

Print Reading for Construction

Residential and Commercial

Write-in Text with 140 Large Prints

Sixth Edition

by

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Introduction



Print Reading for Construction is a textbook for those who wish to learn basic print reading and increase their knowledge of construction drawings. The term *print reading*, as used in this textbook, refers to interpreting and visualizing construction drawings.

Print Reading for Construction is a combination text and workbook, or “write-in text.” The text tells and shows how, and the workbook provides space for meaningful print reading, sketching, and estimating activities. Actual construction prints used with the text can be found in the *Large Prints* folder. They provide realistic job experience. The text is equally applicable for students studying construction, estimating, or construction management.

Print Reading for Construction is intended for technical students, apprentices, and adult workers. It also is designed to be used for self-instruction by individuals unable to attend classes.

Using the Features of This Textbook

A list of *Technical Terms* opens each unit. Study this list before reading the unit. Pay special attention when these terms are discussed. After completing a unit, review the Technical Terms to be sure you understand all of them. All of these terms are also defined in the Glossary.

Learning Objectives are presented to define the most important skills you will learn in the unit. After completing a unit, review these to ensure that you have mastered the new material.

Each unit is followed by *Test Your Knowledge* questions. These brief questions will help you to evaluate how well you understand the topics presented in the unit.

Most units include two or more *Activities* that provide you with practical print reading experience. Many of these will make use of the actual residential and commercial prints contained in the *Large Prints* folder.

The *Glossary* contains hundreds of words with easy-to-understand definitions. When you come across a term you are unfamiliar with, use the Glossary to find its meaning.

Using the Large Prints

The *Large Prints* folder contains six sets of construction prints for the building projects referenced in this text. There are 140 total prints in the folder package. Included are sets for three residential building projects and three commercial building projects.

Print reading activities corresponding to each project are presented in this text. Two of the projects are referenced in the print reading activities in Units 8–17:

- The Marseille Two-Story Residence
- Delhi Flower and Garden Centers Greenhouse and Sales Building

The print reading activities for these projects appear at the end of each unit and are intended to be completed after studying the corresponding unit.

There are four building projects referenced in the *Advanced Print Reading Projects* section of this text. These include two residential projects and two commercial projects:

- Advanced Project A—Mercedes Pointe Residence
- Advanced Project B—The North House Residence
- Advanced Project C—Office and Warehouse
- Advanced Project D—Office Building

The print reading activities for these projects are more extensive in scope and are intended for additional print reading practice.

Organization of Large Prints

Prints in the *Large Prints* folder are arranged so that each building project is printed on one side of the sheets. This organization helps in locating information across multiple sheets. The projects are grouped in the *Large Prints* folder as follows:

Group A:

Front of sheet: The Marseille Two-Story Residence (9 prints) • Advanced Project A—Mercedes Pointe Residence (8 prints) • Advanced Project B—The North House Residence (13 prints)

Back of sheet: Delhi Flower and Garden Centers Greenhouse and Sales Building (30 prints)

Group B:

Front of sheet: Advanced Project C—Office and Warehouse (40 prints)

Back of sheet: Advanced Project D—Office Building (40 prints)

Indexes for Large Prints

The following tables list the prints in the *Large Prints* folder for the projects referenced in Units 8–17. Indexes for the prints associated with the advanced print reading activities appear later in the text where the projects are referenced.

The Marseille Two-Story Residence		
Print Index (9 Prints)		
Print Label	Sheet Number	Sheet Title
M-1	1	Exterior Elevations, Details, and Notes
M-2	2	Foundation Plan
M-3	MP2	Foundation Mechanical/Plumbing Plan
M-4	3	First Floor Plan
M-5	MP3	First Floor Mechanical/Plumbing Plan
M-6	4	Second Floor Plan
M-7	MP4	Second Floor Mechanical/Plumbing Plan
M-8	5	Truss Profiles, Roof Plan, and Details
M-9	6	Exterior Elevations and Sections

Delhi Flower and Garden Centers Greenhouse and Sales Building					
Print Index (30 Prints)					
Print Label	Sheet Number	Sheet Title	Print Label	Sheet Number	Sheet Title
Del-1	1	Title Sheet	Del-16	S1.1	Foundation Plan
Del-2	4	Existing Conditions/Demolition Plan	Del-17	S1.2	West Trellis Foundation Plan
Del-3	5	Grading and Erosion Control Plan	Del-18	S2.1	Roof Framing Plan
Del-4	A0.1	Cover Page and Notes	Del-19	S2.2	Framing Plans and Truss Elevations
Del-5	A1.1	First Floor Plan	Del-20	S3.1	Foundation Sections
Del-6	A1.2	Partial First Floor Plan	Del-21	S4.1	Framing Sections
Del-7	A1.3	Mezzanine Plan	Del-22	S5.1	General Structural Notes and Sections
Del-8	A2.1	Roof Plan	Del-23	P1.1	First Floor Plumbing Plan and Mezzanine Plumbing Plan
Del-9	A3.1	Ceiling Plan	Del-24	P2.1	Plumbing Riser Diagram
Del-10	A4.1	Exterior Elevations	Del-25	M1.1	First Floor Mechanical Plan
Del-11	A4.2	Exterior Elevations	Del-26	M1.2	Mezzanine Mechanical Plan and Schedules
Del-12	A5.1	Interior Elevations and Schedules	Del-27	E1.1	First Floor Lighting Plan
Del-13	A6.1	Enlarged Checkout and Interior Elevations	Del-28	E1.2	Lighting Plans and Schedules
Del-14	A9.1	Wall Sections	Del-29	E2.1	First Floor Power Plan
Del-15	A9.2	Wall Sections	Del-30	E4.1	Electrical Riser Diagram, Panel Schedules, and Notes

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- Mercedes Pointe Residence
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CITY Properties Group, LLC

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Technical Terms

admixture	lintels
adobe brick	loose-fill insulation
aggregates	lumber
angles	mortar
ashlar	mosaic tiles
bent glass	nonferrous metals
bond	open-web steel joists
bond beams	patterned glass
brick masonry	paving brick
building brick	pervious concrete
cement	plate glass
ceramic tiles	plywood
concrete	quarry tile
concrete brick	reflective insulation
concrete masonry unit (CMU)	reinforcing bars
cut stones	rigid insulation
face brick	rough-sawn lumber
ferrous metals	rubble
firebrick	R-value
fired-clay tile	safety glass
flexible insulation	sand-lime brick
float glass	sheet glass
gage system	single-wythe walls
glass	stained glass
glass block	stone masonry
glazed brick	stretcher
gravel	structural clay tile
green building	structural steel
grout	surfaced lumber
header course	sustainability
hydration	sustainable design
insulating glass	terra cotta
kiln-burned brick	thermal insulation
laminating	welded wire fabric (WWF)

Learning Objectives

After completing this unit, you will be able to:

- Identify a variety of basic materials used in construction.
- Identify the basic components of concrete.
- Describe different types of masonry brick, block, and mortar.
- Classify wood as hardwood or softwood.
- Recognize different structural steel shapes.
- Describe various types of glass, plastics, and insulation.
- Identify symbols representing materials on a drawing.
- Explain the fundamentals of green building construction.



It takes many different kinds of materials to construct a building project. Most of these materials are carefully detailed in the project working drawings. Information about materials may also be included in the drawing notes and project specifications.

The purpose of this unit is to provide you with an overview of the most common materials used in building construction. The materials will be discussed as they relate to numbered divisions in the CSI MasterFormat standard. Also discussed are material symbols used on construction drawings and the ways in which materials may be identified on drawings.

Division 31—Earthwork

Aggregates (also referred to as *gravel*) are used for many different construction applications. In building construction, aggregates are typically used for subbase support under concrete slabs and fill around pipes, **Figure 7-1**. Other uses include foundation and underground drainage. Aggregates also serve as one of the three basic ingredients of concrete.

Aggregates start out as solid rock in the earth's crust, and over many thousands of years, are broken down by freeze/thaw cycles and other natural action into pieces of various sizes. The larger pieces are called coarse aggregates or gravel; the smaller pieces are usually referred to as sand or fine aggregates.

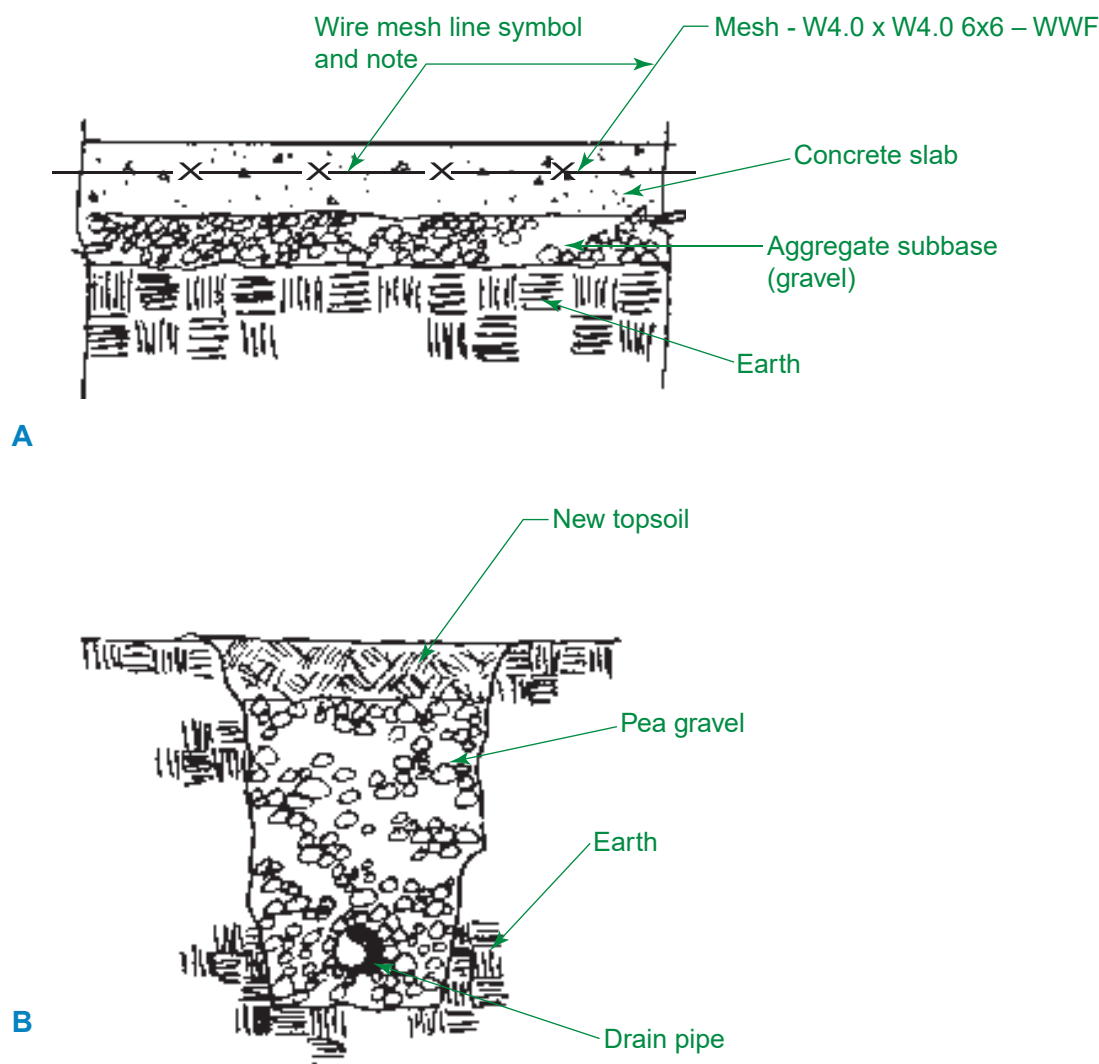


Figure 7-1. Typical uses for aggregates. A—Gravel used as a subbase support for a concrete slab. Note the symbols used for the various materials. Wire mesh, used for reinforcement, is represented by a line symbol consisting of a series of short line segments and a repeating “X” symbol. B—Pea gravel used to fill a curtain or trench drain.

