ramses II</td>
</tr>
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</tr>
<tr>
<td>500–1200 C.E.</td>
<td>Romanesque</td>
<td>El Castillo</td>
</tr>
</tbody>
</table>

Timeline:
- **El Castillo** (850 C.E.)
  - Chichen Itza, Yucatan, Mexico
- **Dome of the Rock** (687–89 C.E.)
  - Jerusalem
MIDDLE AGES

- Kandariya Mahadeva Temple (1025–50)
  Khajuraho, India

- Notre-Dame Cathedral (1163–1250)
  Paris, France

- Chartres Cathedral (1194–1220)
  Chartres, France

- Amiens Cathedral (1220–47)
  Amiens, France

- Salisbury Cathedral (1220–60)
  Salisbury, England

- San Vitale (526)
  Ravenna, Italy

- S. Apollinaire Nuovo (ca. 490)
  Ravenna, Italy

- Hagia Sophia (537)
  Istanbul (Constantinople), Turkey

- St. Mark (1042–85)
  Venice, Italy

- Worms Cathedral (1110–81)
  Worms, Germany

- Pisa Cathedral (1063–92)
  and Baptistery (1153)
  Pisa, Italy

- Amiens Cathedral (1220–47)
  Amiens, France

- Salisbury Cathedral (1220–60)
  Salisbury, England

- Hagia Sophia (537)
  Istanbul (Constantinople), Turkey

- St. Mark (1042–85)
  Venice, Italy

- Angkor Wat (b. ca. 1120)
  Cambodia

- Kandariya Mahadeva Temple (1025–50)
  Khajuraho, India

- Notre-Dame Cathedral (1163–1250)
  Paris, France

- Chartres Cathedral (1194–1220)
  Chartres, France

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  Amiens, France

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- Pisa Cathedral (1063–92)
  and Baptistery (1153)
  Pisa, Italy

- Amiens Cathedral (1220–47)
  Amiens, France

- Salisbury Cathedral (1220–60)
  Salisbury, England

- Romanesque (500–1200)

- Byzantine (324–12th c.)
Gothic
(ca. 1140–1500)
- Amiens Cathedral (1220–47)
  Amiens, France
- Strasbourg Cathedral (begun 1277)
  Alsace, France
- Duomo de S. Maria del Fiore (1377–1436)
  Florence, Italy
  Filippo Brunelleschi
- Façade of S. Maria Novella (1458)
  Florence, Italy
  Leon Battista Alberti

Renaissance
(1350–1600)
- Hall of Supreme Harmony (15th c.)
  Forbidden City, Beijing, China
- Villa La Rotonda (1557)
  Vicenza, Italy
  Andrea Palladio
- Laurentian Library (1524)
  San Lorenzo, Italy
  Michelangelo
- Palazzo Rucellai (1455–70)
  Florence, Italy
  Leon Battista Alberti
- S. Giorgio Maggiore (1566)
  Venice, Italy
  Andrea Palladio
- Tempietto of S. Pietro in Montorio (1502)
  Rome, Italy
  Donato Bramante

Timeline

1300
1400
1500
PREMODERN

Renaissance (1350–1600)


Baroque (1600–1700)

- Façade of S. Susanna (1603) Rome, Italy Carlo Maderno
- S. Carlo alle Quattro Fontane (b. 1634) Rome, Italy Francesco Borromini
- Colonnade Piazza of St. Peter's (1656) Rome, Italy Gianlorenzo Bernini
- Karlskirche (b. 1656) Vienna, Austria Johann Fischer von Erlach
- Taj Mahal (1630–53) Agra, India Emperor Shah Jahan
- Façade of S. Susanna (1603) Rome, Italy Carlo Maderno
- S. Carlo alle Quattro Fontane (b. 1634) Rome, Italy Francesco Borromini
- Colonnade Piazza of St. Peter's (1656) Rome, Italy Gianlorenzo Bernini
- Karlskirche (b. 1656) Vienna, Austria Johann Fischer von Erlach
- Taj Mahal (1630–53) Agra, India Emperor Shah Jahan