There are various kinds of aggregates, such as: *Pea gravel*, small, rounded pieces ranging in diameter from 1/4” to 3/8”.

River gravel, larger aggregates dredged from river bottoms, banks, and flood plains.

Crushed stone, mined stone that has been mechanically fractured to a specified size.

Characteristics of aggregates are:

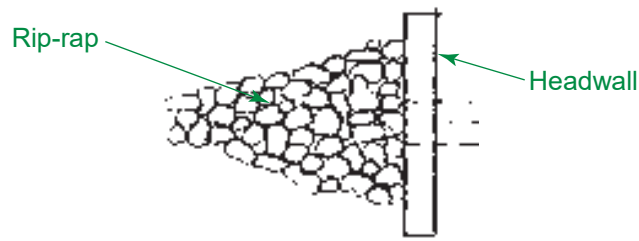
- Soundness
- Chemical stability
- Abrasion resistance
- Grading and sieve analysis
- Percentage of crushed particles
- Particle shape
- Surface texture
- Specific gravity

- Absorption
- Moisture content
- Volume stability

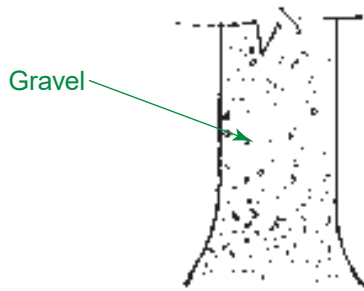
Some gravel drawing symbols are shown in **Figure 7-2**.

Division 03—Concrete

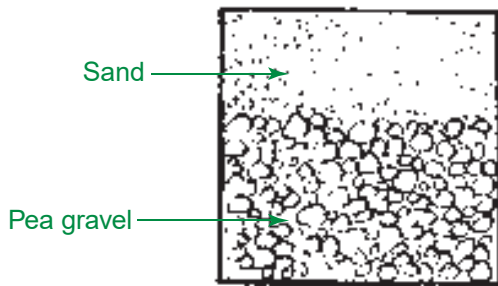
Concrete is one of the oldest building materials, having been used by the Romans as early as 100 B.C. Concrete is a mixture of cement, sand, coarse and fine aggregates, admixtures, and water. When first mixed, it is *plastic* (able to flow and be shaped) and can be cast to take the shape of the formwork provided.



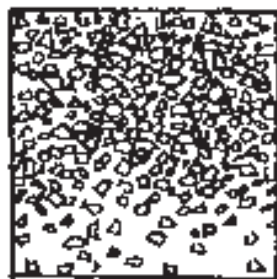
A Headwall and Rip-rap
Plan View



B Gravel Driveway
Plan View



C Pea Gravel and Sand
Section View



D Crushed Gravel
Section View

Figure 7-2. Samples of drawing symbols for gravel. A—Plan view of a headwall with rip-rap used to prevent erosion from drainage water outflow. This type of structure would be found on a site plan. B—Plan view of a gravel driveway. C—Section view of pea gravel with a sand layer above the gravel. D—Section view of crushed gravel.

Hardening of the concrete is caused by a chemical reaction between the cement and water called *hydration*. Most mixtures of concrete set within 4 hours but can take up to 12 hours, depending on the temperature, the volume of the pour, type of cement, and admixtures. When the temperature is below 70°F (20°C), the chemical reaction slows. Very little chemical reaction takes place below 40°F (4°C), and almost none occurs at 32°F (0°C). The rule of thumb is: if you are comfortable, the concrete is comfortable. Concrete continues to harden for months after the initial set, but most placements reach their compressive or design strength within 28 days. Forms can be removed after one to several days or when the concrete can support itself. This should be determined by an engineer and testing lab.

Types of Cement

Cement binds the concrete mixture together. There are five basic types of cement. The most common, used for general construction, is called *Type I Normal Portland cement*. Another variation used in construction is *white Portland cement*. It is light-colored and used chiefly for architectural effects. White Portland cement is made from carefully selected raw materials and develops the same strength as the normal gray-colored Portland cement.

The five basic types of cement include:

- Type I, Normal Cement (most common)
- Type II, Moderate Sulfate Resistance (slow-reacting)
- Type III, High Early Strength (fast-setting)
- Type IV, Low Heat of Hydration (low heat generation)
- Type V, High Sulfate Resistance

These cements, along with aggregates and admixtures, are available to produce special types of concrete. For example, Type IV cement is for low heat generation for large construction building foundation projects, such as dams. Other cements have high early strength to produce concrete that gains strength faster than normal, Type I or II cements, permitting earlier form removal and thus speeding cold weather construction. Still others are more resistant to deterioration caused by sulfates and alkalis in the soil.

Concrete Mixes

A concrete mix should be designed to produce the desired result. Characteristics and properties of concrete depend on the materials, and their proportions, that make up the mixture. This will determine the workability, strength, durability, economy, volume stability, and appearance of the finished hardened concrete. Enough water is added to make the mixture plastic, so that it will flow into the forms. Too much water, however, will reduce the strength and durability of the concrete, so the contractor needs to be careful. A typical mix would consist of 10% cement, 15% water, 25% fine aggregates, 45% coarse aggregates, and 1% to 5% entrained or entrapped air. See **Figure 7-3**. Concrete mixes can vary from job to job and area to area depending on engineering requirements.

Any material added to the concrete mix—other than cement, sand, aggregate, and water—is known as an *admixture*. Admixtures are used to make the mix more workable, retard or speed up hardening, increase freeze resistance, or increase chemical resistance. Common admixtures to concrete include *air entrainment*, used to improve durability in freeze/thaw environments; *retarders*, used to slow down the initial set of fresh concrete, especially in hot weather; *accelerators*, used to speed up the initial set of

fresh concrete in cold weather; *water reducers*, used to reduce the amount of water required for a desired workability and water-to-cement ratio for strength; and *coloring agents*, used for altering the color of the concrete mixture. Concrete is typically transported to the job site in a ready-mix truck. See **Figure 7-4**.

Reinforced Concrete

Concrete has great compressive strength, but very little tensile (pulling) strength. To overcome this weakness, concrete is cast around steel *reinforcing bars*. These bars (commonly referred to as “rebar”) have high tensile strength. As the concrete hardens, it grips the steel to form a bond. The size of the bar is indicated by the bar number, which is a multiple of $1/8"$. For example, a #4 bar is $1/2"$ in diameter ($4 \times 1/8" = 1/2"$). See **Figure 7-5**. Refer to Unit 10 for more information.

Reinforcing bars are round in shape, with projections (called *deformations*) formed in the rolling process to strengthen bonding with the concrete. Bars are placed after the forms are constructed, **Figure 7-6**. The concrete is then cast around the bars.

Sheets of wire mesh are also used for reinforcement. *Welded wire fabric (WWF)* is a prefabricated material used to reinforce concrete slabs, floors, and pipe. It consists of a mesh of steel

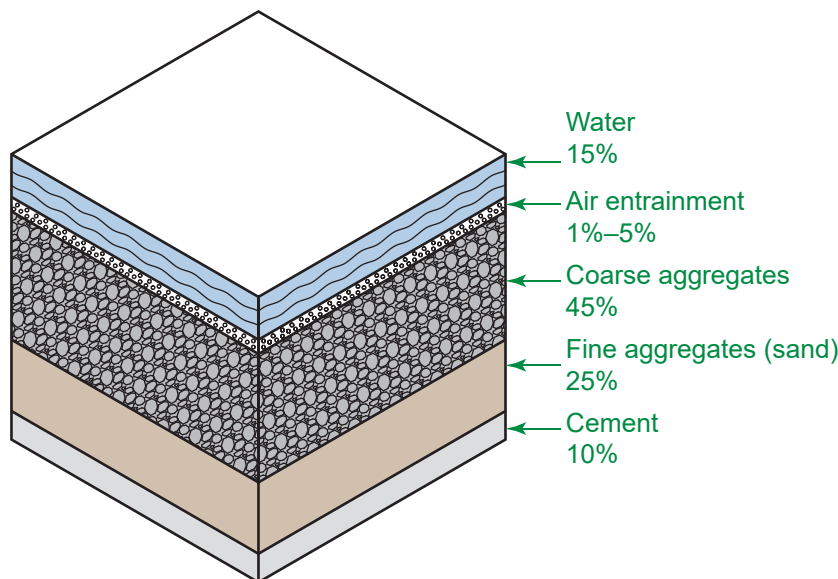


Figure 7-3. Common proportions of materials making up concrete. Proportions can vary depending on local materials, design mix requirements, and air entrainment.



Figure 7-4. A ready-mix truck is typically used to transport concrete to the construction site.

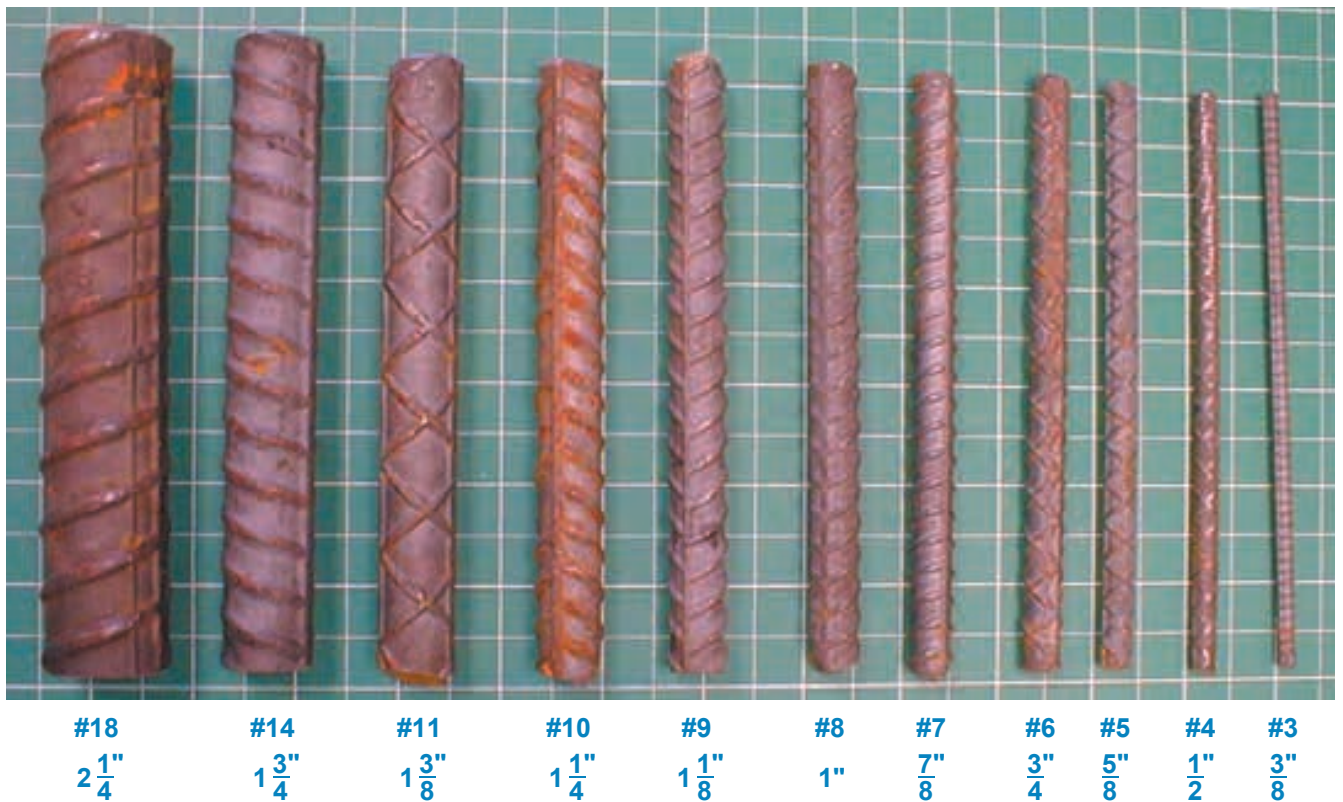


Figure 7-5. Reinforcing steel bars (“rebar”). Bar diameters are identified by a number that is a multiple of $\frac{1}{8}"$. The #18 bar is $2\frac{1}{4}"$ in diameter; the #3 bar is $\frac{3}{8}"$.