Chiswick House (1722–29)
London, England Lord Burlington

Spanish Steps (1723–25)
Rome, Italy Francesco de Sanctis
**Neoclassicism (1750–1880)**

- Monticello (1771–82)
  Charlottesville, Va., USA
  Thomas Jefferson

- Panthéon (1764–90)
  Paris, France
  Jacques Germain Soufflot

- Crystal Palace (1851)
  London, England
  Joseph Paxton

**Georgian (1714–1830)**

- Salt Works (1780)
  Chaux, France
  Claude-Nicolas Ledoux

- Monticello (1771–82)
  Charlottesville, Va., USA
  Thomas Jefferson

**Rococo (1700–80)**

- Chiswick House (1725–29)
  London, England
  Lord Burlington

**Art Nouveau (1880–1902)**

- Tassel House (1893)
  Brussels, Belgium
  Victor Horta

- Art Nouveau (1880–1902)
  Paris, France
  Henri Labrouste

- Bibliothèque Nationale (1858–68)
  Paris, France
  Henri Labrouste

- Crystal Palace (1851)
  London, England
  Joseph Paxton

- Panthéon (1764–90)
  Paris, France
  Jacques Germain Soufflot

- Schauspielhaus (1819–21)
  Berlin, Germany
  Karl Friedrich Schinkel

- University of Virginia (1826)
  Charlottesville, Va., USA
  Thomas Jefferson

- University of Virginia (1826)
  Charlottesville, Va., USA
  Thomas Jefferson

- Boston Public Library (1887–95)
  Boston, Mass., USA
  McKim, Mead & White

- Boston Public Library (1887–95)
  Boston, Mass., USA
  McKim, Mead & White

- University of Virginia (1826)
  Charlottesville, Va., USA
  Thomas Jefferson

- Houses of Parliament (1836–68)
  London, England
  Charles Barry

- Panopticon (1791)
  Jeremy Bentham

- Bank of England (1788)
  London, England
  John Soane

- Marshall Field Wholesale Store (1885–87)
  Chicago, Ill., USA
  H. H. Richardson

- Marshall Field Wholesale Store (1885–87)
  Chicago, Ill., USA
  H. H. Richardson
MODERN

Art Nouveau
(1880–1902)

Modernism
(1900–45)

Late Modernism
(1945–1975)

Arts & Crafts
(1860–1925)

Art Deco
(1920s–40s)

- Casa Milà (1906–10)
  Barcelona, Spain
  Antoni Gaudi

- German Pavilion (Barcelona Pavilion)
  (1928; demolished 1930, rebuilt 1959)
  Barcelona, Spain
  Ludwig Mies van der Rohe

- Eames House (1946)
  Pacific Palisades, Calif., USA
  Charles & Ray Eames

- International Style Exhibition, MoMA
  (1929)
  New York, N.Y., USA

- Villa Savoye (1929)
  Poissy, France
  Le Corbusier

- Falling Water (1937)
  Mill Run, Pa., USA
  Frank Lloyd Wright

- Goldman & Salatsch Store
  (1910)
  Vienna, Austria
  Adol Loos

- Einstein Tower (1921)
  Potsdam, Germany
  Erich Mendelsohn

- Ward Willits House (1902)
  Highland Park, Ill., USA
  Frank Lloyd Wright

- Bauhaus (1925)
  Dessau, Germany
  Walter Gropius

- Red House (1859–60)
  Bexleyheath, England
  Philip Speakman Webb

- Arts & Crafts
  (1860–1925)

- Empire State Building (1930)
  New York, N.Y., USA
  Shreve, Lamb & Harmon

- Exposition Internationale des Arts Décoratifs et Industriels Modernes
  (1925) Paris, France
Timeline

1960

Brutalism
(1950s–70s)