Figure 7-6. This grid of reinforcing steel bars will add strength to the completed concrete foundation.

wires welded together, **Figure 7-7**. It is available in sheets and rolls and many wire sizes.

There are two types of welded wire fabric: *smooth* (or plain), designated by a *W*; and deformed, designated *D*. The “*D*” fabric has deformations along the wire to better develop anchorage in the concrete. Previously, the fabric was specified by gage number, and some drawings still use this system.

Welded wire fabric is further designated by numbers. An example is 6×8–W8.0×W4.0. The

first number (6) gives the spacing of the longitudinal wire in inches. The second number (8) gives the spacing of the transverse wire in inches. The first letter-number combination (W8.0) gives the type and size of the longitudinal wire. The second combination (W4.0) gives information on the transverse wire.

In the example given, the longitudinal wires are 6” apart. The transverse wires are 8” apart. The longitudinal wire is smooth and has a cross-sectional area of 0.08 in². The transverse wire is also smooth with an area of 0.04 in². **Figure 7-8** lists some of the common stock styles of welded wire fabric. **Figure 7-9** shows how mesh is placed in a concrete slab.

Division 04—Masonry

Masonry structures are made from a number of smaller units held together with a bonding material known as *mortar*. Masonry units are manufactured as brick, concrete block, stone, and clay tile. **Mortar** is a cementitious material that bonds the individual units together.

Almost all masonry construction must be reinforced with reinforcing materials. Like concrete, masonry has good compressive strength and poor tensile strength.

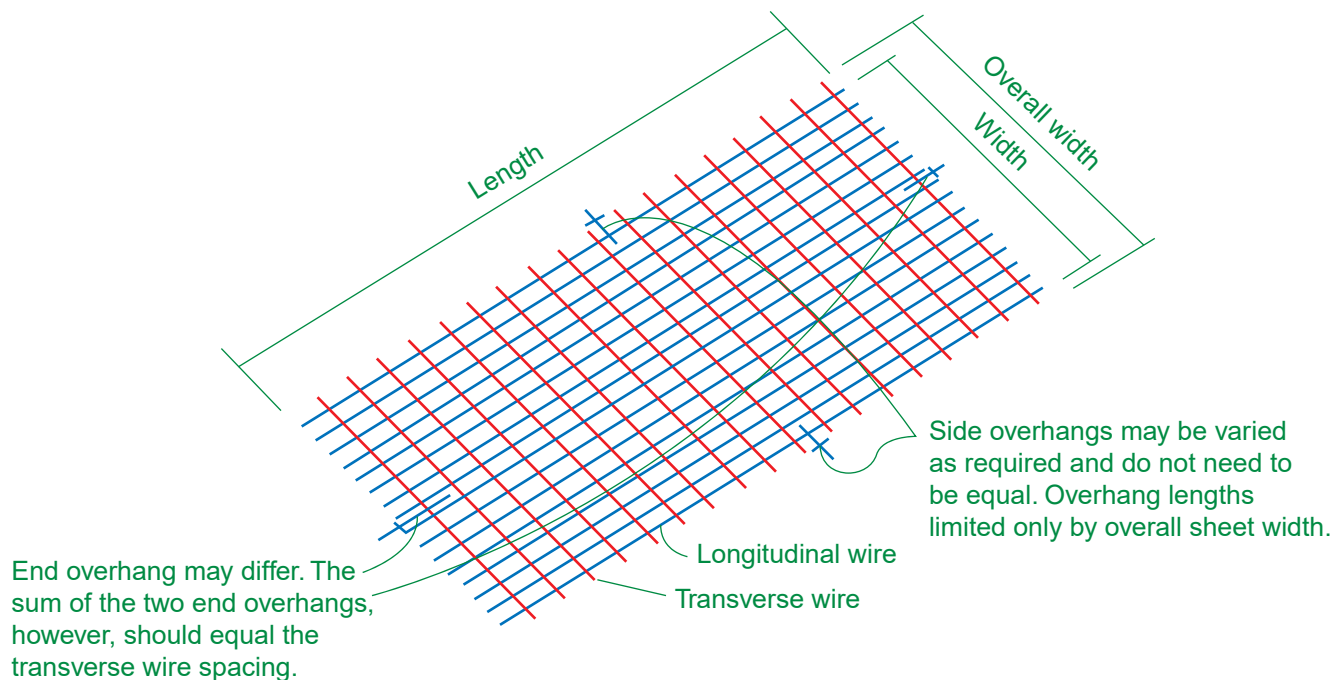


Figure 7-7. Nomenclature used for welded wire fabric. (Wire Reinforcement Institute)

Common Stock Styles of Welded Wire Fabric				
Style Designation		Steel Area (in ² /ft)		Weight (lb/100 ft ²)
New designation (by W-number)	Old designation (by steel wire gage)			
		Longit.	Trans.	
Roll				
6x6–W1.4xW1.4	6x6–10x10	.028	.028	21
6x6–W2.0xW2.0	6x6–8x8*	.040	.040	29
6x6–W2.9xW2.9	6x6–6x6	.058	.058	42
6x6–W4.0xW4.0	6x6–4x4	.080	.080	58
4x4–W1.4xW1.4	4x4–10x10	.042	.042	31
4x4–W2.0xW2.0	4x4–8x8*	.060	.060	43
4x4–W2.9xW2.9	4x4–6x6	.087	.087	62
4x4–W4.0xW4.0	4x4–4x4	.120	.120	85
Sheets				
6x6–W2.9xW2.9	6x6–6x6	.058	.058	42
6x6–W4.0xW4.0	6x6–4x4	.080	.080	58
6x6–W5.5xW5.5	6x6–2x2**	.110	.110	80
4x4–W4.0xW4.0	4x4–4x4	.120	.120	85

*Exact W-number size for 8 gage is W2.1

**Exact W-number size for 2 gage is W5.4

Figure 7-8. Welded wire fabric is available in a number of stock sizes, in either roll or sheet form. (Wire Reinforcement Institute)

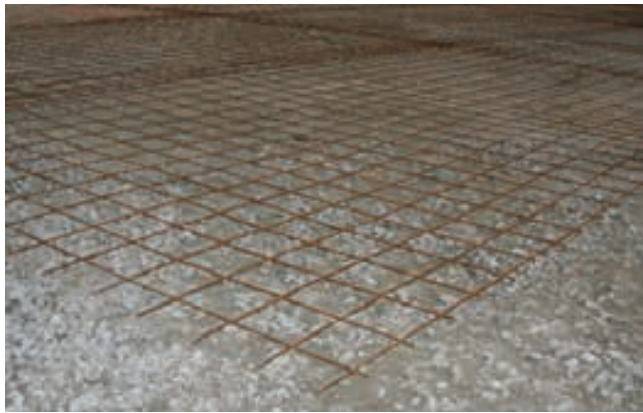


Figure 7-9. Wire mesh ready for slab placement in a concrete slab.

Brick Masonry

Brick masonry uses units (*bricks*) that are manufactured, rather than removed from quarries. There are many types:

- **Adobe brick.** Made from natural sun-dried clays or earth and a binder.
- **Kiln-burned brick.** Made from natural clays or shales (sometimes with other materials added,

such as coloring) and molded to shape, dried, and fired for hardness.

- **Sand-lime brick.** Made from a mixture of sand and lime, molded and hardened under steam pressure and heat.
- **Concrete brick.** Made from a mixture of Portland cement and aggregates, molded into solid or cored units and hardened chemically by the hydration of cement.

There are many types and sizes of brick. Most brick is either building brick or face brick. Some special types are used to a lesser extent.

- **Building brick.** Usually called “common brick,” this is the most commonly used type. It is used for interior and exterior walls, backing, and other applications where appearance is not important.
- **Face brick.** This material is manufactured under more controlled conditions to produce bricks of specific dimensions, colors, and structural qualities. Face bricks are more expensive than building bricks, because of the care going into their manufacture. Face bricks with defects are often sold as common bricks.

- **Glazed brick.** Finished with a hard, smooth coating, this type of brick is used for decorative and special service applications.
- **Firebrick.** Used where masonry units are subjected to extreme heat, such as fireplaces, incinerators, and industrial furnaces.
- **Paving brick.** Used in driveways or areas where abrasion is a concern.

Special bricks are also available in unusual shapes for window sills, rounded corners, and other nonstandard applications.

Brick Symbols

Brick is indicated on plan and section drawings with 45° crosshatch lines. For common brick, the lines are widely spaced; for face brick, the spacing is narrower. See **Figure 7-10**. Firebrick is shown on plan drawings with the usual 45° lines

indicating brick, plus vertical lines that designate it as firebrick.

On elevation drawings, brick is normally indicated by horizontal lines. A note identifies the type of brick. Some architects only draw horizontal lines around the outer surface of brick walls.

Brick Bonds

There are several types of brick bonds, so construction workers should be familiar with those used most widely. A **bond** is the bricklaying pattern. Bonds are designed to improve appearance, add strength, or tie a wythe wall to a backing wall.

The bonds used most widely are common bond, running bond, English bond, English cross bond, Flemish bond, and stacked bond. See **Figure 7-11**.