Hunstanton School (1954)
Norfolk, England
Alison & Peter Smithson

• Palazzetto dello Sport (1960)
Rome, Italy
Pier Luigi Nervi

Late Modernism
(1945–1975)

Kimbell Art Museum (1967–72)
Fort Worth, Tex., USA
Louis I. Kahn

• TWA Terminal (1962)
New York, N.Y., USA
Eero Saarinen

• Carpenter Center (1964)
Cambridge, Mass., USA
Le Corbusier

House III (1969–70)
Lakeville, Conn., USA
Peter Eisenman

• Glass House (1949)
New Canaan, Conn., USA
Philip Johnson

Gehry House (1977–78)
Santa Monica, Calif., USA
Frank Gehry

2000

Postmodernism
(1960s–90s)

AT&T Building (1978)
New York, N.Y., USA
Philip Johnson & John Burgee

• Vanna Venturi House (1964)
Chestnut Hill, Pa., USA
Robert Venturi

• Portland Building (1982)
Portland, Ore., USA
Michael Graves

Deconstructivism
(1980-88)

• Parc de la Villette (1982–85)
Paris, France
Bernard Tschumi

• Wexner Center for the Arts (1989)
Columbus, Ohio, USA
Peter Eisenman

Seattle Public Library (2004)
Seattle, Wash., USA
Rem Koolhaas (OMA)

• Addition to the Louvre (1983–89)
Paris, France
I. M. Pei

• Centre Pompidou (1976)
Paris, France
Reno Piano & Richard Rogers

• AT&T Building (1978)
New York, N.Y., USA
Philip Johnson & John Burgee
Chapter 25: Glossary

**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

**ADA:** Americans with Disabilities Act

**Adaptive reuse:** Changing a building’s function in response to the changing needs of its users.

**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.

**Aalto, Alvar:** (1898-1976) Finnish architect and designer; notable buildings include the Municipal Library in Viipuri, Finland, Paimio Sanatorium, and Baker House at MIT.

**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.

**Annealed:** Metal cooled under controlled conditions.

**Angle:** L-shaped steel or aluminum structural section.
**Arch:** Structural device that supports vertical loads by translating them into axial forces.

**Arcade:** Series of arches on columns or piers.

**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.

**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 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.

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.

Cored 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.

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.

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.

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.

**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.


**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.

**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.

**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.

**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 (19xx), the Unité d’Habitation, and the chapel at Ronchamp.

Ledoux, Claude Nicolas: (1736-1806) French neoclassical architect; notable designs include the Royal Saltworks at Arc-et-Senans, and the Theatre of Besançon.

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.

Louver: 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.

Niche: Recess in a wall, usually for holding a sculpture.

Nominal: Approximate rounded dimensions given to materials for ease of reference.

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.

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.

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.

Prefabriacted 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.

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.

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.

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.
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**Saarinen, Eliel:** (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).

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**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.

**Thermal performance:** Ability of a glass unit to perform as a barrier to the transfer of heat.

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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 BCE - 15 BCE) Roman architect, engineer and writer; most notable for his treatise De Architectura (On Architecture).

W

Walser: 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

JOURNALS & PERIODICALS
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.japanarchitecture.com
Lotus International (quarterly, Italy); www.editorialelotus.it
Metropolis Magazine (monthly, USA); www.metropolismag.com

WEBSITES
www.archinect.com
www.dezeen.com
www.archinform.net
www.designboom.com
www.architectureweek.com
Primary Sources

**Architectural Graphic Standards, 11th ed.**
Charles George Ramsey, Harold Sleeper, and John Hoke; John Wiley & Sons, 2007
CD-ROM also available.
previous editions: 1 (1932); 4 (1951); 5 (1956); 6 (1970); 9 (1994); 10 (2000)

**Neufert Architects’ Data, 4th ed.**
Blackwell Publishers, 2012

**Fundamentals of Building Construction: Materials and Methods, 5th ed.**
Edward Allen and Joseph Iano; John Wiley & Sons, 2008