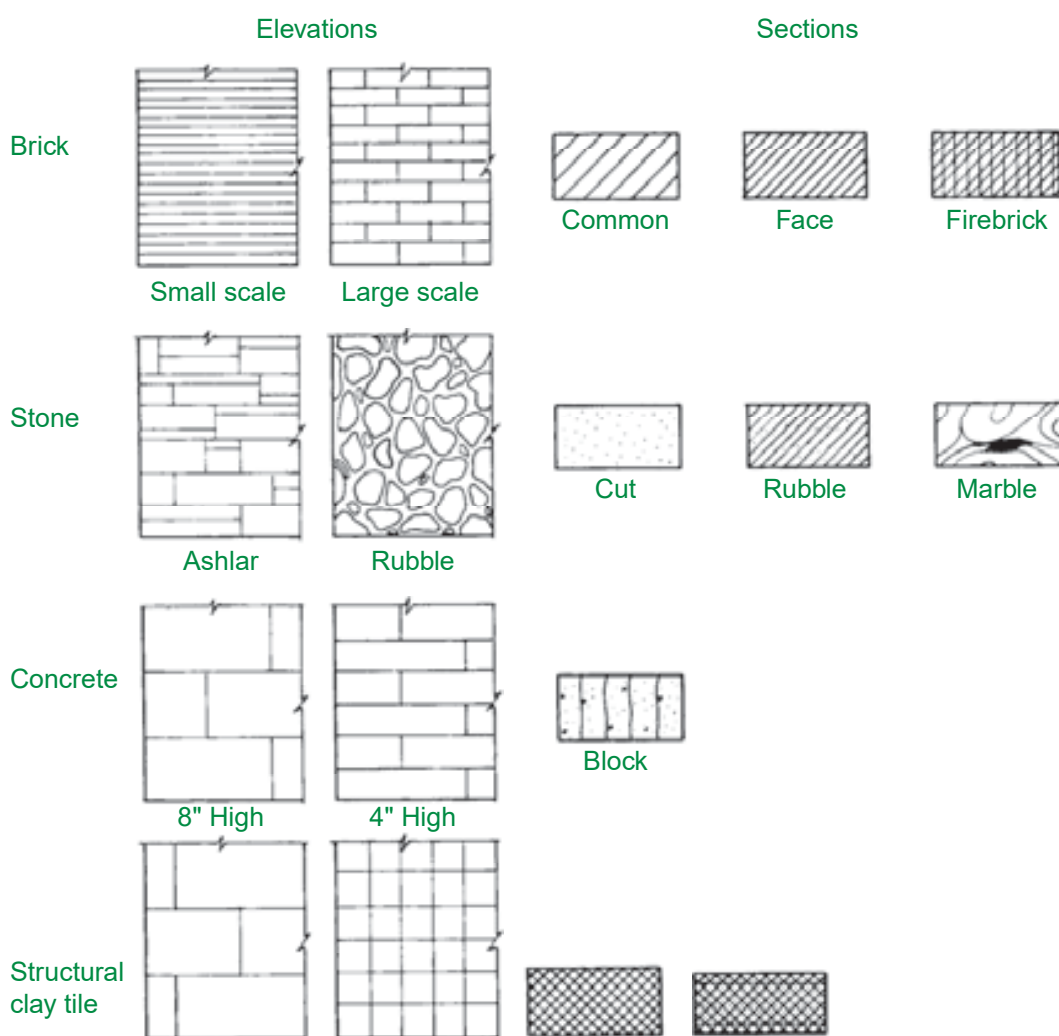
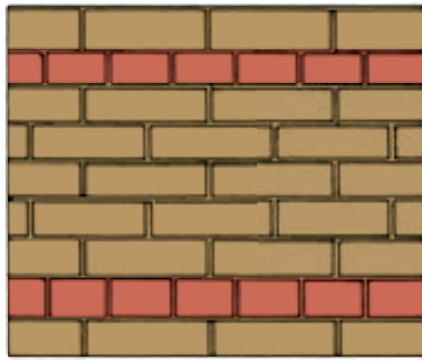
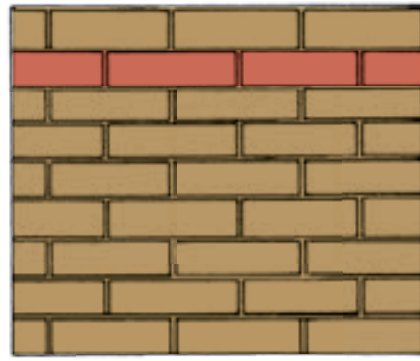


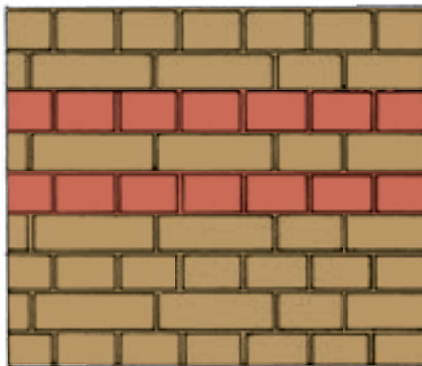
Figure 7-10. Symbols for masonry materials.



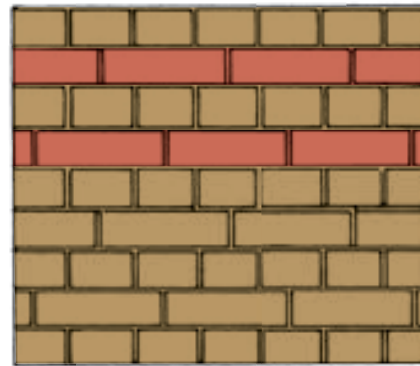
Common bond



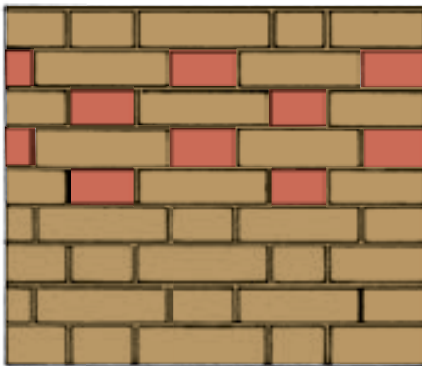
Running bond



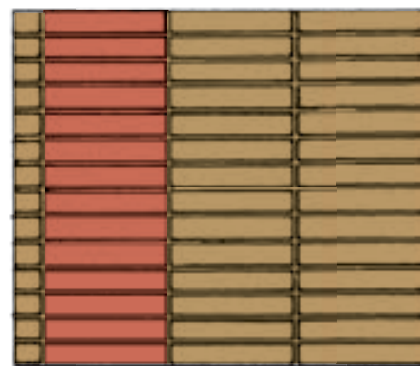
English bond



English cross bond



Flemish bond



Stacked bond

Figure 7-11. Different bond patterns vary the appearance of brick structures.

Brick Positions

Bricks can be positioned in different ways. These positions are used by the architect to develop a design or style in the building, as well as to add to the structural strength of the brickwork. Each position has a name that identifies it. For example, the most common position is the **stretcher**, **Figure 7-12**. It is laid in a flat position, lengthwise with the wall. Bricks in the stretcher position make up a large portion of most walls.

In some bonds, such as the common bond (also called American bond), every sixth or seventh

course is turned 90°. This is done to improve appearance or to tie the face brick with the backing wall. Bricks laid in this manner are called *headers*, and the course is referred to as a *header course*.

Brick Lay-Up

Brick walls can be laid up as *single-wythe walls* that are 8" or more in thickness. These can be solid or have two or more cells (spaces) in them. Sometimes the cells of the brick are filled with granular insulation. Various masonry walls are shown in **Figure 7-13**.

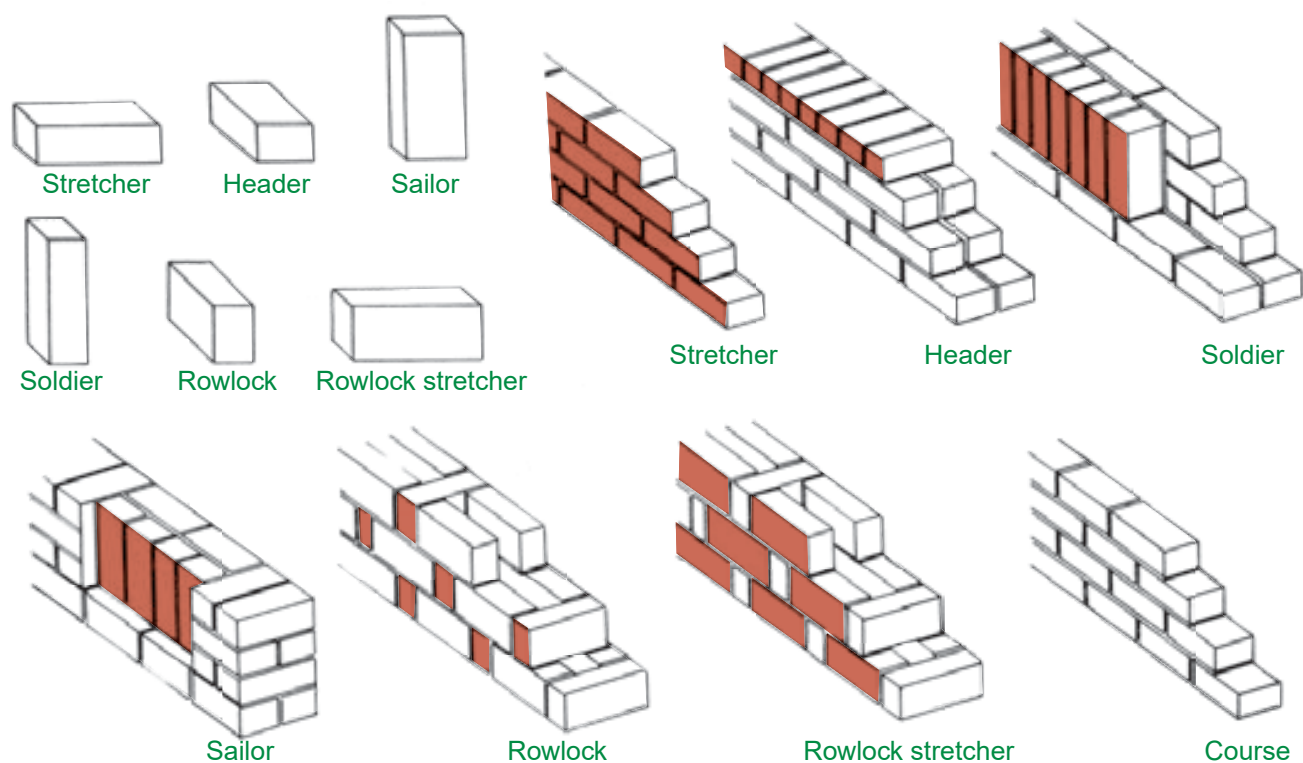


Figure 7-12. Names of brick positions in a wall.

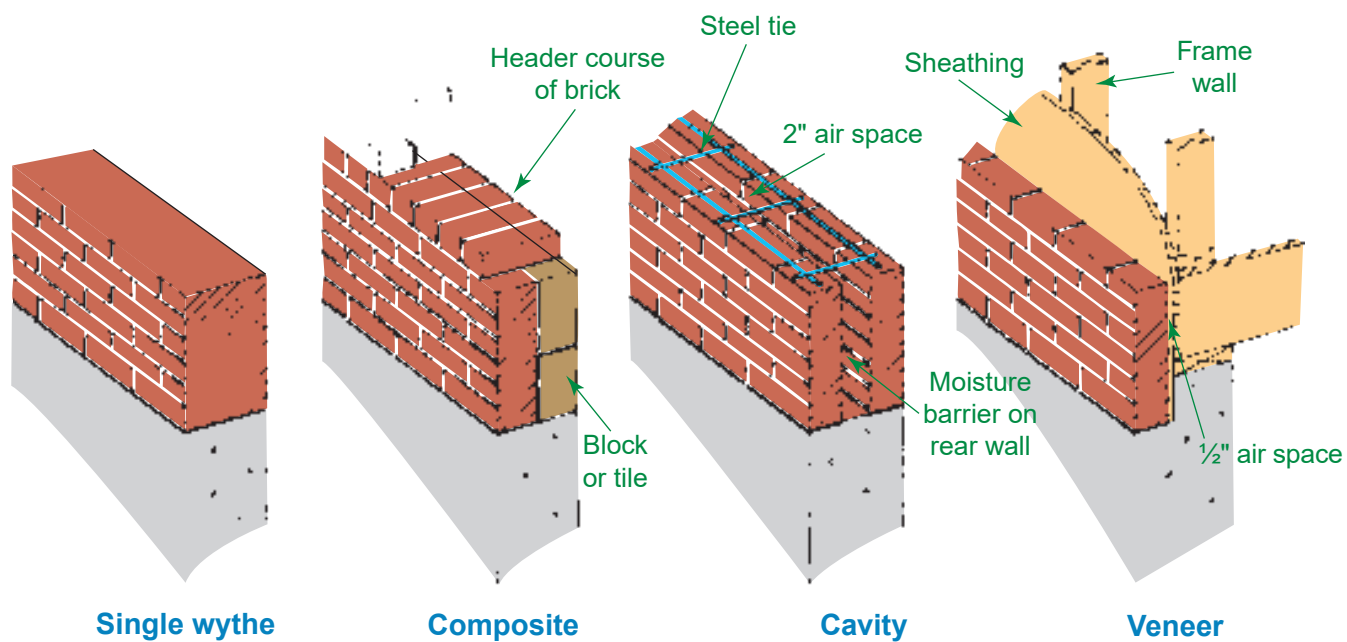


Figure 7-13. Types of masonry walls.

Concrete Masonry Units (CMUs)

Another popular and widely used building material is the *concrete masonry unit (CMU)*, which is formed from Portland cement, sand, and gravel. See **Figure 7-14**. By using different aggregates, such as sand, gravel, expanded shale, and pumice, the manufacturer can control the weight, strength, and acoustical properties of the CMU.

CMUs are made in a variety of sizes, shapes, and densities to meet specific construction needs. The most popular is the standard block, with dimensions of $7\frac{5}{8}'' \times 7\frac{5}{8}'' \times 15\frac{5}{8}''$. When $\frac{3}{8}''$ of mortar is used, this becomes an $8'' \times 8'' \times 16''$ module. Another common block size is the $3\frac{5}{8}'' \times 7\frac{5}{8}'' \times 15\frac{5}{8}''$.

Concrete Block Symbols

Symbols for concrete block in plan and section views are the same as those for concrete with the addition of lines crosswise of the run. Refer to **Figure 7-10**. The elevation view symbol for concrete block is the same as that for poured concrete with lines added to represent the block pattern.

Concrete block can have colored surfaces and special design features. Slump blocks give the appearance of rough adobe brick.



Figure 7-14. The standard block is the most widely used type of concrete masonry unit.

Stone Masonry

The most common materials used in *stone masonry* are granite, limestone, marble, sandstone, and slate. Like concrete, stone has been used as a building material for many centuries. In the past, stones were used for structural members, roofing, and finishing. Due to the development of new materials and methods of construction, stones are now used mainly for their decorative value.

Most stones are removed from a quarry and sent to a finishing mill for final dressing. Some stones are used in their original shapes and surface finishes. Others are cut to a specific shape, size, and finish. These are known as *cut stones*.

Stone masonry can be laid as solid walls of stone or as composite walls backed with concrete block or tile. It is also used as a veneer. Stone walls are classified according to the shape and surface finish of the stone, such as rubble, ashlar, and cut stone. Examples of rubble and ashlar masonry are shown in **Figure 7-15**.

Rubble consists of stones as they come from the quarry or are gathered from a field or stream. Such stones may be smooth with rounded edges, or they may be rough and angular. The random rubble wall consists of stones laid in an irregular pattern with varying sizes and shapes. Other rubble patterns are coursed, mosaic, and strip.

Ashlar stones are squared stones that have been laid in a pattern but not cut to dimensions. There are several ashlar patterns:

- **Regular.** Constructed with a uniform continuous height.
- **Stacked.** Tends to form columns.
- **Broken range.** Consists of squared stones of different sizes laid in uniform courses, but range is broken within a course.
- **Random range.** Neither course nor range remain uniform.
- **Random ashlar.** Course is not uniform and ends are broken, not square.

Cut stones, also known as *dimensional stones*, are cut and finished at the mill to meet the specifications of a particular construction job. Each stone is numbered for location. Unlike ashlar masonry, which is laid largely at the design of the mason, cut stones are laid according to the design of the architect.

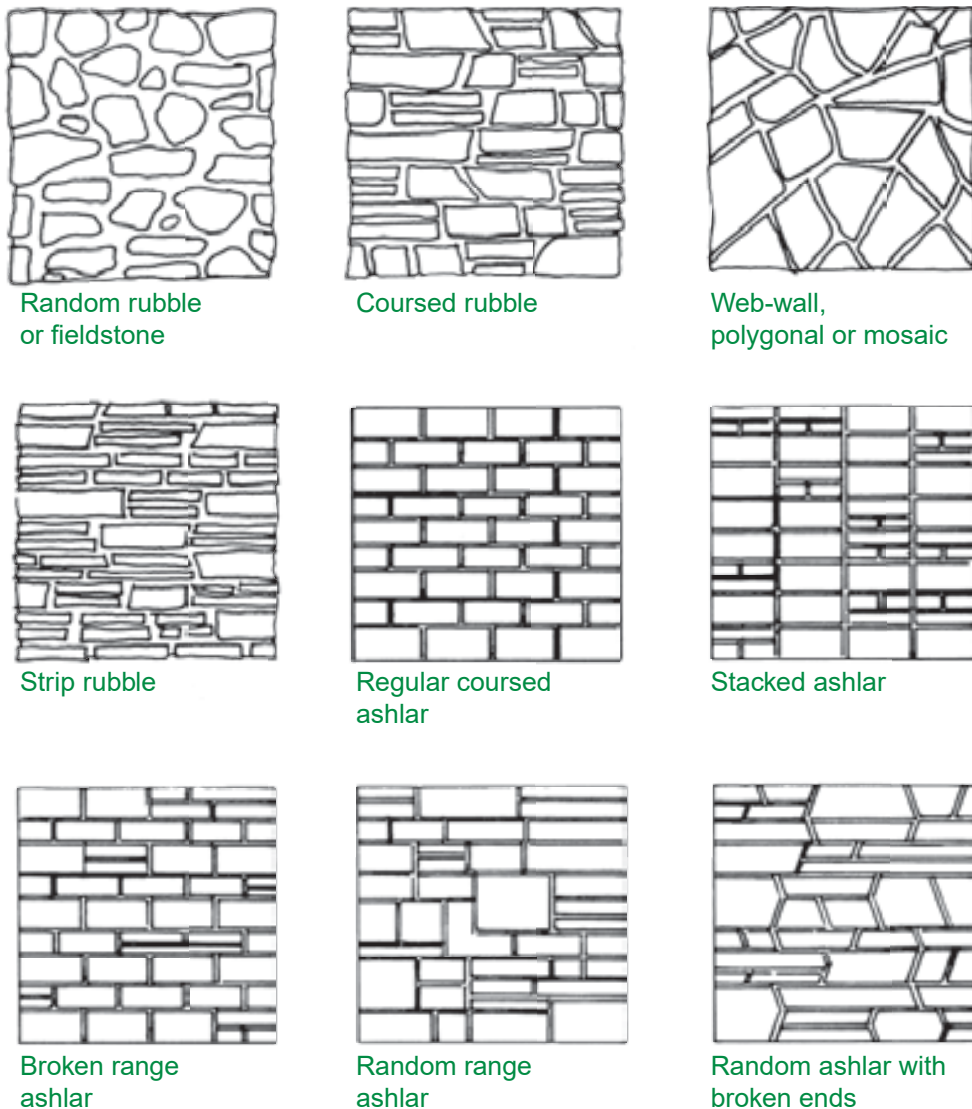


Figure 7-15. Various stone masonry walls, shown in elevation.

Structural Clay Tile

Structural clay tile is made of materials similar to those used in brick, but it is a larger building unit. It has many uses in construction—as load-bearing walls, backup for curtain walls, and fireproofing around structural steel. Rectangular open cells pass through each unit, and tile comes in a variety of shapes and sizes.

Clay tile has largely been replaced with hollow brick and concrete masonry units. Most masonry walls today are composite walls of a finish surface material and a less expensive backup material.

Terra cotta is a type of structural clay tile principally used for nonbearing ornamental and decorative effects.

Gypsum Blocks

Gypsum masonry blocks are used primarily for interior nonbearing walls, fire-resistant partitions, and enclosures around structural steel. Made from gypsum and a binder of vegetable fiber or wood chips, gypsum blocks can be given a plaster finish coat. Gypsum blocks have a face size of 12" × 30" and come in thicknesses of 2", 3", 4", and 6".

Mortar

Mortar is the binding agent used to hold masonry units together. Mortar also compensates for the differences in brick and stone sizes. Metal ties and reinforcement are secured in mortar. Mortar consists of cement, hydrated lime, sand, and water.

The American Society for Testing and Materials has established standards for mortar. There are five different standardized types:

- **Type M** has high compressive strength and good durability. It is used for unreinforced underground masonry.
- **Type S** is also a high-strength mortar. Although its compressive strength is not as high as that associated with Type M, it has a stronger bond and greater lateral strength. It also has the greatest tensile strength of any mortar type. Type S is used for reinforced masonry, unreinforced masonry subjected to bending, and in situations where mortar is the only connection between face brick and backing brick.
- **Type N** is a medium-strength, general-use mortar. It is best used for exposed, above-ground masonry.
- **Type O** is low-strength mortar used for interior, nonbearing masonry. This type of mortar should not be used in applications that will be exposed to freezing temperatures.
- **Type K** has very low strength and should only be used for interior applications when strength is not a concern.

Stone work usually requires a special type of mortar consisting of white Portland cement, hydrated lime, and sand. This mortar prevents stains caused by ordinary cements. Mortar in the joints is normally raked back from the surface as the stone is set. Later, the joint is pointed, using the same mortar or a colored sealant.

Trade associations recommend proportions of cement, hydrated lime, and sand for mortar. Local building codes also set allowable limits. A typical mixture would be 1 part Portland cement by volume, one-fourth part hydrated lime, and 3 parts sand. Water is added as needed to make the mortar workable. Many brick masons use a special masonry cement containing plasticizing agents to make the mortar more workable.

Masonry Accessories

Besides the masonry units and mortar, additional components are needed in masonry construction. Bond beams, joints, lintels, and flashing are needed to complete a wall.

Bond Beams

Concrete masonry walls are usually reinforced horizontally and vertically by constructing

a reinforced beam or column within the wall. This is done by pouring **grout** (a flowable mixture of sand and cement) around reinforcing steel inserted in the units. Special channel blocks are used to form horizontal **bond beams**, using reinforcing steel and mortar or grout. Vertical bond beams are formed by inserting reinforcing bars in a vertical cell after the wall is laid, then filling the cell with grout. Bond beams are typically used over masonry wall openings such as windows and doors, the top of walls, or anywhere that additional strength is required in the wall construction. See **Figure 7-16** for a typical detail showing a bond beam.

Lintels

Lintels are members placed in masonry walls above door and window openings. Lintels are supported on either side of the opening. They can be made of precast concrete, steel, or other materials. The door and window schedule will often include the size and type of lintel used.

Masonry Joint Reinforcement

Masonry walls are reinforced by placing various anchors, ties, and rods in the mortar joints. These reinforcing units are produced in many sizes and shapes for different applications. Reinforcing devices are called out directly on the prints or in applicable building codes.

Division 05—Metals

Metal is used extensively in the construction industry. Large commercial buildings use structural steel. Construction jobs make use of metal windows, doors, studs, beams, joists, wall facings, roofing, plumbing, and hardware.

Kinds of Metals

Metals can be divided into two categories, ferrous and nonferrous. **Ferrous metals** contain iron as a principal element, and usually have magnetic properties. They typically have more strength than nonferrous metals. **Nonferrous metals** contain no iron and do not have magnetic properties. They are typically lighter and less strong than ferrous metals.