**Pocket Ref, 4th ed.**
Thomas J. Glover, Sequoia Publishing, 2010

**Understanding Buildings: A Multidisciplinary Approach**
Esmond Reid; MIT Press, 1994

**Building Construction Illustrated, 4th ed.**

**The Architect’s Studio Companion, 4th ed.**
Edward Allen and Joseph Iano; John Wiley & Sons, 2006

**Skins for Buildings: The Architect’s Materials Sample Book**
David Keuning et al.; Gingko Press, 2004

**Annual Book of ASTM Standards**
American Society for Testing Materials, 2013
Seventy-plus volumes contain more than 12,000 standards available in print, CD-ROM, and online formats.

[www.ansi.org](http://www.ansi.org) (American National Standards Institute)

[www.nist.gov](http://www.nist.gov) (National Institute of Standards and Technology)
## 01_MATERIALS

### 01 Wood

**Laminated Timber Construction**  
Christian Müller; Birkhäuser, 2000

**Wood Handbook: Wood as an Engineering Material**  
Forest Products Laboratory, U.S. Department of Agriculture

**Timber Construction Manual**  
Thomas Herzog et al.; Birkhäuser, 2004

**Detail Praxis: Timber Construction—Details, Products, Case Studies**  
Theodor Hughes et al.; Birkhäuser, 2004

**AITC Timber Construction Manual, 5th ed.**  
American Institute of Timber Construction, 2004

**AWI Quality Standards, 7th ed., 1999**  
www.awinet.org (Architectural Wood Institute)

www.lumberlocator.com

### 02 Masonry and Concrete

**Masonry Construction Manual**  
Günter Pfeifer et al.; Birkhäuser, 2001

**Masonry Design and Detailing for Architects and Contractors, 5th ed.**  
Christine Beall; McGraw-Hill, 2004

**Complete Construction: Masonry and Concrete**  
Christine Beall; McGraw-Hill

**Design of Reinforced Masonry Structures**  
Narendra Taly; McGraw-Hill Professional, 2000

**Reinforced Masonry Design**  
Robert R. Schneider; Prentice-Hall, 1980

**Indiana Limestone Handbook, 21st ed.**  
Indiana Limestone Institute, 2002

www.bia.org (Brick Industry Association)
Concrete Construction Manual
Friedbert Kind-Barkauskas et al.; Birkhäuser, 2002

Construction Manual: Concrete and Formwork
T. W. Love; Craftsman Book Company, 1973

Precast Concrete in Architecture

Concrete Architecture: Design and Construction
Burkhard Fröhlich; Birkhäuser, 2002

www fhwa dot gov (Federal Highway Administration)
www aci-int org (American Concrete Institute)

03 Metals

2012

Metal Architecture
Burkhard Fröhlich and Sonja Schulenburg, eds.; Birkhäuser, 2003

Steel and Beyond: New Strategies for Metals in Architecture
Annette LeCuyer; Birkhäuser, 2003

www corrosion doctors org

04 Finishes

The Graphic Standards Guide to Architectural Finishes: Using MASTERSPEC
to Evaluate, Select, and Specify Materials
Elena S. Garrison; John Wiley & Sons, 2002

Interior Graphic Standards

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Extreme Textiles: Designing for High Performance
Matilda McQuaid; Princeton Architectural Press, 2005

Sweets Catalog
McGraw-Hill Construction, ongoing; www.sweets.com

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American Institute of Steel Construction, 2001; www.aisc.org

Steel Construction Manual, 14th ed.
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Helmut Schultz, Werner Sobek, and Karl J. Habermann; Birkhäuser, 2000

Structural Steel Designer’s Handbook
Roger L Brockenbrough and Frederick S. Merritt; McGraw-Hill Professional, 1999

Steel Designers’ Manual
Buick Davison and Graham W. Owens, eds.; Steel Construction Institute (UK).