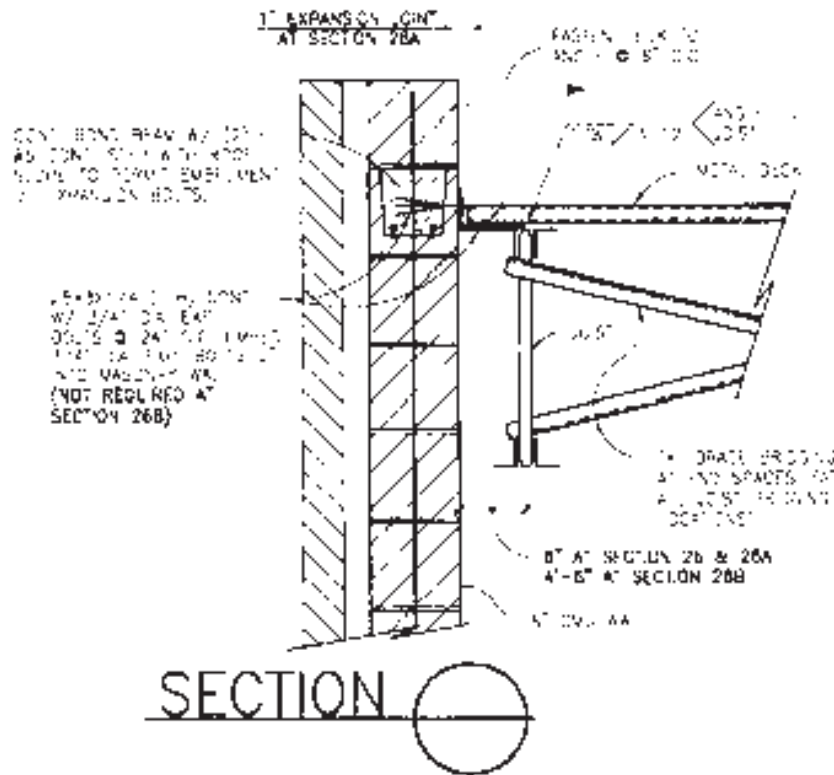


Figure 7-16. Detail showing a bond beam in a concrete masonry unit wall.

Ferrous Metals

Iron. Iron is malleable, ductile, magnetic, and silver white in color. There are many kinds of iron, such as pig iron, cast iron, and wrought iron. Iron is one of the principal ingredients of steel.

Steel. Steel is an iron-based alloy with a carbon content ranging from 0.2% to 2.0%. Depending on the intended use, steel has many chemical compositions. Carbon steel, alloy steel, mild steel, medium steel, tool steel, spring steel, and stainless steel are a few of the varieties available. By varying the carbon content, steel can be made harder and stronger, but it also becomes more brittle. Adding chromium, nickel, and magnesium will make the metal highly resistant to corrosion.

Nonferrous Metals

Aluminum. Pure aluminum and aluminum alloys are used in many building applications where resistance to corrosion is important. Aluminum that is 99% pure is soft and ductile, but therefore weak. Aluminum is typically

used in such building applications as flashing, downspouts, some kinds of roofing, doors and trim, mullions for windows, etc. Aluminum also is made as an alloy with copper added for strength and casting uniformity. Aluminum alloys are made in structural shapes for use as H-beams, I-beams, and angles. Aluminum is also used for some ductwork, screens, and electrical wiring.

Copper. Copper and copper alloys have a high electrical conductivity and are resistant to corrosion. This metal is typically used in construction for water distribution, electrical wiring, and flashing. The particular metal would be indicated on the drawing as a note and most likely detailed in the specifications.

Brass. This metal is widely used for door and window hardware, trim, grilles, and railings. Brass is copper with zinc as its principal alloy element.

Bronze. A copper-tin alloy, bronze also can contain various other elements, such as aluminum or silicon. Bronze resists corrosion and is widely used for ornamental architectural products.

Surface Treatments

Metals used in construction may have protective or decorative surface treatments applied to them. Treatments include:

- **Chroming.** Applying chromium as a finish to a metal surface.
- **Galvanizing.** Coating steel or iron with zinc to resist rusting. Galvanized iron is widely used for flashing and other applications where weather tends to corrode metals.
- **Rusting.** Certain steels are designed to form a protective layer of *rust*, a reddish-brown surface coating formed when the metal is exposed to moisture and air.
- **Electroplating.** An adherent metallic coating deposited by electrolysis. *Electrolysis* is a process that uses electrical current to migrate positively and negatively charged ions from electrodes to the metal product.

Metal Gages

Metal materials less than 1/4" in thickness (often called "sheet metal") are classified in the **gage system**. As shown in **Figure 7-17**, gages typically range from 4 (thickest) to 38 (thinnest). For example, 4-gage metal has a thickness of 0.224", a little less than 1/4", while 22-gage metal is 0.0299" (approximately 1/32").

Wall studs, lintels, window and door frames, and floor joists are made from heavy-gage metals. Thin-gage metals are used for such items as roof flashing, ductwork, roofing, and wall siding.

Steel in Construction

Steel is the most widely used metal in construction, with applications ranging from structural support to reinforcement to decorative uses.

Structural steel is the term applied to hot-rolled steel sections, shapes, and plates, **Figure 7-18**. This includes bolts, rivets, and bracing.

Structural steel shapes are formed by passing heated strips of steel through a succession of rollers that gradually form the metal into the required shape. Structural steel shapes are available in a number of sizes and weights. **Figure 7-19** illustrates some standard shapes, with identifying symbols and designations.

A typical designation for a wide-flange beam would be W12×16, which indicates a beam 12" in depth that weighs 16 pounds per linear foot. A

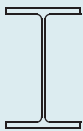
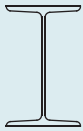





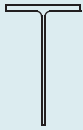
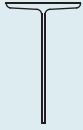


Steel manufacturer's standard gage number	Weight, psf	Equivalent sheet thickness (in.)
4	9.3750	0.2242
6	8.1250	0.1943
8	6.8750	0.1644
10	5.6250	0.1345
12	4.3750	0.1046
14	3.1250	0.0747
16	2.5000	0.0598
18	2.0000	0.0478
20	1.5000	0.0359
22	1.2500	0.0299
24	1.0000	0.0239
26	0.7500	0.0179
28	0.6250	0.0149
30	0.5000	0.0120
32	0.40625	0.0097
34	0.34375	0.0082
36	0.28125	0.0067
38	0.25000	0.0060

Figure 7-17. Gages, weights, and thicknesses of sheet metal.



Figure 7-18. Structural steel beams, columns, web joists, and other shapes are widely used in construction projects. These workers are installing a column onto a concrete footing.

typical designation for a lightweight beam, sometimes called an I-beam, would be S8×23. This indicates that the beam is 8" in depth and weighs 23 pounds per linear foot.

Descriptive Name	Shape	Identifying Shape	Typical Designation	Nominal Size
			Depth Wt/Ft in Lb.	Depth Width
Wide flange shapes		W	W21 × 147	21 × 13
Miscellaneous shapes		M	M8 × 6.5	8 × 2¼
American standard beams		S	S8 × 23	8 × 4
American standard channels		C	C6 × 13	6 × 2
Miscellaneous channels		MC	MC8 × 20	8 × 3
Angles — equal legs		L	L6 × 6 × ½*	6 × 6
Angles — unequal legs		L	L8 × 6 × ½*	8 × 6
Structural tees (cut from wide flange)		WT	WT12 × 60	12
Structural tees (cut from miscellaneous shapes)		MT	MT5 × 4.5	5
Structural tees (cut from Am. Std. beams)		ST	ST9 × 35	9
Zees		Z	Z6 × 15.7	6 × 3½

*Leg thickness

Figure 7-19. Some examples of structural steel shapes.

Steel members are connected to form building frames, **Figure 7-20**. The frame is usually then hidden behind other materials, such as a masonry wall, precast panels, or sheet metal siding.

Steel *angles* (sometimes called *angle iron*) are used as bracing in steel framing and to construct *open-web steel joists* and many other products, **Figure 7-21**. Angles are designated with the letter “L,” followed by the lengths and thickness of the “legs.” For an angle identified as L3×3×1/2, both legs are 3” long and 1/2” thick.

Division 06—Wood, Plastics, and Composites

Wood continues to be one of the chief building materials, **Figure 7-22**. It is used for structural framing (rough carpentry), trim, floors, walls, and cabinetry (finish carpentry and architectural woodwork). Relative to its weight, wood has high strength in compression, tension, and bending. It also has excellent impact resistance. While steps have been taken to substitute other materials, wood remains a valuable and widely used residential construction material.

Wood Classification

Woods are broadly classified as either hardwoods or softwoods. There are many varieties used for construction. These classifications are not an exact measure of hardness or softness (because



Figure 7-21. Open-web steel joists combine strength with light weight.



Figure 7-20. This steel frame is designed to support the entire weight of the building.



Figure 7-22. Wood continues to be the primary building material for residences and for many larger structures, such as this hotel.

this varies) but a general classification based on type of tree. In addition to hardness or softness, woods vary in strength, weight, texture, workability, and cost. Building specifications usually indicate the type and grade of lumber to be used in different parts of the construction.

Wood Classifications	
Hardwoods	Softwoods
Ash	Cypress
Ash, White	Fir, Douglas
Beech	Fir, White
Birch	Hemlock
Cherry	Pine, Ponderosa
Elm	Pine, Southern
Gum	Pine, White
Hickory	Poplar, Yellow
Mahogany	Red Cedar, Eastern
Maple	Red Cedar, Western
Oak	Redwood
Walnut	Spruce

Lumber

When wood is cut into pieces of specific thickness, width, and length, it is called **lumber**. Lumber products include rough framing members (at least 2" thick), such as beams, headers, and posts; finished lumber, such as flooring, door and window trim, paneling, and moldings; and specialty items, such as decorative panels, carved doors, ornamental overlay designs, and turned balusters (stair-rail posts).

Lumber is classified as rough-sawn or surfaced to size. **Rough-sawn lumber** has been cut to size but not dressed or surfaced. **Surfaced lumber** has been dressed or finished to size by running it through a planer. The designation "S2S" is used for lumber dressed on two sides, and "S4S" for lumber that is surfaced or planed on all four sides.

Plywood is a wood product made of several layers of lumber arranged with the grain at right angles in each successive layer and bonded with an adhesive. An odd number of layers is used, so that the grain of the face and back are running in the same direction. The panels are usually 4' × 8' in size, and are available in finished thicknesses ranging from 1/8" to over 1". Because of its modular size and uniformity, plywood speeds

construction and is considered an economical building material.

Interior plywood is bonded with an adhesive that is water-resistant. It is used for cabinetry, rough flooring, and finished walls. **Exterior** or **structural plywood** is bonded with a waterproof adhesive. It is used for wall sheathing, finished walls, roof sheathing, and concrete forms.

Glue-Laminated Timber

The process of **laminating** (bonding layers of lumber together with adhesive) has made it possible to span larger distances and change traditional construction techniques. Wood beams, arches, and other members of nearly any size and shape can be fabricated. These laminated products are made of kiln-dried lumber and prepared for interior and exterior use. These members are usually prefinished at the factory and delivered to the job with protective wrapping.

Division 09—Finishes

Finishes are the visible surfaces of a building, such as gypsum wallboard, paint or wallpaper, ceramic tile, carpeting, wood flooring, and acoustical ceilings. Finishes are, in part, delineated on the drawings and specified in a room finish schedule.

Gypsum Wallboard and Plaster

Gypsum wallboard and plaster products consist of a core of air-entrained gypsum between two layers of treated paper. Wallboard comes in standard 4' × 8' sheets, but is available in 4' × 9' and 4' × 12'. If ordered in truckload quantities, almost any special size desired can be produced. Wallboard is fastened to wood or metal studs with nails or screws, and varies in thickness from 1/4" to 1". Joints are sealed with a joint compound and paper tape to provide a smooth, even surface. The wall can be painted, papered, or given a surface texture to enhance its appearance.

Lath for gypsum plaster walls is available in 16" × 48" sheets with thicknesses of 3/8" and 1/2". The lath is fastened to the studs and a three-coat gypsum plaster finish—scratch coat, brown coat, and finish coat—is applied.

Building papers are available in a variety of types suitable for sheathing walls and roofs. Some papers are reinforced for strength and tear resistance.

Building papers are treated with asphalt, plastic, tar, or other materials. The building paper is usually specified on the print or in the specifications.

Ceramic Tile

There are many kinds of ceramic tiles, commonly referred to merely as “tile,” for use on floors, walls, and other surfaces. Ceramic tile is made from nonmetallic minerals, fired at a very high temperature.

- **Ceramic tiles** come in sizes from $3/8$ " square to $16" \times 18"$ units. Popular wall sizes are $4\ 1/4" \times 4\ 1/4"$, $4\ 1/4" \times 6"$, and $6" \times 6"$. Hexagonal and octagonal tiles are also available. The tiles can be glazed or unglazed. Glazed tiles are usually $5/16$ " thick. Unglazed (faience) tiles vary from $7/16$ " to $3/4$ " thick.
- **Mosaic tiles** can be laid to form a design or pattern. They are normally smaller than $6"$ (typically $1"$) square, and can be glazed or unglazed.

- **Quarry tile** is used for floor coverings and is produced from clays that provide a wear-resistant surface.
- **Fired-clay tile** is used primarily for floor coverings. It is produced from clays and is fired in a kiln to harden the surface.

Tile-Setting Materials

There is a wide variety of tile-setting materials available for use, based on flooring types and final use of the tiling products. Typically, ceramic tile is set in Portland cement, latex adhesive, or epoxy mortar. **Figure 7-23** shows two applications: tile set on plywood using a cementitious backer board with a bond coat, and tile set directly on a concrete slab surface.

The joints between the tiles are grouted, with different types of *grout* available to meet varying kinds of joint and tile exposure. The grout consists of Portland cement modified to meet various joint conditions.

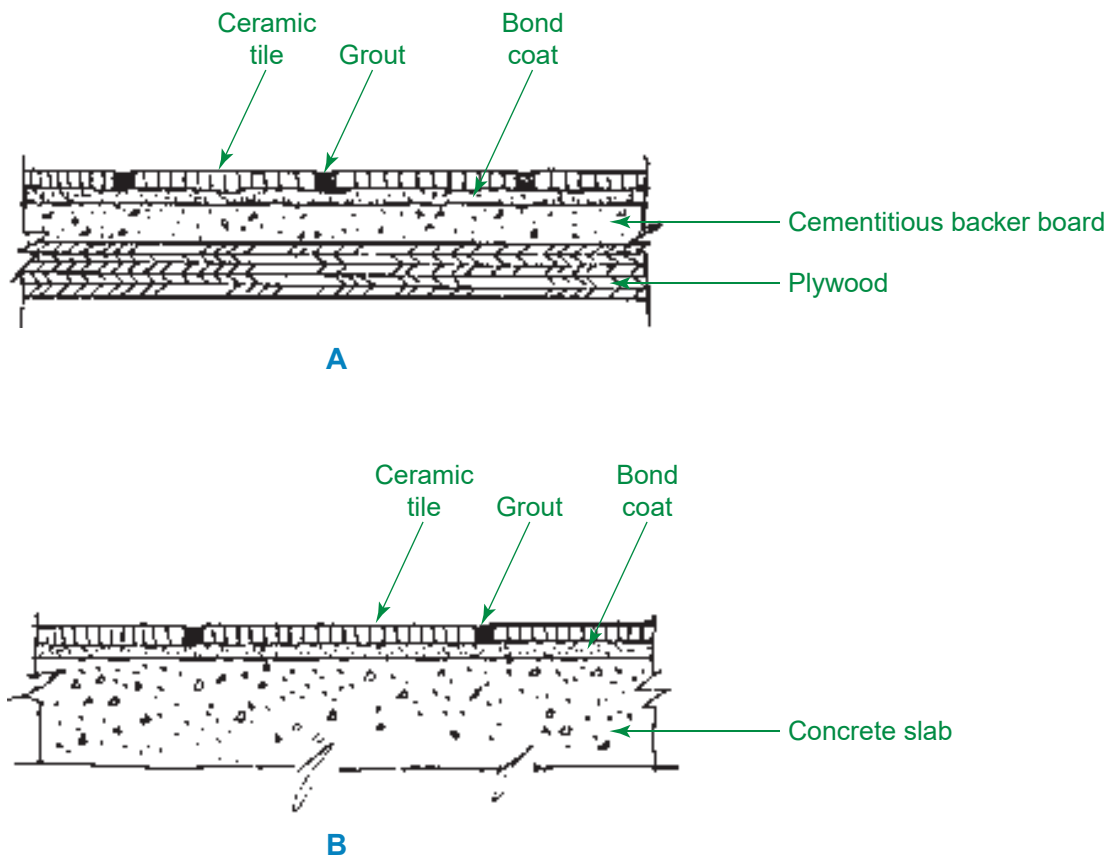


Figure 7-23. Ceramic tile installation. A—Section view of ceramic tile installed on plywood floor with cementitious backer board. B—Section view of ceramic tile installed on a concrete slab.

Glass

Glass is a ceramic material formed at temperatures above 2300°F (1260°C). It is made from sand (silica), soda (sodium oxide), and lime (calcium oxide). Other chemicals can be added to change its characteristics.

Float glass is the most common type of glass. A continuous ribbon of molten glass flows out of a furnace and floats on a bath of molten tin. Irregularities melt out and the glass becomes flat. The ribbon of glass is fire-polished and annealed, without grinding or polishing. Over 90% of the world's flat glass is made by the float process.

After the float process, other processes can further modify the properties of the glass, producing several types:

- **Sheet glass** is commonly used for windows in thicknesses of 3/32" (single strength, or "SS") and 1/8" (double strength, or "DS"). **Thick glass** is sheet glass that is 3/16" to 7/16" in thickness.
- **Plate glass** is sheet glass that has been heat-treated during forming, producing a brilliant surface that is ground and polished when cooled.
- **Bent glass** is produced by heating annealed glass to the point where it softens so it can be pressed over a form.
- **Safety glass** was developed to overcome the hazards of sheet glass in large, exposed, or public areas. Three types of safety glass are available: tempered, laminated, and wired glass.
 - ❑ **Tempered glass** is developed by heating annealed glass to near its melting point, then chilling it rapidly. This creates high compression on the exterior surfaces and high tension internally, making the piece of glass three to five times as strong as annealed glass. Tempered glass can be broken, but it shatters into small, pebble-like pieces rather than sharp slivers. Tempered glass must be ordered to the exact size needed before tempering, because it cannot be cut, drilled, or ground after it has been tempered.
 - ❑ **Laminated glass** consists of a layer of vinyl between sheets of glass. The layers are bonded together with heat and pressure. This glass can be broken, but the plastic layers hold the small, sharp pieces in place.
 - ❑ **Wired glass** has a wire mesh molded into its center. Wired glass can be broken, but the wire holds the pieces together. Wired glass can be obtained with an etched finish, a sandblasted finish, or a patterned finish.
- **Insulating glass** is a unit of two or more sheets of glass separated by an air space that is dehydrated and sealed. Insulating glass units serve as a good insulator for heat and sound transfer. A typical insulating glass installation in a window sash is shown in **Figure 7-24**.
- **Patterned glass** is sheet glass with a pattern rolled into one or both sides to diffuse the light and provide privacy.
- **Stained glass**, sometimes called *art* or *cathedral glass*, is produced by adding metallic oxides in the molten state. This glass can be used in sheets or cut into smaller pieces and made into leaded glass for windows and decorative pieces.

Glass Block

Glass block is made by fusing two sections of glass together. A partial vacuum is created between the pieces, providing good insulating qualities. Edges are left rough to improve the bond with the mortar.

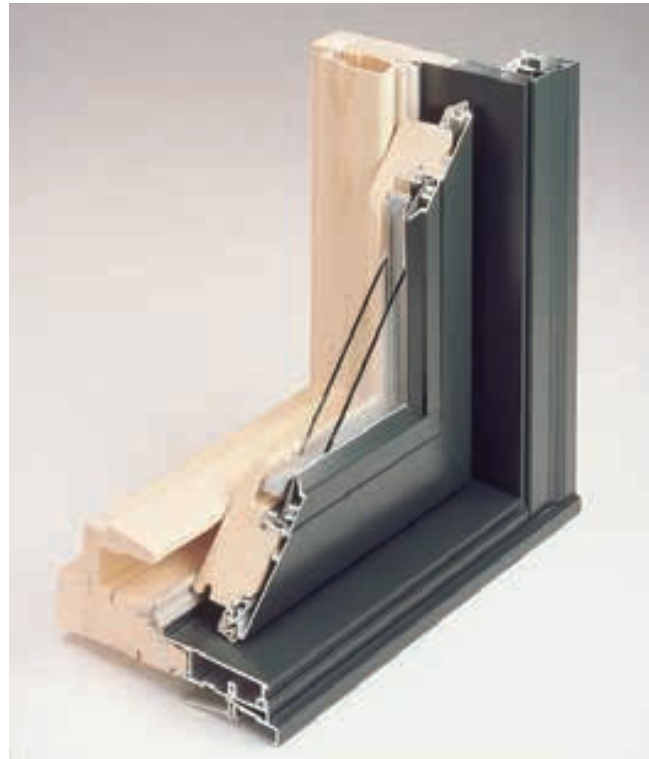


Figure 7-24. Window with insulating glass.
(Marvin Windows and Doors)

Glass block is used in nonbearing applications, such as interior walls, screens, curtain walls, and windows. Blocks are manufactured in three nominal sizes: 6" × 6", 8" × 8", and 12" × 12". Special blocks are available for forming corners and curved panels.

Plastics

Plastics have many uses in construction. Plastic laminates serve as counter tops, door veneer, and wall surfacing. Panels of wood or gypsum are printed, textured, and given a plastic vinyl coating. Plastic rain gutters and downspouts collect and distribute storm water. Plastic pipes are used for water-transmission, sprinkling, drainage, and sewage systems.

Plastics are also used for many trim and ornamental items, such as moldings on doors and simulated wood carvings. Plastic materials are usually noted on the drawing and detailed in the specifications.

Insulation

The purpose of *thermal insulation* is to reduce heat transmission through walls, ceilings, and floors. When the outdoor temperature is warm, insulation keeps the heat from entering the structure. When the outdoor temperature is cool, insulation helps keep the warm air indoors.

Insulation is manufactured in a variety of forms and types to meet specific construction requirements. Each type will have an *R-value* (resistance to heat transfer), depending on the manner of application and amount of material. A high R-value means good insulation qualities. Insulation materials are classified as:

- Flexible (blanket or batt).
- Loose-fill.
- Reflective.
- Rigid (structural and nonstructural).

Flexible insulation is available in blanket and batt form. Blankets come in widths suitable to fit 16" and 24" stud and joist spacing and in thicknesses of 1" to 3 1/2". The body of the blanket is made of mineral or vegetable fiber, such as rock wool, glass wool, wood fiber, or cotton. Organic materials are treated to resist fire, decay, insects, and vermin. Blankets are covered with a vapor

sheet on one or both sides. The vapor barrier is installed facing the warm side of the wall. Batt insulation is made of the same material as blankets, in thicknesses of 2" to 6" and lengths of 24" and 48".

Loose-fill insulation is available in bags or bales. It is either poured, blown, or packed in place by hand. Loose-fill insulation is made from particles of material such as rock wool, glass wool, wood fibers, shredded redwood bark, cork, wood pulp products, or vermiculite. This type of insulation is suited for insulating side-walls and attics of buildings. It is also used to fill cells in block walls.

Reflective insulation, **Figure 7-25**, is designed to reflect radiant heat. It is made from materials such as aluminum foil, sheet metal with tin coating, and paper products coated with a reflective oxide composition. To be effective, the reflective surface must face an air space of at least 3/4". When the reflective surface contacts another material, such as a wall or ceiling, the reflective properties are lost along with the insulating value. This material is often used on the back of gypsum lath and blanket insulation.