Graphic Guide to Frame Construction: Details for Builders and Designers
Rob Thallon; Taunton Press, 2000

www.awc.org (American Wood Council)

06 Mechanical Systems

Mechanical and Electrical Systems in Construction and Architecture, 4th ed.
Frank Dagostino and Joseph B. Wujek; Prentice Hall, 2004

Mechanical and Electrical Equipment for Buildings, 9th ed.
Ben Stein and John S. Reynolds; John Wiley & Sons, 1999

Mechanical Systems for Architects
Aly S. Dadras; McGraw-Hill, 1995

www.buildingwell.org
www.homerepair.about.com
www.efftec.com
www.saflex.com

Sustainable Architecture White Papers (Earth Pledge Foundation Series on Sustainable Development)
David E. Brown, Mindy Fox, Mary Rickel Pelletier, eds.; Earth Pledge Foundation, 2001

Cradle to Cradle: Remaking the Way We Make Things
William McDonough and Michael Braungart; North Point Press, 2002
07 Electrical Systems

Mark S. Rea, ed.; IESNA, 2000

Lighting the Landscape
Roger Narboni; Birkhäuser, 2004

1000 Lights, vol. 2: 1960 to Present
Charlotte and Peter Fiell; Taschen, 2005

www.archlighting.com
www.iesna.org (Illuminating Engineering Society of North America)
www.iald.org (International Association of Lighting Designers)

08 Plumbing and Fire Protection Systems

Fire Protection Systems
A. Maurice Jones, Delmar Cengage Learning, 2008

Plumbing Engineering Design Handbook
American Society of Plumbing Engineers, 2004

09 Building Enclosure Systems

Glass Construction Manual
Christian Schittich et al.; Birkhäuser, 1999

Detail Praxis: Translucent Materials—Glass, Plastic, Metals
Frank Kaltenbach, ed.; Birkhäuser, 2004

www.GlassOnWeb.com (glass design guide)
www.glass.org (National Glass Association)
www.nrca.net (National Roofing Contractors Association)
03_STANDARDS  MEASURE AND DRAWING

10  Measurement and Geometry

Measure for Measure
Thomas J. Glover and Richard A. Young; Sequoia Publishing, 2001

David Adler, ed.; Architectural Press, 1999

www.onlineconversion.com
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11  Architectural Drawing Types

Design Drawing
Francis D. K. Ching and Steven P. Juroszek; John Wiley & Sons, 1997

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Kevin Forseth with David Vaughan; Van Nostrand Reinhold, 1980

John Montague; John Wiley & Sons, 2004

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www.aia.org
www.iso.org
www.constructionplace.com
www.dcd.com (Design Cost Data)
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ARCOM, ongoing; www.arcomnet.com

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Fred A. Stitt; McGraw-Hill Professional, 1999

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www.csinet.org (Construction Specifications Institute)

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13 Hand Drawing

Architectural Drawing: A Visual Compendium of Types and Methods, 2nd ed.
Rendow Yee; John Wiley & Sons, 2002

Francis D. K. Ching; John Wiley & Sons, 2002

14 Computer Standards

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2004; www.nationalcadstandard.org

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Autodesk, 2001

AutoCad 2006 Instructor
James A. Leach; McGraw-Hill, 2005

www.nibs.org (National Institute of Building Sciences)
www.pcmag.com
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#### 15 The Human Scale

- **The Measure of Man and Woman: Human Factors in Design, rev. ed.**
  Alvin R. Tilley; John Wiley & Sons, 2002
- **Human Scale, vol. 7: Standing and Sitting at Work, vol. 8: Space Planning for the Individual and the Public, and vol. 9: Access for Maintenance, Stairs, Light, and Color**
  Niels Diffrient, Alvin R. Tilley, and Joan Bardagjy; MIT Press, 1982
  Both above-cited books draw on information produced by Henry Dreyfuss Associates, a leading firm in the development of anthropometric data and its relationship to design.

#### 16 Residential Spaces

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