Rigid insulation is made of a fiberboard material in sheet form. Common types are made from processed wood, sugarcane, and other fiber. These produce a lightweight, low-density product with good heat and acoustical insulating qualities. Rigid insulation is used as sheathing for walls and roof decks when additional insulation is needed.



Figure 7-25. Reflective insulation installed between exterior and interior walls of an office building. Note the R-value (R-11) printed on the reflective facing.

Material Symbols on Drawings

Besides showing the location and sizes of different construction components, drawings also identify the materials that are used. Materials are identified in several ways:

- A section view on a drawing may contain a pattern that is unique to a specific material.
- Often, materials are specified in the notes included on a drawing. This allows for easy reference.
- Materials are also included in the project specifications.

Materials may be shown differently in plan, elevation, and section views. For example, in **Figure 7-26**, concrete block is represented in the section view as small dots with a scattering of small triangular shapes. On plan views, concrete block is shown with diagonal crosshatch lines or with the concrete hatch pattern.

Section views that cut across structural framing members show these pieces with an “X” within each member. Finished lumber (such as trim, fascia boards, and moldings) is shown in section with the wood end grain. For a wood frame wall on the plan view, the usual practice is to leave the wall blank, **Figure 7-26**. Some architects shade this area lightly to better outline the building and its partitions.

When shown in small scale, plywood is represented with the same symbol as lumber. In section (if the scale permits), lines may be drawn to indicate the plies (not necessarily the exact number). In elevation views, wood siding and panels are represented as shown in **Figure 7-26**.

Symbols for glass consist of a single line on plan drawings and section drawings. The symbol may consist of several lines on large-scale drawings. Glass areas in elevation views are left plain or consist of a series of random diagonal lines.

Introduction to Green Building Technology

Green building refers to design strategies and construction methods used to build structures that make efficient use of resources and energy.

Green building is also known as *sustainable design*. *Sustainability* is the ability of a structure to maintain operational efficiency and have minimal impact on the environment throughout its lifetime. Green building has both environmental and economic benefits. These benefits include the following:

- Protecting the ecosystem
- Improving air and water quality
- Reducing solid and material waste
- Reducing building operating costs
- Improving employee productivity and job satisfaction
- Contributing to the overall quality of life

What does it mean to build green? Simply put, it means to design and construct energy-efficient buildings that are made from sustainable materials and engineered to have minimal environmental impact. See **Figure 7-27**. Green building technology is not only intended to help protect the environment, it is designed to improve on older construction methods and save money. For these reasons, green building technology is becoming more widespread in residential and commercial construction. The following sections serve as an introduction to the primary design considerations and types of products used in green building construction.

Site Selection

Green building starts with the selection of the site, orientation of the building, and proper utilization of the natural terrain. During site development, considerations are made to remove as few trees as possible, control erosion, and control detrimental water runoff. Building materials and products may also be considered during site development. For example, *pervious concrete* (highly porous concrete that allows water to pass through it) can be used to reduce water runoff. Landscaping is another design consideration during site development. For example, trees are located to provide shade where needed. The trees selected should be appropriate for the local climate. In addition, when selecting plants and shrubs for landscaping, it is important to consider local climate patterns. If an area is subject to drought, the landscaping should include plants and shrubs that do not require an abundance of water.


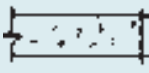

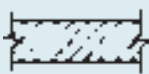
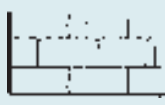





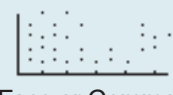




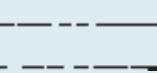



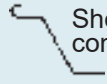
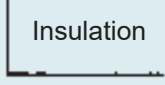
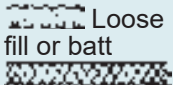
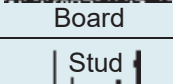
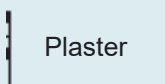






Material	Plan	Elevation	Section
Earth	None	None	
Concrete			Same as plan view
Concrete block			
Gravel fill	Same as section	None	
Wood	Floor areas left blank	 Siding  Panel	 Finish Framing
Brick	Face Common	 Face or Common	Same as plan view
Stone	Cut Rubble	 Cut  Rubble	 Cut  Rubble
Structural steel		Indicate by note	 Specify 
Sheet metal flashing	Indicate by note		 Show contour
Insulation	Same as section	 Insulation	 Loose fill or batt  Board
Plaster	Same as section	 Plaster	 Stud Lath and plaster
Glass			Large scale Small scale
Tile			

Figure 7-26. Symbols used for construction materials.



Figure 7-27. The green roof system installed on this commercial building uses 1' × 2' modules with mature plants. Green roofs have both environmental and economic benefits, including reduction of roof temperature, capture and absorption of storm water, and runoff reduction. (*LiveRoof® Hybrid Green Roof System; courtesy of LiveRoof, LLC*)

Energy Efficiency

Energy consumption is a primary design consideration in green building. The shape of the building and orientation to the sun are important factors in controlling heating and cooling costs. Passive energy strategies can be used to provide solar heat in the winter and shade in the summer. The sun orientation and building shape are also analyzed with respect to other functions, such as lighting the interior spaces of the building. Special construction features can be added to take advantage of natural light. For example, interior windows allow light to penetrate deeper into a building. This saves lighting costs and also has a positive impact on the productivity of the workforce. Additional strategies can be used to reduce lighting costs. Efficient lighting systems with sensor controls allow lights to be powered off automatically when they are not needed. See **Figure 7-28**.

CAD modeling and analysis software is commonly used to design and test energy-efficient structures that utilize green building principles. When used with building information modeling (BIM) software, analysis programs can be used to optimize electrical and mechanical systems. The software evaluates the design data of the building and generates information related to energy performance, including estimated usage and costs.



Figure 7-28. The lighting system in this warehouse utilizes motion-activated lights to reduce energy use.

Material Selection

Material selection plays a significant role in green building construction. The use of recycled and *renewable* (recyclable) materials helps conserve resources and directly impacts the sustainability of the structure. Sustainable materials such as steel and engineered lumber are used in framing to maintain long-term building performance. When selecting materials, the entire life cycle of the structure is considered. For example, products such as steel, aluminum, and plastic are recyclable and can be reclaimed when a building is demolished. Cost is another factor in material selection. Using sustainable building products may come at greater expense, but it may prove more economical. A sustainable building product may cost more than a less efficient product, but it may last twice as long.

Costs associated with transporting materials and building products to the site are also important considerations. When possible, local or regional resources and materials are used to save fuel and other transportation costs. Environmental concerns are also weighed when selecting materials. Certain materials and construction processes release toxins and may be harmful to the environment. For example, some adhesives and finishes emit volatile organic compounds (VOCs) when applied. Water-based products may be available and may offer a safer alternative.

Thermal efficiency is another important consideration in material selection. Products with good insulating characteristics help conserve energy. Well-sealed windows with low thermal transmission, such as low-e and argon-filled units, have high R- values and are highly efficient. These types of windows are designed to reduce heat loss or gain but permit light gain.

Water Efficiency

A clean and plentiful water supply is a valuable resource. In green building projects, water conservation is an important priority. There are many ways water can be used more efficiently. Roof runoff water (recycled water) can be used for toilet flushing, garden irrigation, and other purposes. Many products used in plumbing work are designed for water efficiency, including low-volume fixtures, faucets, and shower heads. Energy-efficient appliances, such as point-of-use water heaters, help conserve water and provide other advantages, such as reduced heat loss.

LEED Building Certification

The US Green Building Council has established the Leadership in Energy and Environmental Design (LEED®) Green Building Rating System. The Green Building Rating System is an accepted standard that provides construction guidelines for builders and municipalities. LEED building certification, available for commercial construction and multifamily residential construction projects, is based on implementation of green building objectives. LEED certification recognizes successful performance of a project in a series of categories in a specific LEED rating system. In the certification process, points are awarded for meeting criteria in each category. The categories include the following:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality (IEQ)
- Locations and Linkages
- Awareness and Education
- Innovation in Design
- Regional Priority

To earn LEED certification, the construction project must score the required number of points in the specific LEED rating system. Four different certification levels are available: Certified, Silver, Gold, and Platinum. The LEED Platinum certification is the highest level attainable.



Specifications for various aspects of concrete work, including reinforcement, formwork, and cast-in-place material, are found in the Construction Specification Institute's Division 03.

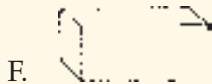
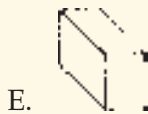
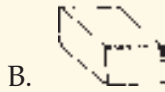
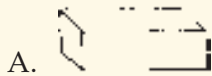
Test Your Knowledge

Name _____

Write your answers in the spaces provided.

- _____ 1. *True or False?* Concrete is stronger when it is in tension (pulled) than when it is in compression (pushed).
- _____ 2. When preparing a batch of concrete, which of the following would not be included?
A. Water
B. Cement
C. Aggregate (sand, gravel)
D. Chemical admixtures
E. All of these items could be included in the mix.
- _____ 3. Which mortar type is best-suited for situations requiring high lateral strength?
A. Type M
B. Type S
C. Type N
D. Type O
E. None of the above.
- _____ 4. What is the difference between interior and exterior plywood?
A. The type of wood used
B. The size of the sheets
C. The type of adhesive used
D. The thickness of the sheets
E. Interior and exterior plywood are identical.
- _____ 5. The steel beam identification W8×15 represents a wide-flange beam _____.
A. 8" deep and weighing 15 pounds per linear foot
B. 8" deep and 15" wide
C. 8" wide and 15" deep
D. 8" deep and 15' long
E. None of the above is correct.
- _____ 6. *True or False?* Nonferrous metals contain little or no aluminum.
- _____ 7. *True or False?* Concrete completely hardens within 48 hours after it is poured.
- _____ 8. Which of the following is *not* considered to be a type of safety glass?
A. Wired glass
B. Plate glass
C. Laminated glass
D. Tempered glass
E. All of these are types of safety glass.
- _____ 9. *True or False?* An air space between two sealed panes of glass serves as good insulation.
- _____ 10. What type of cement would you use in the winter to make the concrete set up faster?
A. Type I, Normal Cement
B. Type III, High Early Strength
C. You wouldn't make concrete in the winter because it might freeze.
D. Use a retarder admixture.
- _____ 11. Give the actual diameter of the reinforcing steel bar listed below:
A. #9
B. #4
C. #8
D. #5
E. #18
A. _____
B. _____
C. _____
D. _____
E. _____

_____ 12. Name the brick positions in the walls indicated below.



- A. _____
 B. _____
 C. _____
 D. _____
 E. _____
 F. _____

_____ 13. What are the two basic kinds of metal?

- A. Ferrous and nonferrous
 B. Steel and copper
 C. Steel and aluminum
 D. Brittle and malleable

_____ 14. What shape does each of the following designations for structural steel indicate?

- A. W
 B. S
 C. C
 D. L

- A. _____
 B. _____
 C. _____
 D. _____

_____ 15. What causes concrete to harden?

- A. Dehydration
 B. Evaporation
 C. Consolidation
 D. Hydration

16. What is the system used to measure the thickness of sheet metal products?

_____ 17. *True or False?* A sheet metal product made from 12-gage metal weighs more than the same product made from 6-gage metal.

_____ 18. Which of the following is a benefit of green building?

- A. Reducing solid and material waste
 B. Improving employee productivity and job satisfaction
 C. Improving air and water quality
 D. All of the above.

_____ 19. *True or False?* Thermally efficient, argon-filled window units have low R- values.

_____ 20. *True or False?* Storm water can be collected from a roof and used for garden irrigation or toilet flushing.



Structural steel is widely used in commercial construction projects.